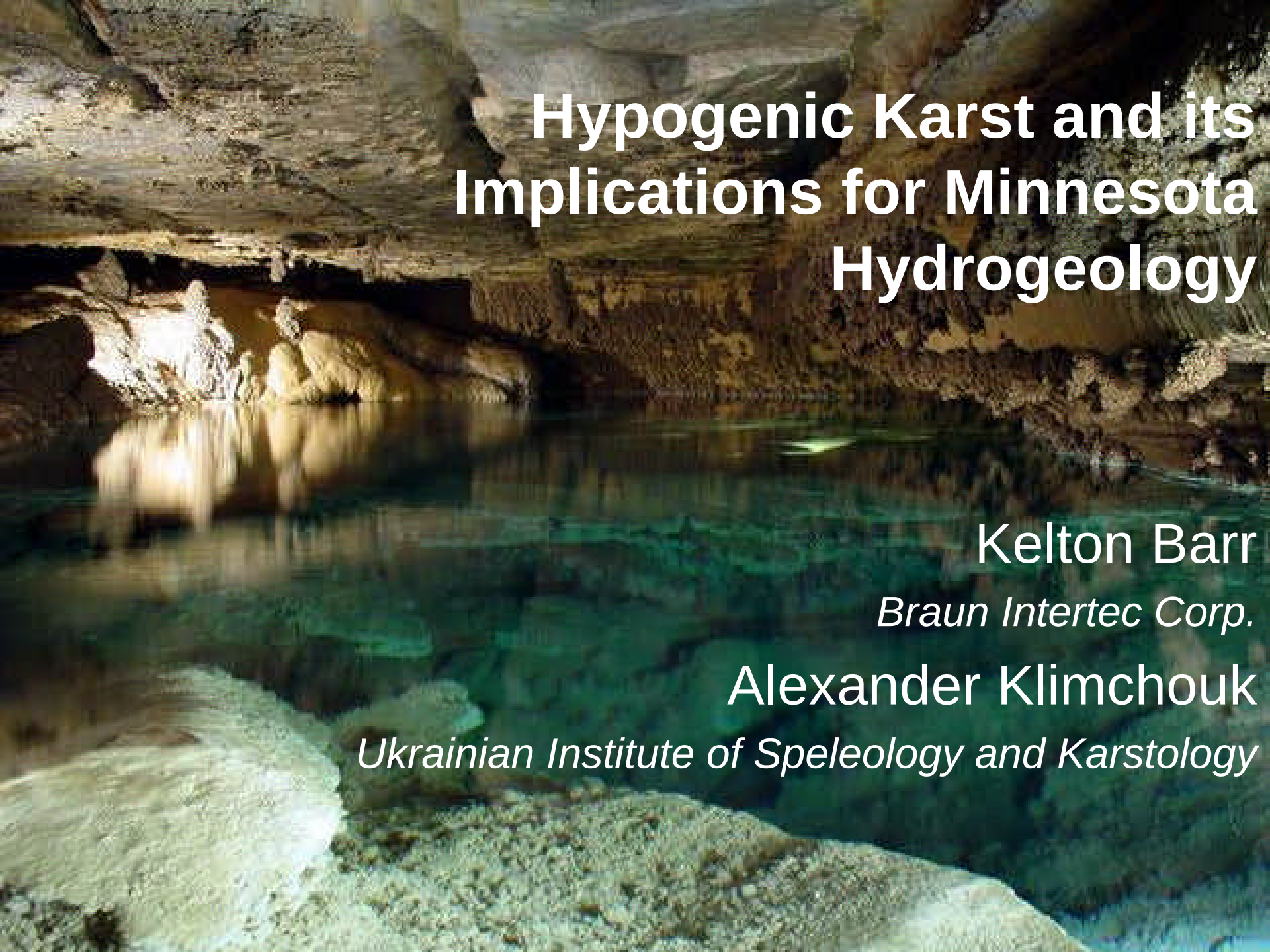

Hypogenic Karst and its Implications for Minnesota Hydrogeology

Kelton Barr

Braun Intertec Corp.

Alexander Klimchouk

Ukrainian Institute of Speleology and Karstology

Barr and Klimchouk (2007)

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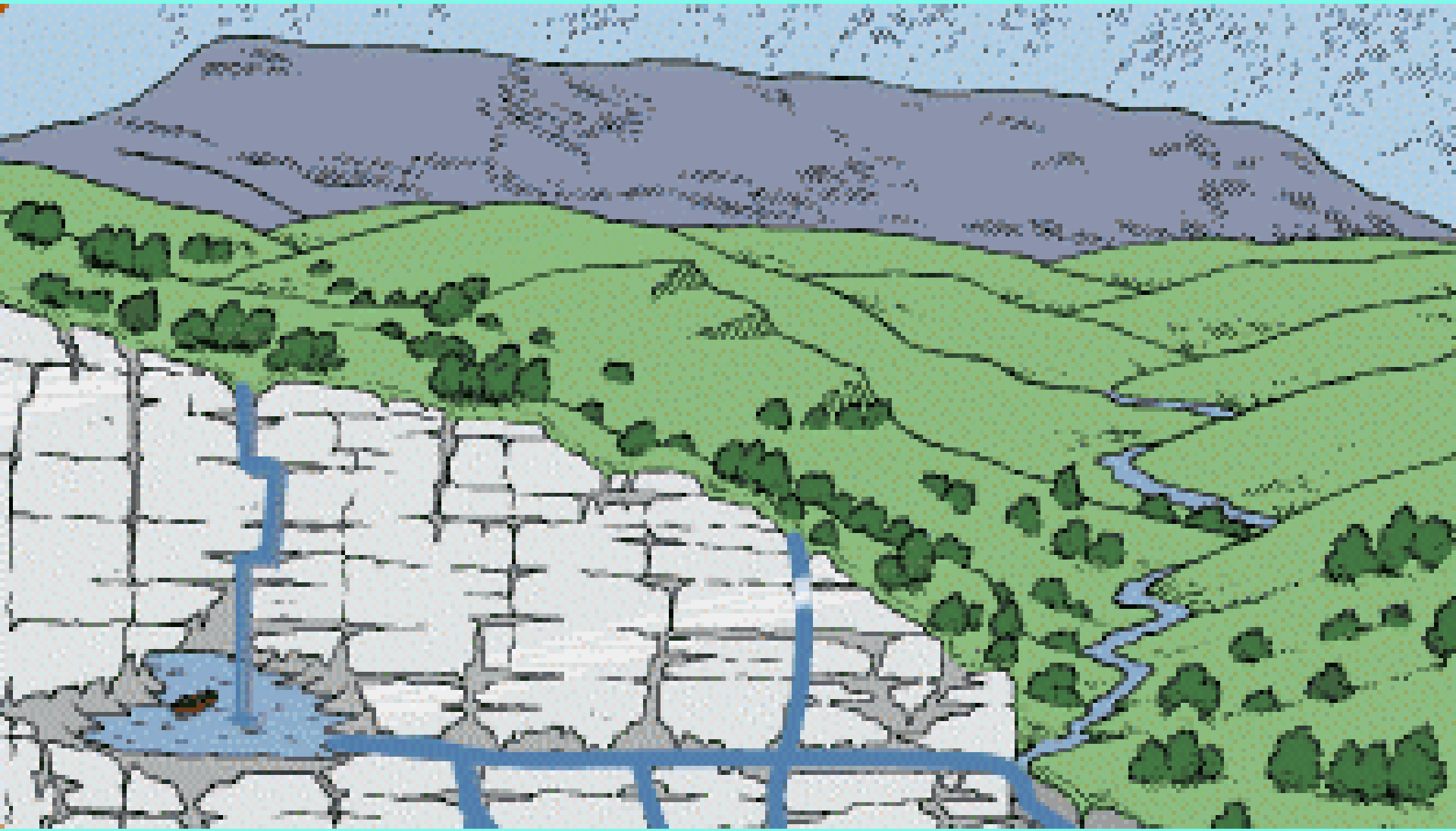

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Source of confusion:

Is KARST a landform or a process?

- *"A limestone plateau marked by sinks, or karst holes, interspersed with abrupt ridges and irregular protuberant rocks; usually underlain by caverns and underground streams." – Glossary of Geology (1960)*

Barr and Klimchouk (2007)

Karst as a hydrogeologic <u>process</u>:

Karst is… “an integrated mass-transfer system in soluble rocks with a permeability structure dominated by conduits dissolved from the rock and organized to facilitate the circulation of fluids.”

–Huntoon (1995)

–Klimchouk and Ford (2000)

Barr and Klimchouk (2007)

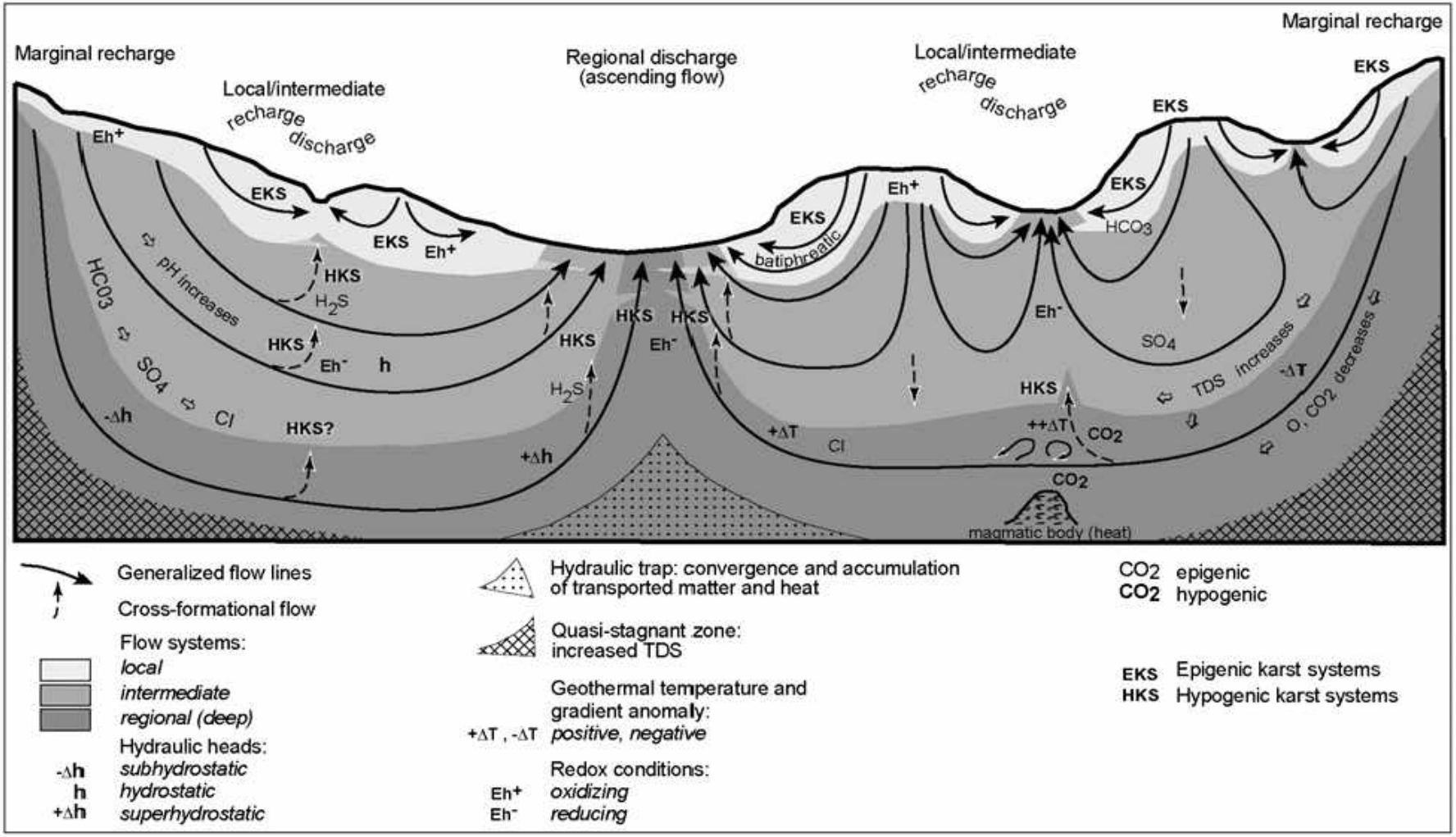
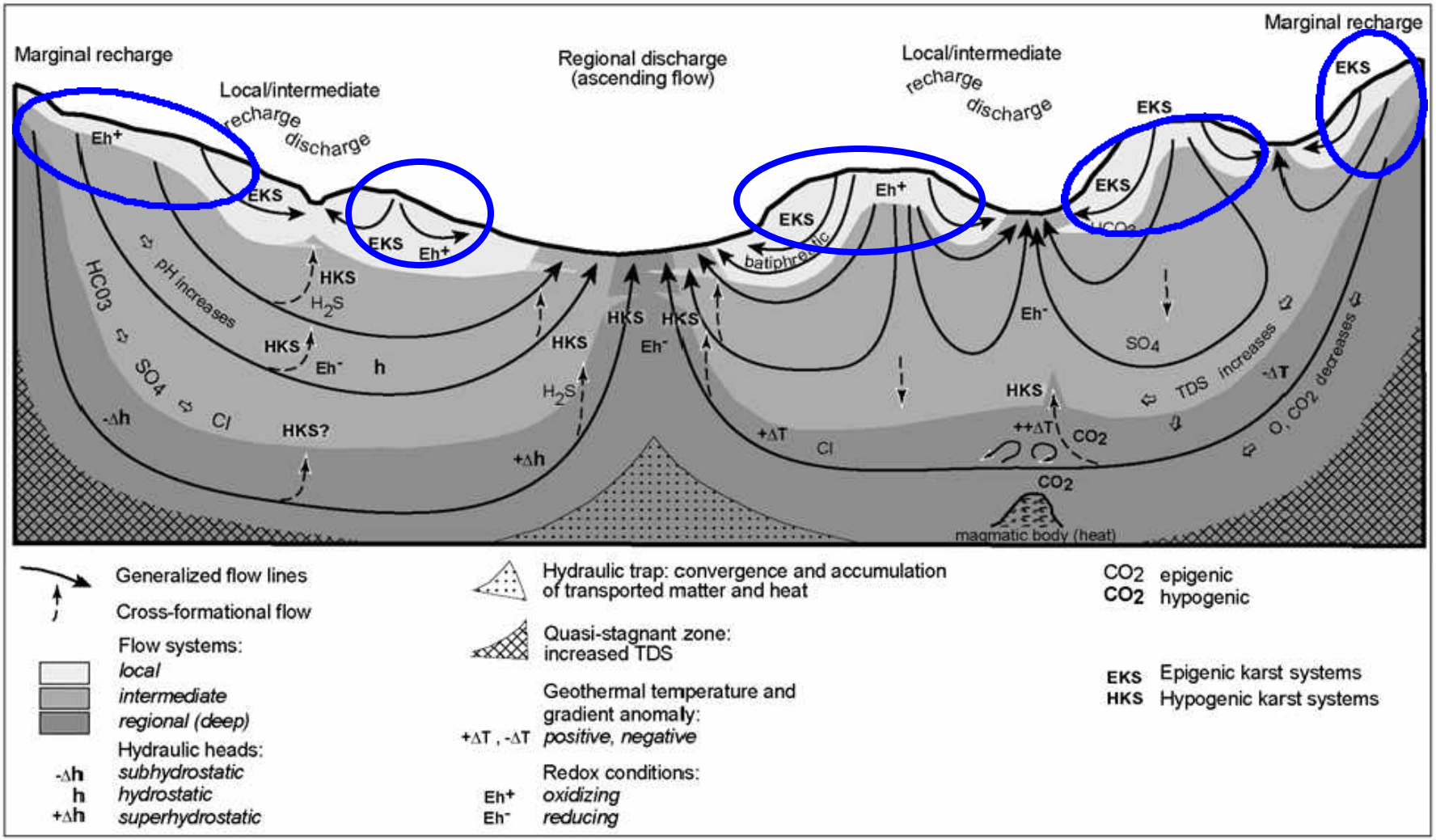


Figure 1. Epigenic and hypogenic karst in the context of basinal groundwater flow. Adopted and modified from Tóth (1999). The figure shows mainly gravity-driven flow in an idealized homogenous basin. In reality, most sedimentary sequences are highly heterogeneous, and gravity-driven flow interacts with other flow mechanisms.

from Klimchouk (2007)



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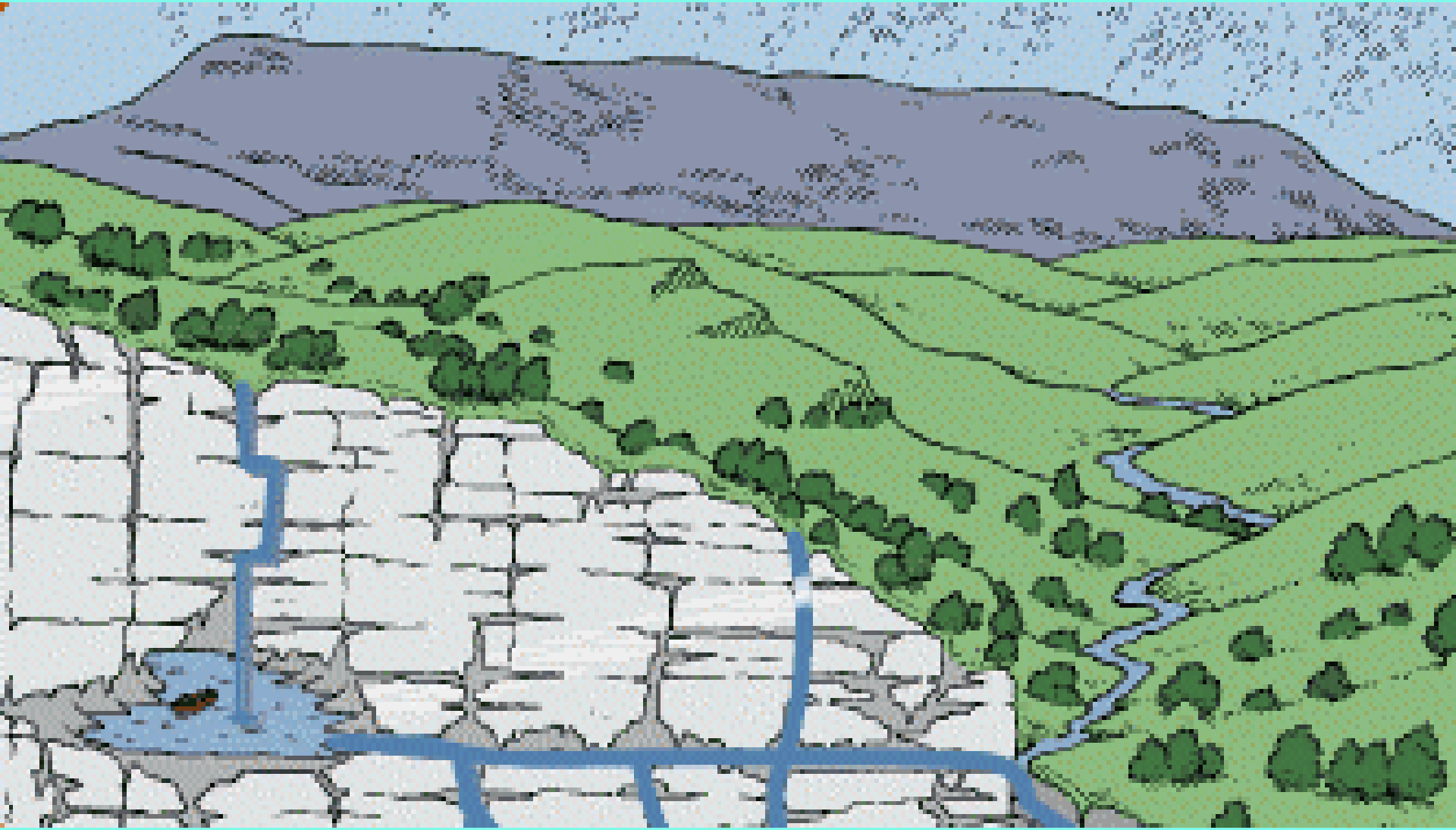
from Klimchouk (2007)

Epigenic karst (Epikarst)



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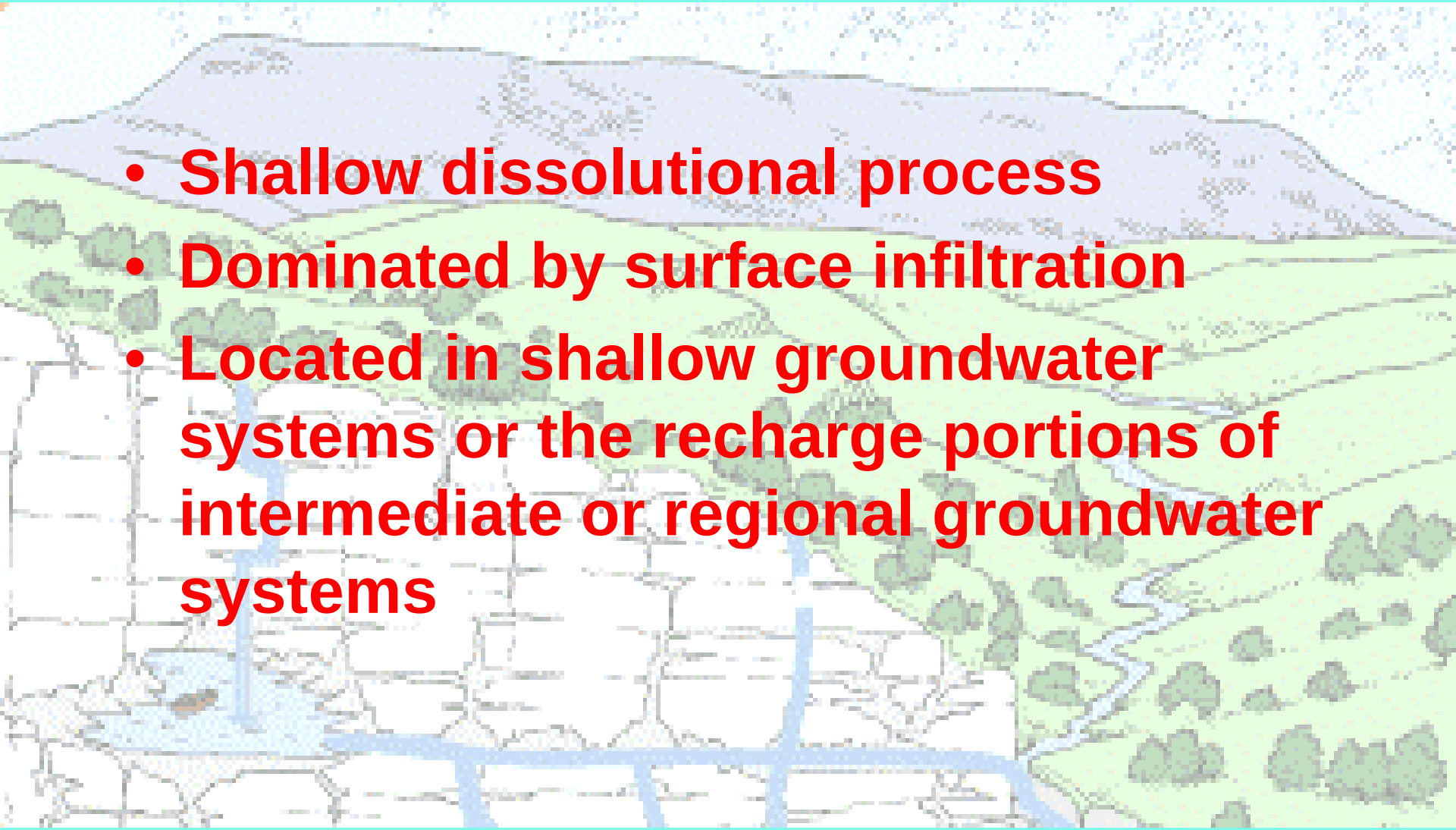
Epigentic karst is…



- Shallow dissolutional process
- Dominated by surface infiltration
- Located in shallow groundwater systems or the recharge portions of intermediate or regional groundwater systems

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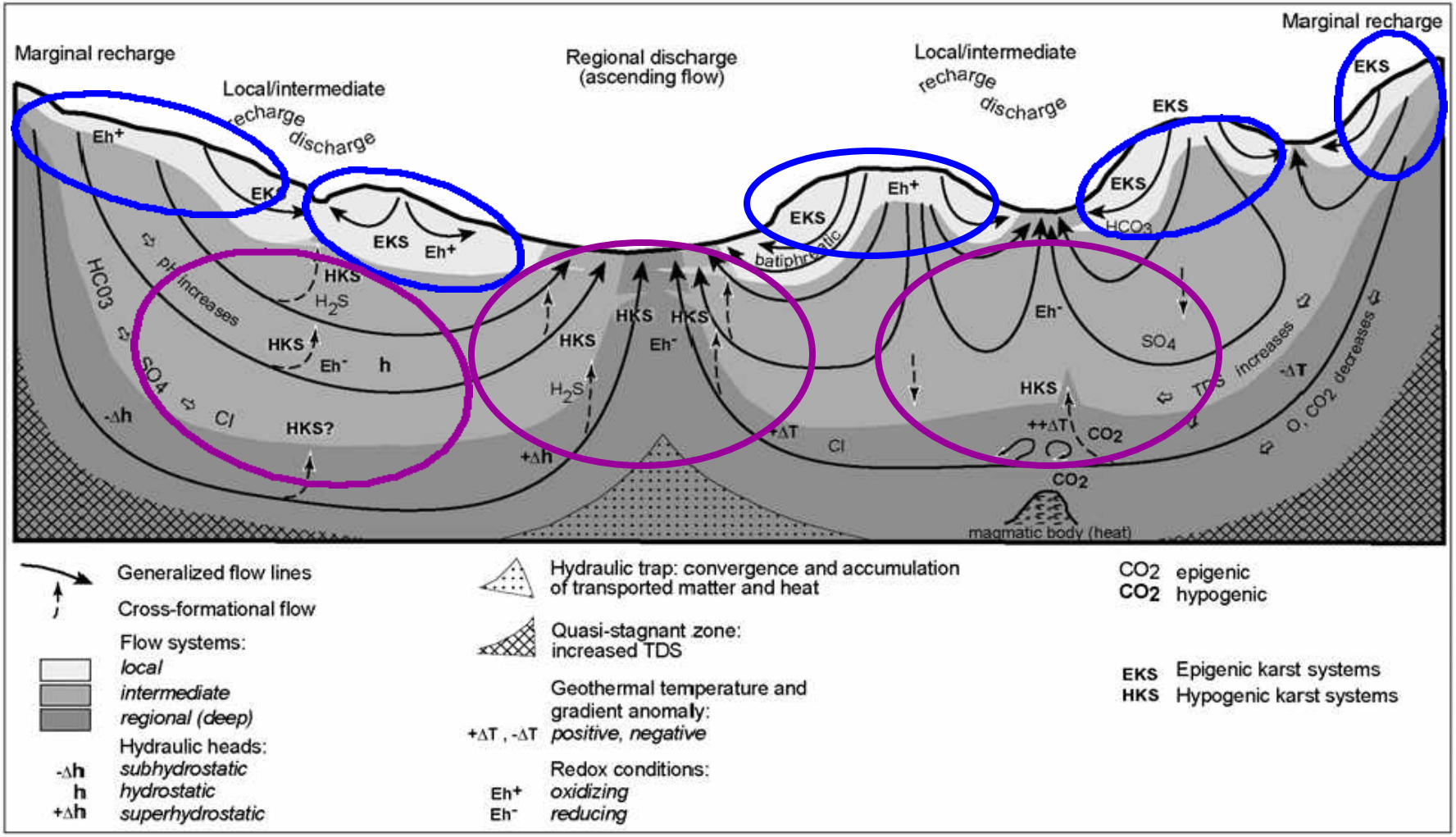

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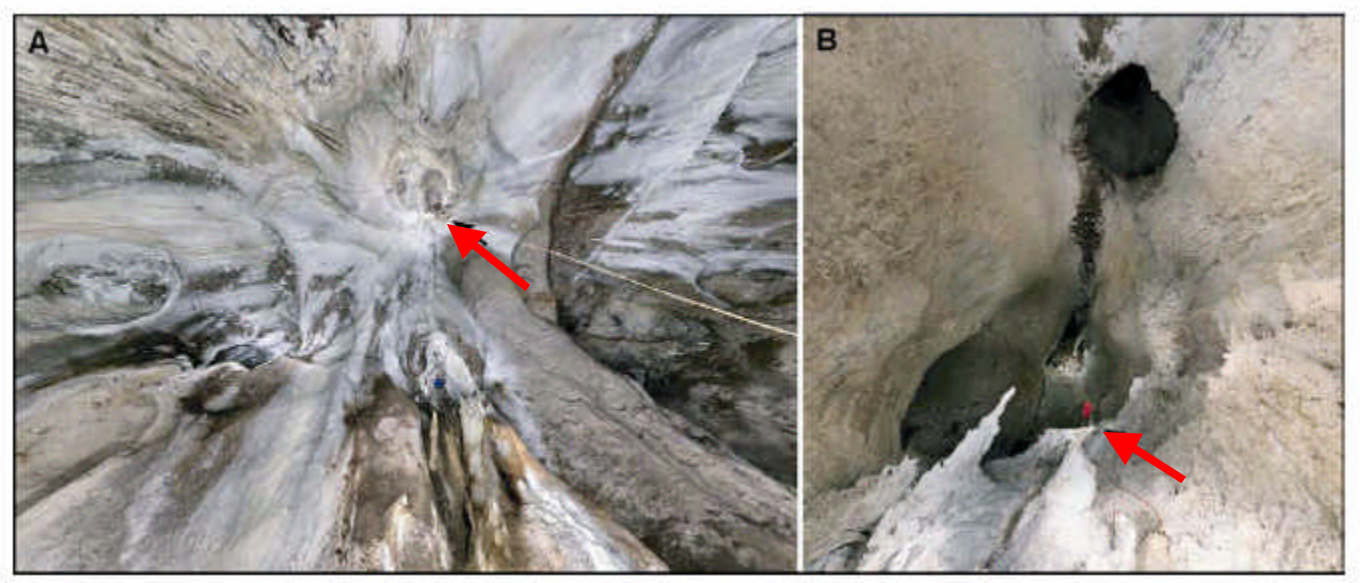
from Klimchouk (2007)

Hypogenic Karst

- Deep dissolutional process
- Dominated by upward flow and gradients
- Associated with discharge regimes of intermediate and regional flow systems



Lechuguilla Cave, Guadalupe Mountains, NM (from Klimchouk, 2007)

Barr and Klimchouk (2007)

Speleogenesis

"the creation and evolution of organized permeability structures in a rock that have evolved as the results of dissolutional enlargement of an earlier porosity."

–Klimchouk and Ford (2000)

Barr and Klimchouk (2007)

Hypogene Speleogenesis

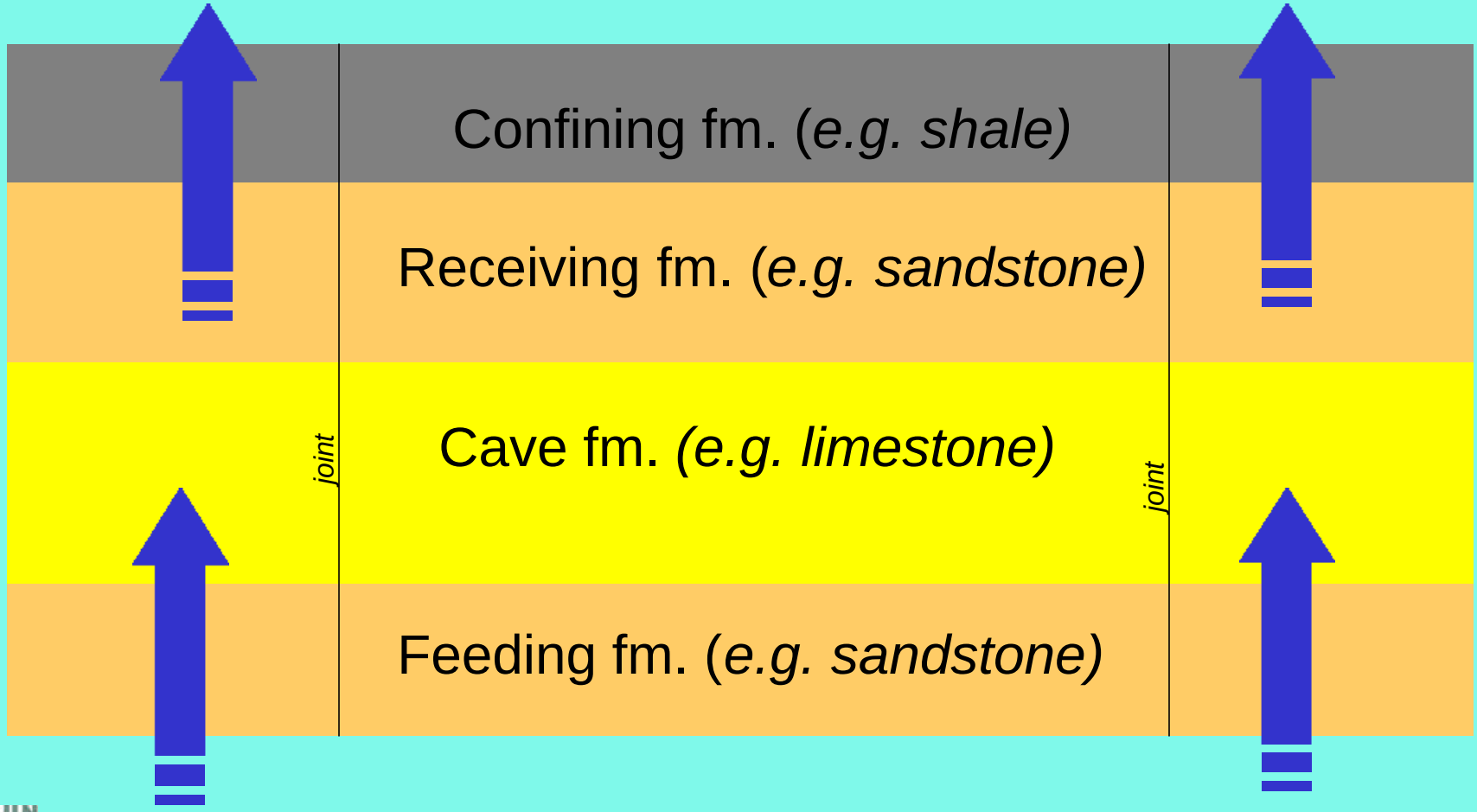
"the formation of caves by water that recharges the soluble formation from below, driven by hydrostatic pressure or other sources of energy, independent of recharge from the overlying or immediately adjacent surface."

–Ford (2006)

Barr and Klimchouk (2007)

Basic steps in hypogenic karst development

1. Initial conditions



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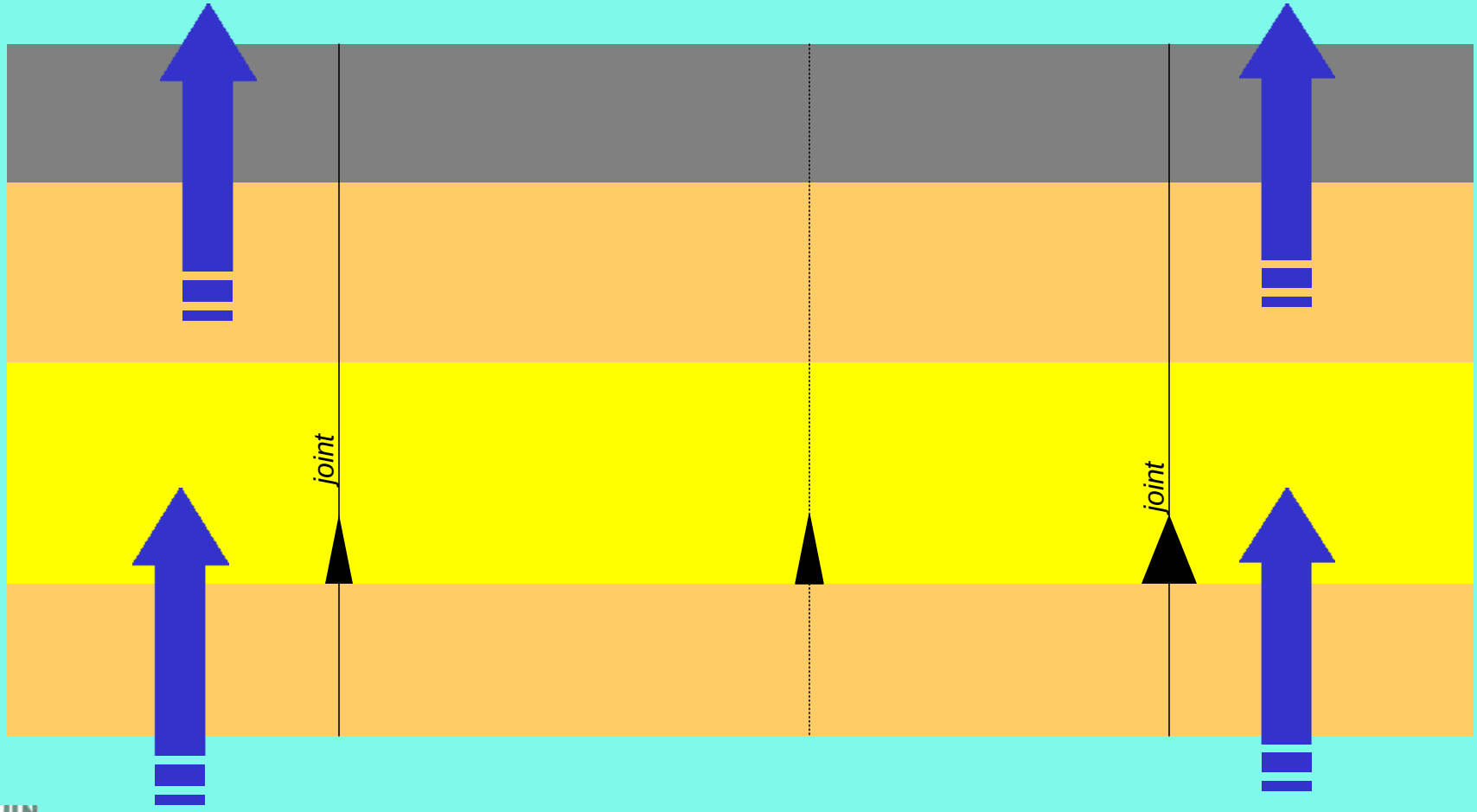
Basic steps in hypogenic karst development
2. Solution enlargement along fractures



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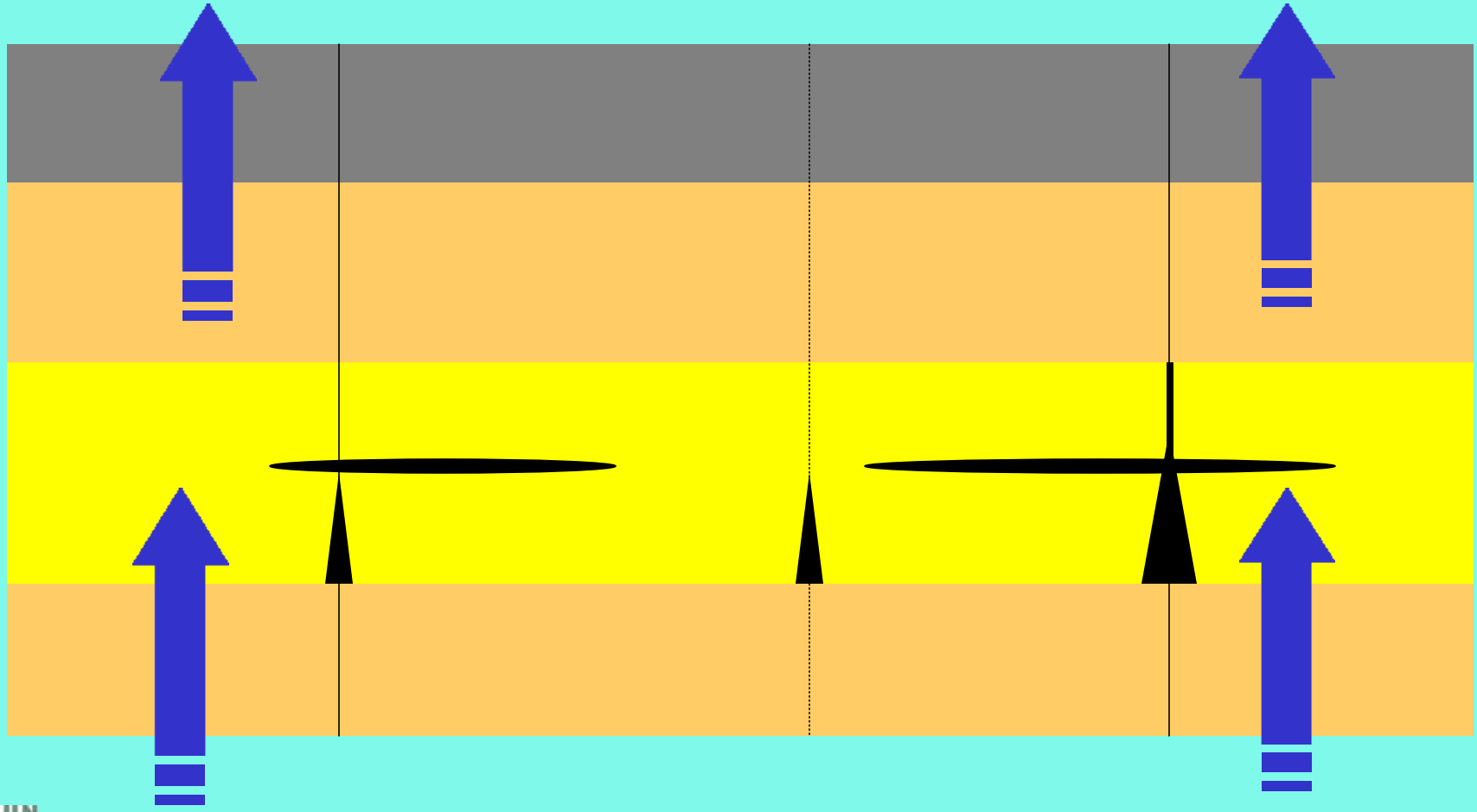
Basic steps in hypogenic karst development

3. Solution enlargement along fractures and beds



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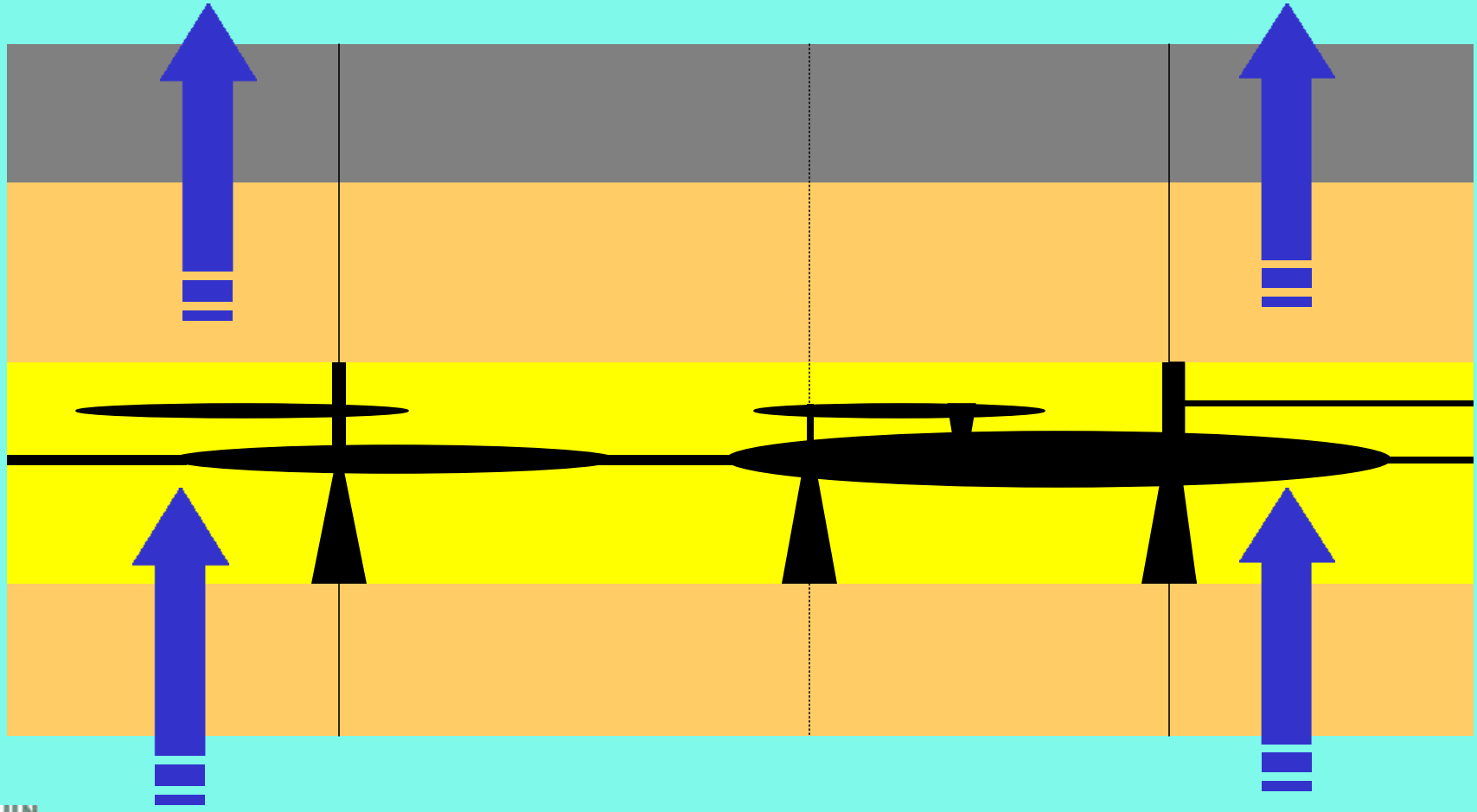
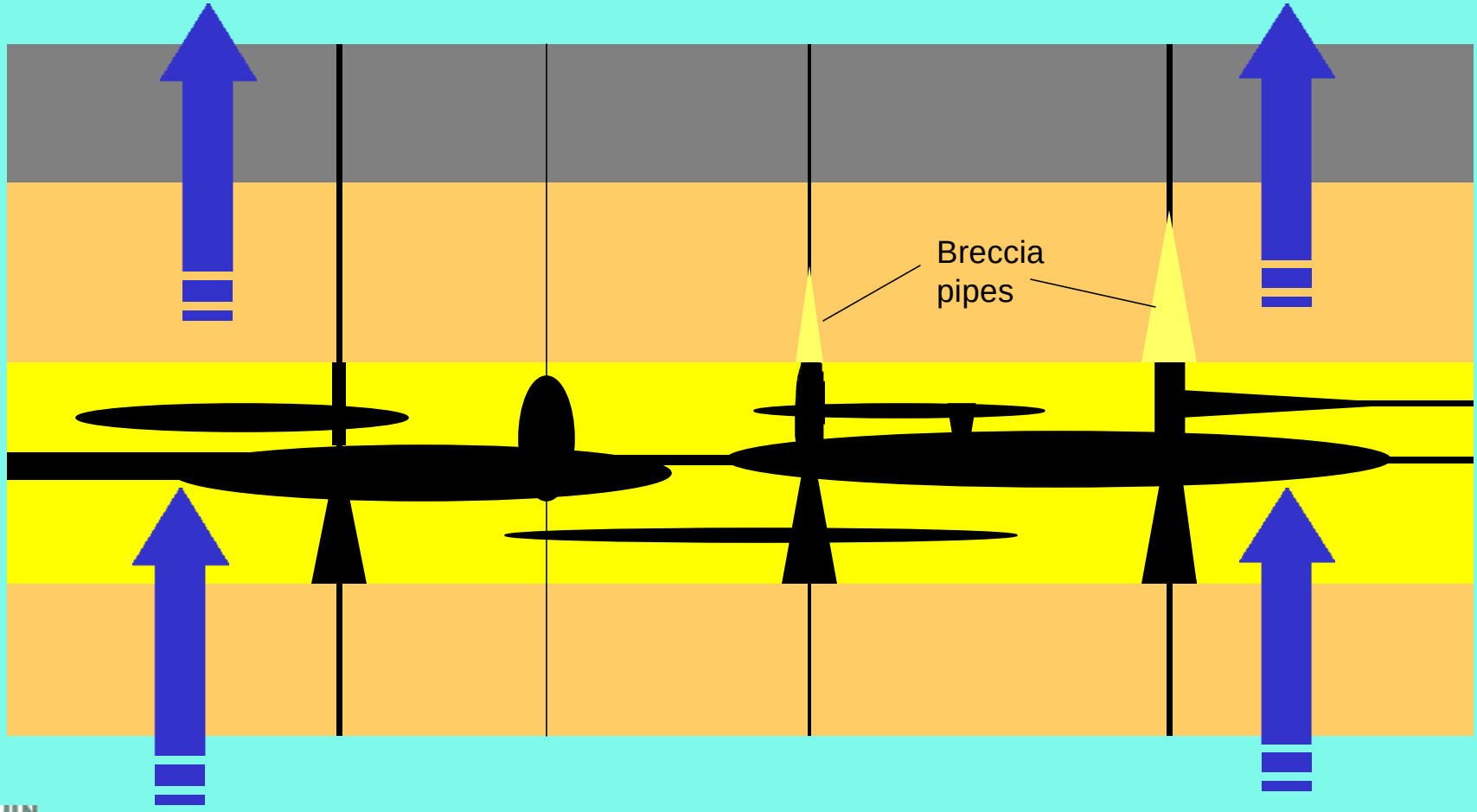
Basic steps in hypogenic karst development
4. Integration of solution enlargements



Barr and Klimchouk (2007)

Basic steps in hypogenic karst development
5. Ongoing evolution of karst system



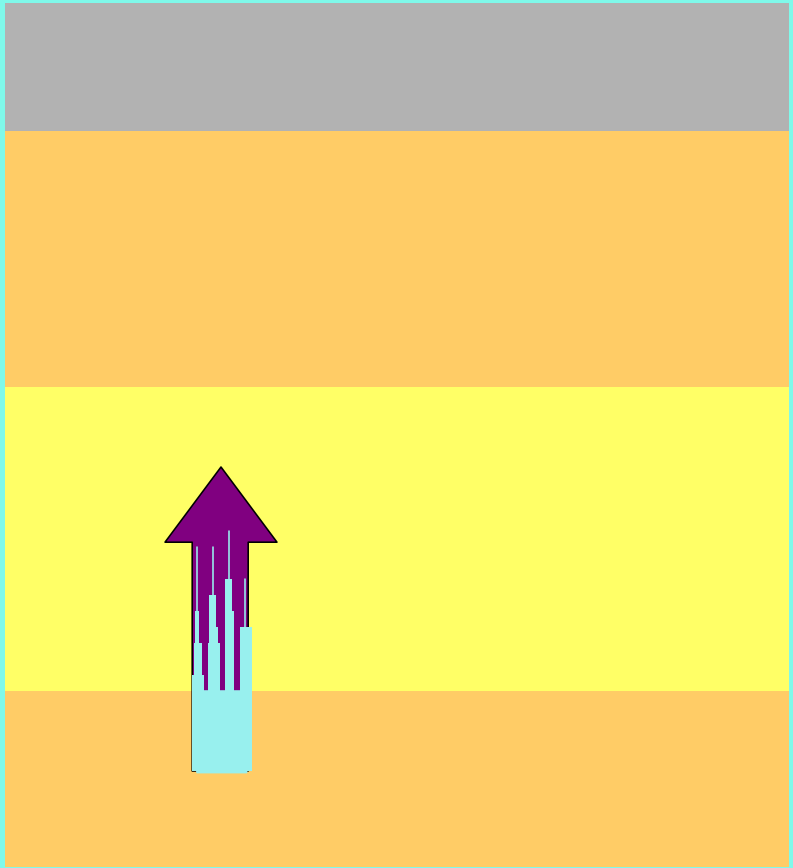
Barr and Klimchouk (2007)

Basic characteristic of hypogenic speleogenesis: **Transverse hydraulic communication**

Implications:

1. Dissimilar water quality entering cave fm.
   - Water chemistry
   - Gas composition
   - Temperature

→disequilibrium and reaction dissolution mechanisms



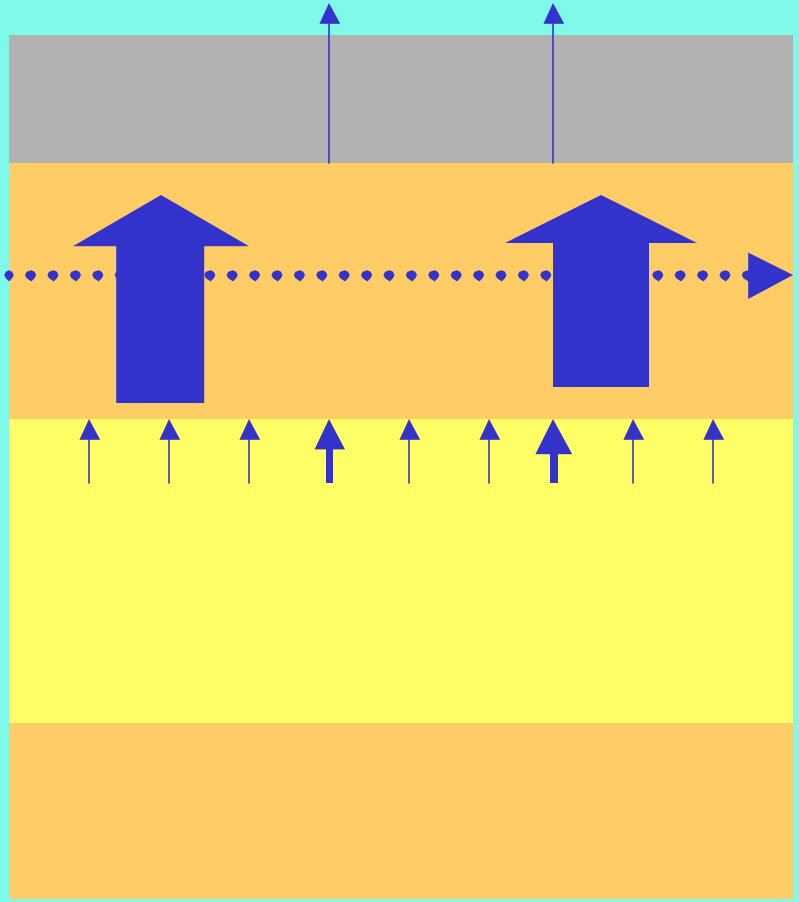
Barr and Klimchouk (2007)

Basic characteristic of hypogenic speleogenesis: **Transverse hydraulic communication**

Implications:

2. Suppression of the positive flow dissolution feedback mechanism.
   - Flow controlled by least permeable formation along pathway

→development of more pervasive conduit system (maze patterns)



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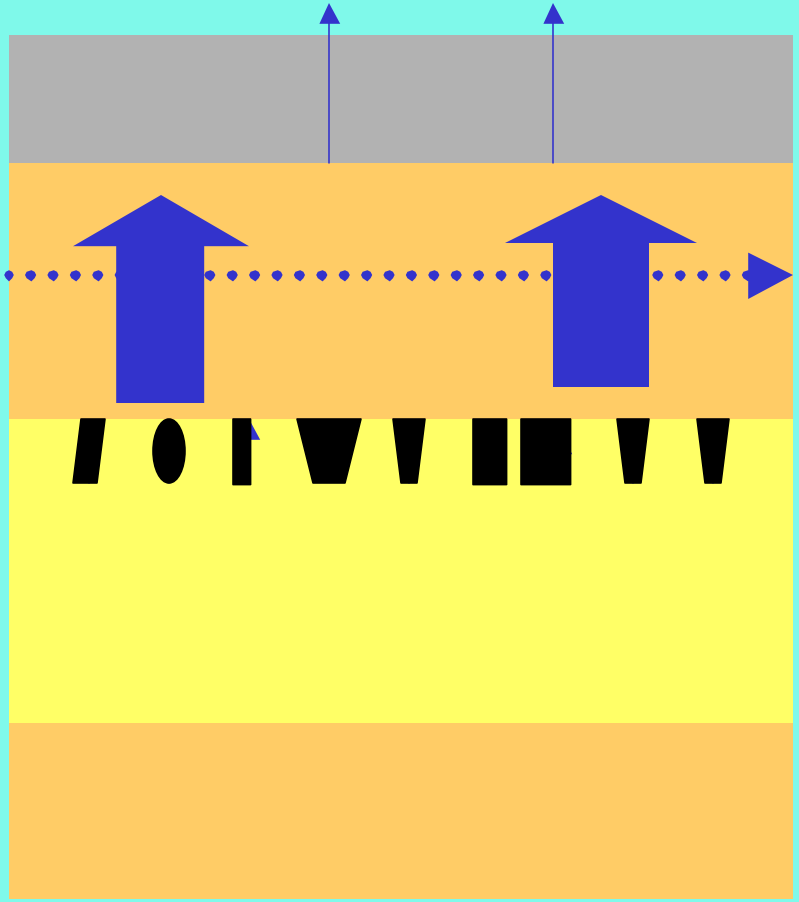


Barr and Klimchouk (2007)

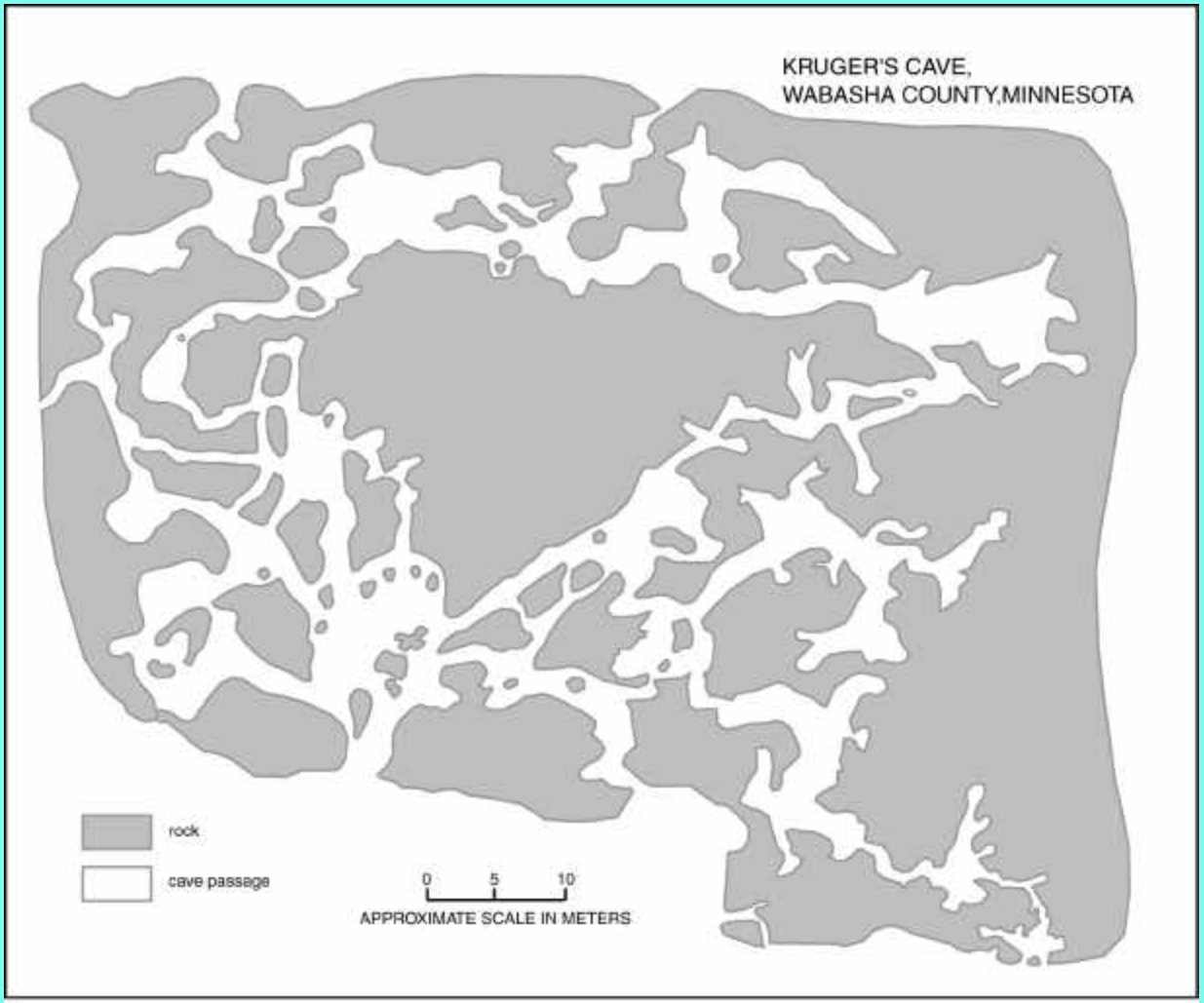
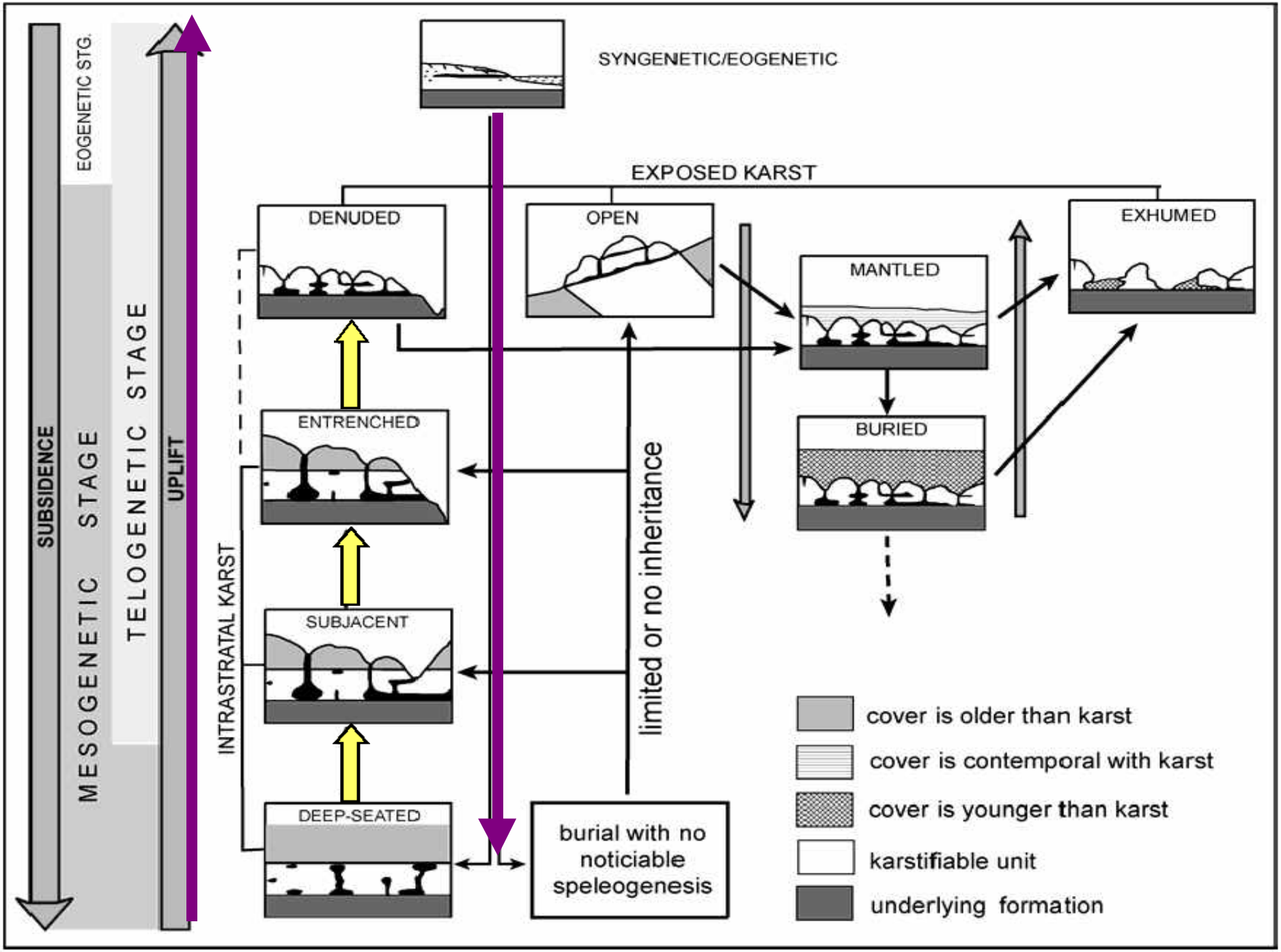


Figure 3

from Tipping (2007)


SUBSIDENCE
EOGENETIC STG.
MESOGENETIC STAGE
TELOGENETIC STAGE
UPLIFT
SYNGENETIC/EOGENETIC
EXPOSED KARST
DENUDED
OPEN
MANTLED
EXHUMED
ENTRENCHED
BURIED
SUBJACENT
INTRASTRATAL KARST
limited or no inheritance
DEEP-SEATED
burial with no noticiable speleogenesis
cover is older than karst
cover is contemporal with karst
cover is younger than karst
karstifiable unit
underlying formation

Identifying hypogenic karst in Minnesota is confusing because:

- Lack of a genetic relationship with overlying or adjacent surfaces
  - Encountered by erosional entrenchment or human activities (drilling, mining, *etc.*)
- Usually encountered after erosion brings hypogenic systems to shallow depths
  - Decoupled from deeper processes that created them.
  - Overprinting by epigenic processes, masking important features

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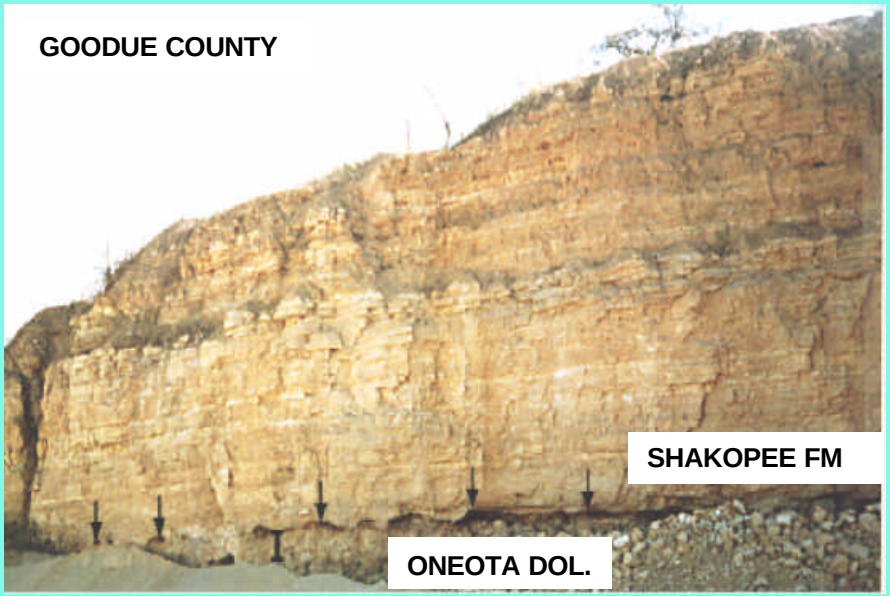
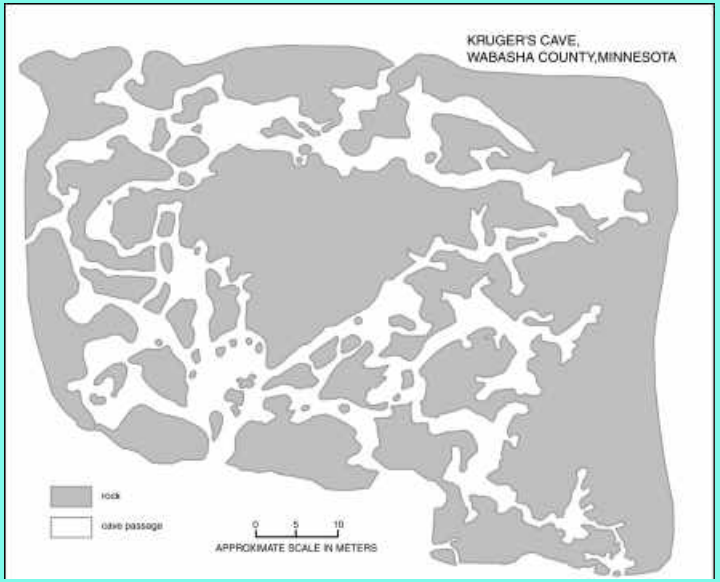
Barr and Klimchouk (2007)

BEDDING PLANE FRACTURES/VUGS (BPFS): EXAMPLE IN PRAIRIE DU CHIEN CARBONATE ROCK





Plan view of this BPF/solution interval

from Runkle (2007), Tipping (2007)

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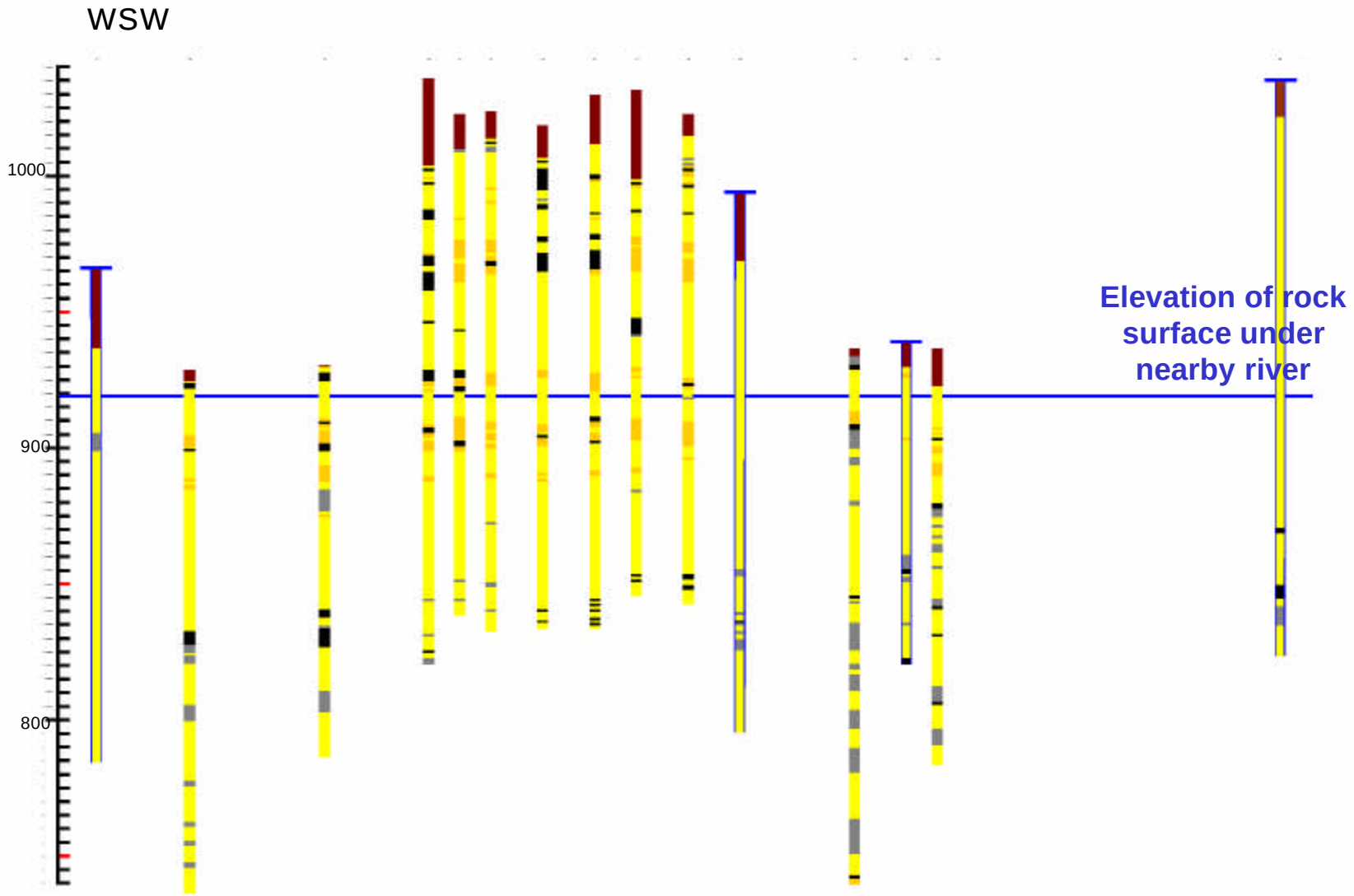
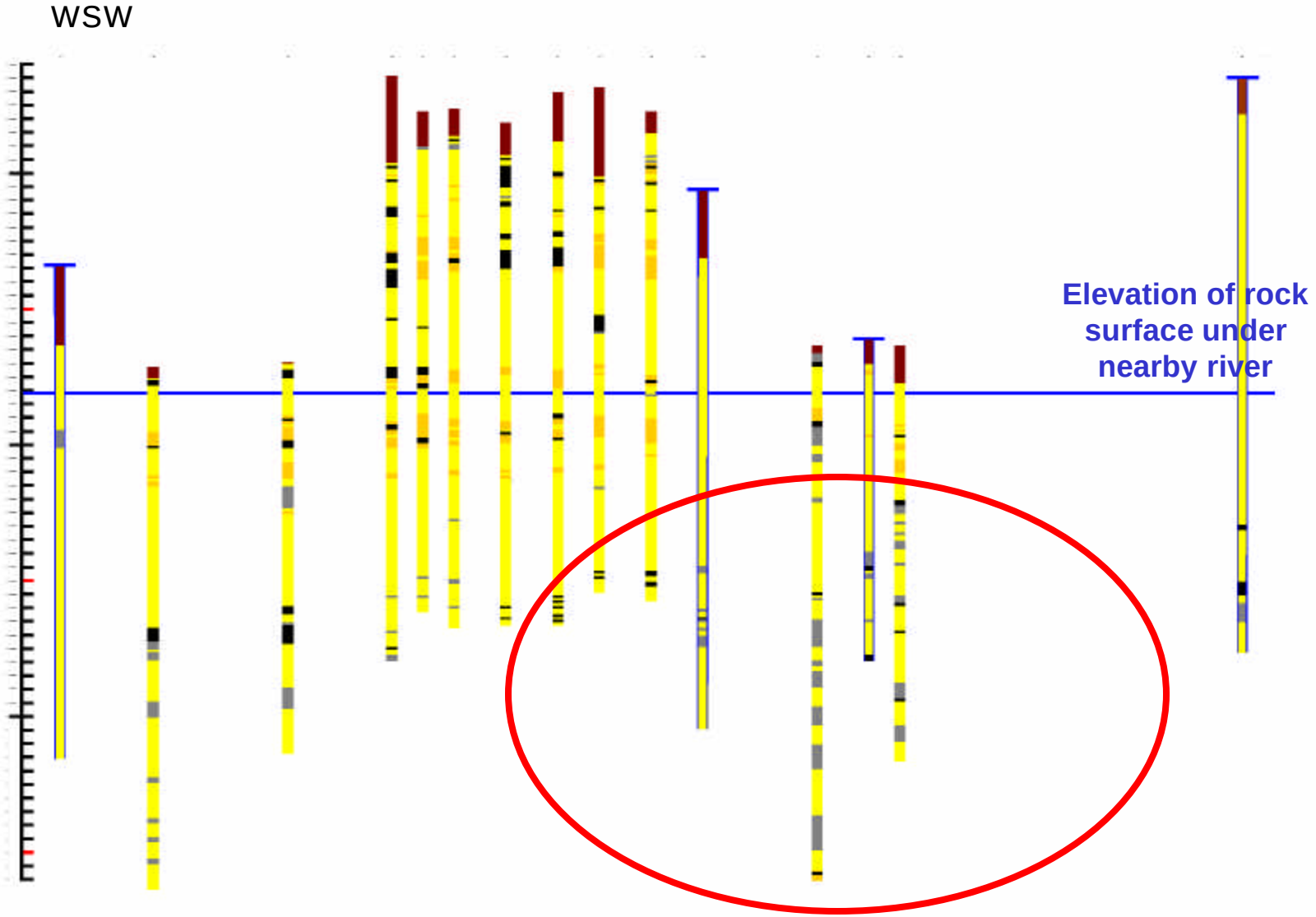
Barr and Klimchouk (2007)



Transect of coreholes and wells – Olmstead County

Barr and Klimchouk (2007)



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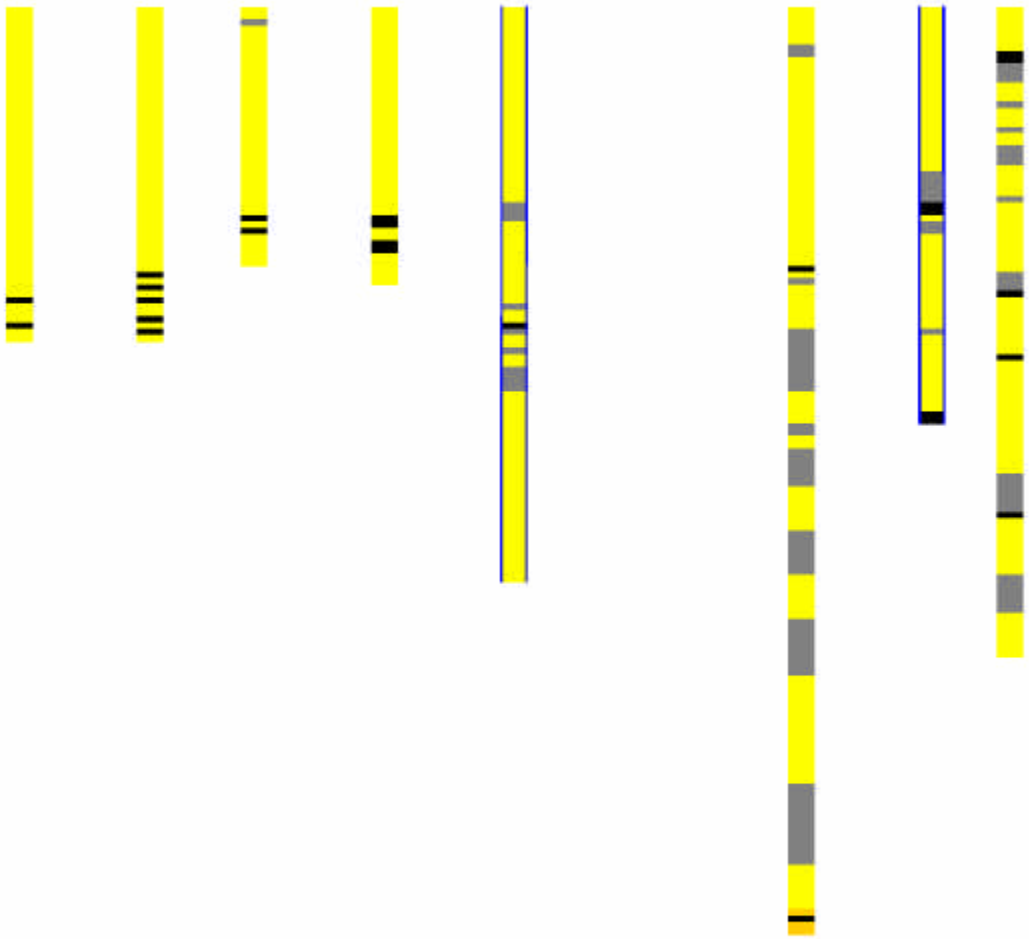
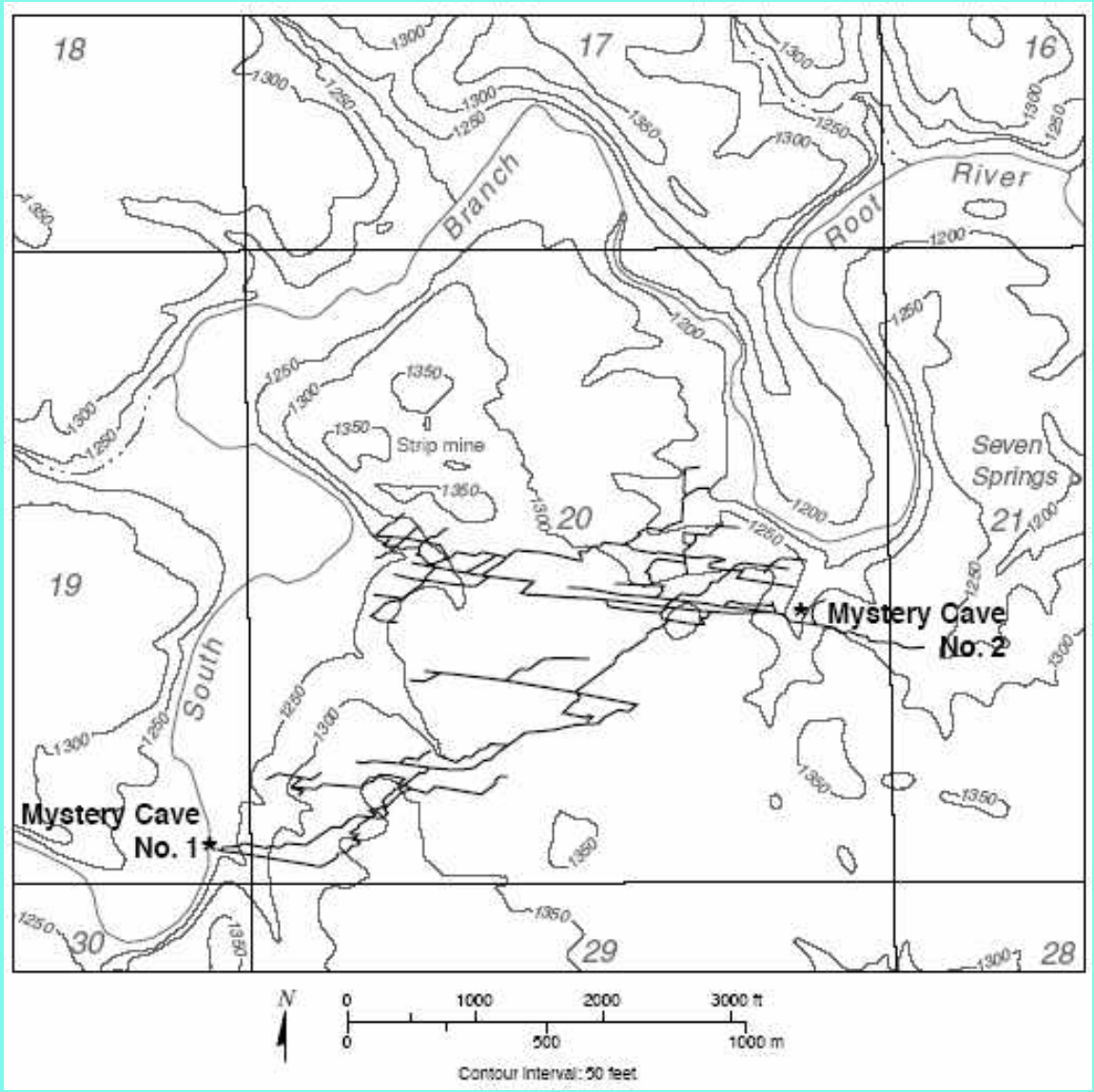
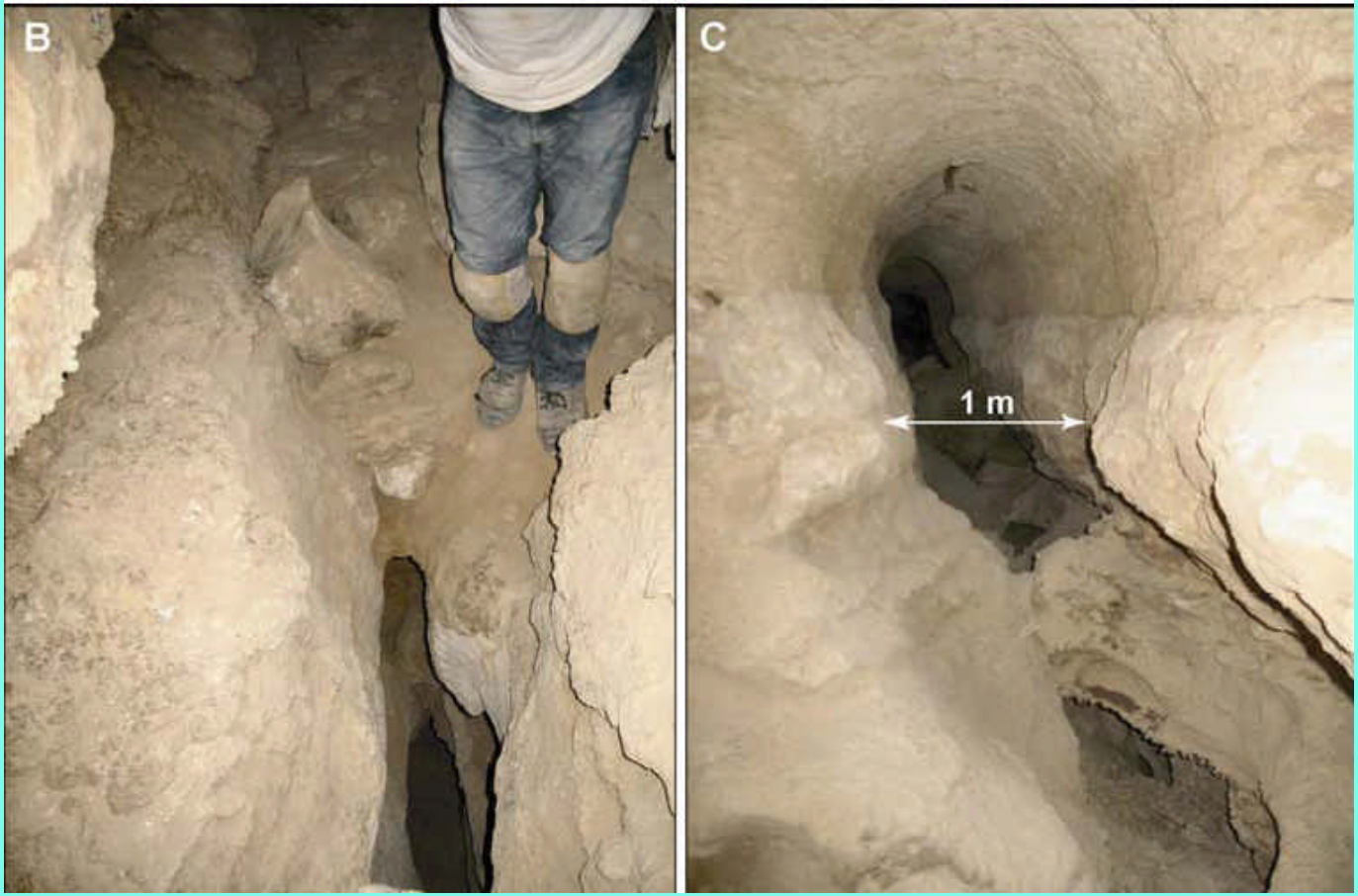


Barr and Klimchouk (2007)



Barr and Klimchouk (2007)

Feeders in Cave Floors



Amazing Maze Cave, TX

from Klimchouk (2007)

Closeup of Feeder in Floor of Mystery Cave, MN

Barr and Klimchouk (2007)

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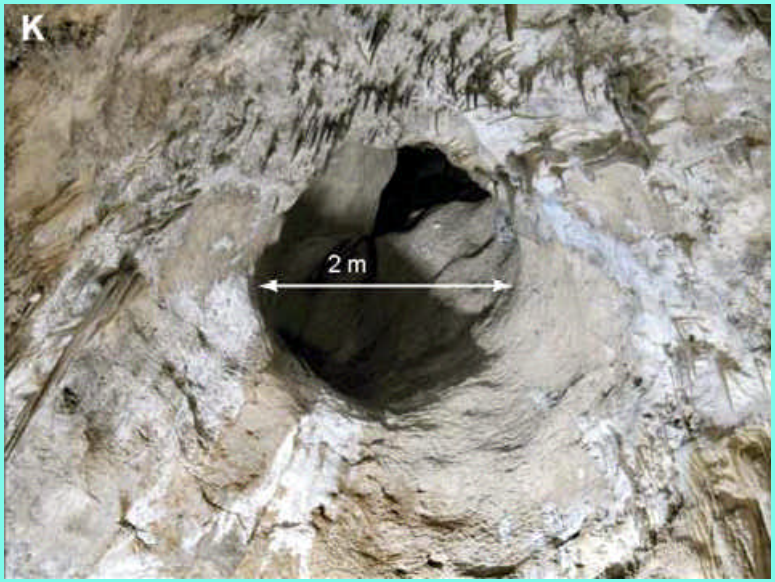
Cupola outlets

Mystery Cave, MN

Wind Cave, SD



Carlsbad Cavern, NM

from Klimchouk (2007)

Barr and Klimchouk (2007)

Closeups of ceiling cupolas in Mystery Cave, MN

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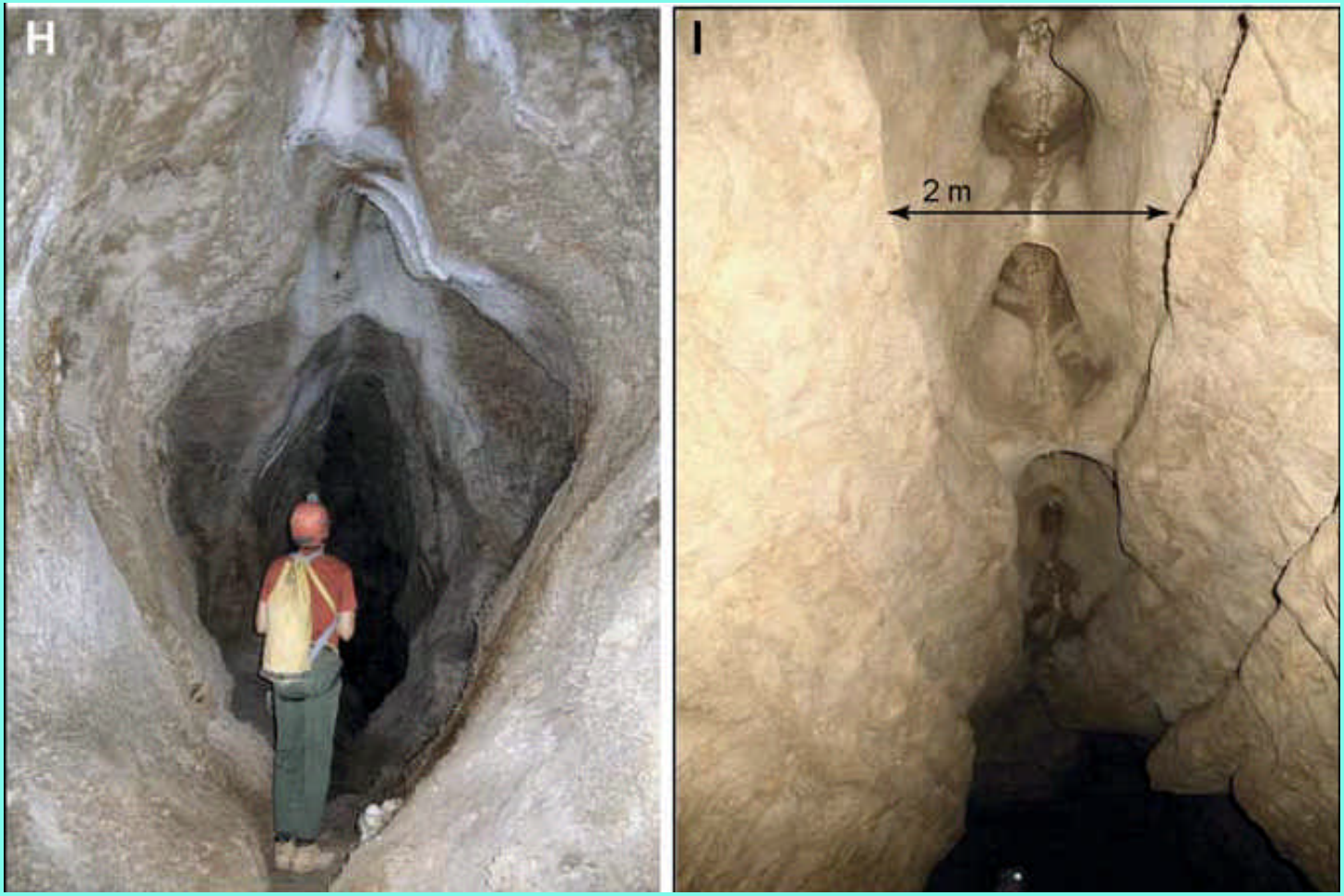
Barr and Klimchouk (2007)

Series of Cupolas in Ceiling Apex

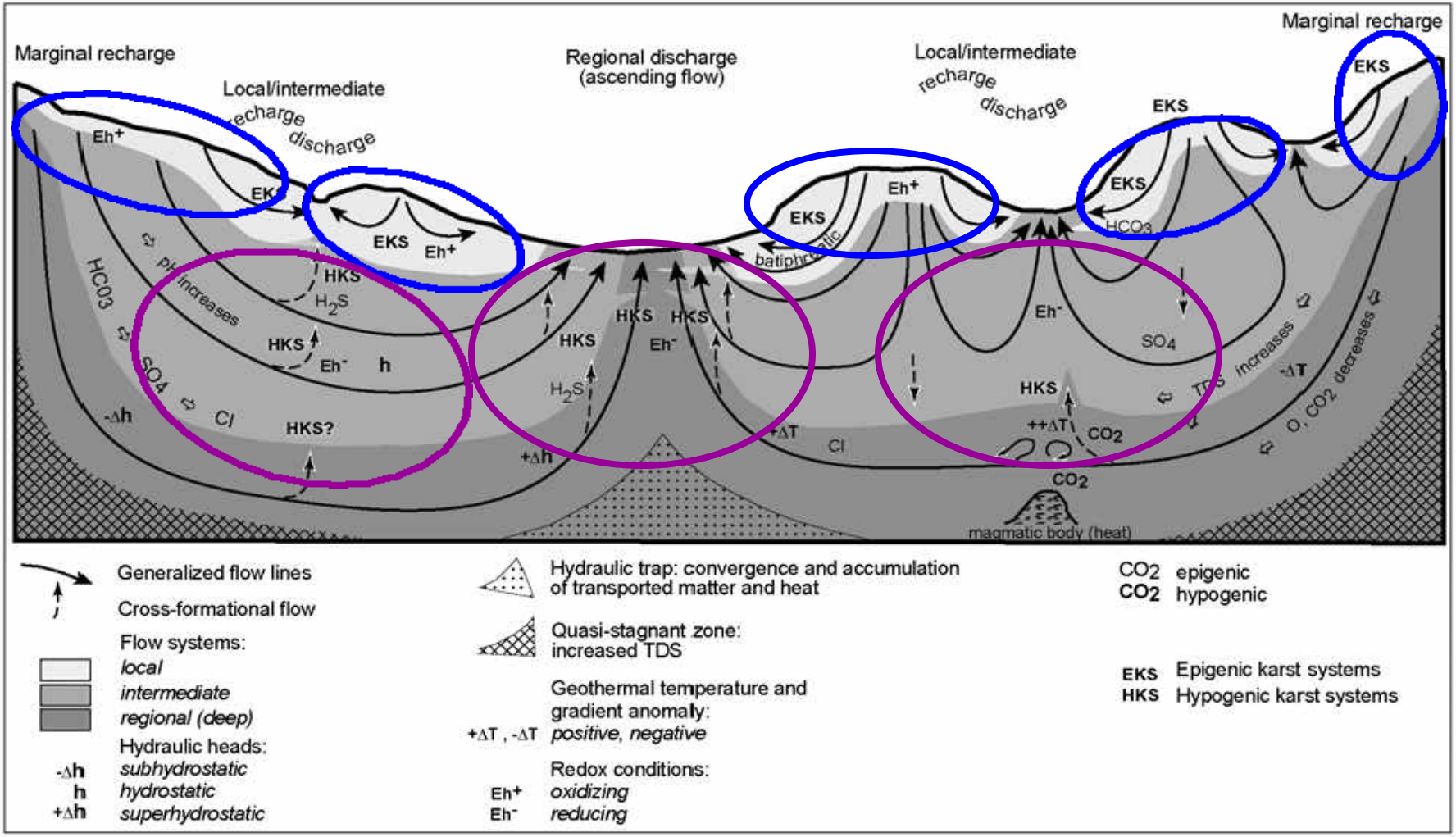


Carlsbad Cavern, NM

Mystery Cave, MN

from Klimchouk (2007)

Barr and Klimchouk (2007)



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from Klimchouk (2007)

Implications of hypogenic speleogenesis

Barr and Klimchouk (2007)

Implications of hypogenic speleogenesis

- Formation of breccia pipes
  - Formed above large cavities in cave fm.
  - Most related to ceiling cupolas
  - ***Sinkhole hazard***

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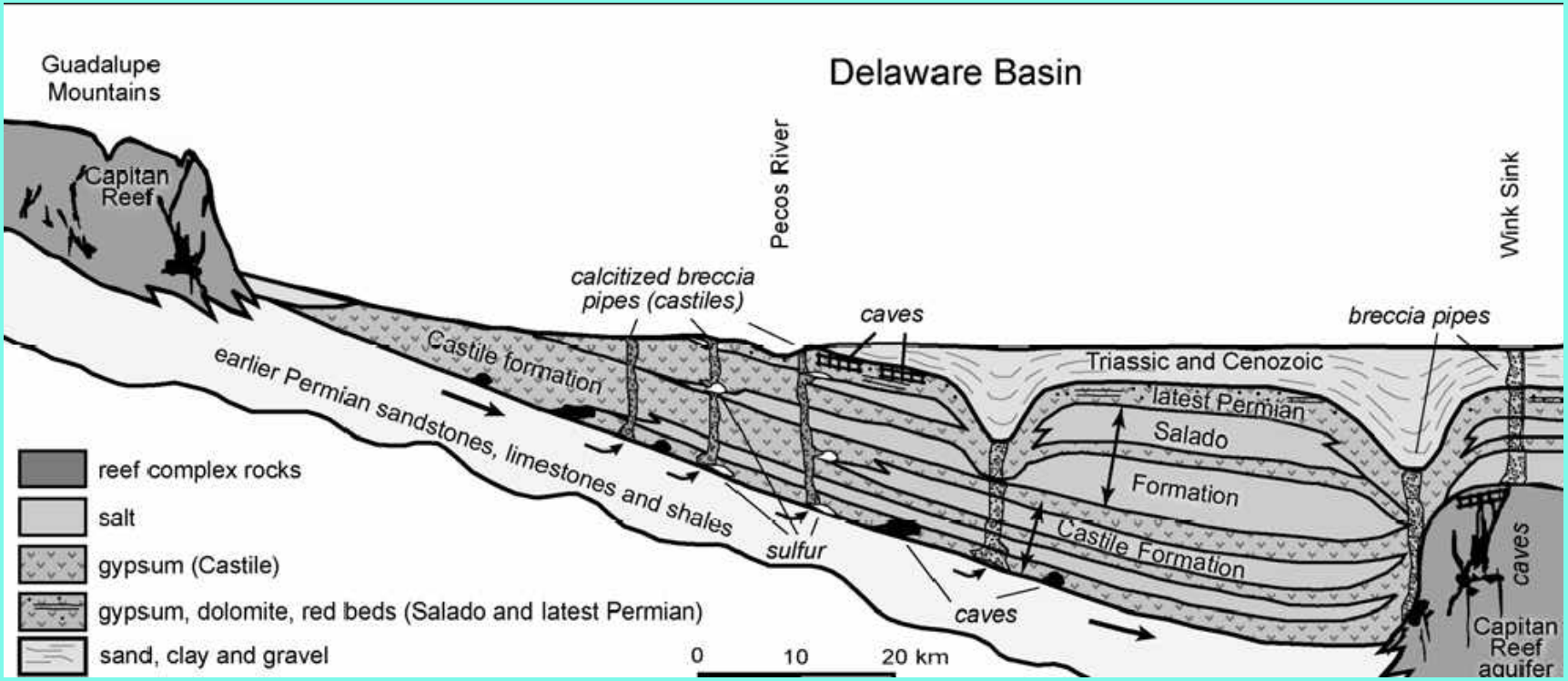
Barr and Klimchouk (2007)

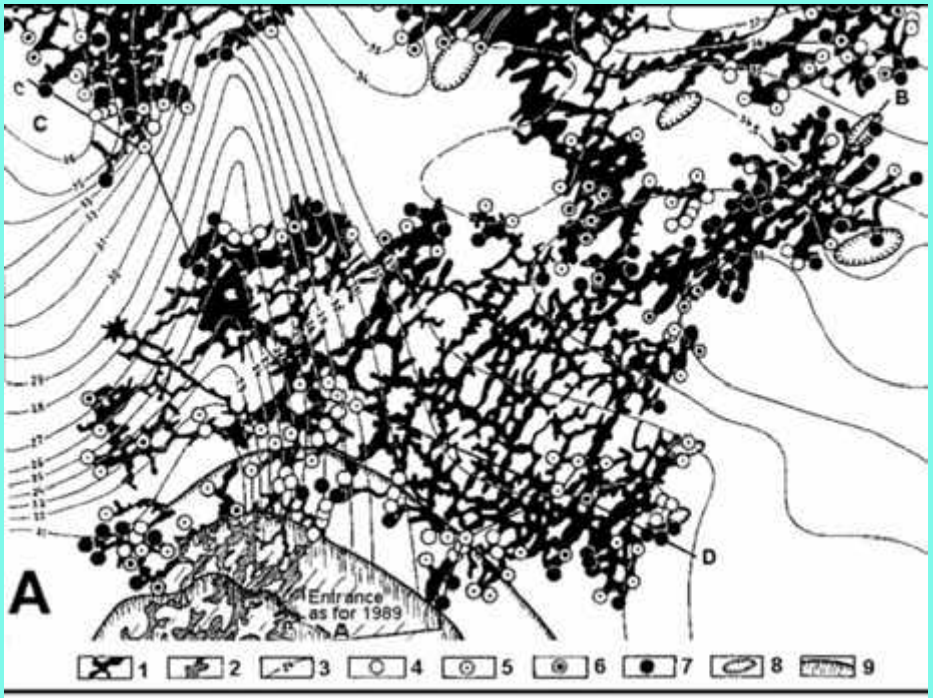
Breccia pipes, NM & TX

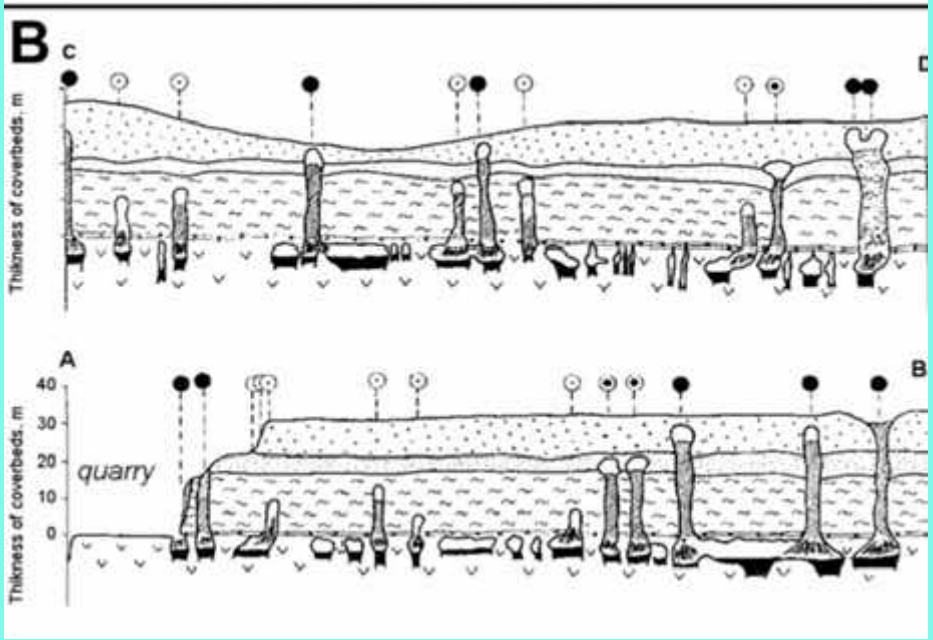


from Klimchouk (2007)

Barr and Klimchouk (2007)

Breccia pipes, Ukraine





Zoloushka Cave

from Klimchouk (2007)

Barr and Klimchouk (2007)

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Barr and Klimchouk (2007)


CM
IN

A second breccia pipe, Woodbury, MN

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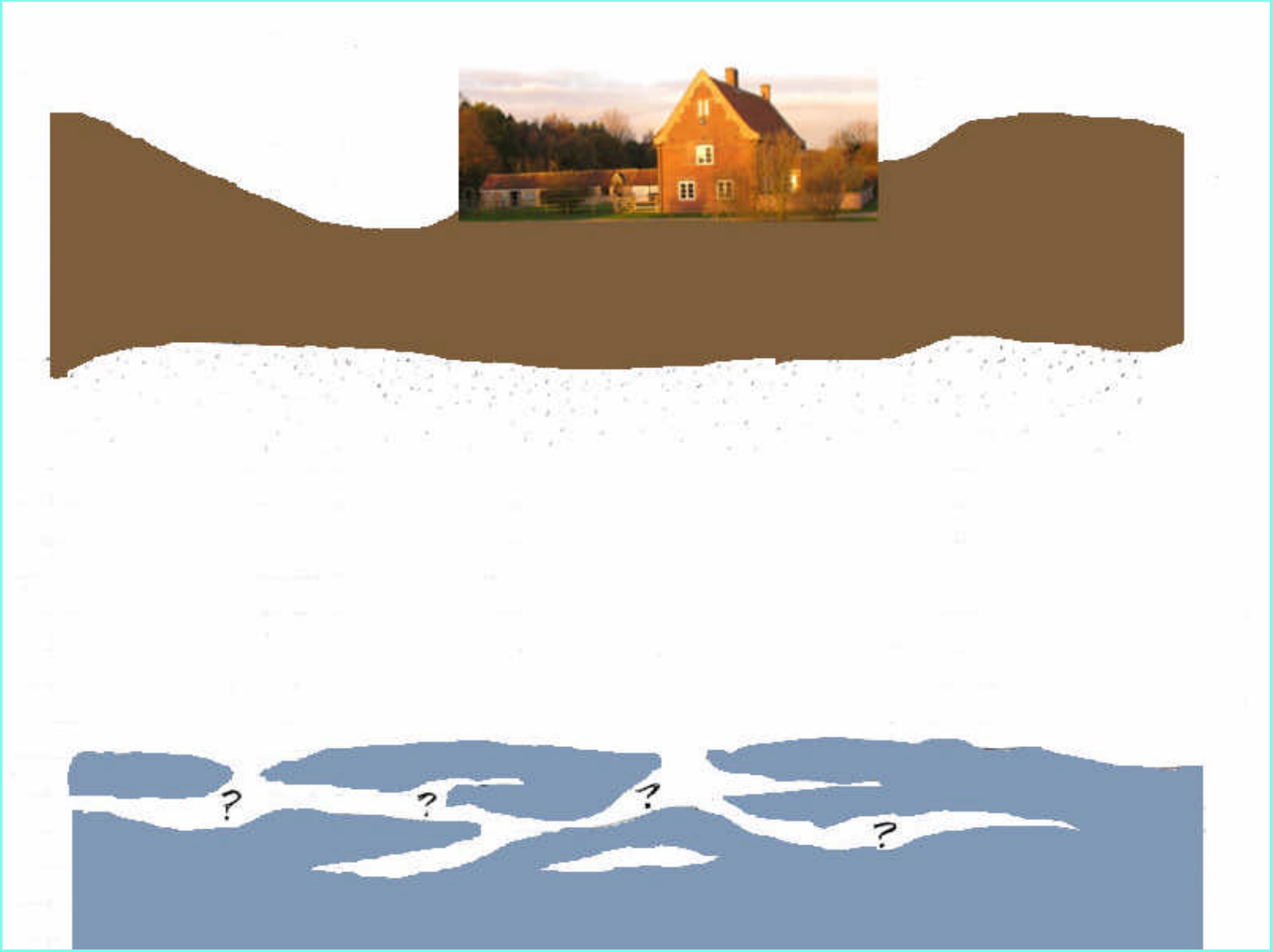
Barr and Klimchouk (2007)



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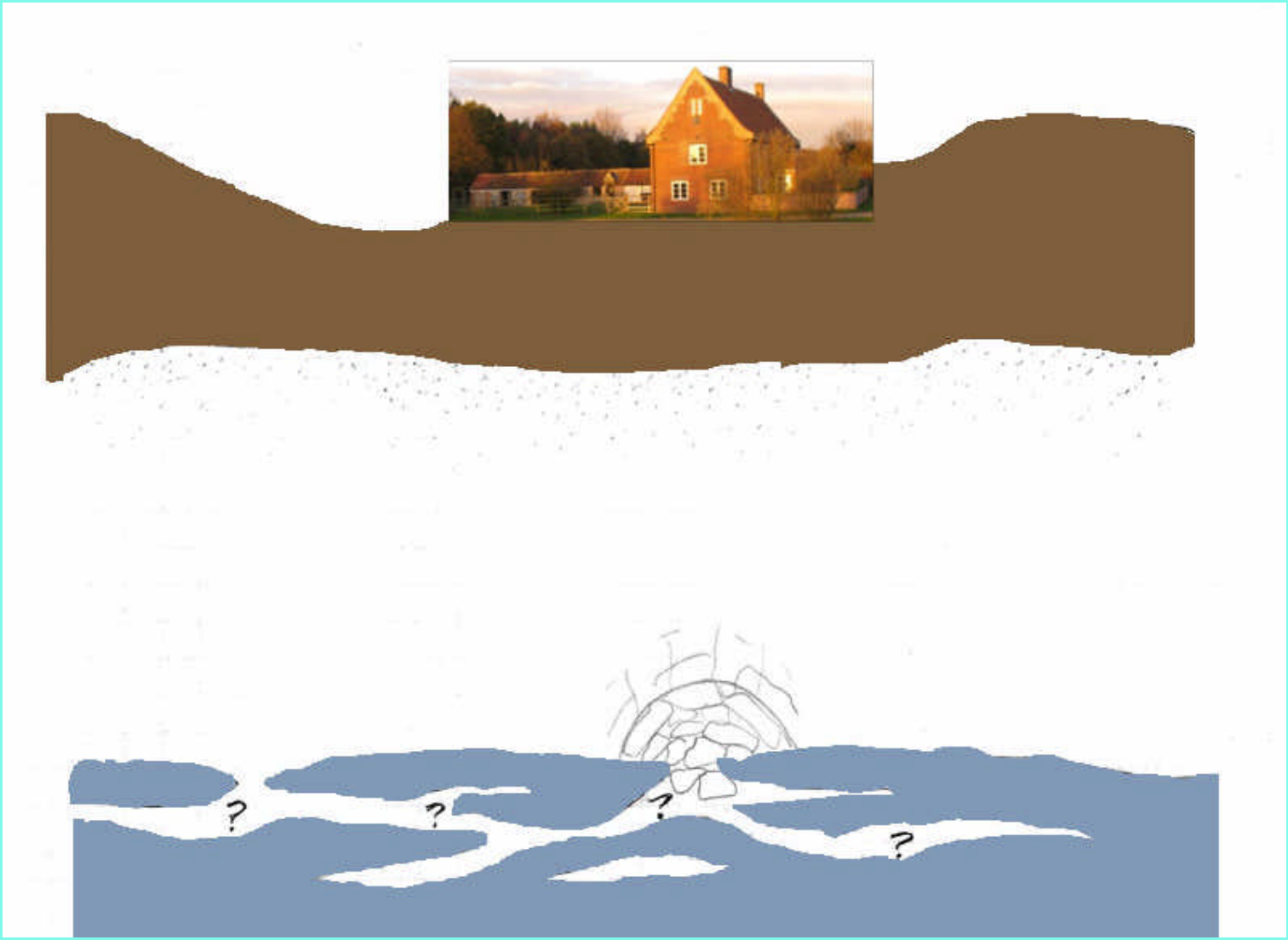

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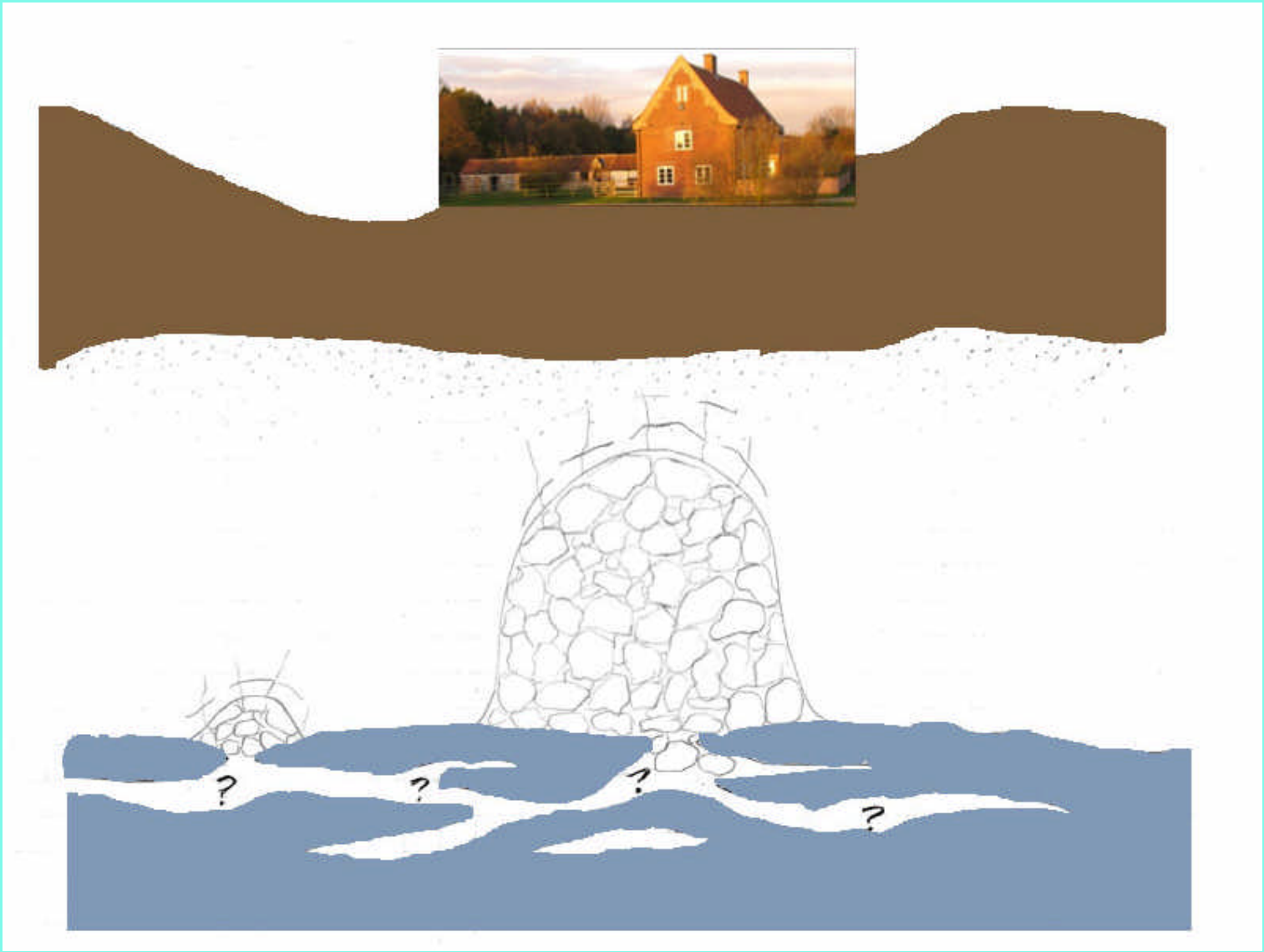

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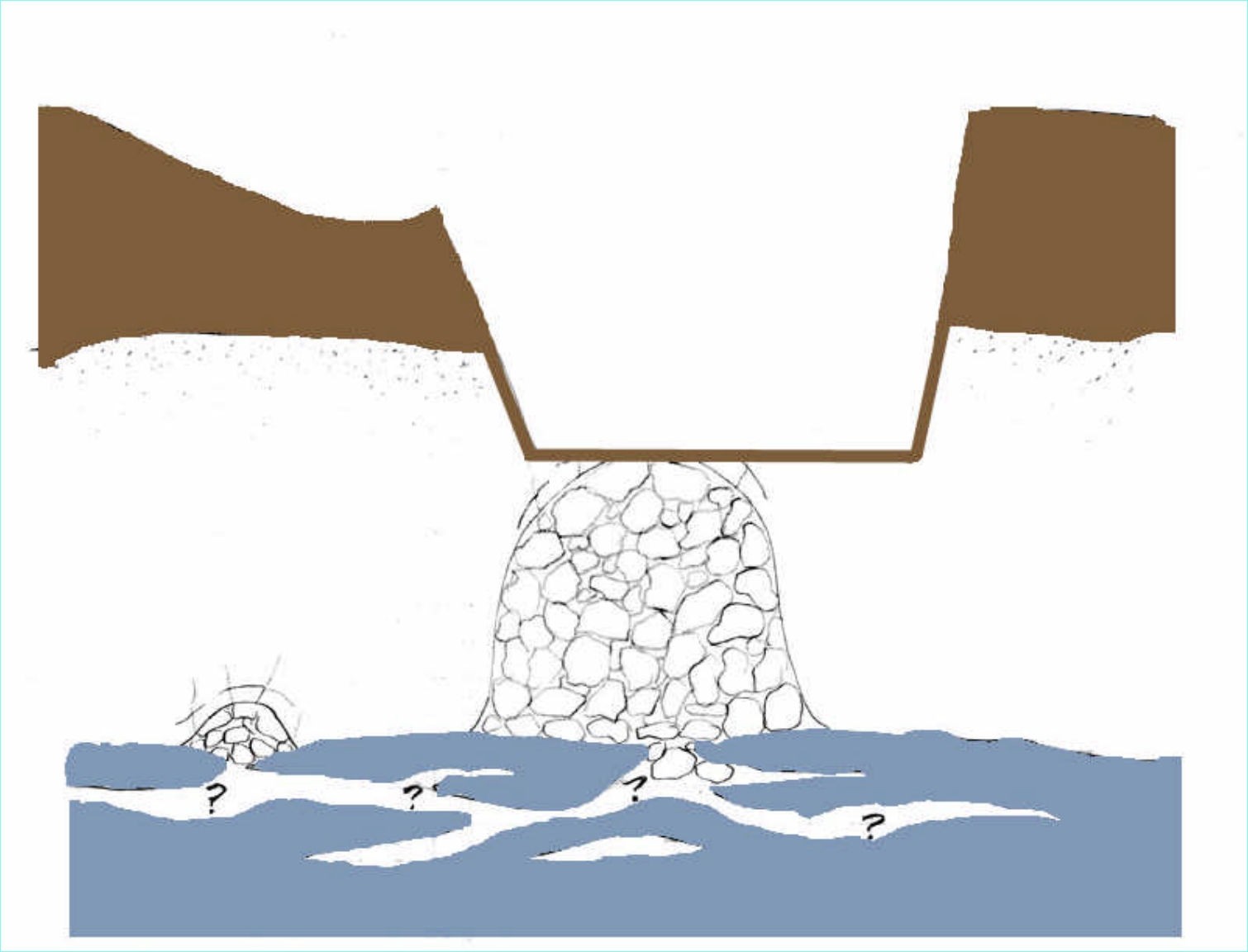

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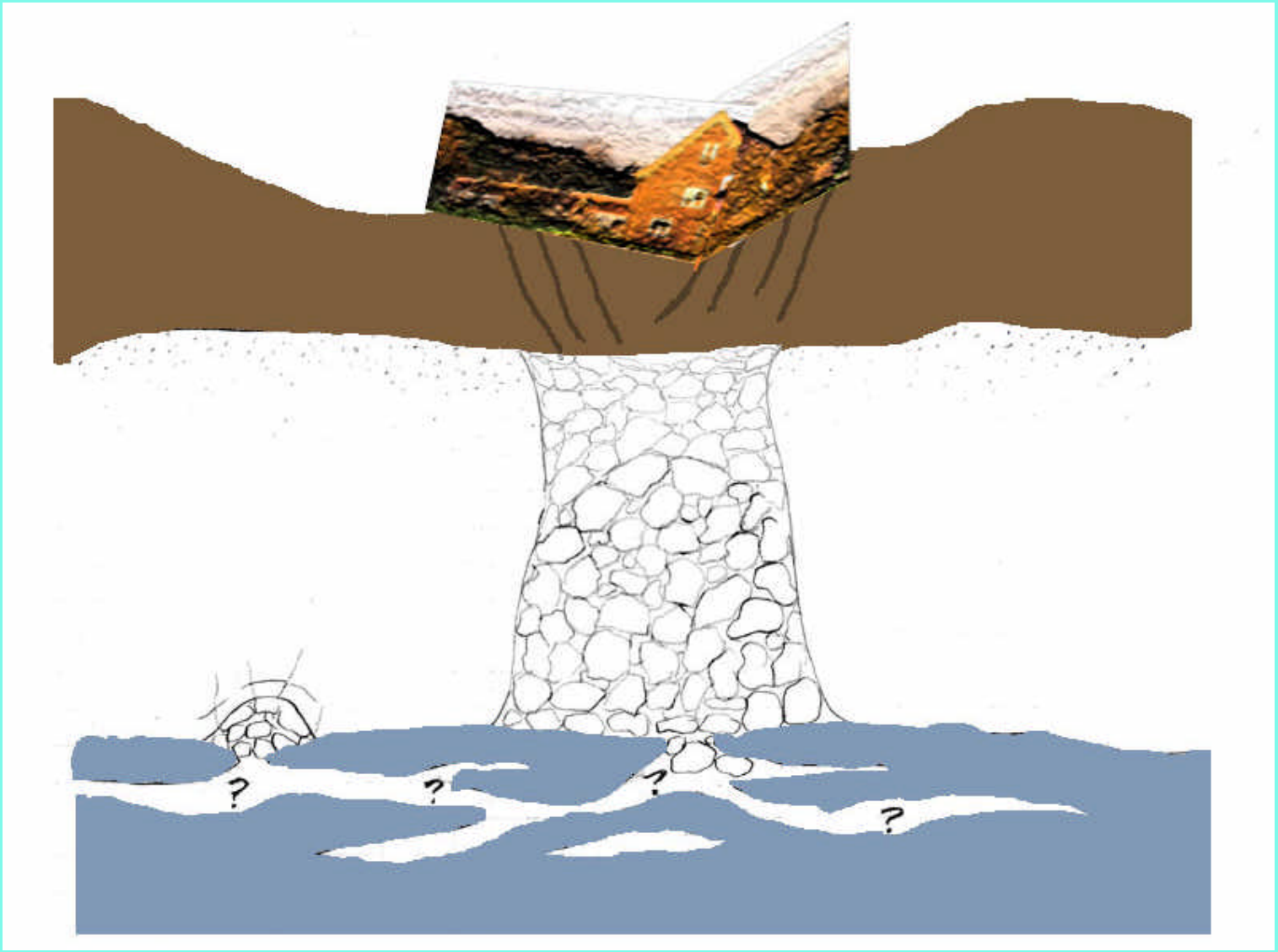

Barr and Klimchouk (2007)

Implications of hypogenic speleogenesis

- Formation of breccia pipes
  - Formed above large cavities in cave fm.
  - Most related to ceiling cupolas
  - ***Sinkhole hazard***
- Different morphologic characteristics
  - 167.3 km/km^2 (HS) *vs.* 16.6 km/km^2 (ES)
  - Porosity: 5.0% (HS) *vs.* 0.4% (ES)
  - ***Better chances of encountering conduits or other karst features***

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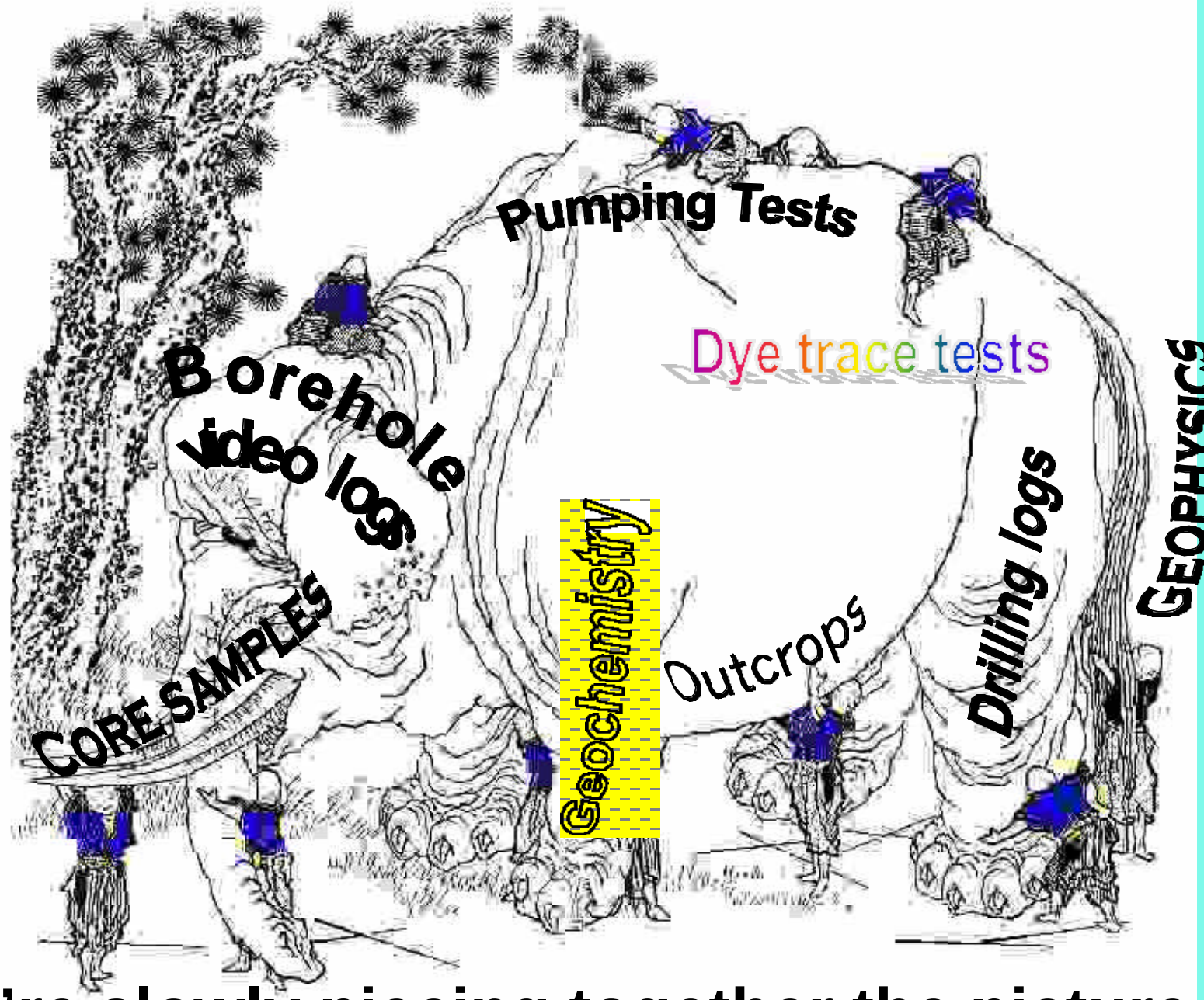
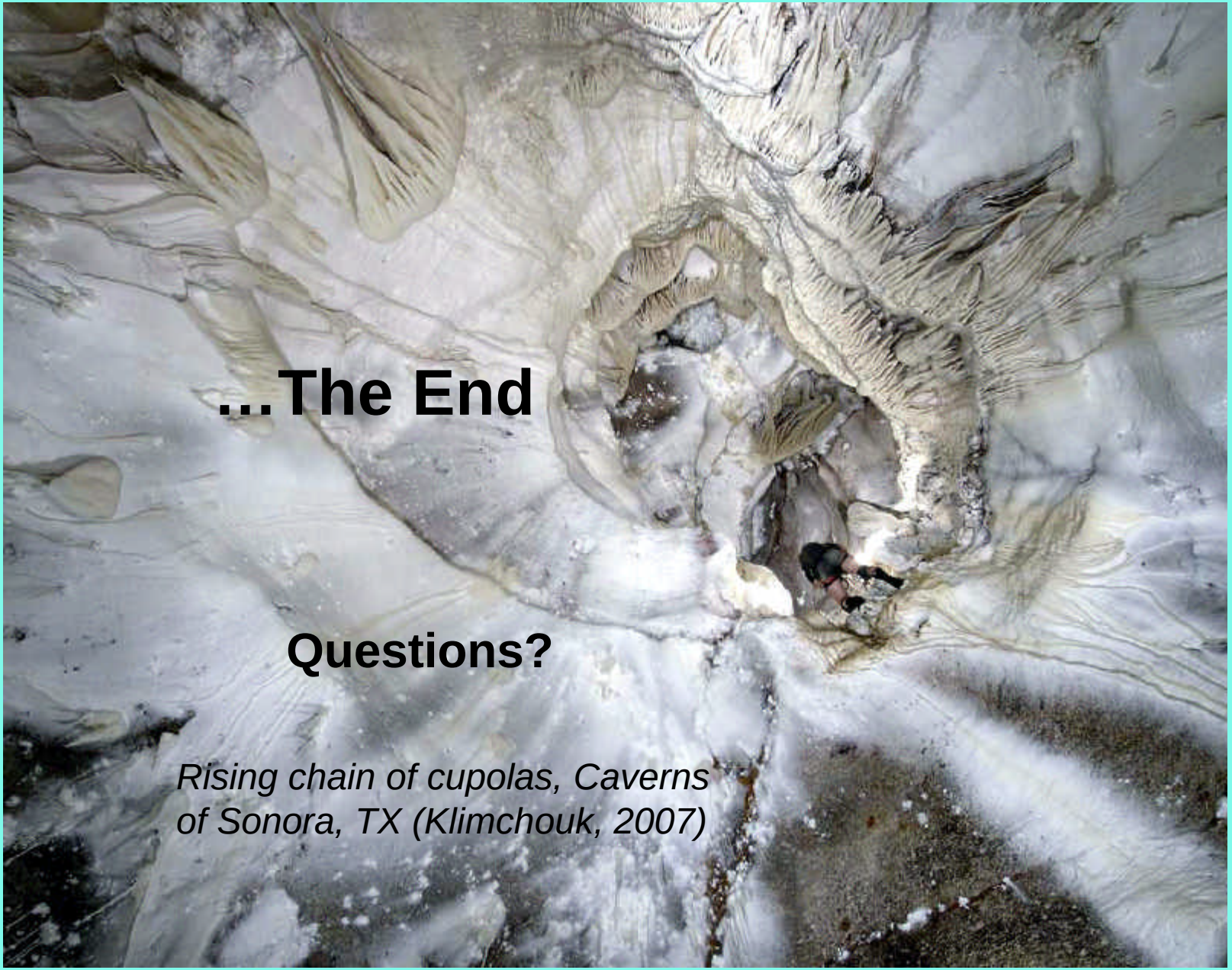
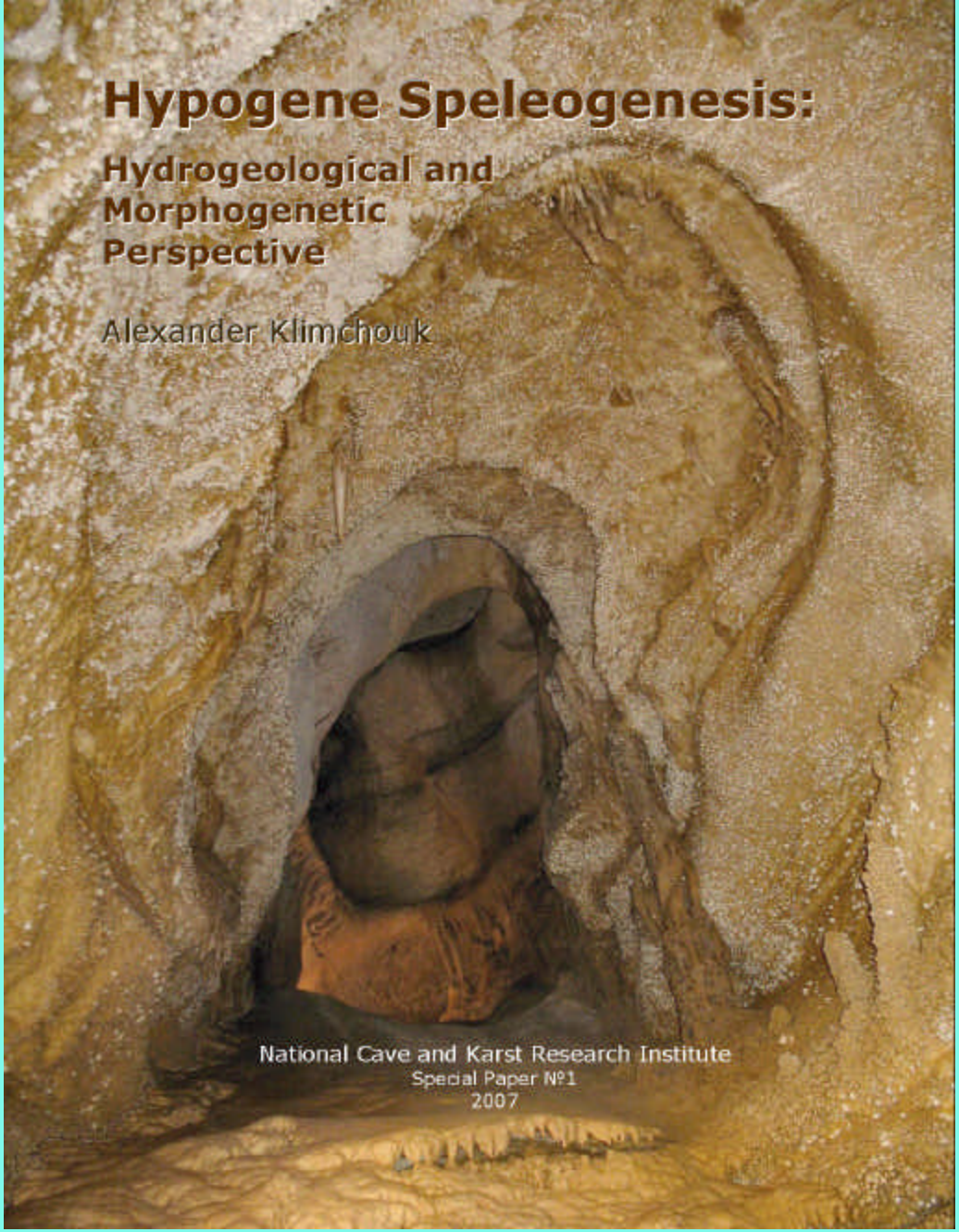
Barr and Klimchouk (2007)



We're slowly piecing together the picture…

Barr and Klimchouk (2007)


…The End
Questions?
Rising chain of cupolas, Caverns of Sonora, TX (Klimchouk, 2007)



Primary Resource:

Hypogene Speleogenesis: Hydrological and Morphogenetic Perspective

by Alexander Klimchouk

National Cave and Karst Research Institute

Special Paper No. 1

2007

NCKRI

1400 Commerce Drive,
Carlsbad, NM 88220

www.nckri.org

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