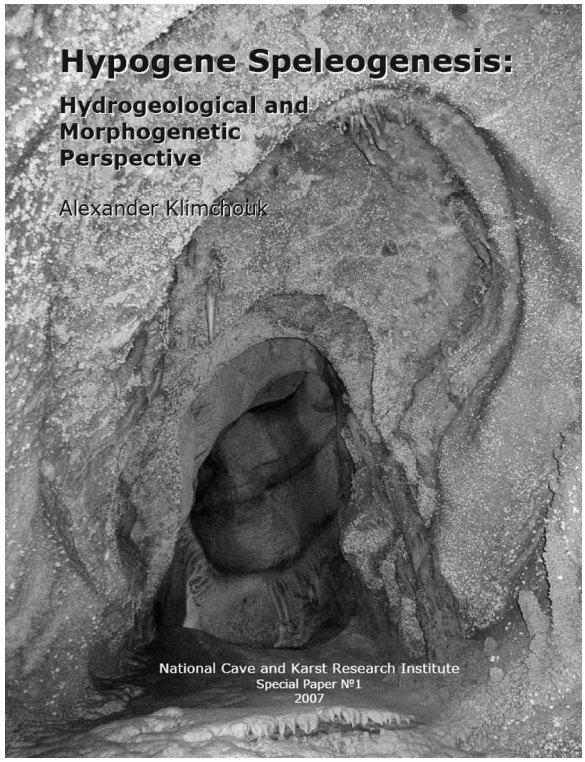
BOOK REVIEW



Hypogene Speleogenesis: Hydrogeological and Morphogenetic Perspective

Alexander Klimchouk, 2007. Carlsbad, N.M., National Cave and Karst Research Institute, Special Paper No. 1, 106 p., 8.5 × 11 inches. ISBN 978-0-9795422-0-6, softbound, $35.

This book was written mainly during Dr. Klimchouk's stay as a Visiting Scholar at the National Cave and Karst Research Institute in 2006–2007. It is an intense compilation of his ideas on hypogenic speleogenesis. Its main thrust is that dissolution in deep artesian or confined basins creates many caves, and that they are under-appreciated by the speleological community. As someone who has had to use non-traditional ideas to understand cave development on carbonate islands and coasts, I agree with his assertion that traditional stream-cave models do not successfully explain all dissolutional cave development. I also agree with him that explorational bias has created a cave database and speleogenetic theories that are skewed toward stream caves. The author also chides the speleological community for its definitions that assume that karst is restricted to carbonate rocks. In preference to Art Palmer's definition of hypogenic caves as those formed where the solutional capacity is derived from deep-seated processes, the author favors that of Derek Ford: "the formation of caves by water that recharges the soluble formation from below… independent of recharge from the overlying or immediately adjacent surface." Caves, in Klimchouk's view, are of three types: (1) epigenic (he prefers "hypergenic" as a parallel to hypogenic), (2) hypogenic, and (3) coastal and oceanic. At first I cheered this three-part classification, as it clearly identified the island caves I work in, but they are never again discussed in the book.

Klimchouk's main concept is that in a large regional aquifer, a significant portion is buried deeply and is confined. These basins are so large that lateral water flow into and out of them is inefficient, and the high hydraulic heads created by the confined conditions produce slow vertical ascending flow across the confining units. Most basins are recharged by water infiltrating from the surface, but in remote areas far from the rising water. The ascending flow is focused on topographic lows where the confining units are thinnest, or where structural or lithologic discontinuities have facilitated vertical flow. Soluble rocks in this sequence, whether carbonate or sulfate (halides are not discussed), initially have very low permeability. However, as water flows upward across them in what the author calls "transverse flow," they become highly permeable. The author considers this a major reorganization of the flow, but it is hard to see why that would be so, as the input from below the cave unit, and the output through the overlying confining unit, needs to be slow. I use the term "cave unit" here, while the author uses "cave formation," as in "geologic formation." But the word "formation" is confusing either as a noun (formation, as in speleothem) or as a verb (formation, as in development). Once the cave unit has reached a permeability equal to that of the confining unit above, with openings still well below cave-passage size, the cave unit would offer no further hydrologic advantage to the regional flow system. Subsequent dissolutional enlargement would be merely a consequence of slow fluid flow through the cave unit. Still, can such caves form? I would say yes, as such basins form over long periods of time and can provide stable flow systems for millions of years, so even if dissolution is very slow, it can still form macroscopic voids. The author invokes thermal gradients or mixing of chemically disparate waters to accomplish dissolution at the cave scale. As the author notes, the growth of openings is non-competitive (i.e., all openings grow without any single one capturing all the water), so enlargement of vugs and joints could occur anywhere ascending water moves through the cave unit. The primary cave outcome would be isolated chambers and fissures, collections of chambers and fissures, or maze caves, as determined by the degree of lateral connectivity or of focusing of the ascending flow. As this flow is very slow and non-turbulent, dissolutional bedrock forms related to convecting water flow are possible, and even expected. This

convection can be thermal, driven by solute density, or both. Because I feel that the author's definition of hypogenic is too restrictive, I call these caves "confined caves" instead of his "hypogenic caves," to describe them by their environment of origin.

So far, so good. But the author is often vague about the water chemistry and dissolutional mechanisms, becoming specific only when describing confined caves now relict at the earth's surface. His ascension model does not work if lateral transport from recharge zones does not continually replace the rising water. Compaction and magmatic sources cannot by themselves supply enough ascending water over the long periods of time needed to accomplish the described speleogenesis. While the author is correct in saying that confined caves have suffered from an exploratational bias, he at the same time infers that his described caves end at the limit of current exploration. His ascending flow argument requires that the caves be laterally restricted, and not connect over a large lateral scale. However, these confined caves include many of the longest caves in the world, such as the gypsum mazes of Ukraine, which have large areal extents, even if their great length is a result of a multitude of closely-spaced passages. The presentation of Lechuguilla Cave (his Figure 17) as a model for his cave theory is instructive. Even with the 2× vertical exaggeration, the input and output points on the profile are widely separated laterally. Given, however, that the author is making his case for large regional aquifers perhaps hundreds of kilometers in lateral extent, this lateral development is minor. In an interesting contradiction, the author on page 94 highlights the usefulness of his confined caves as hydrocarbon reservoirs. Given that his model of confined cave genesis requires slow leakage of water through the overlying confining beds, would not oil and gas also leak away?

The major failing of the book is the re-interpretation of some existing theories of cave development. Art Palmer's maze cave theories take an especially hard beating. The author proclaims, through some shaky arguments, that mazes formed by floodwater or by diffuse infiltration through an overlying caprock do not exist, and that caves described as such are merely enlarged from hypogenic precursors. Palmer considers all mazes in soluble rocks to develop where solutional enlargement is non-competitive (i.e., with all flow paths enlarging at comparable rates). In floodwater conditions, all possible flow paths receive all the water they can handle, regardless of each path's efficiency, hence there is no competition. The same is true for water entering a soluble unit through fractures in an overlying insoluble unit. It is also true for a variety of mixing and hydrothermal models, including the confined cave model postulated by Klimchouk. But his use of the map of Skull Cave, New York (a cave he has never visited) to debunk the floodwater model is especially egregious. Had he ever visited the cave and seen floodwater debris 25 m above the floor, he would realize that the cave does flood. If he had examined the outlet choked with glacial sediment, he would understand the mechanism. Dr. Klimchouk describes, and displays in many well-presented photos, a list of features he claims are diagnostic of confined cave development. These include maze patterns, cupolas, former infeeders in the floors and outlets in the ceilings, and wall grooves, all assumed to form by rising water. Their presence in caves now located in unconfined or vadose environments is a result, in his opinion, of inheritance from a confined cave origin, with the later overprint by unconfined and/or vadose conditions. Dr. Klimchouk has used the idea of overprinting to explain why some caves do not show sufficient evidence to support his model. This is a valid approach, as, by definition, these confined caves cannot be explored until they have been exposed at the earth's surface and are decoupled from their original confined environment. In making that transition, they would likely be overprinted by unconfined and eventually vadose processes. He completely reinterprets the caves of the Guadalupe Mountains in this manner. However, to prove that overprinting can mask the features diagnostic of a former confined-aquifer cave, one should examine caves that formed where confined conditions never existed. If such caves show none of the diagnostic features, then the Klimchouk argument would gain credibility. Otherwise it would be badly weakened.

This brings us back to the neglected third cave category, that of coastal and oceanic caves. Where they are introduced on page 5, the author states that they are treated separately in a later section. But they are not treated at all in the rest of the text. This omission is critical, as these coastal caves display all of the critical dissolutional features that the author describes as unique to his confined cave model, which include cupolas, infeeders, ceiling channels, partitions, etc. They are not only present in coastal caves, they are abundant. These caves have been argued, by myself and co-authors, to be hypogenic, in the Palmer sense, as they form by rejuvenation of solutional aggressiveness by mixing of waters at depth. They contain the features described by Klimchouk because they too form in slow-moving water where processes such as solute-driven convection also operate. But because these carbonates have never been confined or deeply buried, they negate the overprinting argument and demonstrate that the features considered diagnostic of deep confinement by the author are not limited to that mode of speleogenesis. He mentions that coastal caves "…are treated separately because of the specific conditions for speleogenesis determined by the dissolution of porous, poorly indurated carbonates by mixing of waters of contrasting chemistry at the halocline." But coastal caves formed by mixing dissolution are not restricted to eogenetic rocks, as made clear in the paper by Vacher and Mylroie (2002), which Klimchouk cites in his book. One could also argue that, in the case of carbonates, Klimchouk's hypogenic caves are merely the result of rejuvenation of coastal and oceanic caves taken into the mesogenetic zone by burial, and that his confined carbonate caves are an overprint of those caves.

Thus, the single biggest flaw in the book is the author's tendency to dismiss ideas that are not in complete agreement with his own. This is especially discomforting, as he has introduced some interesting ideas and concepts. He devalues his own arguments with incorrect attacks on the work of others. Because of the broad scope of this work, and the many examples provided from around the world, the book initially appears to have a large mass of evidence behind it. But when one realizes that some of the examples given, which are personally known to this reviewer, have been completely misinterpreted, then the reader wonders how much to trust the other interpretations.

This book is interesting, controversial, and dogmatic. Dr. Klimchouk has presented an argument about cave origin under confined conditions that has great potential, but it is an over-reach of an excellent idea. Instead of fitting his model into a continuum of karst processes, he attempts to minimize and cast out (or ignore) other ideas. However, if one can separate the wheat from the chaff, this book contains many useful ideas about karst processes in confined aquifers.

Reviewed by John E. Mylroie, Department of Geosciences, Mississippi State University, Mississippi State, MS 39762 (mylroie@geosci.msstate.edu).