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EXPRESSWAY CONSTRUCTION ON YOUNG KARST IN BRECCIA (VIPAVA VALLEY, SLOVENIA)

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Abstract

During precise and longterm monitoring of expressway construction characteristic but for Slovenia relatively rare karst phenomena were discovered in breccia that lie on a sloping foundation of impermeable flysch. We distinguished characteristic types of caves and initial stages in the development of dolines. The largest and most frequent are caves that developed in breccia above the contact with flysch, smaller and most often filled with fine–grained sediment are caves that occur in the middle of breccia, and of special origin are fissure caves across the slopes. Traces of continuous vertical percolation of water are less distinct. Caves also form in the flysch.
The Vipava Valley lies between the high karst plateaus of Trnovski gozd and Mount Nanos to the north and the low plateau of the Classical Karst to the south. Mount Nanos is overthrust on flysch. Below its steep western edge on the sloping flysch, scree material accumulated and consolidated into breccia that developed into a special young karst.
The surface of the slopes was formed by the mass movement and mechanical weathering of rock, which was accompanied on the flysch bedrock by landslides. Water that flowed above the flysch also dissected the slopes. The thickness of the layers of scree material or breccia varies from place to place. More or less vertical fissures developed in the breccia that indicate tensions in the slopes. During expressway construction when the laying out cuts deeply into the slope, the contact between scree material and breccia and the flysch bedrock showed an extremely fragile balance.

Keywords: karstology, expressway construction, breccia, flysch, Slovenia

1 Introduction

Karstologists have cooperated in planning and studying the construction of Slovene expressways [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22]. A large part of the expressway system runs across karst areas. Our mission is to identify and describe the newly discovered natural heritage, and our knowledge, especially about the caves in the karst, is frequently of technical help to road builders.
The Vipava Valley lies between the high karst plateaus of Trnovski gozd and Mount Nanos to the north and the low plateau of the Classical Karst to the south. Mount Nanos is overthrust on flysch. Below its steep western edge on the sloping flysch, scree material accumulated and consolidated into breccia that developed into a special young karst (Fig. 1).
During precise and longterm monitoring of mototrway construction characteristic but for Slovenia relatively rare karst phenomena were discovered in breccia that lie on a sloping foundation of impermeable flysch. We distinguished characteristic types of caves and early stages in the development of dolines.

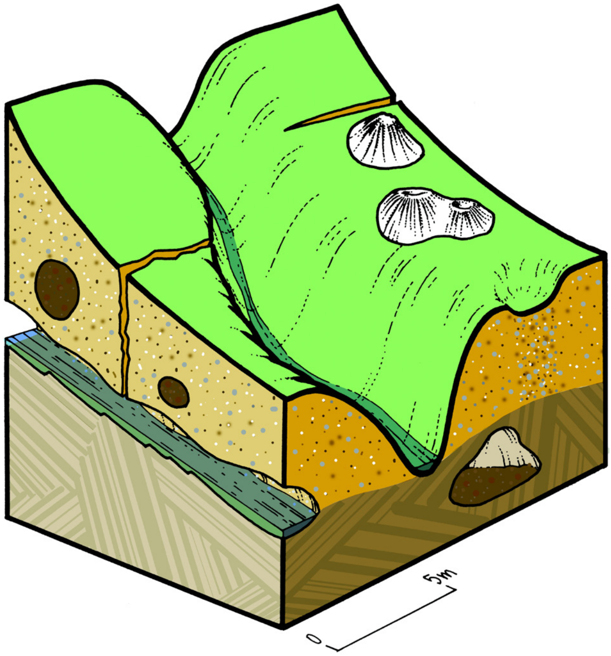

Figure 1 Karst in breccia and flysch below Mount Nanos in the Vipava Valley: surface karren, with small doline and washed belt of breccia below it and caves in breccia, at the contact and in flysch.

2 Site description

The expressway laying out runs across three geomorphologically diverse units along the southwestern slopes of Mount Nanos (Rebrnice and Breg) and the floor of the Vipava Valley. The Breg and Rebrnice slopes are distinct geomorphological units. Mihevc [23] geomorphologically mapped the slopes of Mount Nanos in detail over part of the expressway laying out that runs through the landscape park area. A specific geological thrust structure and specific slope processes and sediments are reflected here in the morphology of the slopes and in botanical anomalies. These features have led to the proclamation of a landscape park covering the southern and western slopes of Mount Nanos.

The surface of the slopes was formed by the mass movement and mechanical weathering of rock, which was accompanied on the flysch bedrock by landslides. Water that flowed above the flysch also dissected the slopes. The thickness of the layers of scree material or breccia varies from place to place. More or less vertical fissures developed in the breccia that indicate tensions in the slopes. During expressway construction when the laying out cuts deeply into the slope, the contact between scree material and breccia and the flysch bedrock showed an extremely fragile balance. After abundant precipitation, numerous smaller streams appeared along the contact between flysch and breccias revealed by the cuts. Many of these streams are exploited for water supply.

Water percolates from the surface in a more or less evenly dispersed fashion through mostly well permeable breccia to the contact with flysch. However, in individual places, traces of continuous percolation of water can be clearly seen in the cross section of breccia and scree material. These are one– to two–meter wide belts of washed scree and breccia, the beginnings of dolines. Above them, small sinkholes formed whose diameters do not exceed three

meters. They are covered with soil. The water from the surface also carries soil containing organic material that further accelerates the dissolving of carbonate rock.
Rainwater has carved rock relief forms on the larger rocks that protrude from the karst surface, the most distinct being flutes and solution pans. Mature flutes take two thousand years to develop [24]. Therefore, the surface of mass movements and landslides on parts of the slopes has not changed significantly for a long time.

3 Results

Many characteristic types of caves formed in the breccia that developed on steep and dissected flysch slopes. The largest and most frequent are caves (20) that developed in the breccia above the contact with flysch, while caves (10) that occur in the middle of the breccia are smaller and most often filled with fine–grained sediment. Fissure caves (10) that cross slopes are of special origin. Traces of continuous vertical percolation of water are less distinct. Caves (5) also occur in the flysch.
Remškar [25] collected data on caves in breccia in the Vipava Valley, specifying types of caves and their origins. He divided them into those that developed along fissures, those formed by streams of water, and rock shelters.

3.1 Caves at the contact of breccia and flysch

These are the most frequently discovered caves in this young karst. The diameter of smaller tubes measures only a decimeter while the height of the largest can reach two meters and their width three meters (Fig. 2). The largest parts of the passages are cupola–shaped widenings. These are narrower and higher along fissures. The size and shape of their cross sections varies distinctly from meter to meter along the length of the passage. In places, the shape of the cave reflects the different stages of breccia cementation. The more consolidated the breccia, the smaller the cross sections of passages are in the same conditions. The composition of the rock also dictates the fine dissection of the circumference of the passages. The floors of caves through which water flows are flysch that is only partly covered with pieces of scree material, while the floors of dry caves are covered by scree material and domes of flowstone since breccia tends to disintegrate. There are smaller stalactites on the longer enduring part of the circumference. The thicker layers of flowstone found at various heights in the cave bear witness to times when the caves were filled with fine–grained sediment.

Figure 2 Cave in breccia at the contact with flysch.

In most cases, individual passages were opened and their connection to a branched network was revealed in only a few places. The largest cave revealed was fifteen meters long. Its central part was a dome–shaped dissected passage. The diameter of the largest dome measured three meters. On the floor, which was largely covered with scree material, a larger stalagmite had formed. We did not observe any traces of water, but a small quantity of water could percolate through the scree material covering the floor of the cave.
Individual caves are filled with fine–grained flysch sediment. Water flowing along the contact carves the flysch bedrock and fills poorly permeable parts of caves. It appears that some of the caves were formed while they were in the process of filling with sediment that is preserved in places and elsewhere was washed away due to the increased conductivity of the caves. Traces of earlier fillings are found in the flowstone crusts preserved at different heights in the cross sections of passages. The lower parts of larger caves are carved deeper into the flysch rock.
Often, only smaller continuous streams that have not yet formed distinctive caves are evident in the cross sections of slopes. After abundant precipitation, they flow side by side. This is the consequence of the high porosity of breccia and its contact with flysch. In most cases, the flysch proves to be a poorly permeable rock, especially its upper layer which is weathered and clayey.
The passages of the revealed caves run down the slope. They occurred due to the flowing of water at the contact of breccia and the flysch the breccia covers. The water permeating through the scree material and breccia congregates on the sloping flysch. Conditions for the formation of caves occur along larger continuous streams. Breccia was carried away in a number of places, and smaller valleys formed alongside the streams.

3.2 Sediment–filled caves

The diameters of these caves do not exceed one meter, and as a rule they are smaller. The cross sections of the caves are more or less circular or elliptical in shape because they usually formed along the contacts between layers of different types of breccia and along fissures. They are found in all the cross sections of breccias, but primarily in the most consolidated and least porous parts of breccia. As a rule they are filled with brown sediment and soil washed from the surface by water.
The contact between the flysch at the bottom and the breccia above is not flat but distinctly undulating and finely dissected. This is the consequence of the diverse geological structure of flysch, its variously lying layers, and the erosive action of water that has flowed and continues to flow either on the contact with breccia or in smaller valleys on the flysch. Even though there is very porous karst on a slope, less permeable sections, sometimes even flooded zones, form locally and occasionally where caves form in the breccia. Sediments, mainly soil washed from the surface, are deposited in them, and the caves widen along the sediments. In one of the wells used as a foundation for a bridge, water began to appear in the breccia several meters above the contact with flysch.

3.3 Fissure caves

Fissure caves form along fissures that developed in breccia. As a rule they cross the slopes. The largest caves, which are several meters or even several dozen meters long, and in places up to one meter wide, are accessible. Most, however, are narrower and do not exceed one decimeter in width. The depth of such caves is conditioned by the thickness of the breccia layers and the characteristics of the fissure. They are shaped by the water percolating in them. Some of these caves are filled with fine–grained sediments and soil where the rock dissolves more rapidly, and the walls of other caves are coated with flowstone. The smallest caves can be completely filled with flowstone.
Caves in flysch

In addition to caves that opened at the contact of breccia and flysch, we also encountered caves that formed in the framework of flysch rock at the contact of marlstone and quartziferous sandstone and of carbonate sandstone and calcarenite.
In some places we observed significant water flow at the contact of carbonate and non–carbonate rock. The contact with non–carbonate rock is not only a water barrier but also an area where water can stagnate and where its level can fluctuate. This causes the washing and carrying away of material, changes in pressure can occur here, and the water can form larger channels. Both limestone and flysch particles are transported along these paths.
In addition, we determined in many places that a small number of underground conducting channels had formed in flysch rock. In places where flysch layers are fractured or folded, water flows along the fissures or spaces between the layers. There is a flow of water along the interbedded contacts due to the almost vertical layers. Water flowing along these contacts carries away flysch material, widens the fissures, and simultaneously periodically or laterally deposits calcium carbonate in different ways. We frequently can observe calcite fillings of fissures that are several centimeters thick. In places the fissures are completely filled, elsewhere up to one centimeter large scalenoedric calcite crystals formed in the fissures, and a number of fissures are covered by a thin (a few millimeters) coat of flowstone. In marlstone with distinctly conchoidal fractures, a number of fissures have been filled with coarse–crystal calcite. It is important to emphasize that the cement is carbonate and that a number of layers can contain much more than 10% of particles of carbonate origin. Therefore both erosion and corrosion occur when water flows through the fissures and along the faults. There is no doubt that karstification takes place to a very small extent.
Heavy weathering of the rock in the interior of the tectonically undeformed block of rock occurs along fissures and faults where the precipitation and surface water flow. Calcium carbonate (flowstone) is deposited at the majority of such contacts.
Caves formed at the contact of marlstone and calcarenite. One of the more characteristic caves of this type, measuring up to five meters in depth and width, opened to the north of the Tabor tunnel at the northwestern part of laying out. Here there are layers of dark grey to black marlstone from a few dozen centimeters to half a meter thick that due to their solidity have a clearly visible conchoidal fracture. The calcarenite is heavily fractured so that numerous calcite veins further increase the content of carbonate. Because the layers have a dip between 70° and 90°, the water passes easily between the layers. Although the calcarenite layers are being intensely dissolved by rainwater, larger cavities or even caves do not form due to the fractured rock.

4 Conclusion

The geological, geomorphological, speleological, and hydrological diversity of Slovenia's karst has been demonstrated also by the study of the karstification of breccia that formed beneath the western slopes of Mount Nanos. Water, in most cases percolating diffusely through the permeable surface of scree material or breccia to the more or less impermeable flysch bedrock, creates young karst phenomena.
Rainwater covers large rocks on the karst surface with flutes and solution pans. Fissures crossing the rock in the direction of the slope indicate tensions in the rock mass and its exposure to sliding. Breccia and scree material lie on slanting flysch, and the majority of water flows along the contact causing their instability.
The percolating water collects where the breccia is most consolidated. Earthworks have revealed the early stages in the formation of unique dolines.
Characteristic types of caves developed in the young and very porous breccia, which is consolidated only in places, lying on the more or less slanting flysch, an impermeable bedrock. The true karst caves are small and their development was influenced by the sediment that as a rule fills them. They formed in a locally and periodically flooded zone and they are often

paragenetically enlarged. The largest caves formed above the contact with the impermeable flysch bedrock where the largest streams join. Their shape reflects the varying degrees of consolidation of the breccia. In areas where the breccia is less solid and along fissures, they rise into domes. Along fissures that are the consequence of the sliding of breccia and scree material down the slanting bedrock of frequently saturated flysch, fissure caves formed across the slope; some of them are very long and wide enough in places to make them accessible. As a rule, their walls are covered with flowstone.
To a very small extent, karstification also takes place inside the flysch where the marlstone or sandstone contains at least calcite cement. Karstification at the contacts of marlstone and calcarenite, where caves several meters in size form, is more significant. In places with almost vertical layers, water quickly percolates into the underground, but the heavily fractured layers hinder the formation of larger caves.
Although the described karst is relatively young, discovered in its early development stages, it still reveals all the characteristics of the karstification of breccia in characteristic geological, geomorphological, and hydrological conditions. Good understanding and knowledge of geological and karstological conditions is the base for future planning and interventions in the karst.

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