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TECTONIC SETTING OF THE POSZUKIWACZY SKARBÓW CAVE AND THE GROBY CAVE (KRAKÓW GORGE, WESTERN TATRA MTS., POLAND)

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Abstract. The study area is located in the Tatra Mts., the part of Western Carpathians. In the Poszukiwaczy Skarbów Cave and the Groby Cave a tectonics structures has been documented. The structural analysis were made. In both caves the following joints set have been identified from 4 maximum of statistic analysis: 157/85 (max.I), 143/63 (max.II), 58/63 (max.III), 304/70 (max.IV). Nevertheless joint set participation of individual caves development have been diverse. In the development of the Poszukiwaczy Skarbów Cave, the most important joint set were latitudinal which is conjugate with fractures of III. maximum. This crossing of joints sets contribute to development of the main chamber. Maximum III has been very important in the evolution of passages of the Groby Cave. Conjugated with joint of max. IV determined the conduit direction. Entrance chamber formed in this place because the overthrust disintegrated a rocks there.

Keywords: cave, tectonics, Tatra Mts., autochthonous sedimentary cover, joint.

Introduction

The Poszukiwaczy Skarbów Cave and the Groby Cave have been known for a centuries by Highlanders and treasure hunters. Origin of these caves has been investigated by Rudnicki (1958a; 1958b) and Wójcik (1960; 1966). They concluded that the caves were subsurface flow channel of the Kościeliska River. The cave sediments have been described by Wójcik (1960; 1966; 1969) and Gradziński & Wójcik (1961). This paper presents tectonic structures identified within the studied caves. Simultaneously it is also the attempt to determine the structural component of the origin of the investigated caves.

Geological setting

The study area is located in the West Tatra Mts. in the western, lowest part of the Kraków Gorge, near its mouth to the Kościeliska Valley. The Kraków Gorge has been developed in autochtonous sedimentary cover (Fig.1A).

Detailed tectonic research of the study area have been accomplished by Rabowski (1925; 1959), (Kotański, 1961) and Piotrowski (1978). Geology of the lower part of the Krakow Gorge has been interpreted by Rabowski and Kotański as cascade folds being in superposition (3 anticlines separated by 2 synclines). The authors suggested presence of the albian marls wedges, which are separated by sequences of the liassic and the malmo-neokomian rocks.

Piotrowski (1978) attributed the origin of such situation by a hinge fault and accompanied faults and flexurals.

The caves entrances are located on the North slope of the Zbójnickie Turnie within the outcrops of the malmo-neokomian limestones (Fig.1B). From the South, Malomo-Neokomian bordered by the Dogger limestone which are 2m thickness. Contact between the Middle and Upper Jurassic and the older rocks (Liassic and Middle Triassic) is tectonic.

Near the bottom of the Kraków Gorge is the boundary between malmo-neokomian and urgonian limestones, of one succession. At the Zbójnickie Turnie area strata dip is 69-82 to NNE (Piotrowski 1978).

Morphology of the studied caves

The Poszukiwaczy Skarbów Cave entrance is located at 1211 m asl. The cave is 330m long and 30,2m denivelation (-15.7, +15.5). The cave is a pattern of corridors which are departing from the main chamber. Most of corridors are freatic tubes, often with a scalops on walls. The latitudinal conduits are cleft, locally with rubble on the bottom.

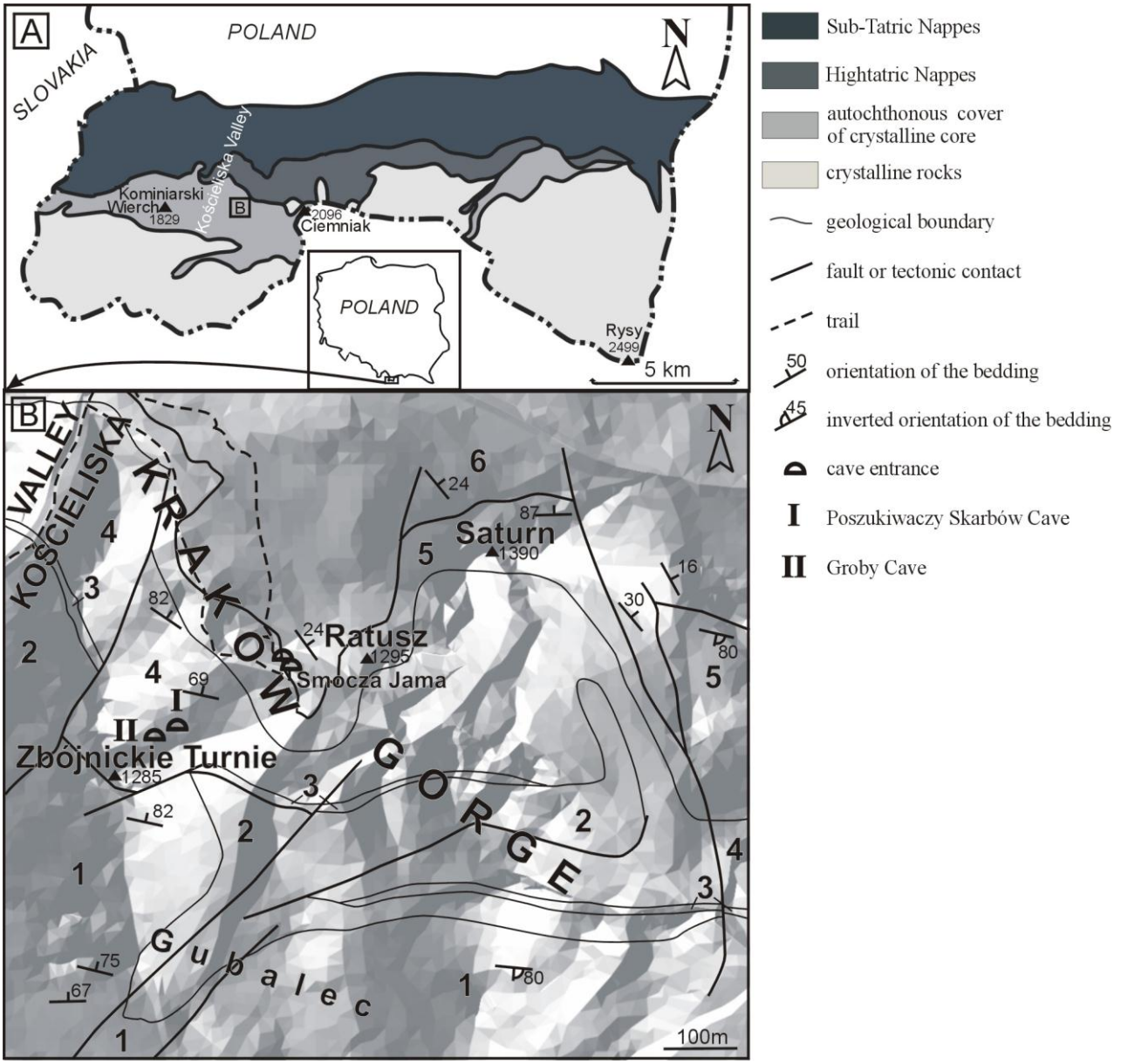

Fig. 1. Location of study area; A: against the background of the geological structure of the Tatra Mountains; B: Geology of the western part of the Kraków Gorge: 1 - Middle Triassic limestone and dolomite, 2 – Lower Jurassic (*Liassic*) sandstone, conglomerate and limestone, 3 – Middle Jurassic (*Dogger*, Smolegowa and Krupianka Formations) crinoidal limestone, 4 – Upper Jurassic-Lower Cretaceous (*Malmo-Neocomian*, Raptawicka Turnia Formation) limestone, 5 – Lower Cretaceous (*Urgonian*, Wysoka Turnia Formation) limestone, 6 –Lower Cretaceous (*Albian)* marls and shales; (*after* Piotrowski, 1978);

The Groby Cave entrance is located at 1227 m asl. The cave has a length of 125 m at 3.7 m depth.

The cave is a one conduit with acute curves. Between curves the corridor is straightforward. The cave corridors mostly have an outwash character. Only the first and the last chamber are developed by water erosion and collapsing processes.

Methodology

Structural studies within the selected caves in the western part of the Kraków Gorge, were carried out on the basis of the detailed structural analysis in order to recognize geometric, kinematic and dynamic features of minor tectonic deformation structures represented by: joints, mesofaults (with accompanying minor structures on the fault surfaces and shears) and veins. A statistical analysis was applied for comparison purposes between caves and to study relationships between tectonic structures and cave network development.

Field works within 8 localities in the Groby Cave and 18 in the Poszukiwaczy Skarbów Cave were conducted in June 2012. The studies were based mainly on the geometrical analysis of various mesoscale tectonic

structures: their morphology, spatial orientations and age relationships (superposition). About 200 measurements of spatial orientation of tectonic structures were made within two studied caves by means of a biaxial geological compass – Freiberg. The resulting data were summarized in the form of structural diagrams (great circles and contour) made in equal-area Lambert-Schmidt projection on the lower hemisphere using SpheriStat software. Rose diagrams – presenting strike directions and dip angles of studied structures – were prepared in TectonicsFP software for joints of dip angle equal or higher than 60˚.

Results

Joints stated within both studied caves are of similar spatial orientation (Fig. 2). Predominate steep and very steep joints, up to vertical positions. Over 50% of all noted joints are those with dip angle higher than 70˚ (Fig. 2). The main maximum is represented by ENE-WSW oriented joints, dipping very steeply towards SSE, and rarely NNW (I – 157/85; Fig. 2). These are normal joints, characterized by large, flat and smooth surfaces.

Joints oriented ENE-WSW, steeply and very steeply dipping towards NNW and much rarer towards the SSE represented by the main maximum on the statistical contour diagram (I – 348/70; Fig. 2A), predominate within the Groby Cave. Subordinate occur the NE-SW joint set dipping mainly towards NW (II – 143/63; Fig. 2A). Other joint sets, like NW-SE and NE-SW (maxima III – 58/63 and IV – 304/70; Fig. 2A) were encountered

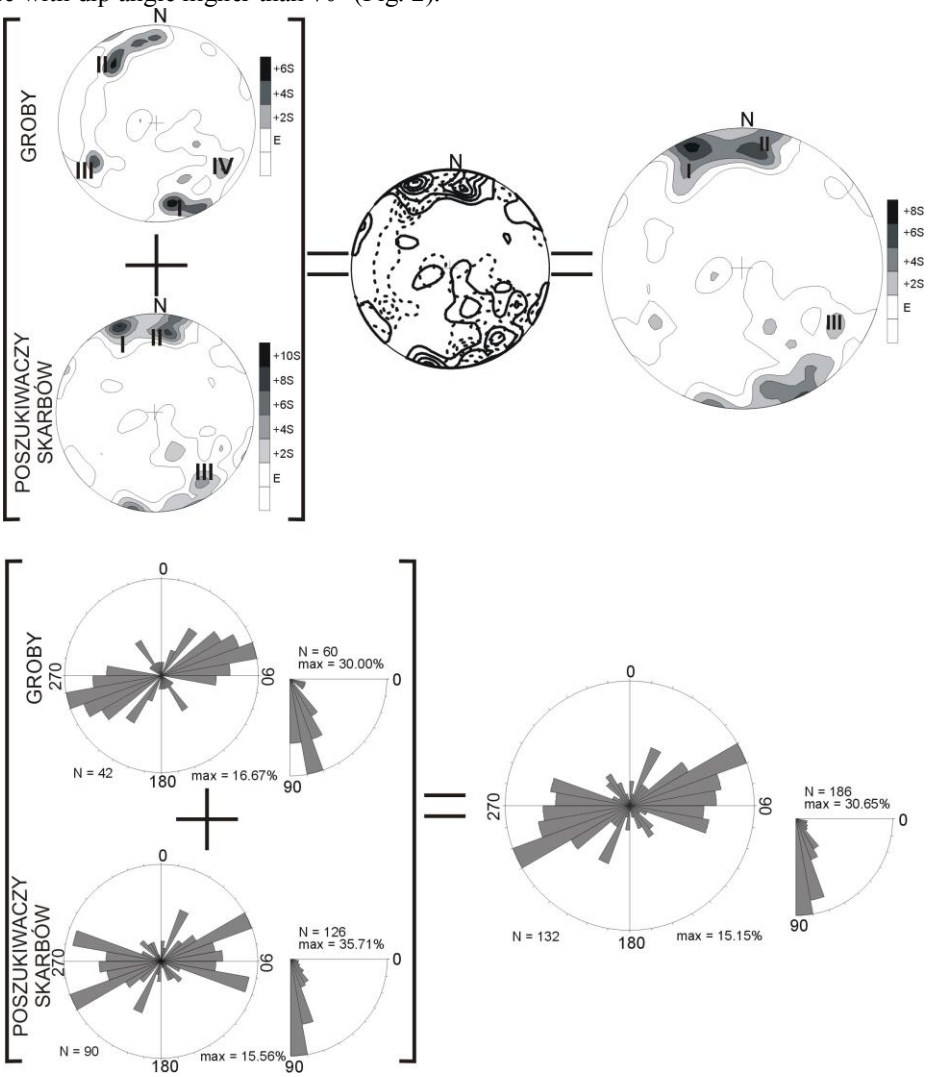

Fig. 2. A – Spatial orientation of joints within studied caves; main maxima: the Groby Cave: I – 348/70, II – 143/63, III – 58/63, IV – 304/70; the Poszukiwaczy Skarbów Cave: I – 157/85, II – 189/70, III – 326/73; both caves together: I – 157/85, II – 186/73, III – 302/67; B – rose diagrams of joints from studied caves.

much less frequently. The last joint set together with joints oriented NNE-SSW, dipping steeply towards the ESE were recognized as conjugate shears. They were developed under extensional regime. During their formation the maximum principal stress axis σ_1 was almost vertical, whereas the minimum principal stress axis σ_3

was subhorizontal, suggesting horizontal widening in the WNW-ESE direction. Subhorizontal joints were observed only locally.

The very gentle longitudinal reverse fault together with accompanying feather fractures such as low-angle Riedel The very gentle longitudinal reverse fault together with accompanying feather fractures such as low-angle Riedel shears (R), and high-angle Riedel shears (R') was recognized within the entrance chamber of the Groby Cave (Fig. 3C). Shears associated with that fault suggest that

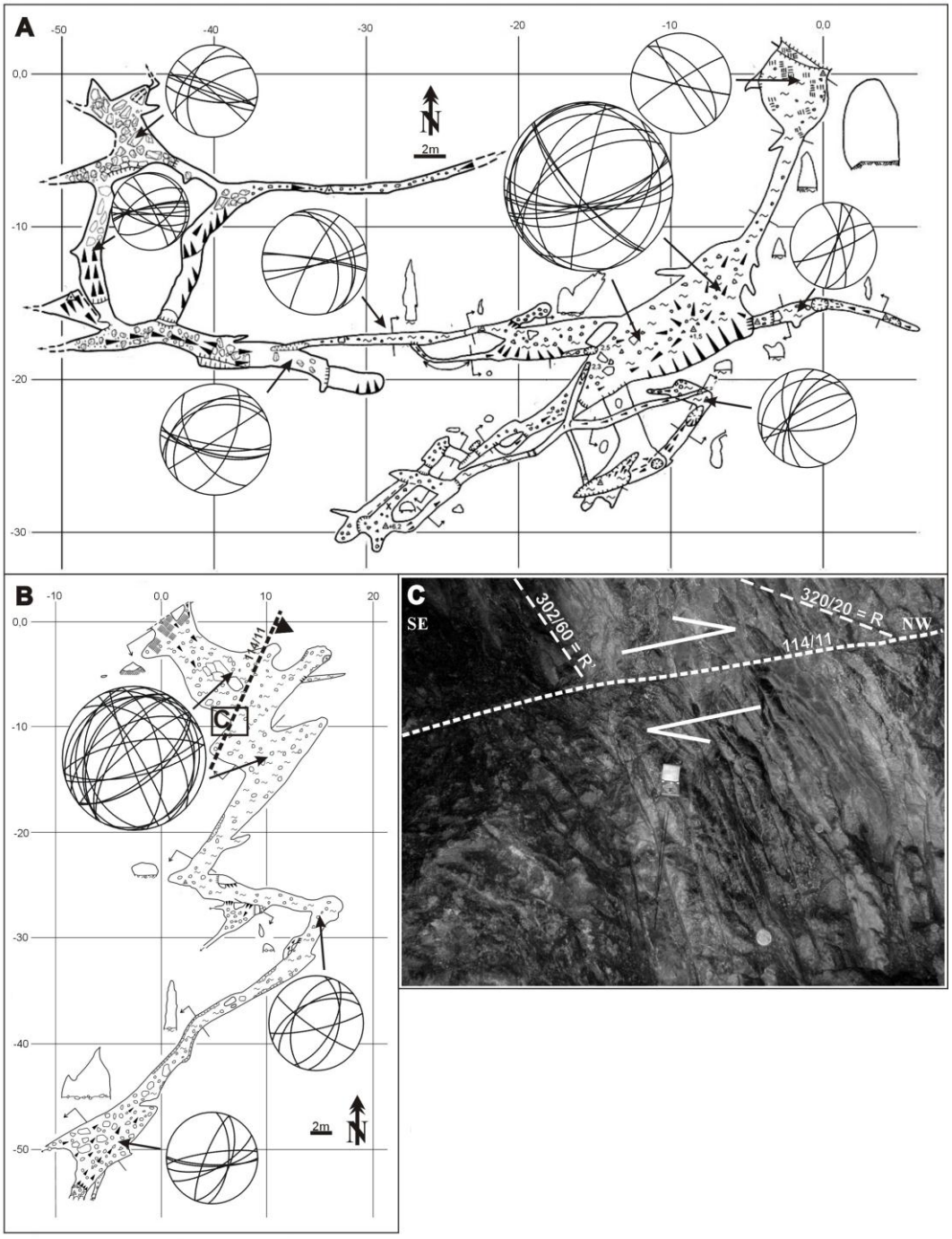

Fig. 3. Structural plan of (A) the Poszukiwaczy Skarbów Cave (topography by Luty, 1994a;Nowak, 2007) and (B) the Groby Cave (topography by Luty, 1994b). C: the thrust and the Riedel shears; located near entrance in the Groby Cave (white arrows is the movements direction)

the turn of relative displacement was up towards the WNW. Steep and very steep sublatitudinal joints predominate within the Poszukiwaczy Skarbów Cave. These are mainly subvertical joints of WSW-ENE orientation represented by the main maximum (I – 157/85; Fig. 2A), but

also rarer NE-SW joints very steeply dipping towards the NW (III – 326/73; Fig. 2A). Only a little less frequent are WNW-ESE joints, dipping towards the SSW, locally also NNE (II – 189/70; Fig. 2A). Other joints directions are much less common, and observed only in some places. Almost vertical NW-SE joints, as well as subhorizontal and dipping at moderate angles towards the NW joints were noted only locally.

Discussion

Both caves developed in tick-bedded/massive limestone of the Raptawicka Turnia Formation. Thus interbedding fissures are excluded from the group of initial structures.

Among disjunctions only one reverse fault with accompanying shears has been documented. It proves that dominant structures which determined the caves development were joints and shears.

This is also supported by a comparison of the great circles diagrams of stated joints with the course of the corridors. That proving the convergence of directions between tectonic structures and the erosion forms (corridors), which developed on them.

In the Poszukiwaczy Skarbów Cave relationship between joints and the latitudinal conduit is very pronounced (Fig. 3A). Cleft morphology and rubble on the bottom of that corridors indicate the joints dominant influence on conduit setting. One of the frequently occurring are 15-60° bearing joints. Seems to be that the main chamber of this cave has been developed in a place of conjugation between the highest density of the most common joints and latitudinal joints.

In the Groby Cave dominate joints of NE-SW, WSW-ENE orientation (max. I – 348/70, II – 143/63, IV – 304/70; Fig. 2), which is reflected by conduit directions (Fig. 3). Subordinate are sublatitudinal joints oriented ENE-WSW, which are also related to the course of passages. The submeridional reverse fault, probably contributed to the development of the inlet chamber. Displacements, which took place along this fault surface induced a stronger disintegration of surrounding rocks as the other part of the cave, making them more susceptible for karstification processes. Furthermore conduit can gain a larger cubature at the same intensity of the process of erosion.

Conclusion

1. In both caves documented incidence of the same joints set. However, joint set participation of individual caves development has been diverse.
2. Predominate clearly seen in the field steep and very steep NE-SW, ENE-WSW joint sets.
3. The most important joint sets in the Poszukiwaczy Skarbów Cave are latitudinal and conjugate with them NE-SW joints, which controlled the development of the main chamber and most of the corridors.
4. The development of the Groby Cave largely depended on the base of sublatitudinal (WSW-EE) and NNE-SSW joint sets. Inlet chamber formed in this place due to the overthrust desintegrated rocks there.

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Abstract

Jaskinia Poszukiwaczy Skarbów i Jaskinia Groby zlokalizowane są w Tatrach, w dolnej, zachodniej części Wąwozu Kraków. W jaskiniach wykonano pomiary orientacji struktur tektonicznych. Następnie wykonano analizę strukturalną, która pozwoliła wyznaczyć 4 główne zespoły spękań: 157/85 (max.I), 143/63 (max.II), 58/63 (max.III), 304/70 (max.IV). Udział poszczególnych zespołów spękań w obu jaskiniach był zróżnicowany. W Jaskini Poszukiwacz Skarbów najistotniejszy w rozwoju jaskini jest zespół spękań równoleżnikowych. Jego sprzężenie ze spękaniami III. maksimum uwarunkowało rozwój głównej komory. Spękania maksimum III są również istotne w rozwoju Jaskini Groby. Sprzężone z zespołem spękań max. IV determinowały kierunek korytarzy jaskini. Komora wstępna w Jaskini

Groby założona jest na nasunięciu, które przyczyniło się do dezintegracji skał i ułatwiło rozwój sali.

Keywords: jaskinie, tektonika, Tatry, autochtoniczna seria osadowe, spękania.