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Cupola-related morphology of the Mesolakkia Caves, Greece

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Cupola is a term that describes dome-shaped solution cavities and they are accompanied by several features such as terraces, cusps, pendants, pillars, rock bridges etc. Their formation has been attributed to a number of processes summarized by Osborne (2004) and thus they are considered as polygenetic (Dublyansky, 2013).

A brief description of the Mesolakkia caves along with a data set with cupola dimensions and images are given. Furthermore, the process of speleogenesis is discussed on the basis of the morphological observations.

Methods

The study of the Mesolakkia caves is based on their morphological features. They are surveyed in two and three dimensions using standard and paperless speleological mapping techniques (i.e. Kalogeropoulos *et al.*, 2008; Trimmis, 2018 and reference therein). Laser distance meter and Suunto compass were used. Rock discontinuities measured with a Clar compass. Identification and interpretation of morphological features follow Lauritzen and Lundberg (2000), Gunn (2004), Ford and Williams (2007), White and Culver (2005) and of speleothems follow Hill and Forti (1997).

Cave description and morphology

Three caves have been found to be opened in the marble of the Pangeon Unit (Rila-Rhodope Massif). These are the Disakia Cave, Small Disakia Cave and Disakia shelter-cave, considered all together part of a uniform cave system, called below Disakia Cave System (DCS).

Disakia Cave: is a relatively small cave. Its entrance is a 3m deep pothole. It consists of (Fig. 1) small rooms and fracture-guided passages of NW-SE direction that are interconnected to each other with small SW-NE passages and windows. Some passages are characteristically high and narrow (Fig. 1F). There is also a number of abruptly terminating passages.

The predominant solution feature noticed are the cupolas that are formed in side-walls and mainly the ceiling. Most of them found to be unrelated to rock fractures and generally wide. Thus, their horizontal diameters appear to be larger than that of the vertical axis. Inside these concave features corroded speleothems, such as stalactites, flowstone and draperies are commonly present. Their length (largest horizontal diameter) ranges from 0.51 to 2.20 m and their width from 0.36 to 1.9 m. Their height is only 0.15 to 0.90 m. Their mean shape is 0.97x0.80x0.48 m. Apart from the small-scale cupolas, there are some cupola-like rooms. In addition terraces, notches, cups, pendants and similar forms are also present.

Cave decoration consists of calcite speleothems that in most cases appear to be corroded or damaged and broken by visitors. It is worth to mention that the cave, and especially its deepest parts display numerous inscriptions with mainly names and in some cases dates. They seem to be of the 20th and 21st centuries but the presence of older inscriptions cannot be excluded since a detailed record of them is pending.

Table 1. Small-scale cupola measurements from the Disakia Cave.

Length(cm)	60	125	120	60	61	51	220	92	83
Width(cm)	36	100	100	57	49	36	190	74	81
Height(cm)	37	90	50	37	27	35	60	15	80

Small Disakia Cave: The entrance of this cave is a small opening on a steep escarpment. Close to the entrance the passage is short and partially filled with fine-grained sediment. In the deepest part there are two rooms interconnected to each other with a small window-like passage, located about two meters higher than the cave floor. The last room is the largest one and displays cupolas and related forms that cut evenly the bedrock and speleothems. The floor in filled with guano.

Disakia shelter-cave: Between the above mentioned caves there is a small cavity presently forming a shelter-cave. This small cave remnant has a diameter of few meters and its walls and ceiling consist a chain of cupolas (Fig. 1D).

Discussion

In the absence of geochemical evidence in DCS, the interpretation of speleogenesis can be grounded only on morphological criteria. In the broader area there are both epigene and hypogene caves (Lazaridis, 2017). DCS consists of chambers interconnected with passages and blind galleries that form a ramiform pattern in ground-plan (see Palmer, 2000). This pattern is indicative of phreatic speleogenesis and genetically placed between spongework and network caves, that means caves formed in mixing zones by aggressive waters of low flow velocity (diffusion dominates) and caves formed mainly related to hydrothermal activity (Dublyansky, 2013). Orientation of passages is strongly affected by discontinuities of the bedrock and especially the more or less vertically dipping groups of joints. Meso-scale features, such as pendants, pillars, cups, terraces, ridges, notches and the predominant forms cupolas that occur on the bedrock are

probably related to the main phase of speleogenesis. Small-scale cupolas and the related solution features that intersect vadose speleothems indicating a post-phreatic process due to condensation corrosion. Other, vadose dissolution forms and forms developed in concentrated lateral flow, such as scallops, are absent in DCS.

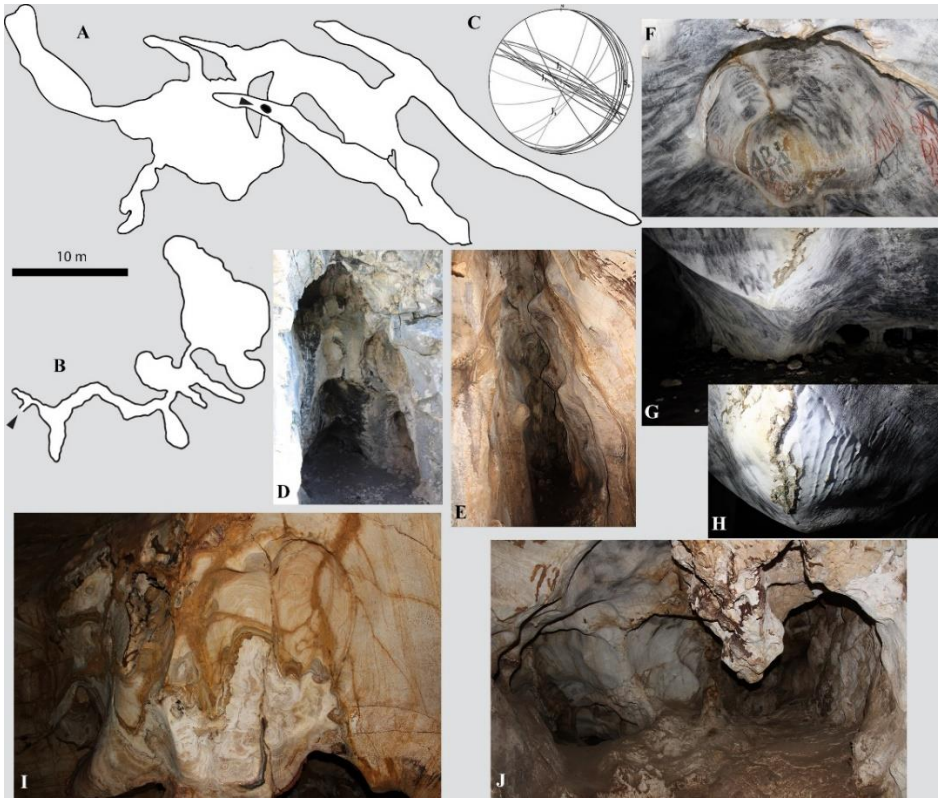

Figure 1. A. Ground-plan of Disakia cave; B. ground-plan of small Disakia cave; C. Schmidt diagram of rock discontinuities; D. view of Disakia shelter-cave; E. narrow and high fracture guided passage in Disakia cave with cusps and terraces related to cupolas; F. typical flat and wide cupola in Disakia cave; G. cusp and ridge separating cupola-shaped rooms in Disakia cave; H. detail of corrosion on the wall of G; I. cupola that evenly intersects the rock and speleothems in small Disakia cave; J. pendant and partitions in small Disakia cave.

Concluding remarks

The meso scale cupolas that form chambers and (e.g. Disakia shelter-cave) and the cave pattern indicate a phreatic origin and dissolution by convecting water bodies. A relation to the hydrothermal speleogenetic phase that has been affected the area (Lazaridis, 2017) cannot be excluded.

Small-scale cupolas and the corroded speleothems are due to condensation corrosion that is post-phreatic but not necessarily distinguished from the speleogenetic process; i.e. hydrothermal speleogenesis.

Further speleological exploration and geological investigation in the broader area could provide more evidence for the speleogenesis.

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