

## Cave sediments and tectonic movements: records in gypsum karst of the Prut River valley

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The allochthonous cave sediments usually contain different paleogeographical records. The most common records are sediments, pollen, bone remains, and paleomagnetic records. We studied the section of cave sediments in Zolushka Cave.

Zolushka (Popeliuszka, Emil Rakovica) Cave is a huge maze in Miocene gypsum, 92 km long, in the border zone between Ukraine and the Republic of Moldova, on the right bank of the Prut River valley. Tectonically it is situated on the eastern edge of the Novoselytsia tectonic depression. The territory has a block structure and consists of a series of different size blocs at different elevations.

It was discovered in 1977. The entrance was outcropped by the industrial production of gypsum by a quarry between villages Criva on the Moldova side, and Podvirne on the Ukrainian side. Besides the large dimensions of galleries, the cave differs from other huge gypsum labyrinths such as caves Optymistychna, Ozerna, Mlynky, and others, with the fact that by the recent time most of the cave was below the water table. Only after the beginning of gypsum exploration in the 1950s, the groundwater table was decreased up to 28 m. Only 2-3 m of the gypsum strata were naturally bedded above the groundwater table. The karst process touched all thicknesses of the sulfate strata because the cave system is of hypogenic origin and was developed by the waters from the underlying aquifer. The regional geological and karstological settings were described in detail by (Andreychouk, 2007; Klimchouk and Andreychouk, 2017).

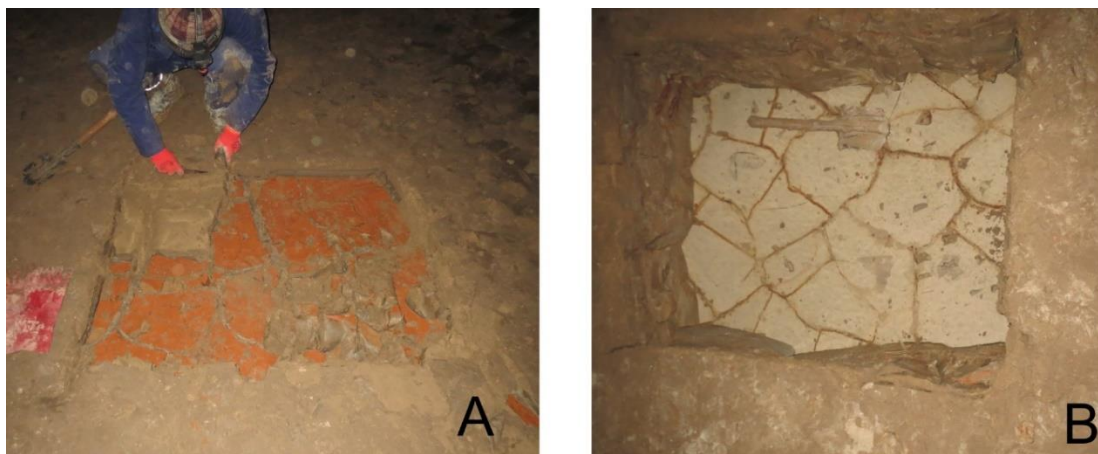
A significant part of the cavities is filled with allochthonous sediments represented with almost only clay. In one of the widest places of the maze, in the Chernivtsi Cavers' Chamber, in the clayey sediments, we dig a prospection pit with the next sequence (Table 1).

**Table 1** Description of cave sediments

Depth, m	Layer description
0.0 – 0.075	light brown, massive loam (redeposited paleosol from the nearby collapse cone), with smears of yellow loess. On the contact - "parquet" – a polygonal structure.
0.075-0.47	soft plastic thinly laminated clay
0.075-0.18 (0.075-0.125)	dark gray clay, light gray below. On the uneven contact of dark and light gray clay, an interbed of red ocher 1 mm.
0.47	an interbed of dusty white quartz sand up to 1 mm.
0.47 – 0.7	the same layering of laminated light gray and yellow clay.
0.7 – 0.74 (0.8)	clay is light brown, lumpy, with manganese oxide at the contacts of the lumps.
0.74/0.8 – 0.87/0.9	brownish-yellow sandy loam, hidden layered
0.9 – 0.94	lumpy loam / clay

Depth, m	Layer description
0.94 – 1.1	sandy loam
1.1 – 1.14	yellow loess
1.14 – 1.53	gravel-sand
1.53 – 1.73	greenish-gray clay, rigid plastic, massive
1.73 – 1.83	rigid plastic yellow clay, at 1.83 – an interbed of ferrugination with drying “parquet”. The surface of the “parquet” - the floor is inclined to the middle of the gallery by 10-15° - the evidence of sediments subsidence at the center of the gallery.
1.83 – 1.9 (2.0)	greenish-gray, rigid plastic to semi-hard clay. At 2.0 (1.9-1.8) with a slope, a layer of ferrugination over the carbonate ash with traces of manganese oxide.

In the north wall, at 1.65 m, can be seen a layer of carbonate plates – a so-called “drapery” that fell from the wall or the ceiling, the same in the eastern wall - a block of the “drapery”. So, the sediments consist mainly of thin-laminated clays of grey, brown, and brown-grey clays. The clay usually is mild. Partly, in the upper part of the sequence, it was dried, decreased in volume, and therefore cracked by the dehydration fissure on the polygons. At the depth of 7.5 cm, it was a very thin interlayer, bear 1 mm thick, of red clay (Fig. 1, A). 47 cm below the floor surface the clay thickness was interrupted by a very thin (nearly 1 mm) interlayer of the fine white quarts (Fig. 1, B). The sand was bedded on the ancient clay floor, also dissected by polygonal fissures. The clay is the product of a very slow erosion of the overlaying Neogene marine clays, that collapse from time to time inside the cave, forming huge collapse cones. The breakdown mechanism in the cave was described by (Klimchouk and Andrejchuk, 2002). Initially, this white quartz sand is bedded below the sulfate strata. The only explanation for the uprising of sand is its liquification at the moment of the ancient seismic event, and the injection of this pulp upwards through the cracks in the sediments.



**Figure 1** Polygonal structures in the sediments of Zolushka Cave. A – ferrugination interbed at the depth of 7.5 cm; B – quartz sand interbed at the depth of 47 cm.

The three layers with polygonal cracks of dehydration, at the level deep below the natural water table, show us that previously the tectonic block containing the cave was at a much higher altitude, and the cave floor was dried from time to time. The block significantly descended during the Quaternary. The physical dating of the mentioned sediments and their paleomagnetic, palynological, and mineralogical studying will allow us to know the time of such a strong earthquake, as well as to estimate the time and speed of the tectonic block descending.

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