The other side of the karst coin – characteristic and diversity of hypogene karst

Druga plat kraškega kovanca – značilnosti in raznovrstnost hipogenega krasa

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Karst

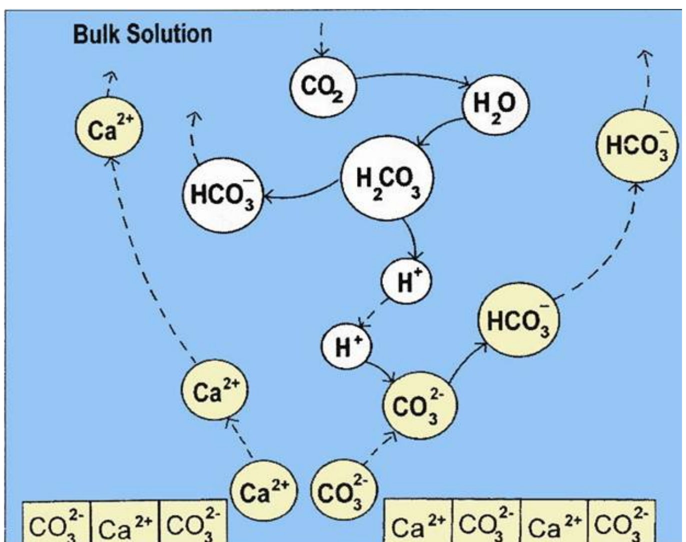
Karst (system) - A terrain formed in soluble and fractured rocks (e.g., limestone, dolomite, marble) => development of **special karst landforms** (depressions, caves, sinkholes, etc.) + extensive **subterranean water drainage**.

An evolving system = caves are both product and carrier of that evolution;

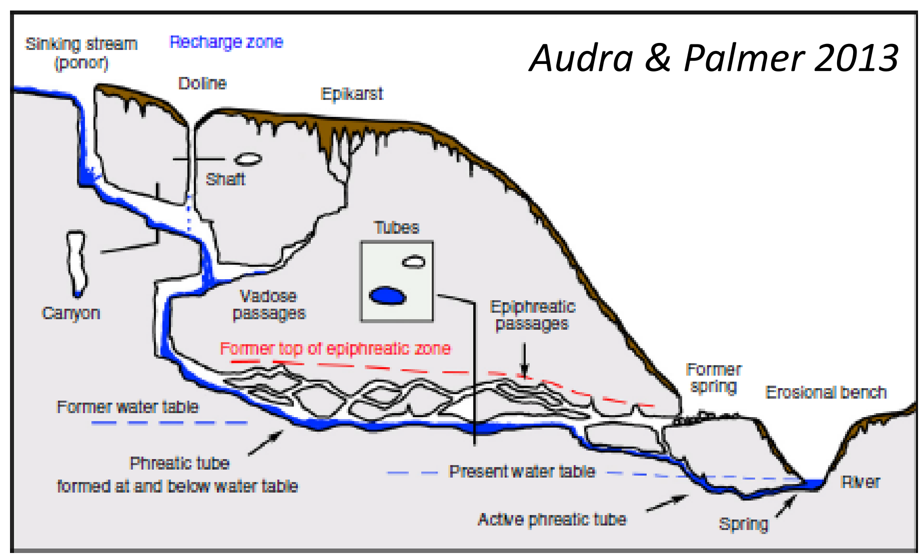
Karst evolution ≈ cave evolution = speleogenesis

Epigene karst – most common, "normal" karst

Soil CO_2 main source of chemical capacity for rock dissolution



Dreybrodt 2004



Audra & Palmer 2013


M. Vattano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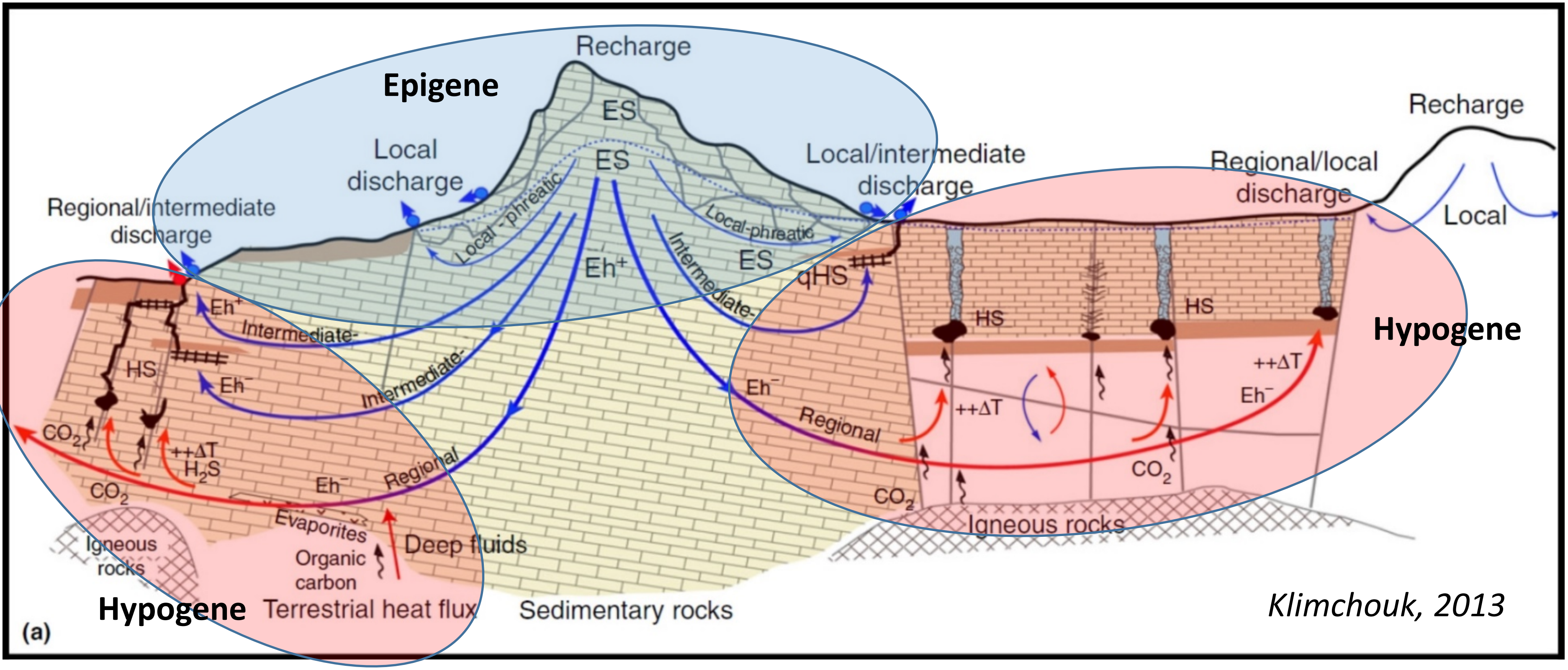
Hypogene karst

Karst systems that develop due to bedrock dissolution by groundwater that recharges the karst rock formation from below (Klimchouk 2007).

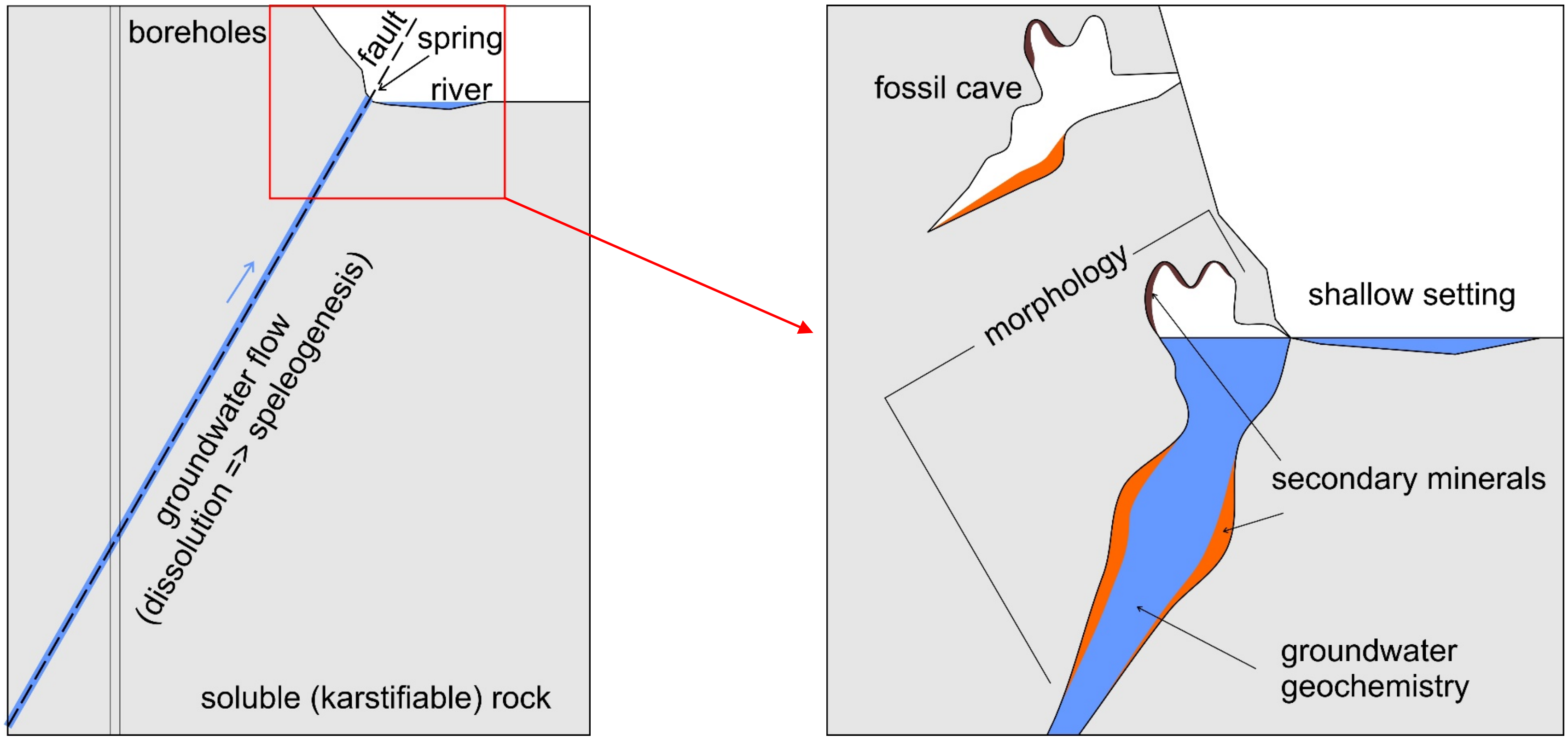
More diverse genetic mechanisms than epigene karst, due to a variety of geochemical processes



Klimchouk, 2013

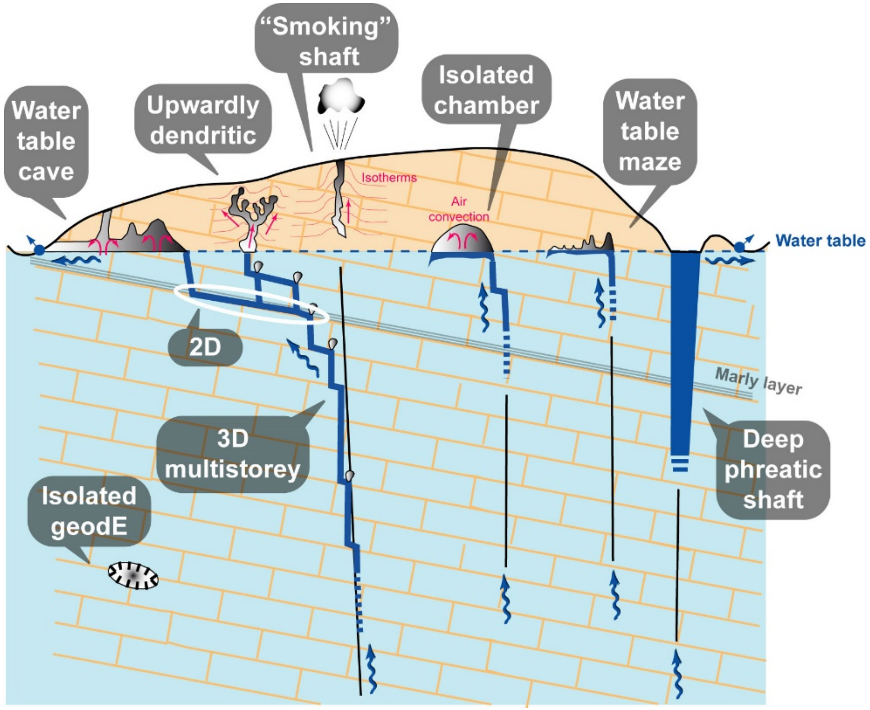
Approaches to study hypogene karst

- Active systems are mostly inaccessible (information from boreholes or shallow settings, i.e., springs)
- Most research focused on fossil systems (accessible after surface erosion)
- What to study
  - Groundwater (in active systems), cave morphology, secondary minerals, bedrock alterations

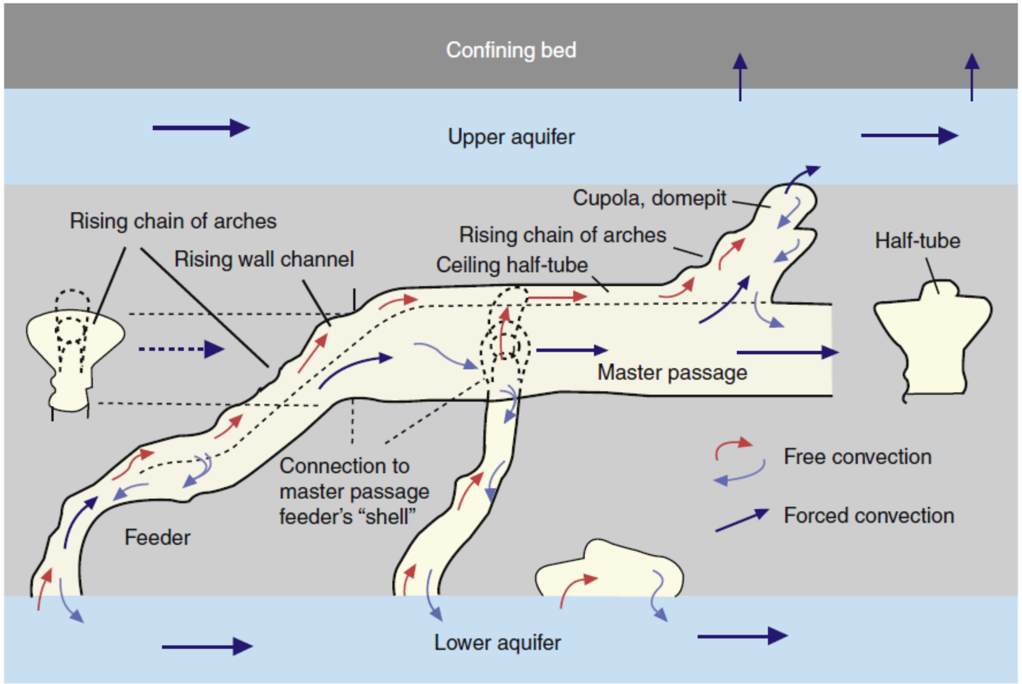


Morphology

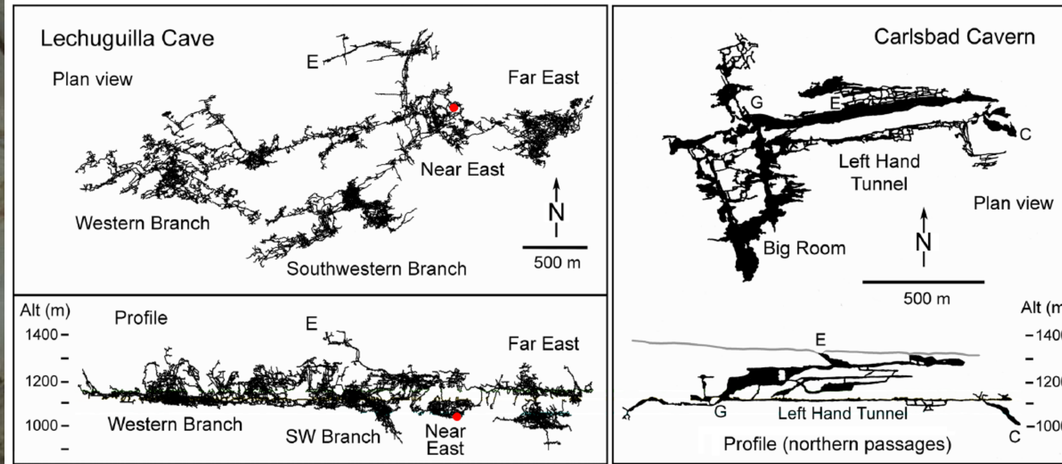
- Strong structural control
- Various cave patterns (individual rooms and chambers, maze passage networks, etc.)
- Feeders, cupolas, half-tube channels; poor relationship with surface topography



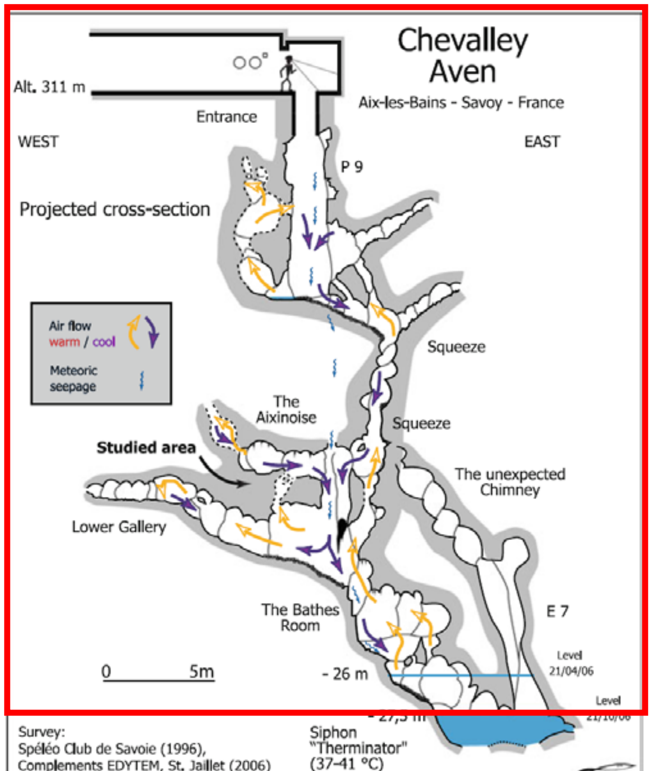
Audra et al. 2009



Klimchouk 2007

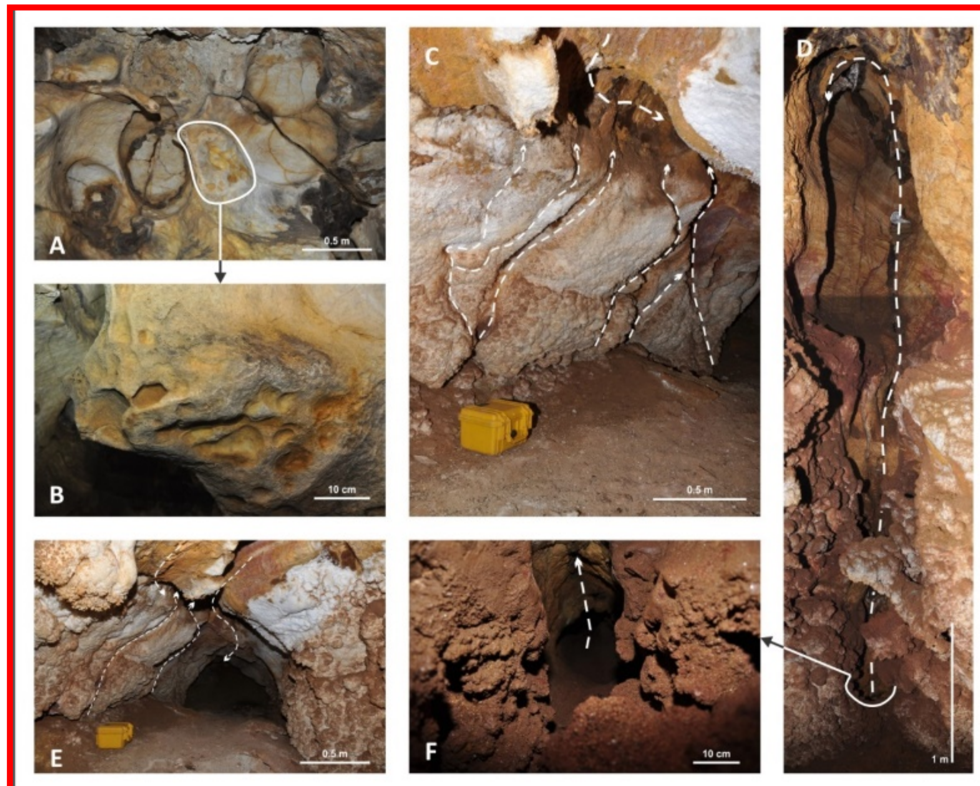


Palmer 2007



condensation-corrosion

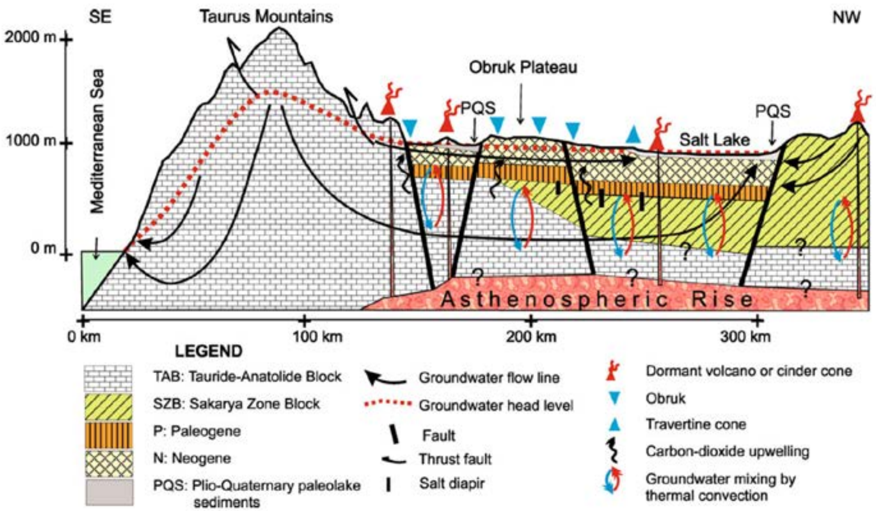
Audra 2017



Provalata Cave, Macedonia (Temovski et al. 2013)

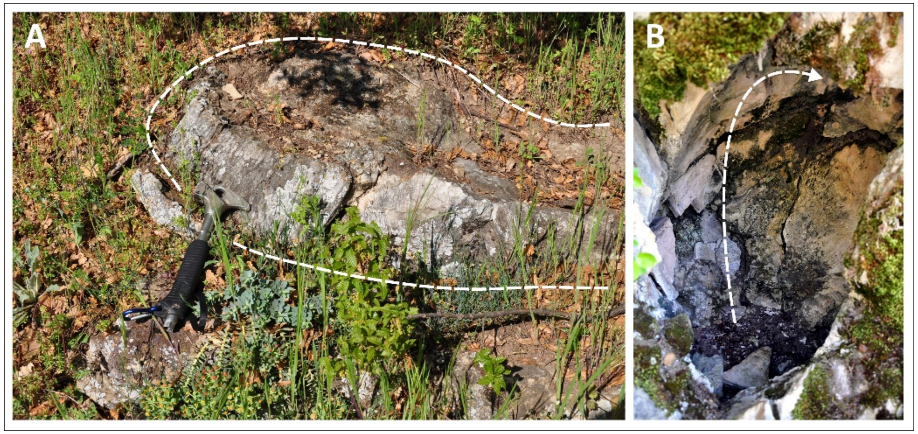
Hypogene karst expression on surface

- Poor relationship with surface topography
- Collapsing (e.g., collapse dolines “Obruks”, Turkey)



Bayari et al. 2017

- Surface erosion reaching hypogene karst

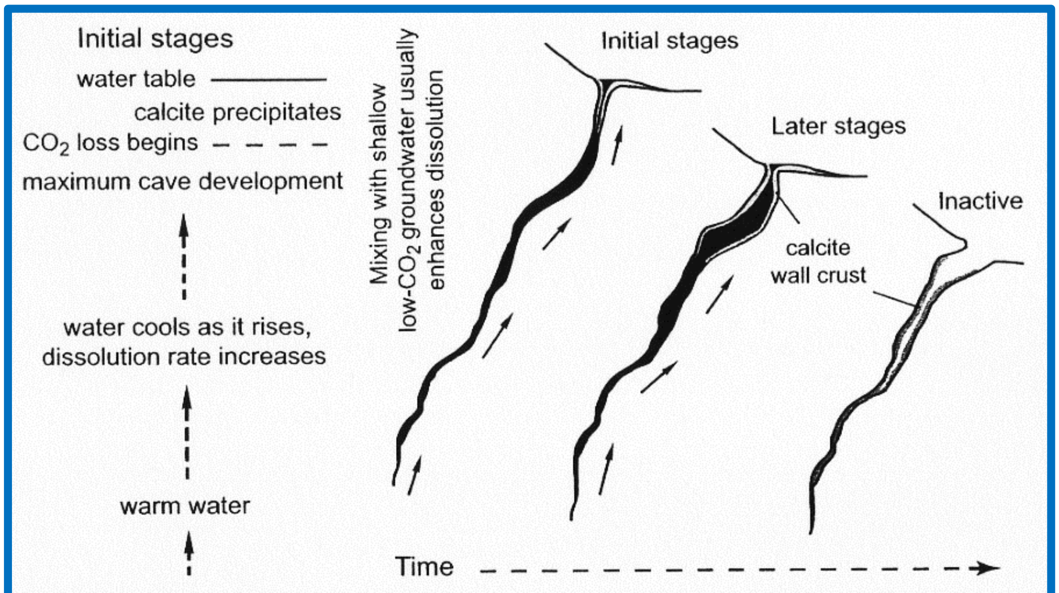


Melnica, Macedonia (Temovski et al. 2013)

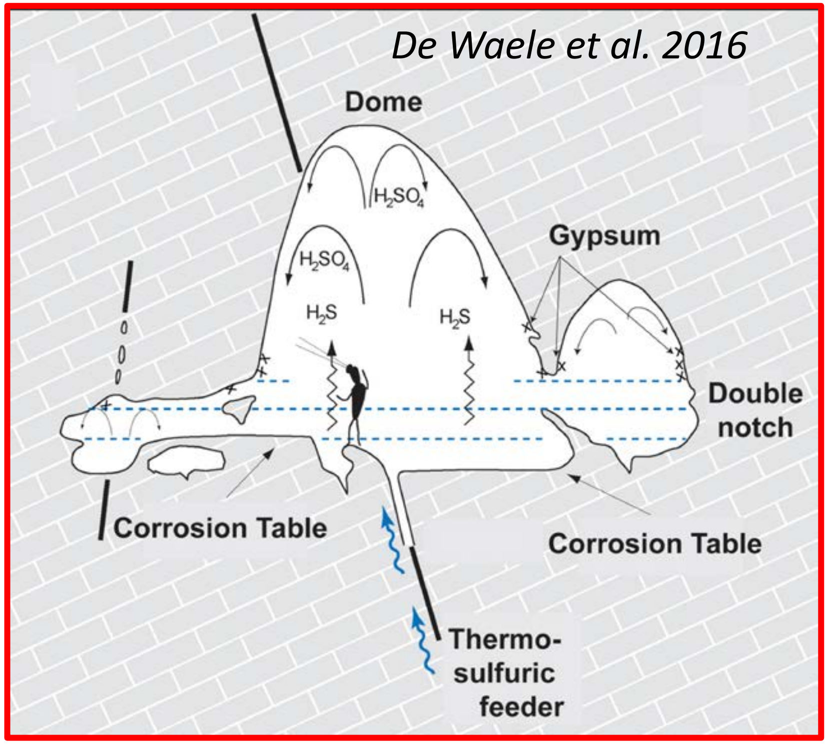
Types of hypogene karst

Two most common genetic types of hypogene speleogenesis

- **Hydrothermal carbonic speleogenesis**
- **Sulfuric acid speleogenesis**
- Dissolution of CO_2 (>H_2CO_3) vs oxidation of H_2S (>H_2SO_4) as the main sources of acidity



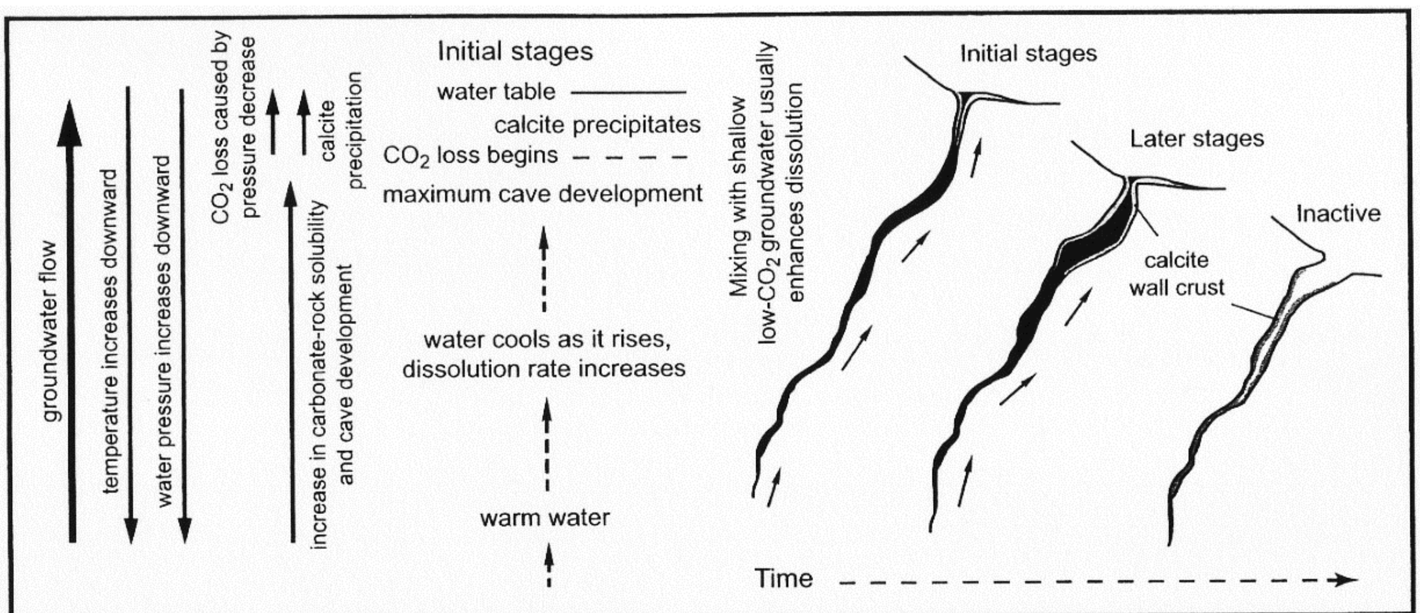
Palmer 2007



Hydrothermal carbonic speleogenesis

- Dissolution of carbonate rock by rising cooling CO_2-rich thermal waters
- High concentration of CO_2
- Increased calcite solubility due to cooling

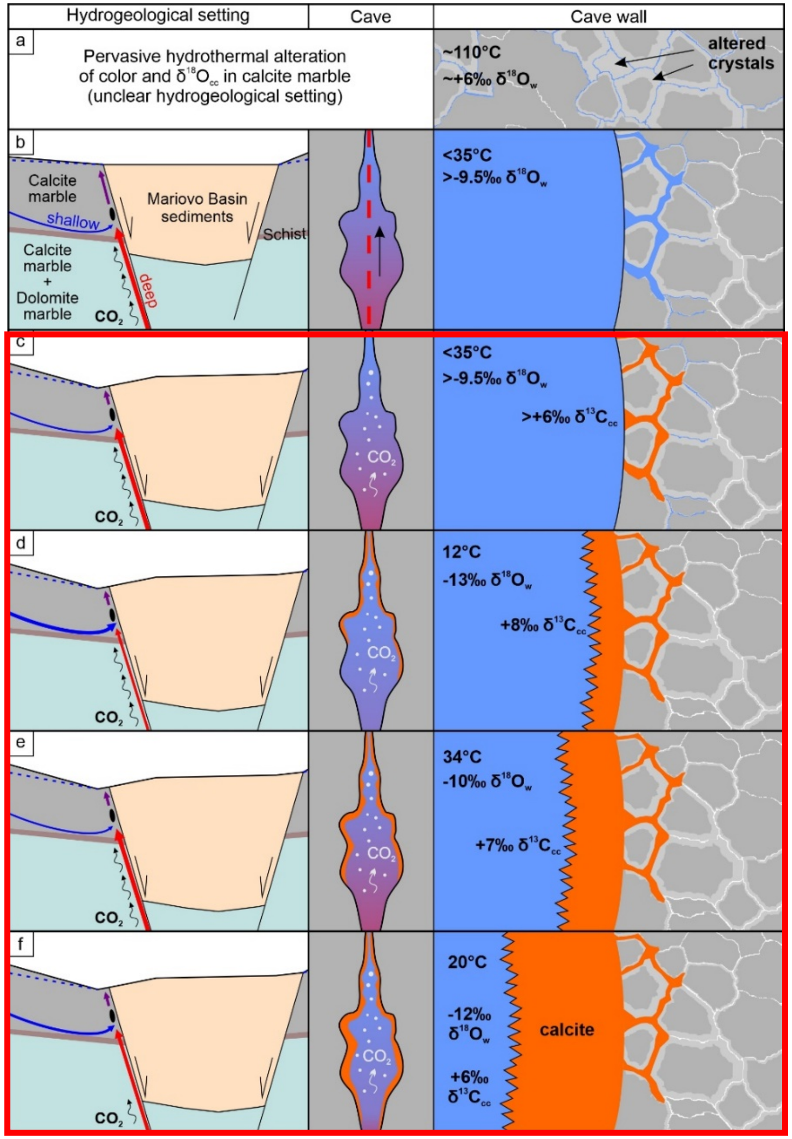
https://mjcave.hu



Palmer 2007

Hydrothermal carbonic speleogenesis

- Dissolution at depth
- Shift to mineral precipitation due to CO_2 degassing in shallower conditions

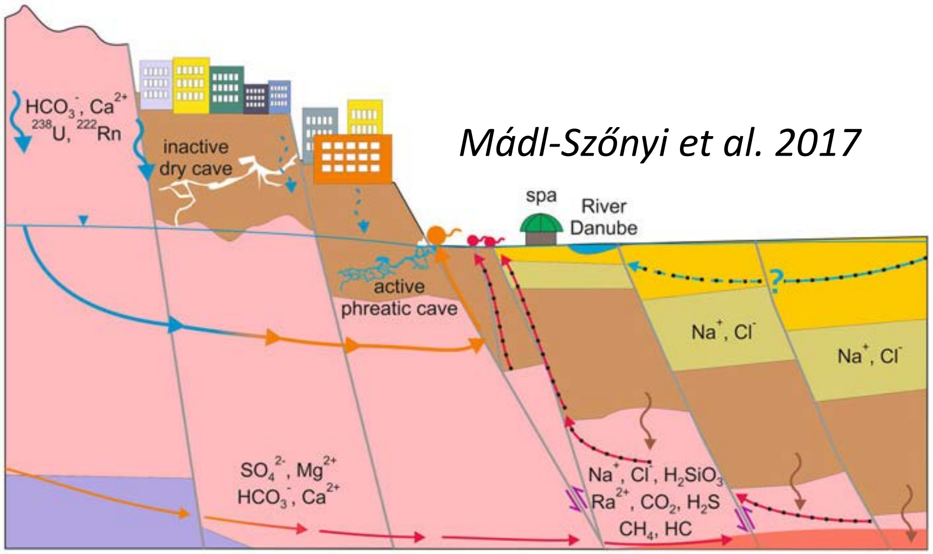


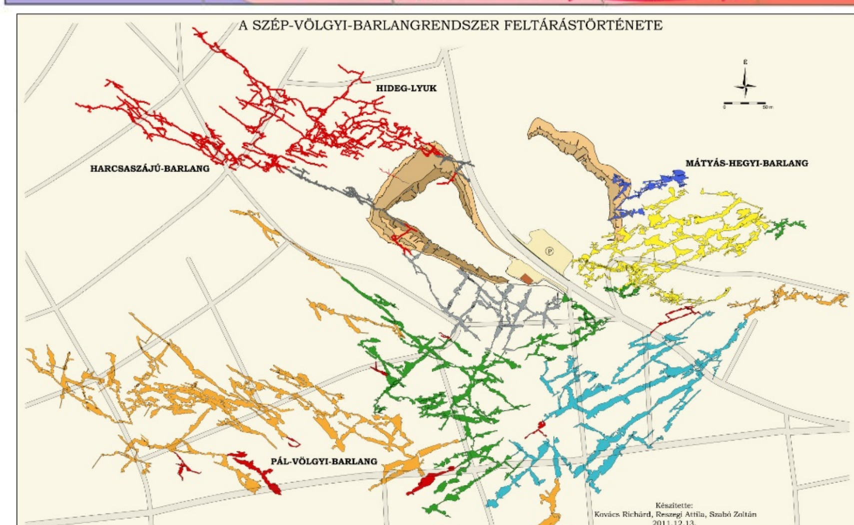
Temovski et al. 2022

Hydrothermal carbonic speleogenesis

- Buda Hills thermal karst, Budapest
 (e.g., Pál-völgy and József-hegy caves)

Mádl-Szőnyi et al. 2017

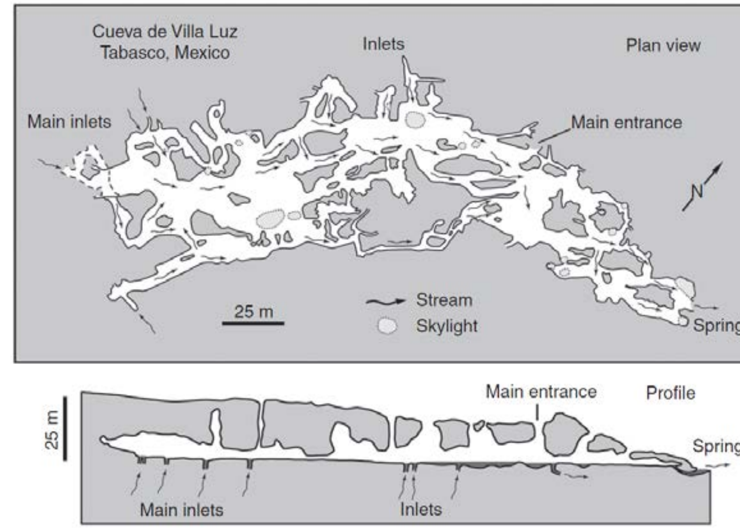




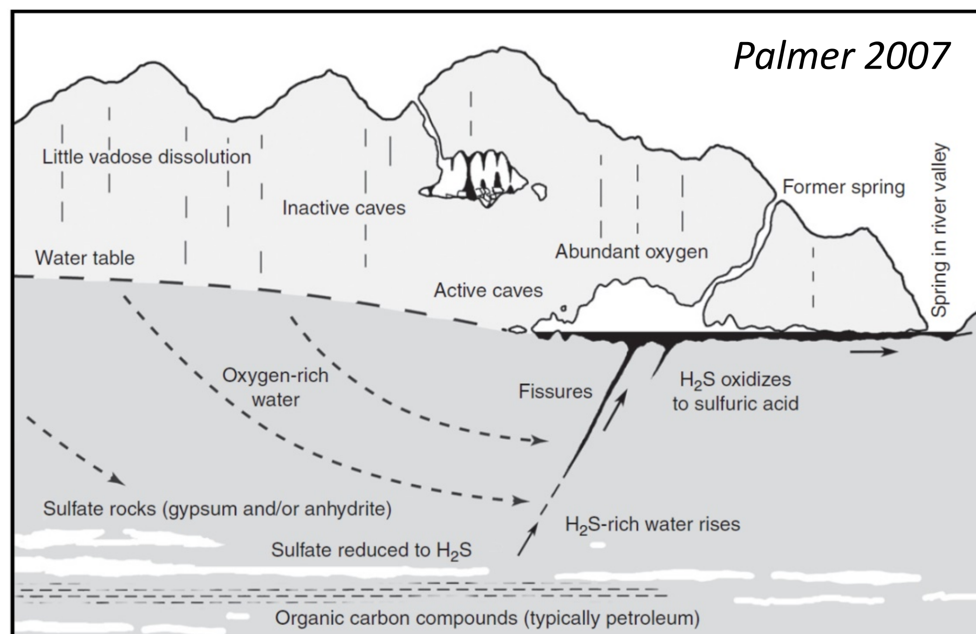
Leél-Őssy 2017

Sulfuric acid speleogenesis

- Dissolution of carbonate rock by sulfuric acid (H_2SO_4)
- Sulfuric acid forms by oxidation of sulfides (typically H_2S)
    - H_2S from reduction of sulfates, magmatic origin



Palmer 2013



Palmer 2007

Sulfuric acid speleogenesis

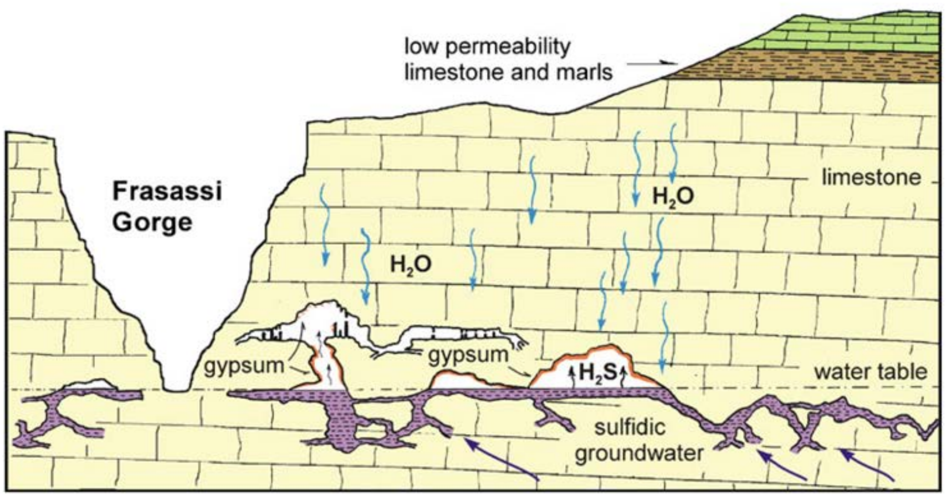
- An increasing number of reported sulfuric acid caves around the world

- Large interest in microbial life of sulfuric caves
  – **potential analog for extraterrestrial environments**!

De Waele et al. 2016

Table 1
Examples of the main sulfuric caves in the world.

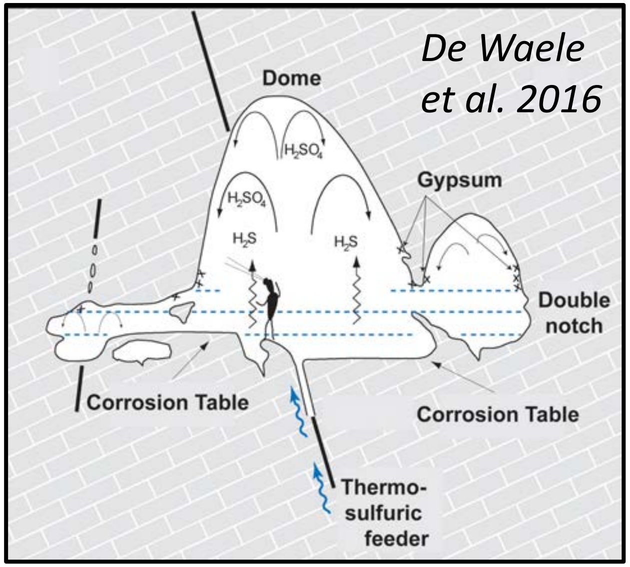
Lower Kane Caves	USA (WY)	Egemeier (1981) and Engel et al. (2004)
Carlsbad Caverns, Lechuguilla Cave, etc.	USA (NM) Guadalupe Mts.	Hill (1987, 1990), Polyak et al. (1998), Palmer and Palmer (2000), Polyak and Provencio (2001), Engel et al. (2004), Calaforra and De Waele (2011), Palmer and Palmer (2012) and Kirkland (2014)
Glenwood Cave	USA (CO)	Barton and Luiszer (2005) and Polyak et al. (2013)
Cueva de Villa Luz	Mexico, Tabasco	Hose and Pisarowicz (1999) and Hose et al. (2000)
Movile Cave	Romania, Dobrogea	Sarbu et al. (1994, 1996)
Frasassi Cave	Italy, Umbria	Galdenzi and Menichetti (1995) and Galdenzi and Maruoka (2003)
Monte Cucco and Faggeto Tondo caves	Italy, Umbria	Galdenzi and Menichetti (1995) and Menichetti (2011)
Acquasanta Terme caves	Italy, Marche	Galdenzi et al. (2000) and Jones et al. (2014)
Montecchio Cave	Italy, Tuscany	Piccini et al. (2015)
Monte Soratte caves	Italy, Latium	Mecchia (2012)
Cala Fetente caves	Italy, Campania	Forti (1985) and Forti et al. (1989)
Santa Cesarea Terme caves	Italy, Apulia	De Waele et al. (2014)
Grotta di S. Angelo	Italy, Calabria	Galdenzi (1997)
Serra del Gufo-Balze di Cristo	Italy, Calabria	Galdenzi (1997)
Iglesiente mine caves	Italy, Sardinia	De Waele and Forti (2006) and De Waele et al. (2013)
Chevalley – Gr. des Serpents	France, Savoie	Audra et al. (2007)
Kraushöhle	Austria, Styria	Plan et al. (2012)
Bad Deutsch Altenburg caves	Lower Austria	Plan et al. (2009)
Diana Cave and Cerna caves	SW Romania	Onac et al. (2009, 2013), Wynn et al. (2010) and Puscas et al. (2013)
Provalata Cave	Rep. Macedonia	Temovski et al. (2013)
Aghia Paraskevi caves	N Greece, Kassandra	Lazaridis et al. (2011)
Rhar es Skhoun, Azrou massif	Algeria	Collignon (1983, 1990)
Nowi Afon Cave	Georgia, Abkhazia	Dublyansky (1980)
Cupp Coutunn Cave	Turkmenistan	Maltsev and Malishevsky (1990)
Tirshawaka Cave	N Iraq	Stevanović et al. (2009)



Galdenzi & Jones 2017

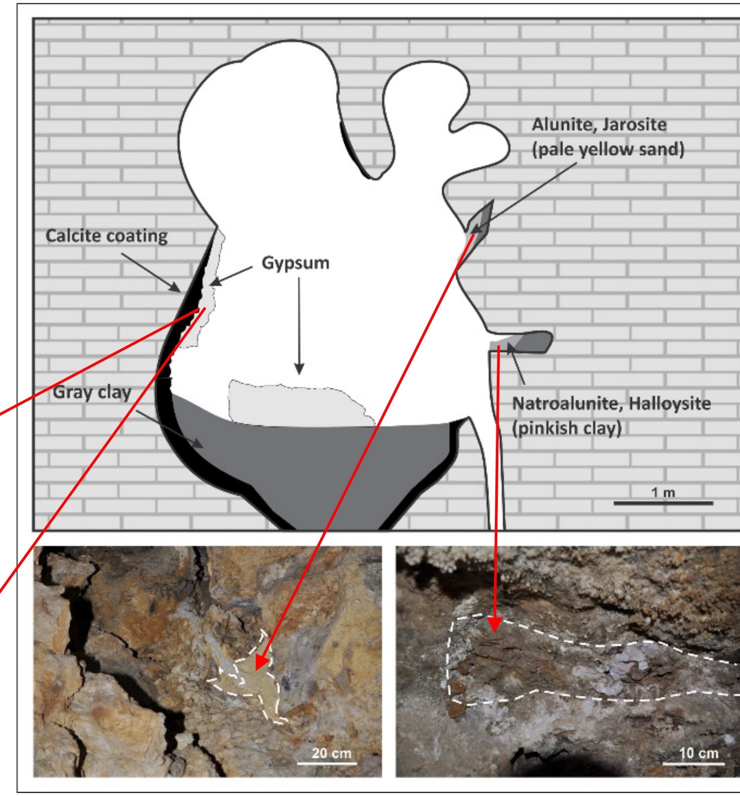
Sulfuric acid speleogenesis

- Characteristic morphology
  - Feeders, wall and ceiling half-tube channels, corrosion-table, water-table nothches, sulfuric karren,
- Cave volume mostly formed above water table (condensation corrosion)



Sulfuric acid speleogenesis

- Characteristic deposits
  - Carbonate rock is replaced by gypsum ($CaSO_4 \cdot 2H_2O$)
  - other sulfate minerals, e.g., alunite (Ar-Ar dating – timing of cave formation!)

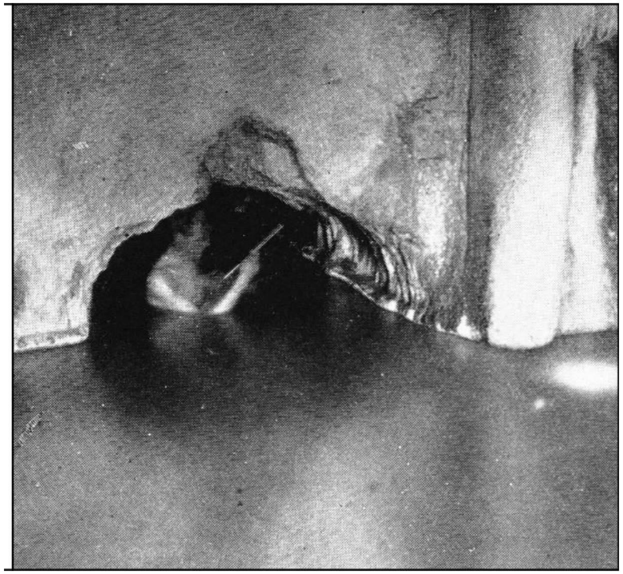


Temovski et al. 2013

How do we identify hypogene caves?

Morphology

Thermal spring cave
(Katlanovo, Macedonia)



Vajić 1928

Paragenesis due to sediment infill
(Camelié Aven, France)

Audra & Palmer 2013

- Cautiously!
- Equifinality of some morphological features

Characteristic cave minerals

- Much more reliable!

- Hydrothermal minerals, replacement gypsum etc.
- Fluid inclusion microthermometry
- Isotopic compositions of minerals

- **The relationship to cave genesis has to be demonstrated!**

Invasion of a karst aquifer by hydrothermal fluids: evidence from stable isotopic compositions of cave mineralization

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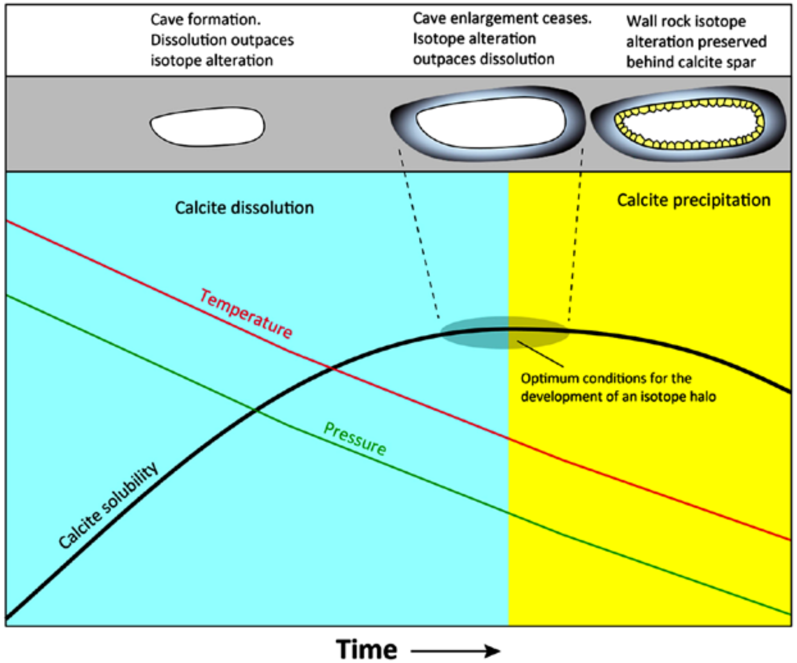
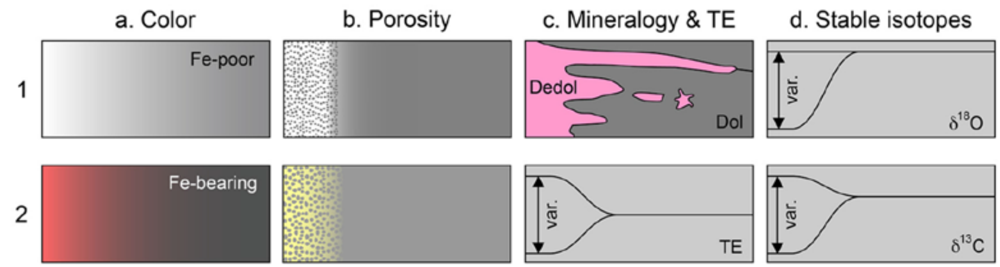
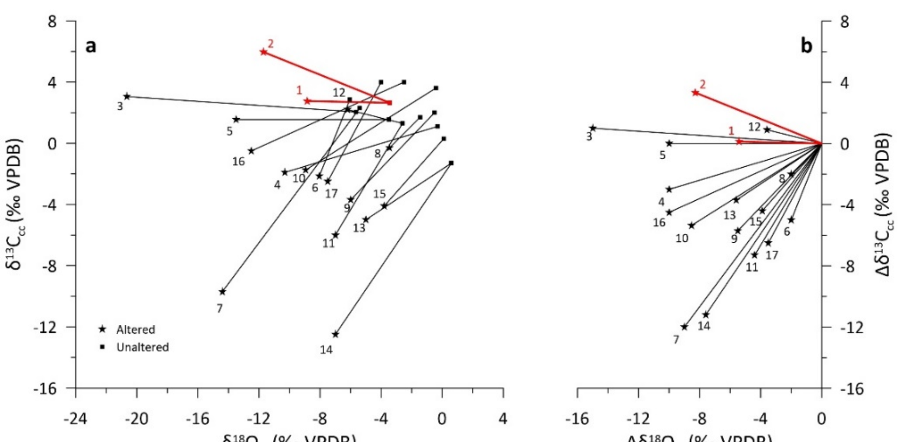
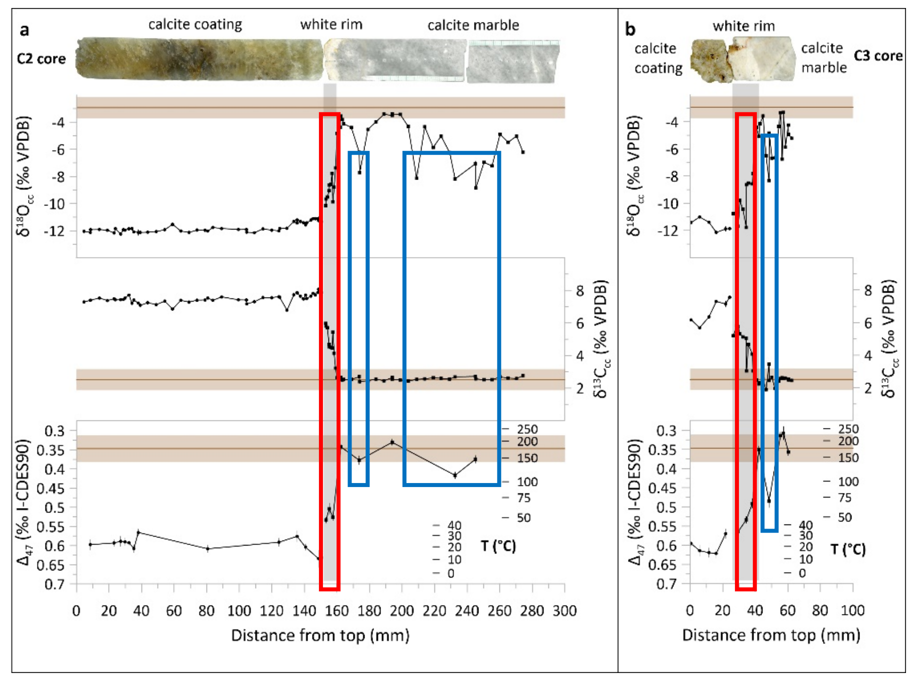
Alterations of bedrock





Spötl et al. 2021





Temovski et al. 2022


Hvala!
Thank you!