15th International Congress of the Geological Society of Greece
Athens, 22-24 May, 2019 | Harokopio University of Athens, Greece
Bulletin of the Geological Society of Greece, Sp. Pub. **7** Ext. Abs. GSG2019-054

Paleo-hydrology of the Stefanina Cave (Greece)

G. Lazaridis[1], K. Fellachidou[1]

(1) Aristotle University of Thessaloniki, Department of Geology, Laboratory of Geology and Palaeontology, 54124, Thessaloniki, Greece, geolaz@geo.auth.gr

The hydrological conditions and development of the epigenetic Stefanina Cave and the maximum paleo-flow discharge in its main passage are investigated on the basis of cave pattern, passage geometry and scallop length.

Scallops are small-scale morphological features that form asymmetric dissolution pockets due to turbulent flow of a solvent over a soluble surface. Caves are ideal environment for the formation of scallops that indicate forced flow of unsaturated water along a pressure head. In deep-phreatic setting, where dissolution takes place by convecting water bodies, scallops are absent. Furthermore, these pockets are also indicators of flow direction due to their asymmetry and a reverse relationship between their size and the flow velocity of the fluid (Curl, 1966; Curl, 1974; Lauritzen, 1989).

The Stefanina Cave or Lakkia Cave (N40.78183 E23.61357 WGS84; Fig.1) is located NE of the Stefanina Village at about 850 m above sea level (a.s.l.) in the northern slope of the Neromanna stream. The area consists of metamorphic rocks such as marbles and gneisses in alternations that belongs to the almost 3 km thick Kerdylion Series of the Serbomacedonian Massif. The cave is opened in the "upper marble horizon" (20-350 m thick) with white marble (coarse crystalline thick layered), bluish crystalline limestone (fine-grained, thin bedded) intercalated with schists, amphibolites and gneisses.

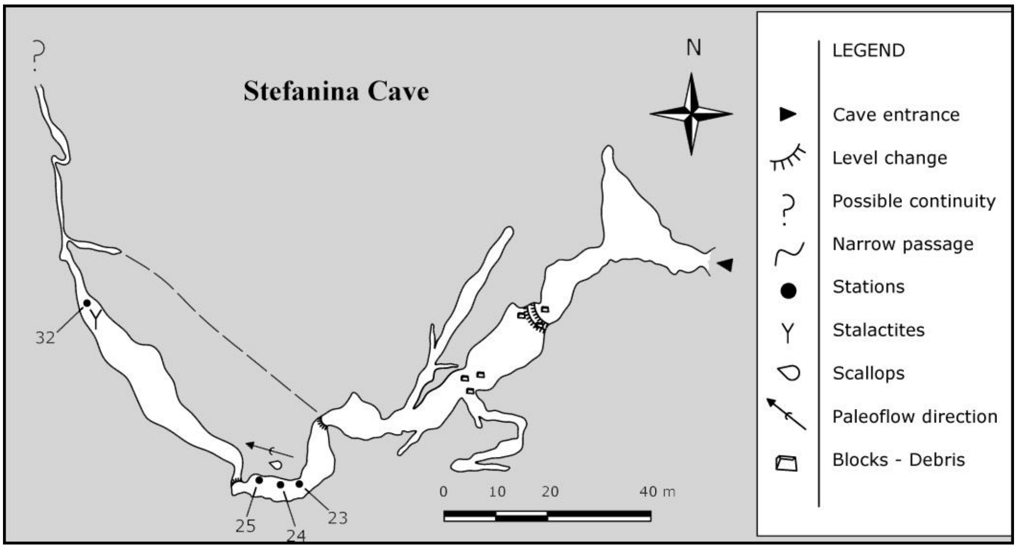

Figure 1. Ground-plan of the Stefanina Cave

Methods

The cave surveyed according to standard cave techniques (i.e. Kalogeropoulos *et al*., 2008; Trimmis, 2018 and reference therein). Rock discontinuities were measured with CLAR compass. Terms and morphological descriptions of caves can be found in Lauritzen and Lundberg (2000), Gunn (2004), Ford and Williams (2007), White and Culver (2005). The gathered data were processed in the spreadsheet program ScallopEx (Woodward and Sasowsky, 2009). The calculations run for 5°C water temperature. The estimated flow velocities were statistically analysed in the software PAST 3.2 (Hammer *et al*., 2001).

Description and results

The explored part of the Stefanina Cave is 210 m long and covers an area of 1250 m^2. Total passage length is 325 m and forms a branchwork horizontal pattern (Palmer, 2000). The height difference between the entrance and the deepest explored part is about 30 m, giving a hydraulic gradient about 0.2. At about 120 m from the entrance a meandering vadose canyon is formed and sediment fill has been eroded revealing the carbonate bedrock. After that point the conduit forms a keyhole passage in cross section and becomes gradually narrow and more canyon like (Fig. 2).

In figure 1 survey stations 23-25 where scallops measured are depicted. In addition, a number of measurements are taken between and after these stations. In total about 400 scallops where measured in 30 locations, at different heights inside the passage. The estimated peak flow velocity ranges from 0.4 to 2.7 m/s (mean=1.32; s=0.46, n=30; Fig. 2E). The null hypothesis of normal distribution cannot be rejected. The highest and lowest values appear as outliers. However, the smaller values have been found inside the meandering canyon at locations inside of bends, where lower values are expected. Based on these values and the dimensions of the passage measured from the cross sections, a peak flow discharge equal to 2.2 m^3/s is estimated.

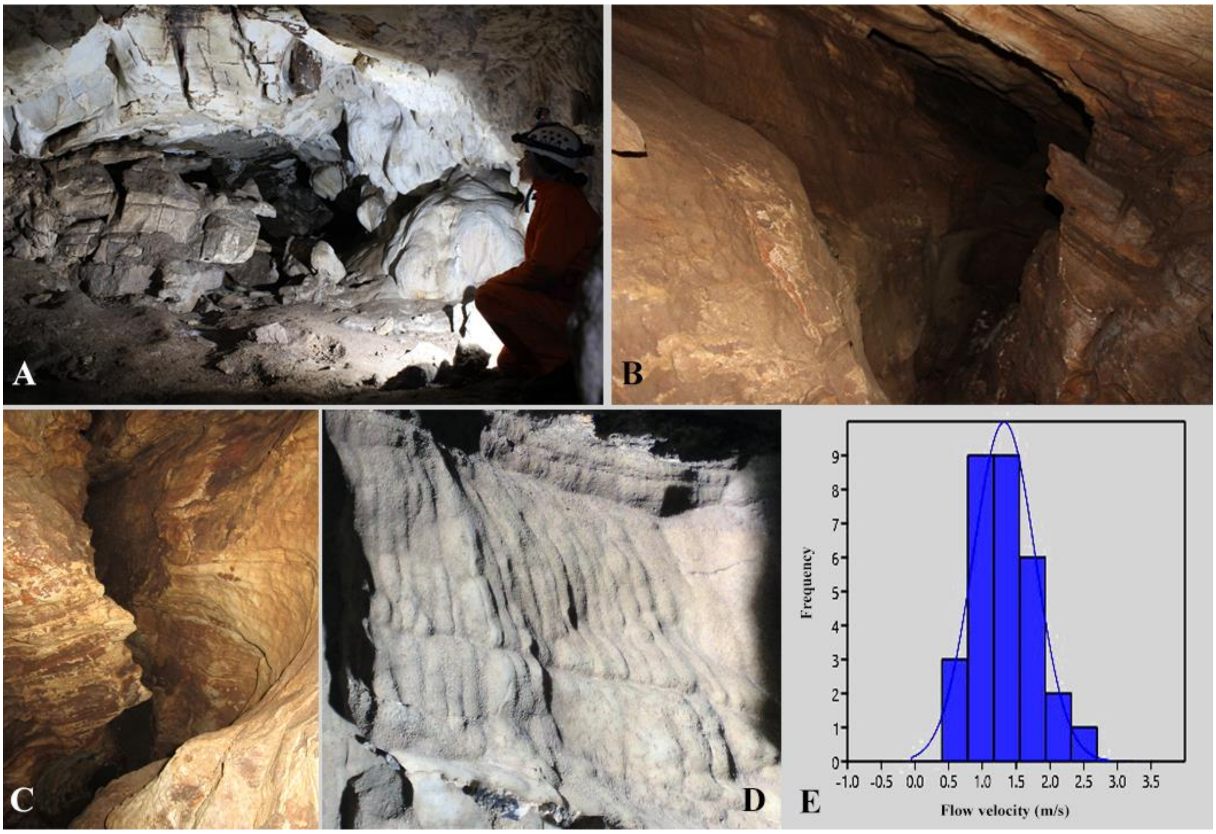

Figure 2. A. View of the main passage at the upstream part of the cave; B. Keyhole section with the phreatic upper and the vadose canyon power part; C. bend in the meandering channel; D. wall detail with scallops; E. histogram with scallop-based estimations of flow velocity in the area of survey stations 23-25.

Concluding remarks

- The Stefanina Cave has a branchwork pattern in ground-plan that is commonly related to recharge via karst depressions (Palmer, 2000). The passages are both curvilinear and angular, related to foliation and fractures, respectively. It is mainly developed along the foliation of the host rock.
- The cross section in the upstream part of the cave indicates a phreatic passage.
- The keyhole cross section found in that canyon passage at about the middle part of the explored cave, is indicative of a second stage of developed after water table drop.
- The peak discharge estimated in the keyhole cross section is indicative for that area and it is expected to be higher further inside the cave due to the existence of lateral passages.

References

Curl, R.L., 1966. Scallops and Flutes. Transactions Cave Research Group of Great Britain, 7(2): 121-160.

Curl, R.L., 1974. Deducing Flow Velocity in Cave Conduits from Scallops. National Speleological Society Bulletin, 36(3): 22.

Ford, D., Williams, P.D., 2007. Karst hydrogeology and geomorphology. John Wiley and Sons Inc.

Hammer, Ř., Harper, D.A.T., & Ryan, P.D., 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis–Palaeontol. Electron, 4: 9.

Kalogeropoulos, I., Lazaridis, G., Tsekoura, A., 2008. Methodology of cave mapping: comparing routings. 4th Pancretan Speleological Symposium. Hellenic Speleological Society, Rethymnon, Crete, Greece http://ese.edu.gr/media/seminars/sem_notes/hartografisi/survey_methods.pdf

Lauritzen, S.E., 1989. Scallop Dominant Discharge. Proceedings of the 10th International Congress of Speleology, Budapest, Hungary, 123-124.

Lauritzen, S., Lundberg, J., 2000. Solutional and erosional morphology of caves. Klimchouk, A., Ford, D.C., Palmer, A.N., Dreybrodt, W. (eds.) Speleogenesis. Evolution of Karst Aquifers. Huntsville: National Speleological Society.

Lazaridis, G., 2017. Hypogene Speleogenesis in Greece. In: Klimchouk, A., Palmer, A.N., De Waele, J., Auler, A.S. & Audra, P. (eds.) Hypogene Karst Regions and Caves of the World. Springer, 225-239.

Palmer, A., 2000. Hydrogeologic control of cave patterns. Speleogenesis: Evolution of Karst Aquifers. Huntsville: National. Speleological Society, 77-90.

Trimmis, K.P., 2018. Paperless mapping and cave archaeology: A review on the application of DistoX survey method in archaeological cave sites. Journal of Archaeological Science: Reports 18, 399-407.

White, W.B., Culver, D.C., 2005. Encyclopedia of caves, Elsevier Amsterdam (The Netherlands).

Woodward, E., Sasowsky, I.D. 2009. A spreadsheet program (ScallopEx) to calculate paleovelocities from cave wall scallops. Acta Carsologica, 38(2-3): 303-305.