ANDYSEZ 55

HYPOGENE CAVES

– Andy Spate

Your editor has asked me to address the issue of hypogene or hypogenic karst as various people keep mentioning at ACKMA meetings and in the Journal to the mystification of many.

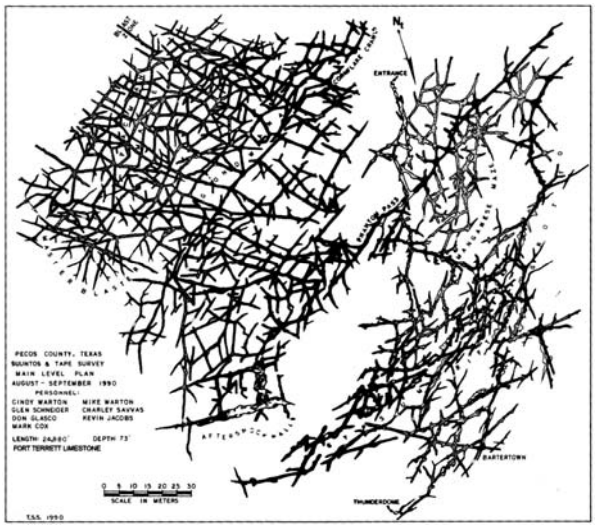
There is no better way to introduce the topic than to quote from the introduction to Alexander Klimchouk's latest textbook, *Hypogene Speleogenesis: Hydrological and Morphogenetic Perspective* (Klimchouk, 2007, page 3):

> Most of the studies of karst systems are concerned with shallow, unconfined geologic settings, supposing that the karstification is ultimately related to the Earth's surface and that dissolution is driven by <u>downward</u> meteoric water [rainfall] recharge. Such systems are epigenic (hypergenic). Concepts and theories developed for unconfined karst systems overwhelmingly predominate in cave and karst science, particularly in karst hydrology and geomorphology, forming a core of the current paradigm. Hypogenic karst, originating <u>from depth</u> and not related to recharge from the overlying surface, although recognized during the last two decades, remains poorly understood and integrated into the bulk of karst science. [emphasis mine]

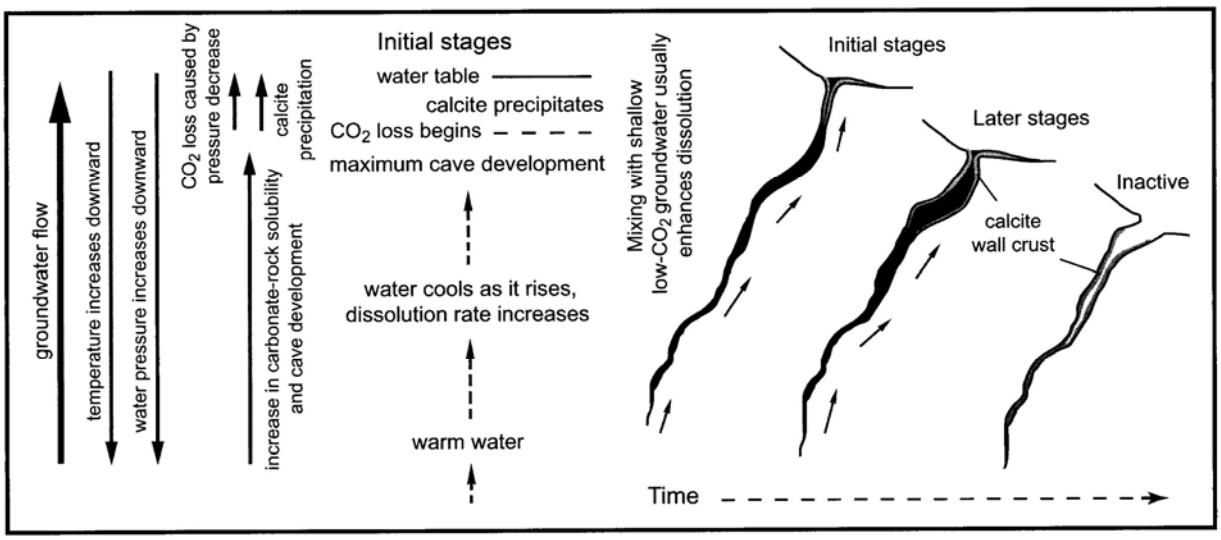
Note, first of all, the similarity between the two words – hypogenic and hypergenic – dangers here. Just as there is between hypothermia and hyperthermia – the former is what you get at Yarrangobilly and the latter at Chillagoe!

The reasons for the 'concepts and theories developed for unconfined karst systems' being dominant in the literature is not hard to understand – epigenic karst systems are the most common systems found where karst science began. But, increasingly, the importance of hypogene karst systems is being recognized and many of the cave shapes, sizes and complexities that epigenic theory does not explain very well can be accounted for by revising our thinking to consider groundwater flowing upwards. Klimchouk and others suggest that 10-15% of caves worldwide are hypogenic – and in many places (such as around Carlsbad Caverns) almost all or all are of hypogenic origin.

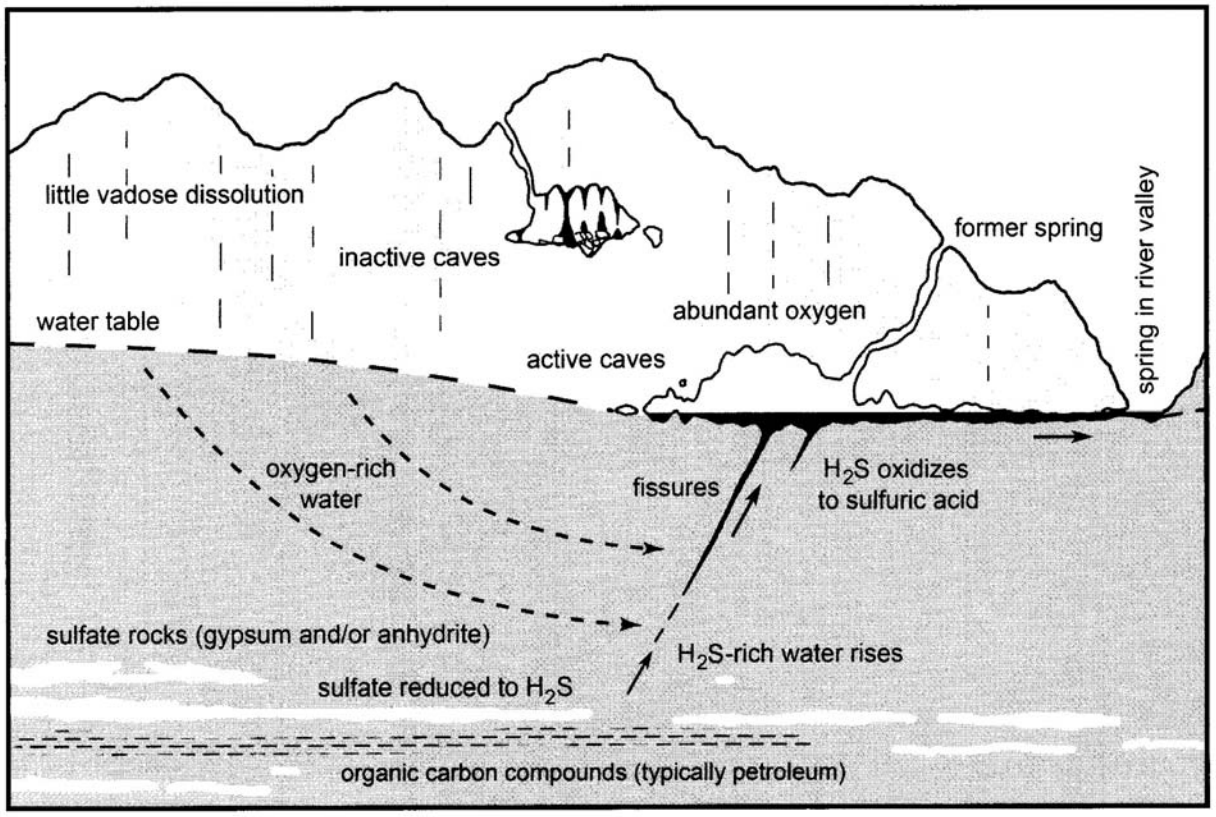
However, hypogene concepts and theories do not explain all of the complexities found in karst systems either – as I have said so frequently in former ANDYSEZs there is yet again a spectrum of karst forms arising from downward flowing waters and from those produced by ascending water.



Amazing Cave, Texas, USA. A multi-story maze cave in stratified Cretaceous limestone. An example of confined transverse speleogenesis in which dissolution by sulfuric acid took place. (From Klimchouk 2007, figure 43, page 72).



The concept of thermal cave origin: Hot groundwater rises toward an outlet and gains aggressiveness as it cools. At low water pressures near the water table, loss of carbon dioxide causes calcite to precipitate on the cave walls. (Palmer 2007, figure 8.47, page 213).



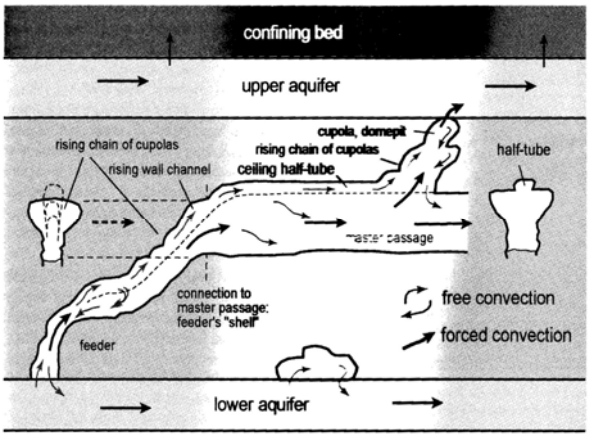
A typical setting for the origin of sulfuric acid caves. Deep flow of oxygen-rich water may be scant or absent, so that nearly all dissolution takes place at or near the water table. Enlargement by sulfuric acid also occurs in the air-filled parts of the cave where H_2S and oxygen are absorbed by moisture on bedrock surfaces. (From Palmer 2007, figure 8.55, page 217).

First we had better define a few more terms:

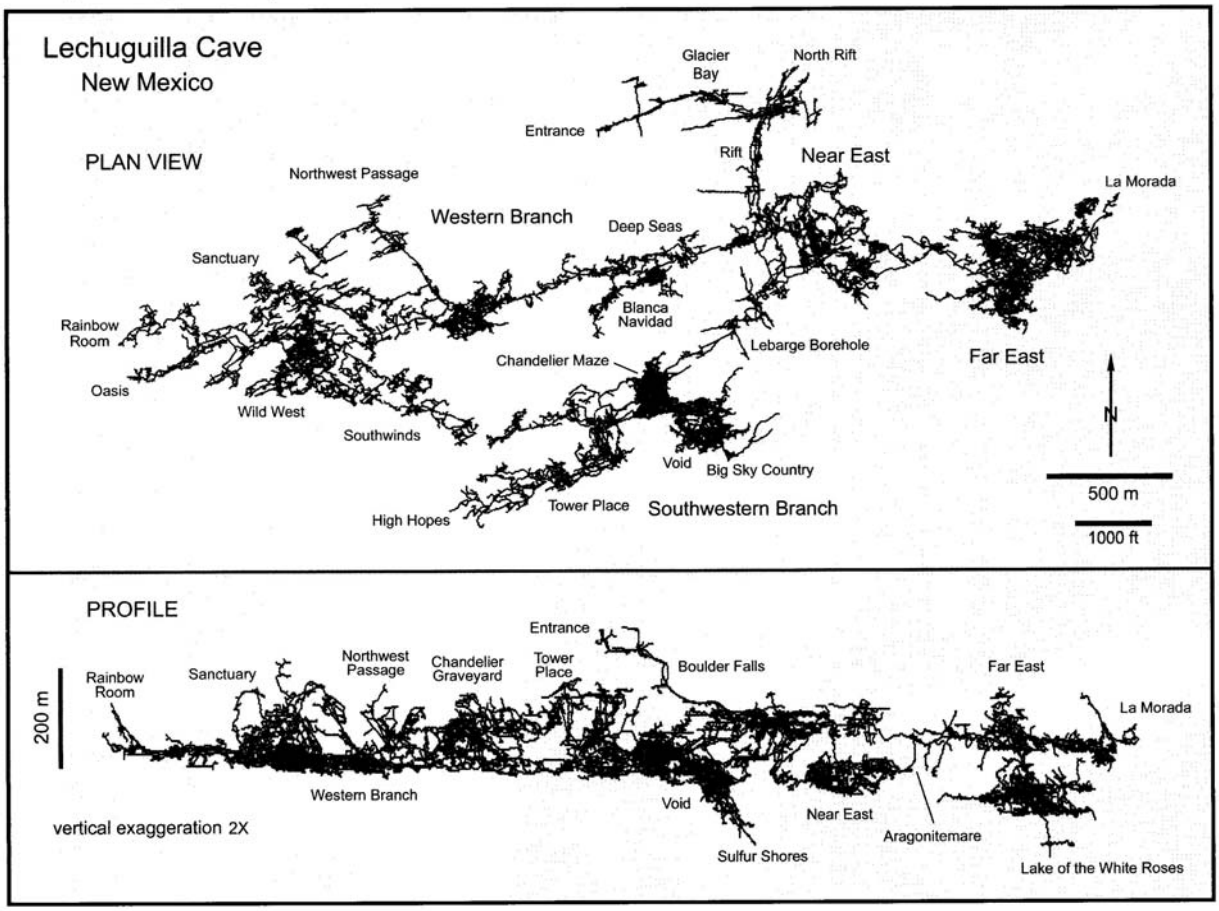
> **Unconfined aquifers:** An aquifer in which the water table is at or near atmospheric pressure and is the upper boundary of the aquifer. Because the aquifer is not under pressure the water level in a well is the same as the water table outside the well.
>
> **Confined aquifer:** (also known as artesian or pressure aquifers) exist where the groundwater is bounded between layers of impermeable substances like clay or dense rock. When tapped by a well, water in confined aquifers is forced up, sometimes above the soil surface. This is how a flowing artesian well is formed.
>
> **Confining layer:** Geologic material with little or no permeability or hydraulic conductivity. Water does not pass through this layer or the rate of movement is extremely slow. May be also known as an aquiclude or aquitard.

Most Australian cave systems are in unconfined aquifers – but given the extreme age of many systems in the Eastern Highlands they may have been confined in the past. And, indeed, confinement is not always needed for upward flowing waters as can easily be seen at Yarrangobilly and elsewhere in the Eastern Highlands. In fact the entrance to Jersey Cave is a former rising tube as is the major karst spring at Hollin Cave. The water rises from several tens of metres below the level of the Yarrangobilly River.

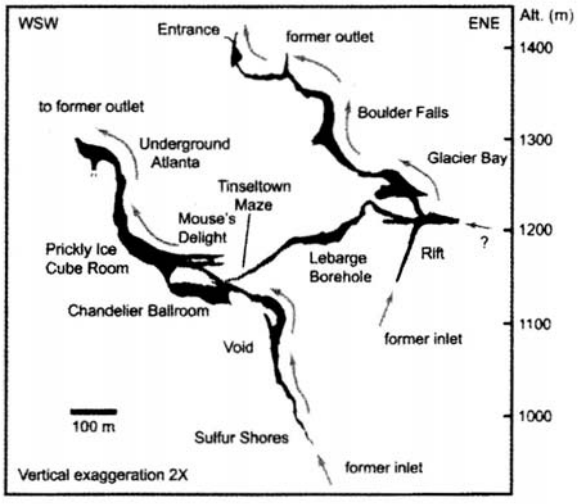
After many ANDYSEZs I hope you are all comfortable with the idea of meteoric waters (= rainfall and run-on from surrounding non-karstic rocks with their dissolved carbon dioxide and various organic acids derived from vegetation) eating away at the limestone as they move downwards through the soil and limestone beneath.



The morphologic suite of rising flow, diagnostic of confined transverse origin of caves. The geometry of a cave segment, the relative scale of the features and hydrostratigraphy on this diagram is directly representative for Ozerna Cave in western Ukraine. However, the diagram is generic and elastic; it can be stretched vertically, and complexity can be added to account for multiple lateral stories. The arrangements of the forms, will repeat itself on each story, and functional relationships between the forms will remain the same. (From Klimchouk 2007, figure 19, page 36).



Map and profile of Lechuguilla Cave, Carlsbad Caverns National Park, New Mexico. Note rifts in the lower part of the cave [Sulfur Shores and Lake of the White Roses], which formerly conveyed [feeders] H_2S-rich water upward toward the water table; the concentration of maze patterns above them; and the ascending character of higher level passages towards surface outlets [the Entrance series, near La Morada and near the Sanctuary].
(From Palmer 2007, figure 8.67, page 223).



Projected vertical profiles through part of the Lechuguilla Cave, showing the nearly independent flow systems through the entrance series and through the Sulfur Shores-Underground Atlanta systems.
(From Klimchouk 2007, figure 47, page 76).

What about waters which may be moving upwards under a variety of flow regimes and mechanisms. Consider a garden hose full of water – elevate one end – water will flow out the other. A very simple confined aquifer. Also think about the litre of water you pour into one end – a litre will come out – but it is not the same litre you put in! It may have different chemical characteristics depending on what rocks it has passed through on its way.

Hypogene caves are often maze caves (as are some epigenic caves) with clearly ascending passages – examination of the figures I have taken from Klimchouk (2007) and Palmer (2007) will demonstrate various features of hypogene caves. The figure captions are those from the two texts consulted with some minor amendments. Table 1 below gives some parameters of caves in confined and unconfined cave settings. Although the sample Klimchouk uses is not large and the inferences may not be completely statistically valid there are clear differences between the two types of caves.

Hypogene waters can become acidic through at least two mechanisms. Firstly there is enrichment with carbon dioxide at depth – high pressures can ensure high levels in the groundwater. The source for such high carbon dioxide levels is probably associated with volcanism. Far more acid groundwaters can develop where substances such as sulfur minerals are oxidized to form sulfuric acid. The sulfur minerals are often associated with petroleum deposits. Not only will such waters rapidly produce large and complex caves on many levels but the may also produce weird and wonderful speleothems.

Clear Australian examples of hypogene caves can be seen at Jenolan and Wellington in New South Wales. The water-filled collapse dolines (cenotes) of the Yucatan Peninsula, Mexico, are thought to have been of hypogenic origin and Elery Hamilton-Smith and others have argued that the cenotes around Mount Gambier have hypogenic origins. Certainly the carbon dioxide well at Caroline which produces about 21,000 tonne of carbon dioxide annually suggests that there is plenty of the gas available to acidify the local groundwaters. Raw liquid from the well contains approximately 90-94.5% carbon dioxide and 6.5-10% impurities. These impurities include sulphur compounds (mainly hydrogen sulfide), nitrogen and a number of light and heavy hydrocarbons (Ecos 2001). The gas comes from two geological levels in the Otway Basin basal sediments at 2,500 and 2,800 metre below the surface. But are the very similar collapse forms on the Nullarbor similarly of hypogenic origin? We need more information in both places.

Table 1. Average characteristics of conduit patterns for confined and unconfined settings (Klimchouk 2007, Table 2, page 86). Note the order of magnitude difference in the three parameters between confined and unconfined settings. Passage network density is the ratio of cave length to the area over which the cave extends (the cave field); areal coverage is the fraction of the cave field occupied by passages in map plan view; cave porosity is the volume of passages within the cave block.

Parameter	Settings			
	Unconfined	Confined		
		Whole set	Gypsum caves	Limestone caves
Passage density (km/km^2)	16.6	167.3	157.4	191.9
Areal coverage (%)	6.4	29.7	28.4	33.0
Cave porosity (%)	0.4	5.0	4.8	5.5

REFERENCES

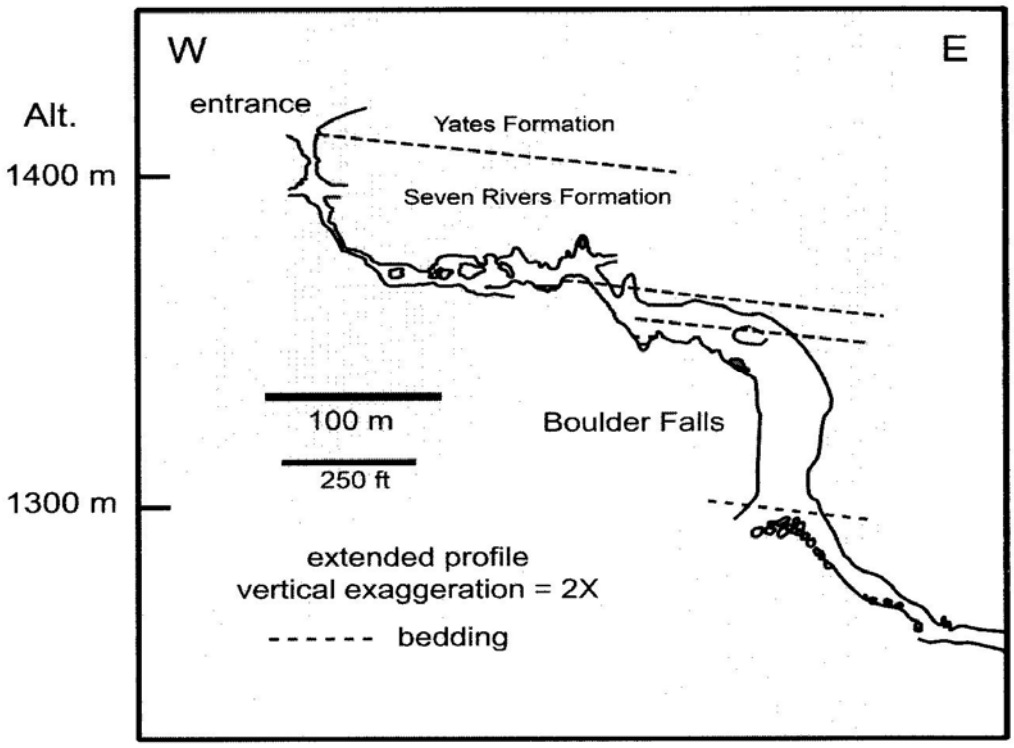
Ecos 2001, Air Liquide Australia Ltd, Caroline Carbon Dioxide Purification Plant, Environmental Impact Report.

Klimchouk AB 2007, *Hypogene Speleogenesis: Hydrological and Morphological Perspective*. Special Paper no. 1, National Cave and Karst Research Institute, Carlsbad, New Mexico.

Palmer AN 2007, *Cave Geology*, Cave books, Dayton, Ohio.

I have recommended Arthur Palmer's book before – it is probably the best single text on caves and karst in print at this time.

The next ANDYSEZ will deal with solution pockets, bell holes and similar speleogens. Julia James has consented to be a guest ANDYSEZer.



Profile of the entrance section of Lechuguilla Cave, which shows the curving, non-vertical walls of shafts formed by ascending water. The passages are roughly concordant to the strata because the rising water was deflected up-dip along the bedding planes. (From palmer 2007, figure 8.70, page 224).