

The Geological Setting of Križna jama

by

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Zusammenfassung

Geologisch gesehen liegt die Križna jama in einer Synklinale zwischen dem Bloke-Plateau und der Idrija-Störungszone. Die ältesten Gesteine in dieser Synklinale sind aus der Oberen Trias, die jüngsten stammen aus dem Oberen Jura. Dazwischen liegen Serien von Kalken, die entweder geschichtet sind, Linsen und Dolomitnester aufweisen. Die Gesteine in der Synklinale sind nur wenig gestört, doch zeichnen lokale Störungen gemeinsam mit tektonisierten Schichtflächen für die Entstehung einiger Passagen der Križna jama verantwortlich. Letztere liegen vor allem in Kalken des Unteren- bis Mittleren Jura, wohingegen nur die Passagen am äußersten nordwestlichen Ende in der Kontaktzone mit oder aber bereits in Dolomiten des Unteren Jura liegen. Die Speläogenese der Križna jama ist auch abhängig von den obertriassischen Dolomiten, da diese das Oberflächenwasser des Bloke-Plateaus ableiten und dadurch die Hydrologie sowie die allochthonen Sedimente in der Križna jama beeinflussen. **Schlüsselwörter:** Križna jama, Geologie, Kalke, Slowenien

Summary

From the geological point of view, Križna jama is located in a syncline between the Bloke plateau and the Idrija fault zone. The oldest rocks in this syncline are Upper Triassic dolomites, while the youngest are Upper Jurassic limestones. Between them are series of limestones with strata, lenses or nests of dolomites. The syncline shows relatively weak faulting but local faults, together with

tectonized bedding planes, can guide the formation of some Križna jama passages. The latter are mainly located in Lower-Middle Jurassic limestones, while only the passages at the furthest north-eastern end are located at the contact with (or already in) Lower Jurassic dolomite. The speleogenesis of Križna jama also depends on Upper Triassic dolomite since this drains surface water on the Bloke plateau and affects the hydrology of Križna jama and allochthonous sediments in it.

Keywords: Križna jama, geology, limestone, Slovenia

Izvleček

Križna jama je geološko gledano umeščena v sinklinalo med Bloško planoto in Idrijsko prelomno cono. V sinklinali so najstarejše kamnine zgornje triasni dolomiti, najmlajše pa zgornje jurski apneneci. Med njima se nahaja serija apnencev, v katerih se mestoma pojavljajo plasti, leče ali grozdi dolomita. Blok je tektonsko relativno slabo razlomljen, čeprav lahko lokalni prelomi skupaj s tektoniziranimi ležniki lokalno vplivajo na potek podzemnih rogov Križne jame. Slednji ležijo večinoma v spodnje in srednje jurskem apnencu, le skrajni severovzhodni deli se dotikajo oz. že ležijo v spodnje jurskem dolomitu. Na oblikovanje Križne jame vplivajo tudi zgornje triasni dolomiti na Bloški planoti, saj s površinskim zbiranjem vode vplivajo na hidrološke značilnosti Križne jame ter pojav alohtonih sedimentov v njej.

Ključne besede: Križna jama, geologija, apnenec, Slovenija

1. Previous Investigations

The first geological observation of the entrance part of Križna jama (up to the first lake) is closely related with palaeontological research in the cave. Therefore it was done by Austrian geologist Ferdinand von Hochstetter in 1881, who digged out more than 2,000 bones of cave bears at the end of 19th century. MILOVANOVIČ (1937, ex

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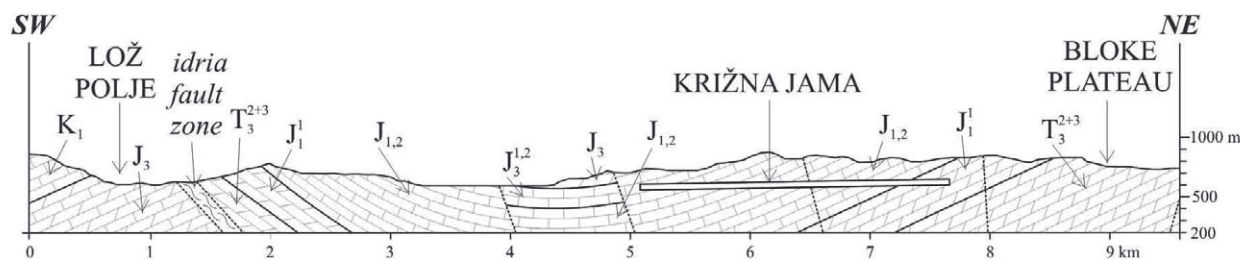


Figure 1: Schematic geological cross-section perpendicular to the syncline's axis (Bloke plateau-Lož polje) with position of Križna jama (modified after GOSPODARIČ, 1974).

PLENIČAR, 1953) investigated liasic limestones in the SE periphery of Cerknica polje that is wider area of Križna jama. In 50-ies the wider area of Cerknica polje was investigated by geologist PLENIČAR (1953). The main purpose of his work was to define geological structure of Cerknica polje. About 62 boreholes were drilled at that time in the bottom of Cerknica polje and also some lithological and tectonical studies were done by PLENIČAR (1953). And finally, wider area around Križna jama was mapped and described in the framework of Yugoslav Elementary geological map, which was done for this area between 1959 and 1963. The geological settings are presented on the geological maps Ribnica and Postojna in the scale 1:100,000 and in the Commentary of Elementary geological maps (BUSER, 1965; PLENIČAR et al., 1970). Later on the area between Bloke plateau, Cerknica and Lož polje was studied by GOSPODARIČ (1974) from geological and karstological point of view. He made some significant conclusions on stratigraphical, sedimentological and tectonical conditions of this area. Geological observation of inner parts of Križna jama was primary done by first cavers (semi-speleologists; PLANINA, 1965; PUC, 1986), in 70-ies by GOSPODARIČ (1974) and later by PRELOVŠEK (2006).

2. Litostratigraphy

The carbonate block between Bloke plateau, Cerknica and Lož polje is composed of relatively simple sequence of carbonate rocks of Upper Triassic to Upper Jurassic age. Generally, strata are not much moved in horizontal or vertical direction but they are significantly bended in so called Dinaric (SE-NW) direction. This bending produces a simple syncline (Fig 1). On the surface syncline is recognized by a sequence of carbonate rock that grows progressively younger toward the axis of syncline. The youngest rocks are therefore found at the fold's axis and the oldest more than 2.5 km from the syncline axis. Entrance of Križna jama lies only 1 km NE from the syncline's axis, therefore the strata dip in Križna jama is about 25 degrees toward SW (GOSPODARIČ, 1974). In the longitudinal section (NW-SE) syncline is beginning near Cerknica and continues through Križna jama toward syncline of Racna gore. On Racna gora the axis of syncline is composed of even younger, Lower Cretaceous carbonates.

Southern and western part of Bloke plateau is completely composed of Upper Triassic rocks. This very thick layer of light grey dolomite is due to low hydraulic gradient and tectonic deformations non permeable for water. Two main brooks appear at Bloke plateau, which are important for the aquifer around Križna jama – Bloščica and Farovščica. Because of thickness and tectonic movements, complete thickness of Upper Triassic dolomite is difficult to measure – it is just estimated from 750 to 1,500 m (BUSER, 1965; PLENIČAR et al., 1970). Its low resistance to physical weathering produces usually parallelepipedic gravel (PLENIČAR, 1953) which completely covers compact base layers of dolomite and produces thicker soils in comparison with limestones. On steeper slopes dolomitic soils creep to hill's foot and produces well-expressed colluviums. Such colluviums can be easily noticed at Bloke plateau and below Slivnica mountain. High rates of physical weathering results in low-energy and quite leveled Bloke plateau. In Upper Triassic dolomites caves are quite rare; usually they develop as ponors where dolomites are fractured but not tectonically crushed. Higher degree of tectonic crushed Upper Triassic dolomites can be found on the SW side of syncline near the Idria fault zone where it acts as hydrological barrier. Fossils due to secondary dolomitization are absent (PLENIČAR, 1953).

Lower Jurassic dolomite unconformably lies on Upper Triassic dolomites. Due to syncline structure dolomites are exposed on the surface as two stripes: northeastern and southwestern. On northeastern stripe are placed settlements Bločice, Bloška Polica and part of the settlement Grahovo and on the southwestern Goričice, Podcerkev and part of the settlement Stari trg pri Ložu. From the viewpoint of physical weathering, Lower Jurassic dolomites are similar to Upper Triassic dolomites. Therefore, outcrops of this light grey and bituminous dolomite on the surface are quite rare. Because of its composition (cemented fine-grained particles), incomplete solution produces fine-grained sand, which is incorporated in the soil matrix. In the majority of sequence fossils are rare while in some less dolomitized sequence we can find many shells of *Lithios problematica* (PLENIČAR et al., 1970). Fossil-bearing strata usually contain few millimeters thick layers of clay within bedding planes. Thickness of Lower Jurassic dolomites is estimated from 140 to 410 m (BUSER, 1965; PLENIČAR et al., 1970). Since they lie closer to the syncline's axis, 420 m of the



Figure 2: Dolomite nest (in black) in Lower-Middle Jurassic limestones as can be seen in water passage of Križna jama 2. In Križna jama dolomite nests are rarer.

upper part of Blata passage in Križna jama are developed in this dolomite (PRELOVŠEK, 2006) and probably northern ending passage of Pisani rov (GOSPODARIČ, 1974). In the Blata passage the transition between Lower-Middle Jurassic limestone and Lower Jurassic dolomite is clearly visible – limestone can be seen all the way from Kalvarija to the place 300 m northern from the Mišnica, where SW dipping limestone strata are replaced by dolomite strata dipping in the same direction. Transition occurs in few meters. It is interesting that morphology of the Blata passage is not much changed at transition, only microforms on the cave walls disappears because of dolomite's fine-grained structure. We can observe also gradual narrowing of passage from 20 m in limestone to around 10 m in dolomite. The most important strata for Križna jama are Lower-Middle Jurassic limestones, where all the passages (except 420 m of Blata passage and few tens of meters of Pisani rov) are developed. Thickness of strata is estimated from 500 to 750 m (PLENIČAR et al., 1970). Since the strata dip of Lower-Middle Jurassic limestones is not larger than 25 degrees, 7,800 m long Križna jama's horizontal passages could develop in not more than 750 m thick strata. According to Folk's classification these limestone is classified as micrite and oomicrite. Since the limestone sequence was secondary dolomitized, dolomite layers,

lenses and nests can be found within Lower-Middle Jurassic limestone. In the Middle Jurassic rocks they can completely prevail. In Križna jama Lower-Middle Jurassic dolomite is nicely visible as wall jag due to its slower dissolution rates. In Križna jama 2 they are easily recognized since they are usually covered with black (manganese or organic?) coating (Fig. 2).

Upper Jurassic carbonates lies in the axis of syncline southwestern from Križna jama. Since they are represented as dolomites and Štebrščica spring lies on the contact between Lower-Middle Jurassic limestone and Upper Jurassic dolomites we prefer those dolomites as less permeable for underground water flow. Due to lower secondary porosity they influence the piezometric water level in the hinterland and indirectly influence also on the water levels in Križna jama and Križna jama 2.

In the area between Bloke plateau, Cerknica and Lož polje Cretaceous strata are not preserved and were probably eroded by dissolution in the past. The nearest outcrops are located 5 km SE from Križna jama and do not have any influence to Križna jama.

The youngest sediments of Pleistocene and Holocene age cover karst poljes (Cerknica and Lož polje) and other closed depressions (Bloke plateau and Bločice "uvala"). In Pleistocene were deposited also the sediments which are



Figure 3: Allochthonous sediment on the corrosion shelf deposited between 1st and 2nd lake in Križna jama.



Figure 4: Collapsed zone above 2nd lake in Križna jama.

found in Križna jama as cave fillings (GOSPODARIČ, 1974). According to its lithological composition (Upper Triassic dolomite, Lower Jurassic dolomite, chert, oolitic bauxite, and Lower-Middle Jurassic limestone; GOSPODARIČ, 1974) their provenance is nearby Križna jama and in the northern part of Bloke plateau. They were deposited almost in the all passages in Križna jama up to 5 m above present-day water level. The best preserved sediments of this type are found at Križna gora and Kalvarija, where the erosion was very limited due to more than 10 m wide passages. In other parts of a cave they are presented as erosional remnants (Fig. 3). The same sediments are found also downward from Križna jama – in Križna jama 2. Present-day stream in Križna jama transports and deposits just fine sand, silt and clay. Almost all along Pisani rov, Blata passage and Jezerski/Glavni rov sinter is deposited in channel in the form of flowstone and rimstone dams.

3. Tectonic Settings

Initial development of passages is strongly related to ductile deformation of carbonate strata. Development of passages is based on rock solubility, water aggressiveness, hydraulic gradient and interconnected network of cracks.

Amongst them we can place also tectonized bedding planes since bedding planes as such are impermeable for water. They become permeable after tectonic displacement which opens the bedding plane so much, that enables the water flow along it. Therefore tectonic action is necessary for cave development.

Carbonate rocks behave differently on tectonic stress as some other sedimentary, metamorphic or magmatic rocks. Therefore ČAR (1981) distinguishes between three different tectonic zones regarding to degree of fracturization: fissured zone, collapsed zone and crushed/mylonite zone. The most suitable zone for underground passage development is the first one since it enables the water flow and still supports the stability of passage roof. Collapsed zone is suitable for water flow but when the passage grows, the stability of roof is reduced. The passage can be preserved only if the collapsed blocks are constantly removed by erosion or corrosion. Crushed and mylonite zone are usually unsuitable for passage development since the rocks are completely crushed in tectonic clay, mylonite and breccia and usually additionally clayed by turbid water flow (ČAR, 1981). Usually, such zone acts as hydrogeological barrier and directs water flow to the surface or along zone. Such a case is the central part of Idria fault, where the majority of movement occurred. Drilling into the



Figure 5: Cross section of main water passage near Ponor with well expressed bedding planes. Along bedding planes the channel was formed.

bottom of Cerknica polje showed many crushed rocks (PLENIČAR, 1953). Despite the observation of slight water flow through the bottom of Cerknica polje (PLENIČAR, 1953), crushed rocks are usually impermeable for water and this is the main cause for polje formation. Since the crushed zones are bounded with much more permeable collapsed and fissured, they are permeable for corrosive water and this enables underground flow parallelly with or perpendicularly to poljes. In such a tectonic zone lies majority of Križna jama passages. If the collapsed zones were not cemented with calcite, usually breakdowns are extensive and numerous.

Although Križna jama lies several kilometers from Idria fault zone carbonate massive between Bloke plateau and Cerknica polje did not suffer any important tectonic movement. Therefore syncline is very well preserved in the area of Križna jama. Major movement occurred 4 km southwestern from Križna jama, where syncline is cut and we have tectonic junction of Upper Triassic dolomite and Upper Jurassic limestone with very different dipping. Although, there are some minor tectonic movement nearby Križna jama, for example as fault-junction of Upper Jurassic dolomites border Middle Jurassic limestones in the axis of syncline (GOSPODARIČ, 1974). Relatively slight tectonic movements are observed also in Križna jama. Majority of these strike-slip faults have N-S direction and are initiative features for many passages, i.e. passage Ponor, passage between 3rd and 5th lake, passage between Goba and Otok. Less common but not less important are faults in northwest-southeast and northeast-southwest direction where some big collapse chambers are formed (Cerarjeva dvorana, northwestern part of Suhi rov, Križna and Kristalna gora, collapse chambers in Blata passage). At some places tectonic deformation at collapsed zone was not so intensive and the rock still supports the roof without significant breakdown (Fig. 4). Particularly important are movements along bedding planes which have strong influence on water permeability. Since they are dipping

toward southwest, they prefer water movements generally in E-W direction. Such relation between dipping of strata and water movement can be seen at Glavni/Jezerski rov by the Ponor (Fig. 5), at the lower part of Pisani rov and at the lower part of Blata passage.

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