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MORPHOLOGY OF CZARNA CAVE AND ITS SIGNIFICANCE FOR THE GEOMORPHIC EVOLUTION OF THE KOŚCIELISKA VALLEY (WESTERN TATRA MTS.)

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Abstract: Czarna Cave represents phreatic cave with multiple loops. No cave level developed at the water table was detected. The cave was later modified by invasion vadose waters and breakdown processes. The phreatic paleoflow directions were analyse from the asymmetry of scallops. The paleoflow was directed from the east to the west, that is in a direction of the Kościeliska Valley. Therefore, this valley represented the main discharge zone of the region during the formation of Czarna Cave.

Key words: scallops, cave development, karst hydrology, Western Carpathians

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INTRODUCTION

The Western Tatra Mts. represent an Alpine-type massif uplifted and subjected to complex evolution since the early Neogene (cf. Burchart, 1972). The present topography of the Western Tatra Mts. resulted mainly from late Neogene erosional processes and Pleistocene glaciations. The studies on the geomorphic evolution of the Western Tatra Mts. have been concentrated on the role of Pleistocene glaciations and on the present-day processes (see Klimaszewski, 1988, 1996 and literature quoted herein). On the contrary, the pre-Quaternary history has been considered to a lesser extent.

The analysis of solutional caves can serve as useful tool to reconstruct geomorphic evolution of Alpine-type massifs composed by karst rocks, at least in some parts. The Western Tatra Mts. belong to this category (Głazek *et al.*, 1979; Głazek & Grodzicki, 1996; Głazek, 1997). Solutional caves are formed in dependence on the location of discharge and recharge points (Palmer, 2000), which depends on local geological and morphological conditions (see Ford & Williams, 1989; Palmer, 2000). Thus, the analysis of spatial distribution and morphology of inactive solutional caves can contribute to the reconstruction of geomorphic evolution of studied areas.

There were some attempts to reconstruct the development of solutional caves in the Western Tatra Mts. (Rudnicki, 1958, 1967; Wójcik, 1966, 1968; Grodzicki, 1970, 1991) with geomorphic applications. These studies have been mainly concentrated on the massif of Czerwone Wierchy, and the Kościeliska Valley (Dolina Kościeliska). Czarna Cave (Jaskinia Czarna) is one of the longest and most spacious caves located in this valley. The older opinions related to its origin and development seem to be at variance with the field data, therefore they have to be discussed.

SPELEOLOGICAL AND GEOLOGICAL SETTING

Czarna Cave is an extensive inactive solutional cave located on the eastern slope of the Kościeliska Valley in the Western Tatra Mts. with more than 6 km of passages (Fig. 1; Grodzicki *et al.*, 1995). The cave is developed between ca. 1150 m and 1450 m a.s.l. and has three entrances (Fig. 2). The main western entrance is situated in the rock cliff called Organy at 1326 m a.s.l. and 285 m above the valley bottom. Nearby at 1294 m a.s.l. the second entrance is located. The third entrance is located on the south-western slope of the Pod Wysranki Gully (Żleb pod Wysranki) at 1404 m a.s.l. The main passage of Czarna Cave is more than 1 km long. It extends north-eastwards from the main entrance up to big sump (Colorado), situated near the third entrance. The sump is filled with muddy sediments. The vertical extent of the

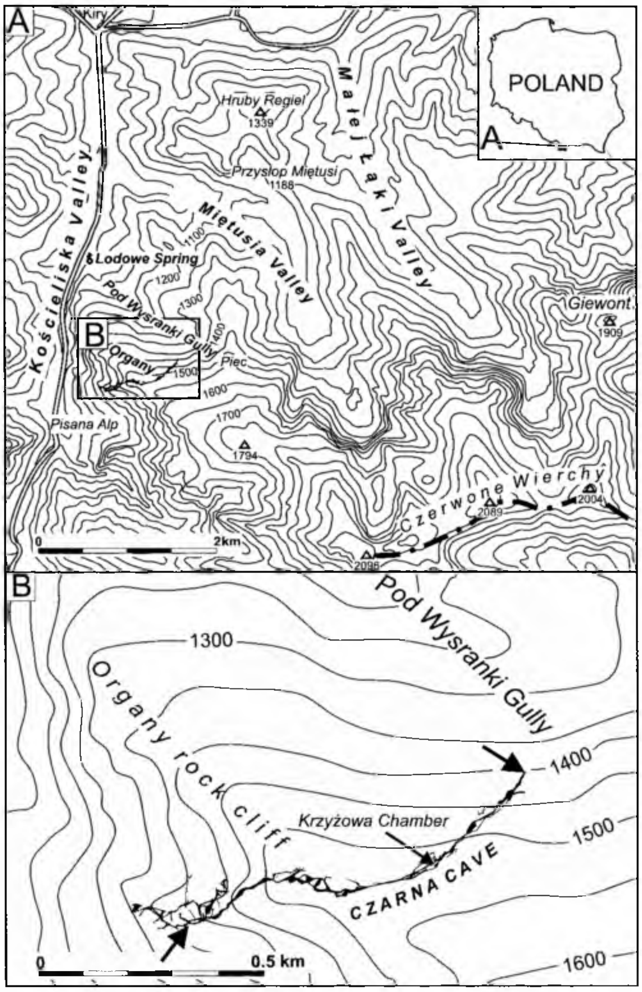

Fig. 1. Location of Czarna Cave (black outlines after Grodzicki *et al.*, 1995; some of passages are omitted for the clarity), big arrows indicate the western and northern entrances

main passage reaches 150 m. The cave is now inactive, without any perennial watercourses. Some small and ephemeral underground streams occur, especially during snow melt and after heavy precipitation. They disappear in small sinks. The dye-tracing tests carried out in the sixties of the last century proved that the water flows towards the Lodowe Spring (Lodowe Źródło), the main karst spring in that area (Dąbrowski & Rudnicki, 1967).

Most of the cave passages are developed in the thin-bedded Middle Triassic carbonates up to 800 m thick (Kotański, 1959). Only the eastern parts of the cave originated in the Upper Jurassic–Lower Cretaceous thick-bedded limestones ("Malmo-Neocomian limestones"), which are 200 m thick (Lefeld *et al.*, 1985). Carbonate rocks belong to tectonic unit of Organy (Rudnicki, 1967; Grodzicki, 1978) constituting part of the allochthonous High-Tatric Unit.

The majority of big caves in the Tatra Mts. are developed, similarly to Czarna Cave, in the Czerwone Wierchy Massif. Active caves of this area are situated in Miętusia and Małej Łąki valleys located eastwards from the Kościeliska Valley. They are drained by Lodowe Spring too (Rudnicki, 1967; Głazek *et al.*, 1979; Głazek & Grodzicki, 1996; Głazek, 1997). The modern karst groundwater flows

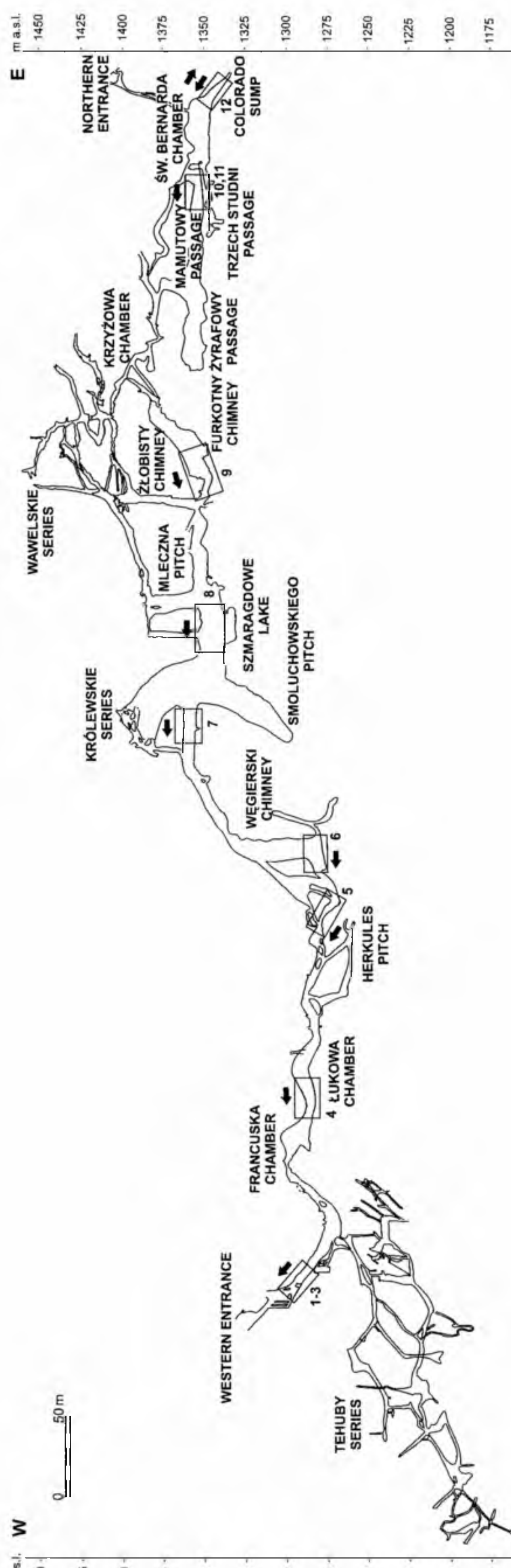

Fig. 2. Schematic profile through Czarna Cave, simplified and improved after Grodzicki *et al.* (1995), some of passages are omitted for the clarity, areas where scallops were studied are indicated by shaded rectangles with numbers refered to Table 1, the paleowater flow is indicated with arrows

through High-Tatric Unit are confined by overlying Cretaceous marls and Lower Triassic shales of overthrusted Sub-Tatric units in the north. Therefore, the modern karst flows are oriented in latitudinal direction, that is perpendicularly to the main meridional valleys.

METHODS

The observations of spatial pattern of cave passage were carried out mainly in the main passage of Czarna Cave. The authors used the published cave maps (Kujat, 1979; Grodzicki *et al.*, 1995) and the unpublished documents (cave maps and data collected during cave survey) stored in the Archive of Sekcja Taternictwa Jaskiniowego KW-Kraków (Caving Section of Kraków Mountaineering Club). The map by Grodzicki *et al.* (1995) was verified and improved in the cave by means of a fibre-glass tape and a geological compass with clinometer.

The morphology of cave passages was examined, too. Cross-sections of passages and the presence of scallops were especially studied. Scallops are small oval niches, which occur on cave walls and ceilings (see Figs 7, 8). They develop in turbulent flow conditions (Rudnicki, 1960; Curl, 1966; Lauritzen & Lundberg 2000 and references quoted herein). They are elongated with the flow direction. Scallops are asymmetrical in longitudinal cross-sections. The steepest side of the scallop always faces downstream as proved experimentally (e.g., Rudnicki, 1960; Goodchild & Ford, 1971; Blumberg & Curl, 1974). Therefore, scallops represent good indicator of a flow direction. They are often used as a tool in reconstruction of groundwater paleoflow in caves.

FIELD DATA

The main passage of Czarna Cave comprises spacious passages and chambers, which further in this article are called passages for the sake of simplicity. The direction of the main passage from the western entrance to Krzyżowa Chamber is latitudinal developed along bedding planes of Middle Triassic carbonates. Between Krzyżowa Chamber and Colorado Sump the orientation is in the SW–NE direction, guided by fault planes (Fig. 1).

The main passage is composed of several loops and in the dimension of length and depth it shows distinctive zigzag array (Fig. 2). The particular loops with vertical extent more than 50 m are clearly visible near the western cave entrance. The main passage is separated by vertical pitches or chimneys several dozens meters deep or high respectively (e.g., Smoluchowskiego Pitch, Żłobisty Chimney). Such vertical forms developed mainly along the fissure/fissure or fissure/bedding plane intersections.

The major part of main passage shows breakdown morphology modified by collapses of slab type or, usually, of block type (see White & White, 2000), which deposited a large amount of blocks of different size on cave bottom. The disintegration of beds was facilitated by presence of: (i) bedding planes, especially in Middle Triassic carbonates, (ii) tectonic fissures (mainly fault surfaces; Fig. 3), and (iii) tectonic breccias developed along the faults.

Fig. 3. Exposed fault surface, which facilitated breakdown processes, collapsed debris are visible on passage floor, Żyrafowy Passage

The western part of the cave was also strongly modified by chip breakdowns due to ice wedging mechanism (White & White, 2000). This part of the cave is congealed during the winter time (Grodzicki *et al.*, 1995). Here, the frost action also contributed to origin of polygonal soils (Pulina, 1968).

The breakdown processes modified the morphology of cave passages and obliterated their original cross-sections. Nevertheless, in several places the original morphology of the passages are preserved. In such places the passages are of sub-circular or lenticular cross-sections with the height of several metres (Figs 4, 5). Cave morphologies prove that the passages developed in phreatic conditions (cf. Bretz, 1942; Rudnicki, 1958; see also Lauritzen & Lundberg, 2000 and references quoted herein).

The passages with vadose morphology are rare. They occur usually beneath the chimneys. They are canyons incised into the floor of older phreatic passages (Fig. 6), parallel pitches developed due to the knick point recession process (e.g., the pitch near the western entrance), and cave karren.

Scallops on cave walls (Figs 7, 8) occur especially in passages with preserved original phreatic cross-sections. Detailed observations of scallops were carried out in 12 sections within the cave (see also Kicińska, 2002, in press). The results are presented in Table 1. The scallop length vary from 1 cm to more than 60 cm. Except one point, scallop asymmetry clearly shows the general paleoflow direction from the east to the west. In the Colorado Sump (see Fig. 9) small and large scallops are developed. The smaller ones up to 15 cm in length, occur on the walls and ceiling near the muddy sediments blocking the sump. They indicate east-

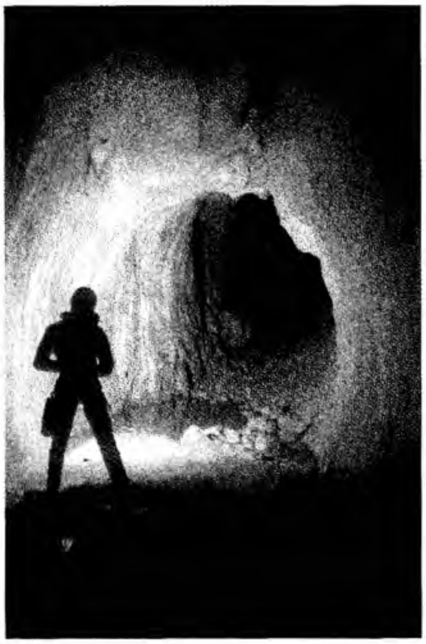

Fig. 4. Mamutowy Passage displaying typical phreatic cross-section; the passage is developed within "Malmo-Neocomian limestones" along tectonic fracture

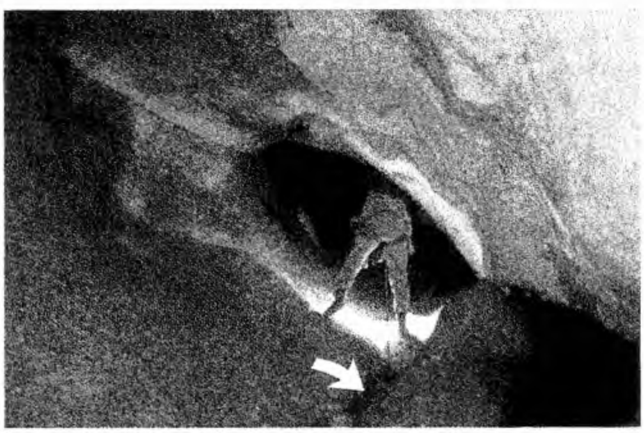

Fig. 5. Steeply dipping Herkulesa Pitch (viewed from the bottom towards the head) developed under phreatic condition within Middle Triasssic carbonates along bedding plane. Originally, the pitch constituted the upward part of phreatic loop; later it was slightly modified under vadose conditions which are manifested by small canyon incised in the bottom (arrow)

ward direction of paleoflow, that is towards the sump. However, large scallops, which can be found on the western wall several meters westward, show the opposite – westward – direction. Scallops do not overlap each other. Therefore, it is impossible to state direct superposition.

DISCUSSION

Collected field data offered new light on the origin of Czarna Cave, which can be indirectly utilised for reconstruction of geomorphic evolution of the Kościeliska Valley. The discussion will concentrate on: (i) the problem of

Fig. 6. The entrance to Trzech Studni Passage viewed from the Św. Bernarda Chamber, the primary sub-circular cross-section is visible; the vadose entrenched canyon developed due to water invaded through the chimney in the ceiling of the passage

Fig. 7. Scallops on the southern wall of Mamutowy Passage, the direction of paleoflow (arrow) is from the left to the right, that is from the east to the west. Length of photograph equals ca. 0.8 m

Fig. 8. Large scallops on the north-western wall of Colorado Sump, the direction of paleoflow (arrow) is from right to left, that is from the north-east to the south-west

Table 1

Distribution and characteristics of observed scallops; numbers placed in left column refer to Fig. 2

Number	Location	Minimal and maximal length of scallops [cm]	Mean length of scallops [cm]	Amount of measured scallops	Paleo-flow direction
1	passage below the entrance pitch	18 - 30	24	6	W
2	passage below the entrance pitch	50 - 60	55	5	W
3	passage below the entrance pitch	20 - 50	35	40	W
4	Łukowa Chamber	8 - 12	9	6	W
5	passage between Herkules Pitch and Węgierski Chimney	4 - 9	7	70	W
6	passage below Węgierski Chimney	20 - 25	22	15	W
7	passage between Wegierski Chimney and Smoluchowski Pitch	3 - 7	5	200	W
8	above Szmaragdowe Lake	18 - 22	20	40	W
9	passage below Furkotny Chimney	1 - 9	4	150	W
10	Mamutowy Passage	4 - 7	6	23	W
11	Trzech Studni Passage	4 - 12	7	160	W
12	passage near Colorado Sump	7 - 15 34 - 68	9 48	7 3	E W

existence of so-called cave levels in Czarna Cave and (ii) paleoflow direction during the origin of the cave.

PROBLEM OF CAVE LEVELS

Spatial pattern of cave conduits, occurrence of phreatic loops and presence of passages displaying phreatic profiles prove that Czarna Cave developed under phreatic condition. It belongs to cave type with multiple loops and corresponds to the State 2 within the "Four State Model" *sensu* Ford and Ewers (1978). The vertical amplitude of particular loops reaches several dozens of metres. Cave conduit of such type is developed in spite of relative high fissure frequency in the allochthonous High-Tatric Unit (see Piotrowski, 1978). It is not an exception in the Alpine-type regions. Similar situation (i.e., development of deeply looping phreatic caves in an Alpine setting) was described, for example, by Jeannin *et al.* (2000) from Lake Thun area in Switzerland.

Table 2

Cave levels in Czarna Cave according to the selected papers dealing with this topic. The values of altitude placed in italics are recalculated by the present authors assuming the altitude of Pisana Alp (1010 m a.s.l.) as the valley bottom

	Wójcik, 1996	Rudnicki, 1967	Wójcik, 1968	Grodzicki, 1970	Grodzicki, 1991
altitude location of cave level [m a.s.l.]	*1191-1213* *1233-1255* *1269-1297* *1283-1339*	1350 1400-1420	*1191-1213* *1233-1255* *1269-1297* *1283-1339* *1370-1410*	1100 1230 1340	1170 1300 1380

There is a lack of well defined phreatic/vadose transition points in the cave (cf. Palmer, 1987, 2000). Thus, the position of paleopiezometric surface cannot be precisely fixed. However, one can presume that some horizontal passages acted as bypasses or isolated vadose trenches (e.g., Mamutowy and Żyrafowy passages). Due to later strong reshaping of the passages by breakdowns, their origin cannot be precisely determined. Nevertheless, it can be assumed that horizontal sections of passages formed probably slightly below or slightly above the local paleopiezometric surface.

Taking into account field observations and interpretations resulted from them it becomes obvious that the main passage of Czarna Cave represents one complex cave conduit with vertical extent of more than 150 m (i.e., between ca. 1250 and 1400 m a.s.l.). As it represent one generation looping conduit, it should be named a cave storey (*sensu* Ford, 2000). The storey developed mainly under phreatic condition at different depth below the piezometric surface.

The previous ideas (Wójcik, 1966, 1968; Rudnicki, 1967; Grodzicki, 1970, 1991) concerning the origin of Czarna Cave were based, more or less, on the so-called watertable theory (*sensu* Swinnerton, 1932). The theory assumes, that the cave conduit develops near the piezometric surface. The surface, in turn, is situated at the altitude of the discharge point represented by karst spring draining the particular cave. Thus, the cave levels define ancient fluvial base-levels. All the above authors interpreted the horizontal passages in Czarna Cave as fragments of few independent cave levels (Table 2). They regarded particular cave level as a record of a stabilization of fluvial base-level.

According to data given above, the main passage of Czarna Cave should be regarded as a single cave storey. This fact implies, that the position of some horizontal passage sections does not correspond to cave-level position, that is to the position of ancient fluvial base-level. Klarenbach (1998) indicated that the so-called Tehuby series (i.e., the lowermost series of Czarna Cave) establishes an independent cave storey, younger than the main passage. The Tehuby series developed under phreatic condition well below the piezometric surface (Tomasz Klarenbach, 1998 – personal information). Thus, the analysis of the cave in a sense of the "Four State Model" (Ford & Ewers, 1978) clearly indicates that the ideas of presence of several cave

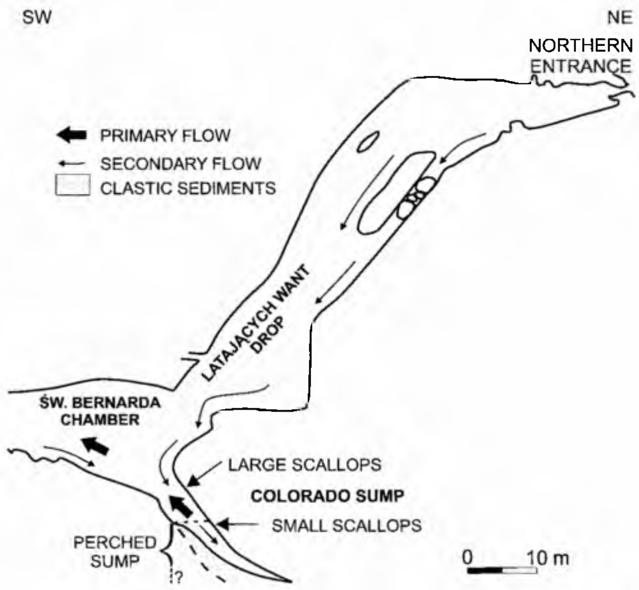

Fig. 9. Profile through the eastern series of Czarna Cave (after Kujat, 1979 and unpublished data stored in Archive of STJ KW-Kraków). Paleoflow directions are indicated (arrows)

levels constituting the cave have no reasons. It is worth mentioning, that Kicińska (2002, in press) also has questioned the presence of cave levels within other caves in the Western Tatra Mts.

Vertical – vadose – conduits of Czarna Cave are younger than the principal phreatic conduits dissected by them. Almost all of them represent invasion vadose caves of a proglacial type (see Głazek *et al.*, 1977, 1979; Głazek, 1997). The water widened the bedding planes and tectonic fissures (Fig. 6) producing typical vadose features (e.g., deep vertical pitches and knick point retreated canyons; see Fig. 9). Vadose water migrating down also remodelled some older phreatic conduits.

DIRECTION OF PALEOFLOWS IN CZARNA CAVE

The previous authors (Wójcik, 1966, 1968; Rudnicki, 1967; Grodzicki, 1970, 1991), who studied the origin of Czarna Cave did not analyse the asymmetry of scallops. Their researches were mainly based on spatial pattern of cave passages. Grodzicki (1970, 1991) formulated most distinctively the idea that the water crossed Czarna Cave from the west to the east, that is from the Kościeliska Valley to the Pod Wysranki Gully. Wójcik (1966, 1968) presented a similar opinion in indirect way. On the other hand, Rudnicki (1967) claimed that eastern parts of the cave were drained towards the east, and western ones towards the west.

The new data obtained from analysis of scallop asymmetry show that paleoflow was directed from the north-east towards the south-west, that is from the Pod Wysranki Gully to the Kościeliska Valley (see also Kicińska, 2002, in press). The western side of the big terminal sump of Colorado, which has not been explored up to now, is the only point in the cave, where the opposite paleoflow direction was detected. The asymmetry of small scallops displays direction from the west to the east, that is towards the sump. However, the asymmetry of large scallops shows the direction towards the west (Fig. 8). This complex situation can be explained as follows. Large scallops are older, they originated during the slow flow under phreatic condition (see also Lauritzen & Lundberg, 2000). Later, after the cave was drained, invasion water carved the steep passage of Latających Want Drop (Fig. 9). The water subsequently flowed down through Colorado towards the east still under vadose conditions. The water deposited its clastic load into downward apex of Colorado increasing the hydrostatic head upstream. A perched sump was created, which led to the origin of small scallops. Therefore, the primary direction of paleoflow is from the east to the west, similarly to other points in Czarna Cave.

The opinion of Grodzicki (1970, 1991), who situated the main discharge zone in the present Pod Wysranki Gully and denied the presence of the Kościeliska Valley at that time can be fully rejected in the light of above-mentioned analysis and interpretation. Based on the present data, the main discharge zone from Czarna Cave was situated somewhere in the middle course of the Kościeliska Valley in the vicinity of the present Pisana Alp (Polana Pisana). This point, was later destructed by fluvial erosion and subsequent recession of valley slopes. The discharge point can be regarded as the former counterpart of the present Lodowe Spring, since it obtained water through the karst conduits from the east. The water flowed from the Czerwone Wierchy Massif, which was definitely much larger than nowadays.

The uranium-series dating of speleothems shows that Czarna Cave was drained already before 1 Ma ago (Nowicki *et al.*, 2000). Therefore, it acted as an active cave conduit during Neogene (cf. also Głazek & Grodzicki, 1996). The above-presented interpretation indicates that: (i) karst discharge pattern during Neogene was similar to the present one and (ii) the Kościeliska Valley represented the main entrenched valley since it acted as a main discharge zone. Waters from the Czerwone Wierchy Massif was captured by the underground karst conduits and supplied the catchment of the Kościeliska Valley, already during Neogene.

GENERAL CONCLUSION

Czarna Cave developed mainly under phreatic conditions. Its main passage constitutes one cave storey formed between 1250 m and 1400 m a.s.l. The storey is composed of several phreatic loops. No cave level originated near the water table is detected within the cave. The water flowed through the cave from the east towards the west. Thus, the main discharge point was located in the Kościeliska Valley, which acted as a main valley during the formation of Czarna Cave.

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Streszczenie

MORFOLOGIA JASKINI CZARNEJ I JEJ ZNACZENIE DLA GEOMORFOLOGICZNEGO ROZWOJU DOLINY KOŚCIELISKIEJ

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Analiza morfologii i przestrzennego rozmieszczenia jaskiń krasowych jest użytecznym narzędziem w rekonstrukcji rozwoju geomorfologicznego obszarów krasowych (Ford & Williams, 1989; Palmer, 2000). Takim obszarem są Tatry Zachodnie, które od neogenu przechodziły skomplikowaną ewolucję geomorfologiczną (Klimaszewski, 1988, 1996). Jaskinia Czarna jest jedną z większych jaskiń tego rejonu. Pomimo tego, geneza tej jaskini nie została dotychczas zadowalająco wyjaśniona, a wyrażane do tej pory poglądy dotyczące jej rozwoju stoją w sprzeczności z obserwacjami terenowymi.

Jaskinia Czarna jest położona w Tatrach Zachodnich na prawym orograficznie stoku Doliny Kościeliskiej (Fig. 1; Grodzicki *et al.*, 1995). Długość jaskini przekracza 6 km. Jej główny ciąg znajduje się pomiędzy głównym, zachodnim otworem, usytuowanym na stoku Doliny Kościeliskiej, a błotnym syfonem Colorado (Fig. 2). Otwór północny jest zlokalizowany ponad tym syfonem, na stoku Żlebu pod Wysranki. Długość głównego ciągu przekracza 1 km, a deniwelacja 150 m.

Jaskinia Czarna jest rozwinięta w utworach triasu środkowego i malmo-neokomu elementu Organów stanowiącego część wierchowej jednostki allochtonicznej. Jaskinia jest obecnie nieaktywna i pozbawiona stałych cieków wodnych. Barwienie okresowych cieków wodnych w jaskini wykazało jej połączenie hydrologiczne z Lodowym Źródłem będącym głównym krasowym źródłem w tym rejonie (Dąbrowski & Rudnicki, 1967). Źródło to odwadnia większość dużych jaskiń położonych w masywie Czerwonych Wierchów i jest zasilane głównie przez wody płynące równoleżnikowo ze wschodu, to jest poprzecznie do przebiegu walnych dolin tatrzańskich (Rudnicki, 1967; Głazek *et al.*, 1979; Głazek & Grodzicki, 1996; Głazek, 1997).

Autorzy wykonali analizę rozmieszczenia przestrzennego korytarzy Jaskini Czarnej. Kierunek paleoeoprzepływów zrekonstruowano na podstawie asymetrii zagłębień wirowych (*scallops*; Tabela 1; por. Rudnicki, 1960; Curl, 1966; Lauritzen & Lundberg, 2000 i literatura tam cytowana).

Układ korytarzy ciągu głównego Jaskini Czarnej oraz ich poprzeczne przekroje dowodzą, że jaskinia ta rozwijała się jako system wielu, połączonych z sobą pętli freatycznych (Ford & Ewers, 1978; Ford & Williams, 1989; Ford, 2000). Deniwelacja pojdyńczych pętli sięga kilkudziesięciu metrów. Część korytarzy o poziomym rozwinięciu, np. Korytarz Mamutowy i Korytarz Żyrafowy, stanowiła zapewne korytarze typu obejść lub izolowanych wadycznych rozcięć (*bypass*, *isolated vadose trench*; Ford & Ewers, 1978; Ford & Williams, 1989; Ford, 2000). Niestety późniejsze zmiany morfologii jaskini wywołane przez procesy zawaliskowe uniemożliwiają precyzyjne ustalenie punktów przejścia pomiędzy strefą freatyczną i wadyczną (Fig. 3; por. Palmer, 1987, 2000).

Zebrane obserwacje świadczą, że główny ciąg Jaskini Czarnej powstał na zróżnicowanej głębokości poniżej piezometrycznego zwierciadła wód krasowych (Fig. 4, 5). Stanowi on więc jedno genetyczne piętro (*cave storey*) rozwinięte w warunkach freatycznych (por. Ford, 2000). Nie można więc wyróżniać w jego obrębie tzw. poziomów jaskiniowych (*cave levels*) odpowiadających dawnemu poziomowi zwierciadła wód i w przybliżeniu dawnemu poziomowi bazy erozyjnej. Powyższy pogląd neguje dotychczasowe koncepcje dotyczące rozwoju Jaskini Czarnej (Wójcik, 1966, 1968; Rudnicki, 1967; Grodzicki, 1970, 1991; patrz też Tabela 2), które opierały się w większym lub mniejszym stopniu na teorii Swinnertona (1932). Teoria ta zakłada rozwój jaskiń krasowych jako w przybliżeniu horyzontalnych ciągów powstających w pobliżu zwierciadła wód.

Freatyczne ciągi Jaskini Czarnej były już po osuszeniu modyfikowane przez wadyczne przepływy, zapewne o charakterze wód inwazyjnych pochodzących z topnienia pól firnowych lub lodowców plejstoceńskich (por. Głazek *et al.*, 1977, 1979; Głazek 1997). Wody te ukształtowały pionowe studnie i kominy młodsze od głównego ciągu i w wielu miejscach rozcinające go. Spowodowały także lokalne wadyczne modyfikacje starszych freatycznych ciągów (Fig. 6, patrz też Fig. 9).

Analiza kierunków paleoprzepływów w Jaskini Czarnej wykonana na podstawie obserwacji zagłębień wirowych w dwunastu miejscach w jaskini wykazała jednoznacznie, że pierwotnie przepływ ten skierowany był ze wschodu ku zachodowi (a dokładnie z północnego wschodu ku południowemu zachodowi) czyli ku Dolinie Kościeliskiej (Fig. 2, 7, 8, 9). Dlatego nieaktualne są dotychczasowe poglądy dotyczące kierunków paleoprzepływów w tej jaskini, wyrażane najbardziej zdecydowanie przez Grodzickiego (1970, 1991). Powyższe obserwacje wskazują, że w czasie aktywnego freatycznego przepływu poprzez główny ciąg Jaskini Czarnej, czyli w neogenie (por. Nowicki *et al.*, 2000), główna strefa odwodnienia była położona w Dolinie Kościeliskiej w rejonie dzisiejszej Polany Pisanej. Świadczy to, że już wówczas dolina ta była jedną z najniżej wciętych dolin Tatr Zachodnich. Można zatem przyjąć, że Jaskinia Czarna stanowi dawny, nieaktywny odpowiednik dzisiejszego systemu Lodowego Źródła. Prowadziła ona bowiem wodę z masywu Czerwonych Wierchów ku zachodowi, w stronę Doliny Kościeliskiej, tak jak ma to miejsce współcześnie w tym systemie.