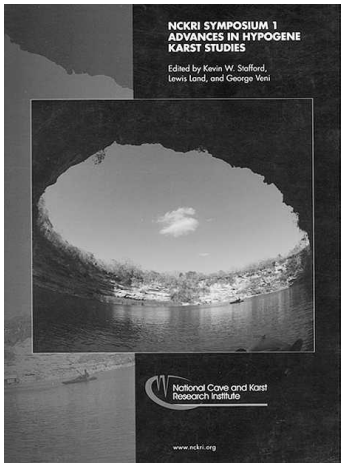
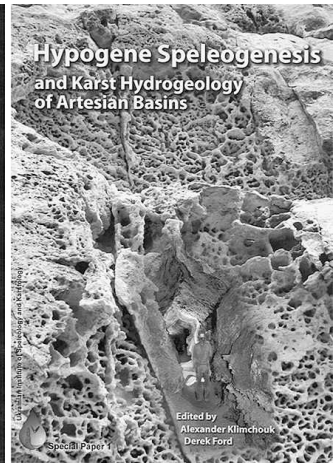
BOOK REVIEW





Advances in Hypogene Karst Studies

Kevin W. Stafford, Lewis Land, and George Veni (eds.), 2009. Carlsbad, New Mexico, National Cave and Karst Research Institute Symposium 1, 182 p., 8.5 × 11 inches, $50 plus shipping from sales@nckri.org. ISBN 978-0-9795422-4-4

Hypogene Speleogenesis and Karst Hydrogeology of Artesian Basins

Alexander Klimchouk and Derek Ford (eds.), 2009. Simferopol, Ukraine, Ukrainian Institute of Speleology and Karstology Special Paper 1, 292 p., 8.2 × 11.7 inches, $50 plus shipping from nssbookstore.org. ISBN 978-966-2178-38-8

For most of the past several centuries, students of caves and karst were satisfied with a single, underlying conceptual model. Meteoric water interacted with soluble bedrock, usually limestone or dolomite, sometimes gypsum, and occasionally salt. Differential dissolution on exposed land surfaces produced the characteristic karst landforms: closed depressions, sculptured bedrock, and residual hills of unusual shape. Infiltration of meteoric water through closed depressions and sinking streams developed caves with great varieties of lengths and patterns. The inlet points and their sources, combined with the outlet points at springs, allowed the identification of karst drainage basins and the underlying karst aquifers. Karst systems took on a tremendous variety of detail, depending on local climate and geologic setting, but the underlying processes were the same—a single concept.

This concept was challenged in the later decades of the 20th century. Studies of caves such as those in the Guadalupe Mountains of New Mexico and the Black Hills of South Dakota, as well as the giant maze caves of Ukraine, have revealed other processes involving upward migrating fluids, some of them at high temperatures or carrying sulfuric acid in addition to carbonic acid. The concept of deep-seated or hypogenetic speleogenesis had been born. These ideas were summarized in Alexander Klimchouk's *Hypogene Speleogenesis* (reviewed by John Mylroie in the *Journal of Cave and Karst Studies* 70, 129–131, 2008). The hypogene concept has now received enough attention to warrant two symposia, the proceedings of which are the volumes reviewed here.

The Stafford et al. book consists of fourteen papers that describe the influence of deep groundwater flow on the origin of caves and related features. It is based on presentations at a special session at the 2008 national meeting of the Geological Society of America. This volume represents a North American point of view, as twelve of the fourteen papers are by US and Canadian authors. The book is very nicely produced, with color photographs and illustrations throughout.

In the first chapter, Alexander Klimchouk describes hypogene cave origin, with special attention to the rise of water across stratal boundaries in the distal portions of regional and intermediate-scale groundwater systems. A suite of characteristic cave features is described, including floor slots, wall grooves, ceiling channels, and cupolas, all of which he attributes to rising groundwater. In the next chapter, however, John and Joan Mylroie urge caution in ascribing these features solely to rising groundwater. They cite examples of sea-coast caves in poorly lithified limestones that contain most or all of the features described in the previous chapter, but which have never been in confined settings or exposed to rising groundwater. Short-term flooding by epigenic processes also produces many such features.

Marcus Gary and John Sharp document several deep Mexican springs that are fed by rising groundwater, with CO_2, H_2S, and mild heat supplied by volcanic sources. They introduce the term *volcanogenic karst* for features originating in this way. Their type example is El Zacatón, a 319 m water-filled shaft that is one of the deepest known in the world. Philippe Audra and coauthors describe cave folia, which consist of arrays of sub-horizontal fungus-like calcite growths. They attribute these deposits to hypogene degassing of CO_2 on the basis of morphological features such as bubble-trails inscribed in the cave walls by the escaping gas.

A collection of field examples follows, each documenting a specific aspect of hypogene processes. Kelton Barr and Calvin Alexander describe depressions in Minnesota where water rises into valleys buried by glacial deposits and causes collapse at the outlets, a topic of growing concern to engineers and land-use managers. Paul Burger examines structural and facies control of caves in the Guadalupe Mountains of New Mexico. These are sulfuric acid caves

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formed by the oxidation of rising H_2S. He demonstrates, for example, that maze patterns in the caves strongly correlate with paleokarst and early tectonic breccias.

George Veni and Lynn Heizler use Robber Baron Cave, in Cretaceous limestone of south-central Texas, as an example of cave origin by rising groundwater. Ceiling cupolas and residual bedrock bridges across passages are cited as representative byproducts. Van Brahana et al. describe an unusual cave in Arkansas in which epigenic passageways have intersected much older rooms lined with calcite spar crystals up to 1.9 m long. Isotopic signatures indicate that the calcite was of hypogene origin with temperatures greater than 100 °C. Relationships to dolomitization, brecciation, and Mississippi-Valley-type ore deposits are discussed.

Three chapters concern hypogene processes and features in Permian gypsum in southeastern New Mexico and western Texas. This area is one of the least-studied karst regions of the USA. Ray Nance and Kevin Stafford describe caves and surface karst features with hypogenic characteristics, such as calcitization of evaporites, sulfur deposits, and solution breccias. These are attributed to the influence of hydrocarbons carried by rising water. Kevin Stafford et al. describe regional flow patterns related to the Pecos River. The river has long served as a target for groundwater rising under semi-confined conditions. Hypogene dissolution has produced multi-story caves, oil-field porosity, and surface depressions. Lewis Land discusses the impact of deep-seated processes on the water resources of the area. Karstic artesian basins supply nearly all of the water necessary to sustain a level of population growth and agricultural development that would otherwise be impossible in this semi-arid region.

Three chapters concern the application of hypogene karst processes to economic geology and regional tectonic history. Harvey DuChene provides field evidence that oil fields north and west of the Guadalupe Mountains supplied the hydrogen sulfide that formed the local caves (e.g., Carlsbad Cavern). He relates the changes in oil-field character, groundwater patterns, and cave development to block faulting in the Rio Grande Rift zone to the west. Derek Ford interprets the paragenesis of carbonate-hosted sulfide ores in the Nanisivik mining area of Baffin Island, northern Canada. He interprets the ore as having formed along the interface between saline water and gas or oil about 1600 m below the surface, with simultaneous carbonate dissolution and ore deposition. Langhorne Smith describes hydrothermal petroleum reservoirs in Ordovician rocks of eastern North America that formed in dolomitized zones around basement-rooted trans-tensional faults. Dissolution and mineralization along the faults was accomplished mainly by rising thermal fluids. Natural gas is abundant in and around elongate fault-bounded structural lows (interpreted to be negative flower structures). This timely chapter transcends the usual boundaries of karst studies by concentrating on deep-seated tectonic and geochemical processes, as well as their application to petroleum geology.

The Klimchouk and Ford volume contains the thirty-nine papers presented at the International Conference on Hypogene Speleogenesis held at Chernivtsi, Ukraine, in May 2009. Thirty-six of the papers are in English and three are in Russian. Contributions are from Europe, Russia, Australia, Brazil, the US, and Canada. Once identified, it appears that hypogene caves are everywhere.

The opening paper by Alexander Klimchouk and the two following papers by Philippe Audra and his colleagues set out to identify the characteristic morphological forms that result from hypogene speleogenesis: cave patterns with elaborate three-dimensional structure, cupolas, half-tubes, and the planated surfaces associated with condensation-corrosion. Morphological forms can be subject to multiple interpretations. More solid evidence is provided by mineral deposits, especially the isotopic composition of coarsely crystalline calcite. Dublyansky and Spötl describe oxygen isotope ratios in the calcite coating of cavities in a cave in the Austrian Alps that identify the temperature of waters that moved through the cave.

Microbial processes are known to be important catalysts in the geochemical reactions of hypogene speleogenesis. P.J. Boston and her colleagues give an overview and an assessment of their importance.

Modeling of hypogene systems is extremely difficult because there are few hard data on the sources, early flow paths, and chemistry of the fluids. Three attempts are made to at least describe the mechanics of fluid flow. Rehrl, Birk, and Klimchouk offer a generic model showing how fracture systems might be expected to evolve. Dreybrodt, Romanov, and Kaufmann describe a quantitative model for mixing-corrosion that can be applied to coastal karst with freshwater-saltwater mixing zones. It should also be applicable to deep-seated upwelling fluids. Another approach to modeling of mixing zone karst is described by Antoine Lafare and his colleagues and applied to the Mediterranean karst.

As might be expected, most of the papers describe specific hypogene caves that the authors think they have identified, or to caves where hypogenetic processes are thought to have played an important role. There is an amazing diversity of sites. There are the Obruks, giant collapse shafts in Turkey (Bayari and colleagues). There is the endokarst of Mallorca (Ginés and colleagues). There are the hypogene caves of the Italian Apennines (Sandro Galdenzi), which include the important Frasassi Caves, in which much microbiology research is now underway. Beyond these, there are examples of hypogene caves from Austria, Slovenia, Israel, the Crimea, Brazil, Poland, Romania, Greece, Norway, Russia, Jordan, and Saudi Arabia, to name only the main localities.

In this collection of papers from both symposia, there is some impressive progress and at least one serious gap. As to progress, caves of hypogenetic origin have been

identified from many regions and in many environments. Additionally, many caves, clearly remnants of the development of contemporary watersheds, also have an initial hypogenic component. The gap is the absence of any detailed geochemical model for a dissolution process where rising groundwater alone is responsible for cave origin. Fluids percolating up from depth are rarely seen and are difficult to analyze.

These books illustrate that karst processes can extend to considerable depth and involve chemical processes that are seldom observed at the surface. Readers who wish to apply the methods discussed here should keep in mind that interpretations must be compatible with regional groundwater flow rates, chemical environments, and the geologic time frame and that many relict geomorphic features can be attributed to more than a single process. These important books show the wide range of these interpretations and applications.

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