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. GSG2019-053

Drawing a paragenetic cave passage in MatLab

G. Lazaridis[1], D. Voulanas[2]

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

Paragenesis (Roth (1937; Renault 1958; 1968; Ford 1971; Ford and Ewers, 1978; Lauritzen and Lauritsen 1995; Bella and Bosák, 2015) is a poorly understood process of cave passage upwards enlargement that results in a variety of geomorphological features. It is observed in phreatic cave systems, when groundwater velocity reduces resulting in permanent deposition of transported sediment that protects the lower part of the passage from dissolution (only negligible dissolution has been observed; i.e. Vaughan, 1998). Theoretically the process is limited upwards to the water table. Such passages are known from caves in carbonates, gypsum and salt (i.e. Frumkin, 1998; Pasini 2009, 2012). Paragenesis has been considered related to periglacial environments (Farrant and Smart, 2011; Lauritzen, 2013).

Although, most authors consider paragenesis as a result of dissolution, others (Roth, 1937; Kunský, 1950) a result of mechanical erosion and Pasini (1975, 2009), uses the term “erosion” sensu lato, including mechanical erosion, physical dissolution and corrosion. Farrant and Smart (2011) reviewed the role of alluvation and paragenesis in speleogenesis. However, direct observation on paragenetic processes is obscured either by sediment filling or by their phreatic nature.

The aim of this study is to geometrically reproduce the cross-section shape of a paragenetic canyon in order to investigate the controlling factors of the process.

Methods

In order to investigate the development of a paragenetic passage a geometric perspective is applied in Matlab. The first step starts with the cross section of a circular phreatic passage and the following steps represent the sum of three agents, deposition, corrosion, and corrasion that act simultaneously on the perimeter of the cross section. At the first step, deposits cover the half of the passage height and shields the lower part from corrosion and corrasion. This is an assumption in order to simplify the computations. Although dissolution occur on the covered by sediment passage and within the sediments, its action has been found to be negligible in comparison with the rest passage (Vaughan, 1998) and thus it is ignored. Corrosion acts isotropically at the wet perimeter of the fully flooded passage and actually it is set at a well-accepted maximum of 0.1 mm/year. Corrasion is considered to act upwards due to buoyancy of suspended load. A heterogeneous flow regime with stratification and formation of a bottom layer, mainly stationary is assumed. The abrasion by suspended sediment and kinetic energy flux are estimated according to Anderson (1986); for the relation of suspended sediment and flow velocity a data series from the Blue Hole spring, Central Kentucky, USA is used (Reed et al., 2010). Sediment supply is considered uninterrupted.

Illustration of the passage development done in MATLAB environment, attempting to describe the geometrical evolution of the points and the ceiling trace seen in Figure 2. The passage width at each step n is defined as the intersection of the sediment level and the cave ceiling (flooded part of the passage cross section) of the n-1 step. The ceiling is traced as the sum of corrosion and corrasion. Both agents are related to fluid velocity. Sediment level is set as a pseudo-random percentage of the water-filled part of the passage at n-1 step.

Results

The cross-section of the passage is drawn first as the result of dissolution that gave a continuously widening upwards passage. This shape differs significantly from what is the canyon-like shape of a paragenetic passage. Then the calculation is repeated with the contribution of erosion *sensu lato* that acts upwards. In this case the result resembles a paragenetic canyon. This is due to the high rate of erosion that is higher than that of dissolution. Furthermore, the rate of erosion *s.l.* is only indicative since the data for the suspended load come from a spring during flood. However, a key point on these results is that dissolution is directly related to flow velocity, whereas abrasion scales with flow velocity to the fifth power (Whipple et al., 2000). The results are intriguing and largely based on the initial assumptions for the calculations. However, there are some studies on abrasion and dissolution rates in cave passages, such as Newson (1971). In the Cheddar cave in Mendip dissolution is found to be 75 times higher than abrasion, except of years of significant flooding events where abrasion was two times higher than dissolution. Although this seems to be insignificant it is the result of mainly only one flooding event in a year, whereas paragenesis takes place in phreatic fully flooded caves, where these conditions are permanent. Cooper et al. (2014) have similarly shown the paragenesis as the result of dissolution and mechanical erosion.

Conclusions

- A cross section of a paragenetic canyon is drawn in MatLab by using geometrical relations of passage’s key points, equations for abrasion process and empirical data.
- This concept supports that paragenetic canyon is explained by high erosion s.l. rate.
- In contrary to dissolution, which is directly proportional to flow velocity, abrasion scales with flow velocity to the fifth power.

- Flood-like conditions favour paragenesis, as it is shown by the necessity for high abrasion rates.

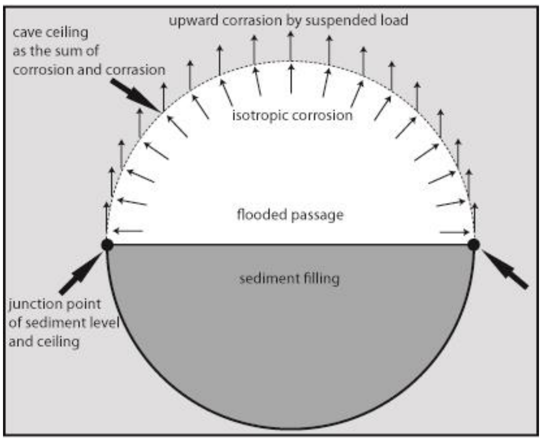

Figure 1. Sketch showing the basic concept of geometric development of a phreatic passage during paragenesis.

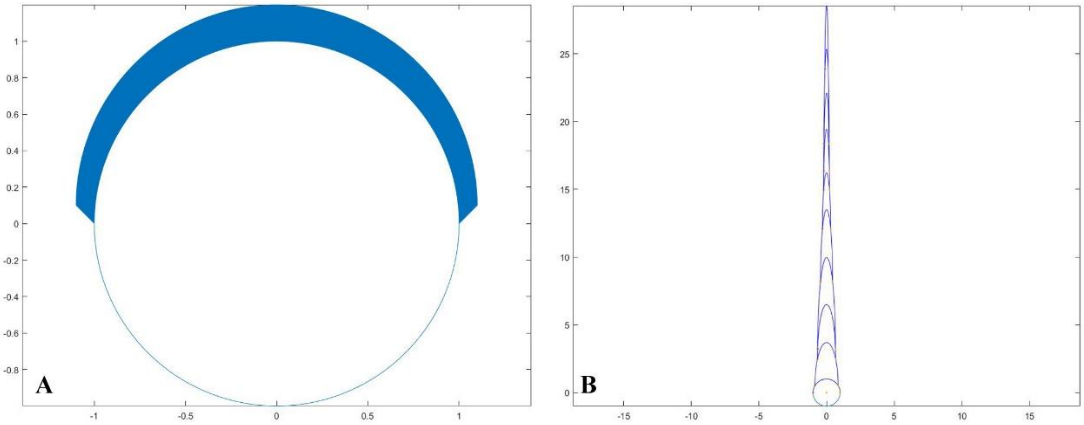

Figure 2. Modification of passage cross-section due to A. corrosion for a duration of 1000 years and B. abrasion and corrosion for a duration of 10 years.

References

Bella, P. and Bosák, P., 2015. Ceiling erosion in caves: early studies and Zdeněk Roth as author of the concept. Acta Carsologica, 44(1).

Cooper, M. P., Perne, M., Covington, M. D., 2014. Simple shear stress approximations and a first step in modeling mechanical erosion in caves. 2014 GSA Annual Meeting in Vancouver, British Columbia, 2014.

Farrant, A., 2004. Paragenesis. Encyclopedia of Caves and Karst Science. Fitzroy Dearborn. New York, 569-571.

Farrant, A. R., Smart, P. L. 2011. Role of sediment in speleogenesis; sedimentation and paragenesis. Geomorphology, 134, 79-93.

Ford, D., 1971. Geologic structure and a new explanation of limestone cavern genesis. Transactions of the Cave Research Group of Great Britain, 13, 81-94.

Frumkin, A., 1998. Salt cave cross-sections and their paleoenvironmental implications. Geomorphology, 23, 183-191.

Ford, D. C., R. O. Ewers, 1978. "The development of limestone cave systems in the dimensions of length and depth." Canadian Journal of Earth Sciences 15(11): 1783-1798.

Kunský, J., 1950: Kras a jeskyně. - Přírodovědecké nakladatelství, 163 pp., Praha.

Lauritzen, S.-E. Paragenesis: The “Royal Mark” Of Subglacial Speleogenesis. 16th International Congress of Speleology, 2013 Brno. 366 - 367.

Lauritzen, S., A. Lauritsen 1995. "Differential diagnosis of paragenetic and vadose canyons." Cave and Karst Science 21(2): 55-59.

Newson, M. D., 1971. A model of subterranean limestone erosion in the British Isles based on hydrology. Transactions of the Institute of British Geographers, 55-70.

Pasini, G., 1975. Sull’importanza speleogenetica dell’“Erosione antigravitativa”. Le Grotte d’Italia, 12, 297-326.Pasini, G., 2009. A terminological matter: paragenesis, antigravitative erosion or antigravitational erosion? International Journal of Speleology, 38, 4.

Pasini, G., 2012: Speleogenesis of the “Buco dei Vinchi” inactive swallow hole (Monte Croara karst sub-area, Bologna, Italy), an outstanding example of antigravitative erosion (or “paragenesis”) in selenitic gypsum. An outline of the “post-antigravitative erosion”. - Acta Carsologica, 41, 1, 15–34.

Renault, P., 1958: Eléments de spéléomorphologie karstique. - Annales de Spéléologie, 13, 1–4, 23–48.

Renauly, P. 1968. Contribution à l'étude des actions mécaniques et sédimentologiques dans la spéléogenèse. Annales de spéléologie, 530-596.Vaughan, K., 1998. A Quantitative Analysis of Interstitial Fluid-Chemistry and Limestone Dissolution Rates within the Clastic Sediment of a Karst Aquifer Conduit, Mammoth Cave, Kentucky.

Whipple, K.X., Hancock, G.S. and Anderson, R.S., 2000. River incision into bedrock: Mechanics and relative efficacy of plucking, abrasion, and cavitation. Geological Society of America Bulletin, 112(3), pp.490-503.