Cavernous Porosity Development and Mississippi Valley-Type Mineralization as Recorders of Multi-Sourced Diagenetic Waters Migrating Through the Ordovician Galena Group Limestone (Trenton), Kane County, NE Illinois, USA*

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Abstract

Tens-of-centimeter scale calcite crystals concentrically zoned with sulfide minerals and growing within meter-scale solution cavities along NW-trending fractures were recently discovered in Kane County, northeastern Illinois in the Ordovician Galena Group limestone (Trenton). On the basis of plane-light and cathodoluminescent petrography and scanning electron microscopy, a series of diagenetic events are identified within the cavities that consist of dissolution followed by dolomite, marcasite, pyrite, and calcite precipitation, and later hydrocarbon migration. The paragenetic sequence, in conjunction with changes in δ13C, δ18O, and 87Sr/86Sr concentrations in calcite growth zones, reflect changes in the fluid chemistry and the source of the subsurface diagenetic waters migrating through the midcontinent. Isotopic values suggest the existence of at least two distinct fluids that flowed through fractures following the development of solution cavities. Isotopic values in calcite zones record each fluid getting heavier in δ13C and lighter in δ18O with respect to time. The youngest calcite zones record significantly lighter δ18O (-9.27 to -5.24 ‰) and δ13C (-10.58 to -3.27 ‰) than the older zones implying a warmer fluid and a possible genetic relationship to hydrocarbon generation and/or migration.

The paragenesis revealed in this study is comparable to that of the world famous Upper Mississippi Valley Zn-Pb mining District in northwest Illinois, suggesting that migrating warm fluids were widespread throughout northern Illinois and surrounding areas, resulting in the formation of massive solution cavities, dolomitization, and the subsequent deposition of Mississippi Valley-type minerals. However, on the basis of the paragenetic sequence and the isotopic values for diagenetic calcite cements precipitated within solution cavities in northeastern Illinois, at least two paleo-fluids are identified that may be genetically related to the fluids that were responsible for the Upper Mississippi Valley ore deposits and cavernous porosity development at the productive Albion Scipio hydrocarbon reservoirs in the Michigan Basin. Determining the paragenetic sequence coupled with geochemical characterization of the solution cavity calcite and associated minerals in the Galena carbonates in northeastern Illinois will assist in mapping paleo-fluid flow throughout the midcontinent and aid in mineral and hydrocarbon exploration.

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Introduction

- What is cavernous porosity
- Relationship to Mississippi Valley-Type (MVT) deposits
- Tracking down the fluids
- Research site and other Hydrocarbon Producing Fields with Cavernous Porosity
- Hypothesis
- Results
- Conclusion

Cavernous Porosity

- **A pore system characterized by large openings, or caverns**

  - for classification sake, the lower limit of a cavern is the smallest opening an adult person can enter

  - much cavernous porosity is of solution origin; however the term is merely descriptive and not genetic

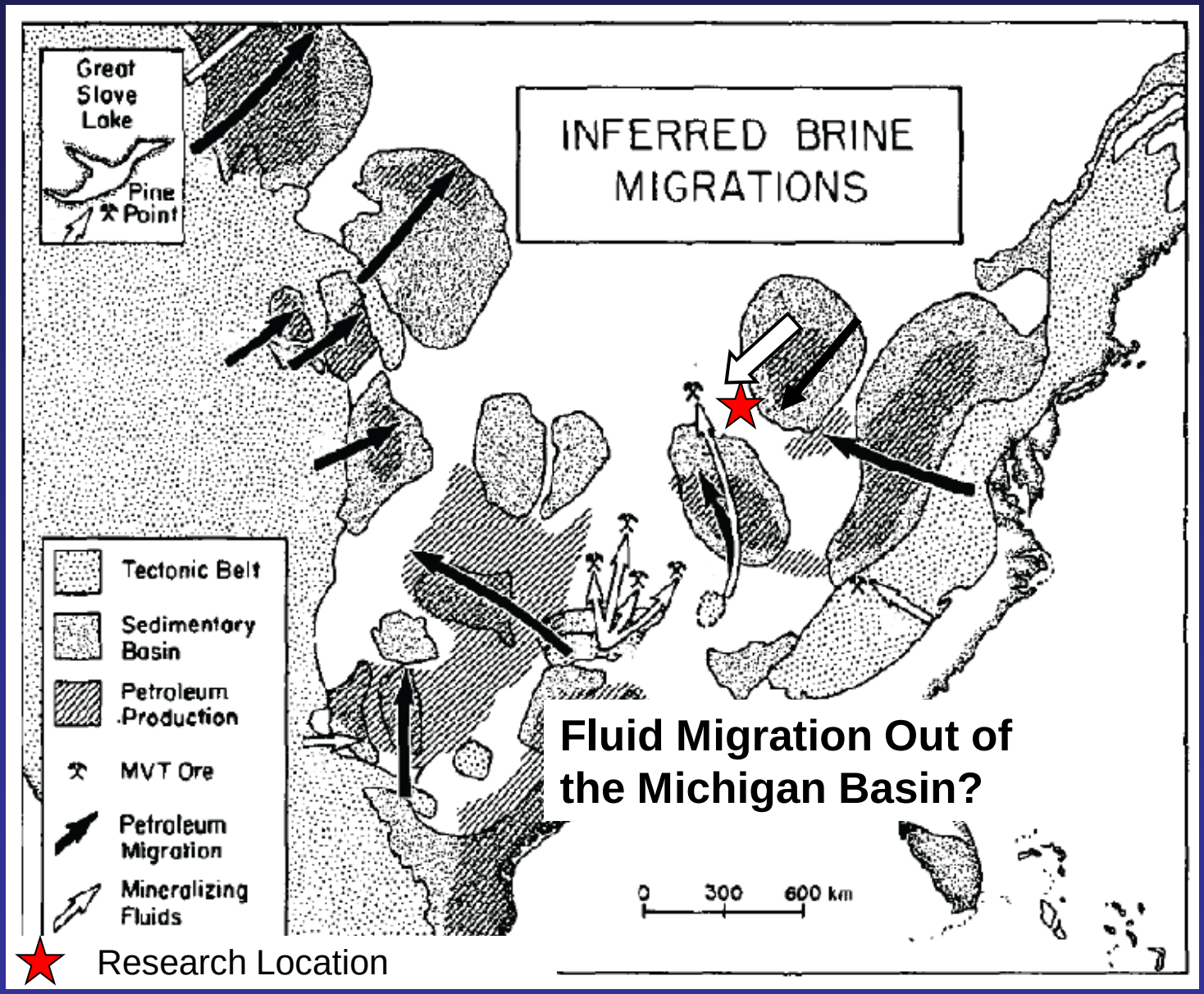
  - a recognizable drop of the drill bit

  - too large to identify in core

Choquette and Pray, 1970

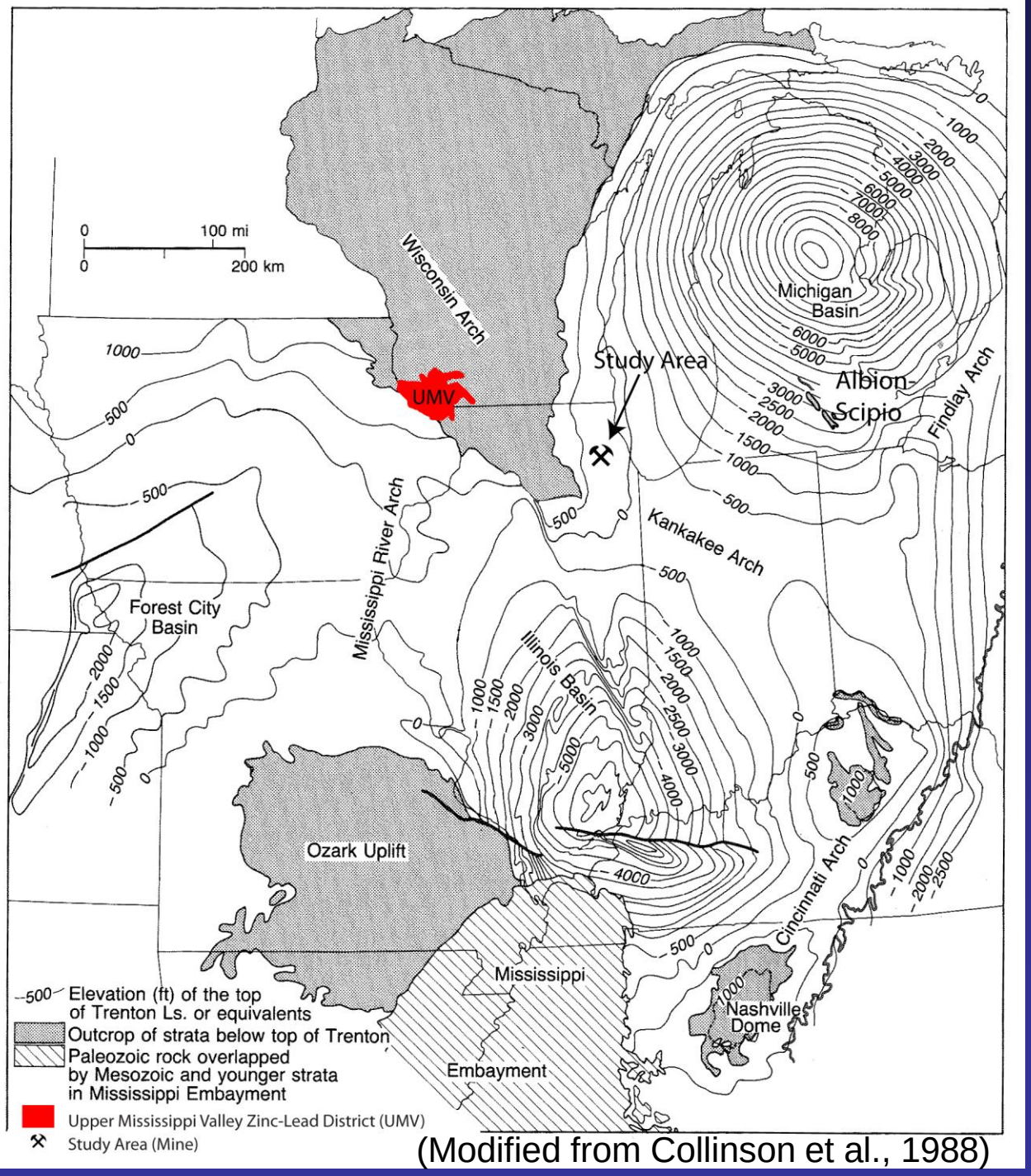
Cavernous Porosity

MVT Deposits and Fluids



(Modified from Bethke and Marshak, 1990)

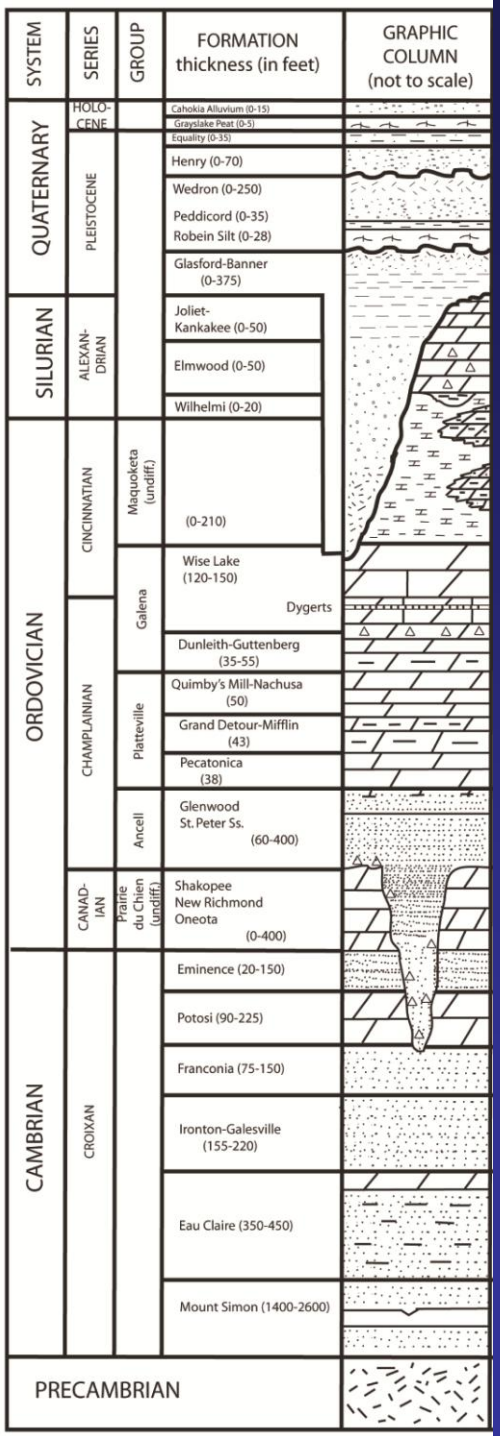
Basins, Arches, and Cavernous Porosity



(Modified from Collinson et al., 1988)

- SW Michigan Basin
- Wisconsin and Kankakee Arch
- Upper Mississippi Valley Zn-Pb District
- Albion-Scipio

Stratigraphy of Northeastern Illinois

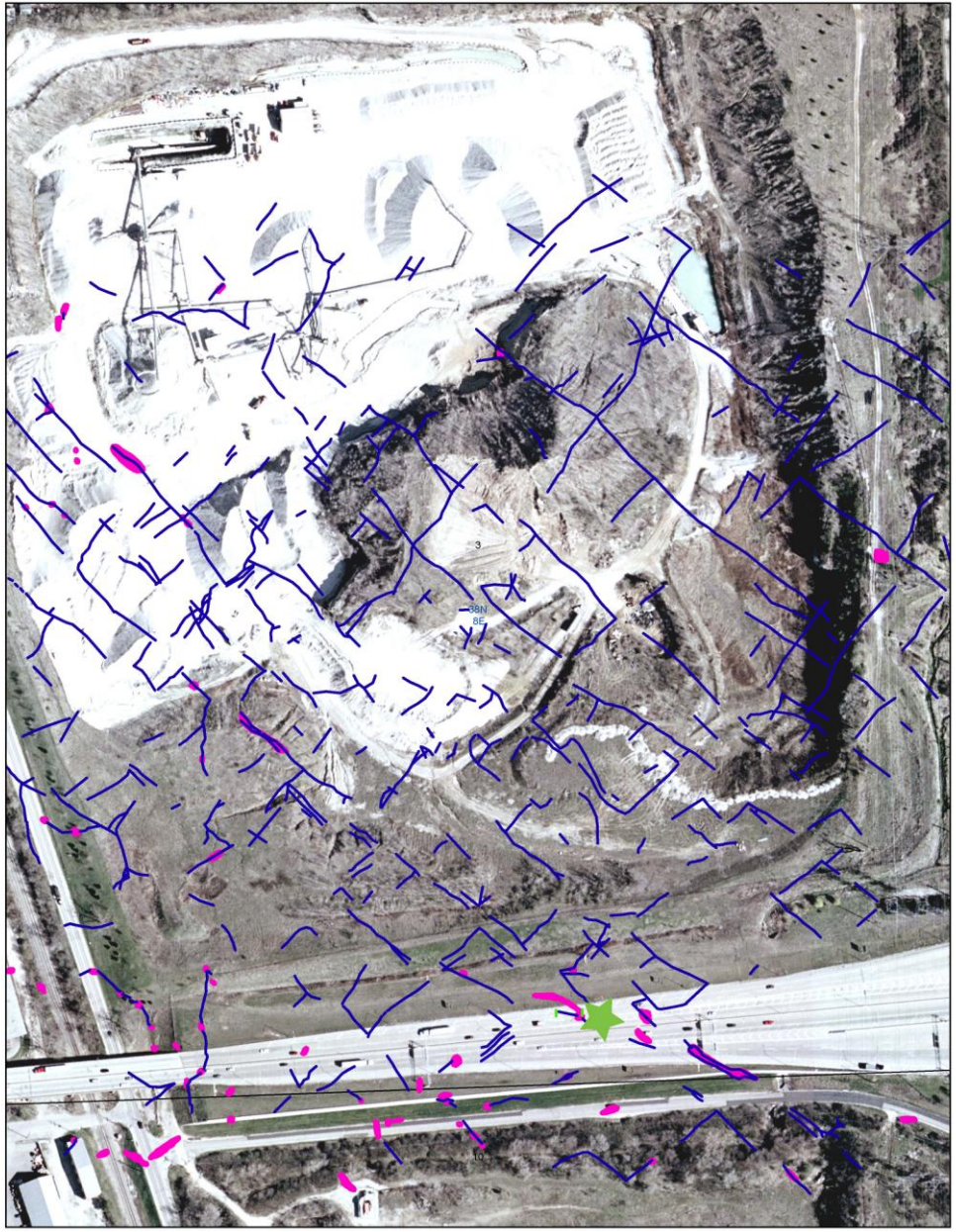


Top of Galena (Trenton)

- Galena-Platteville is a thick carbonate sequence that is partially to mostly dolomitized
- Thin beds of bentonite throughout
- Overlain by the shale (Maquoketa)
- Underlain by sandstone (Glenwood-St. Peter)

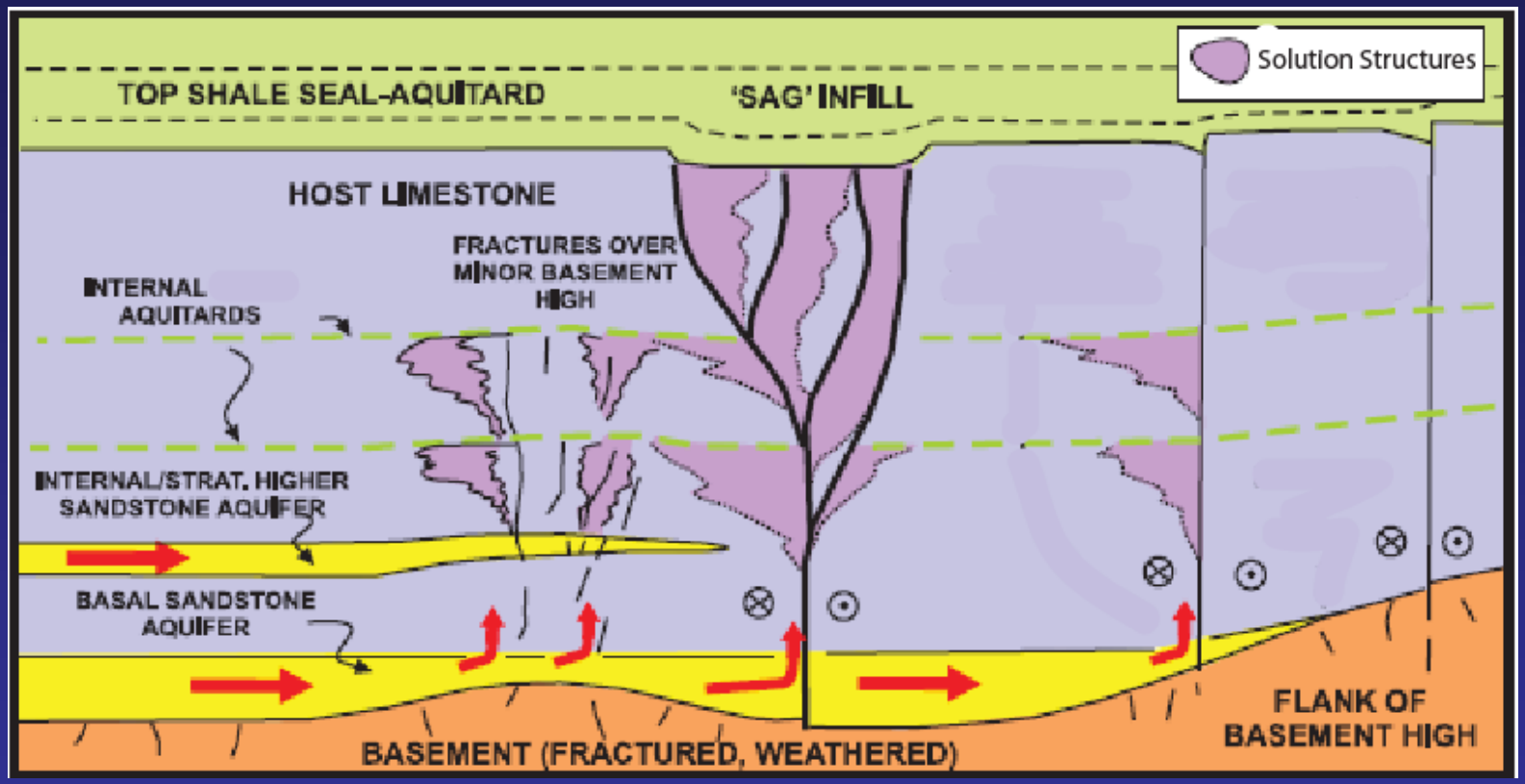
Modified from Collinson et al, 1988

Conco Mine Fracture and Cavity Overview Map



- Fractures and Cavities in the subsurface Galena
- Prominent NE-SW and NW-SE fractures.

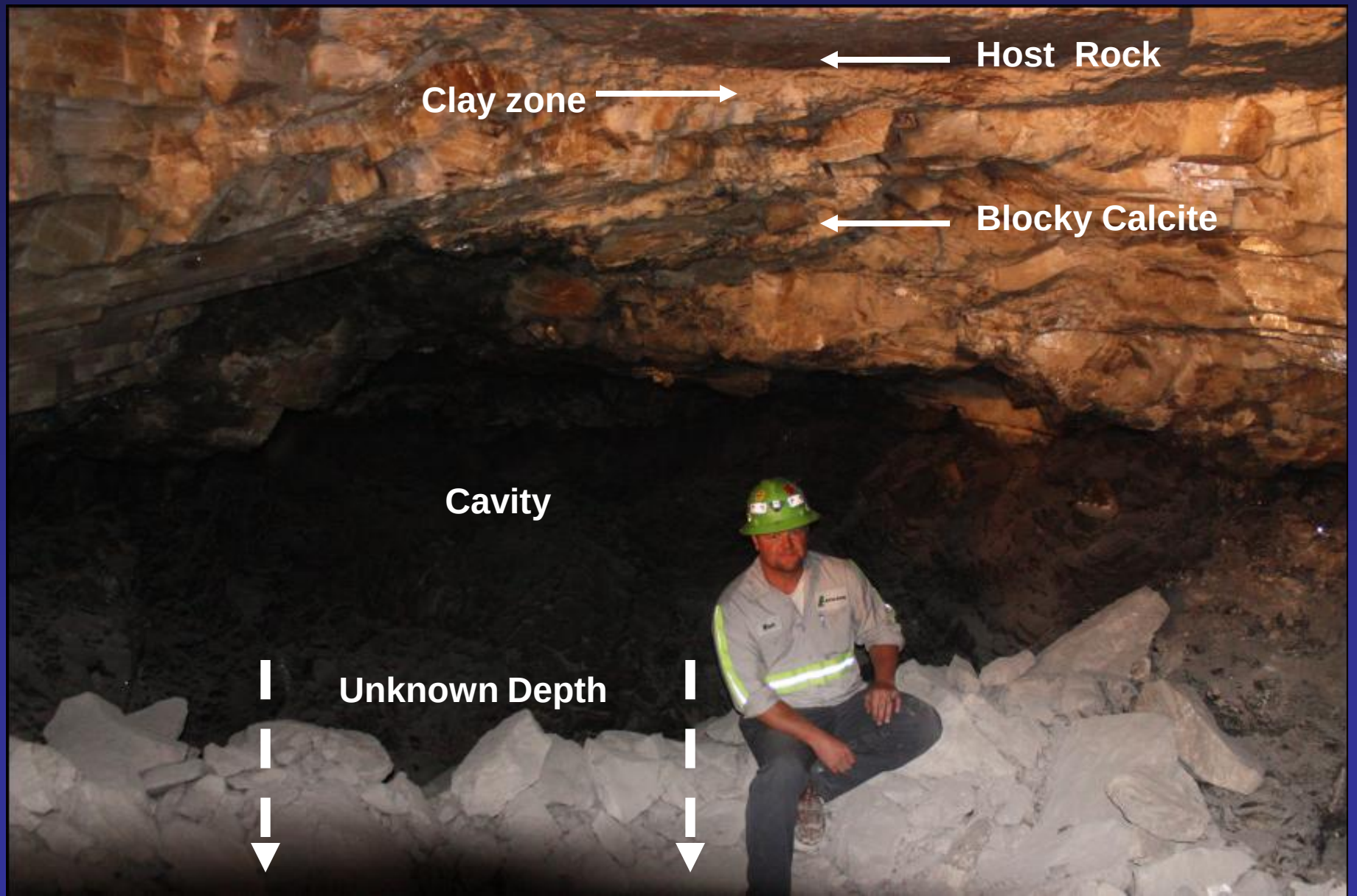
Fluid Migration and Diagenetic Model



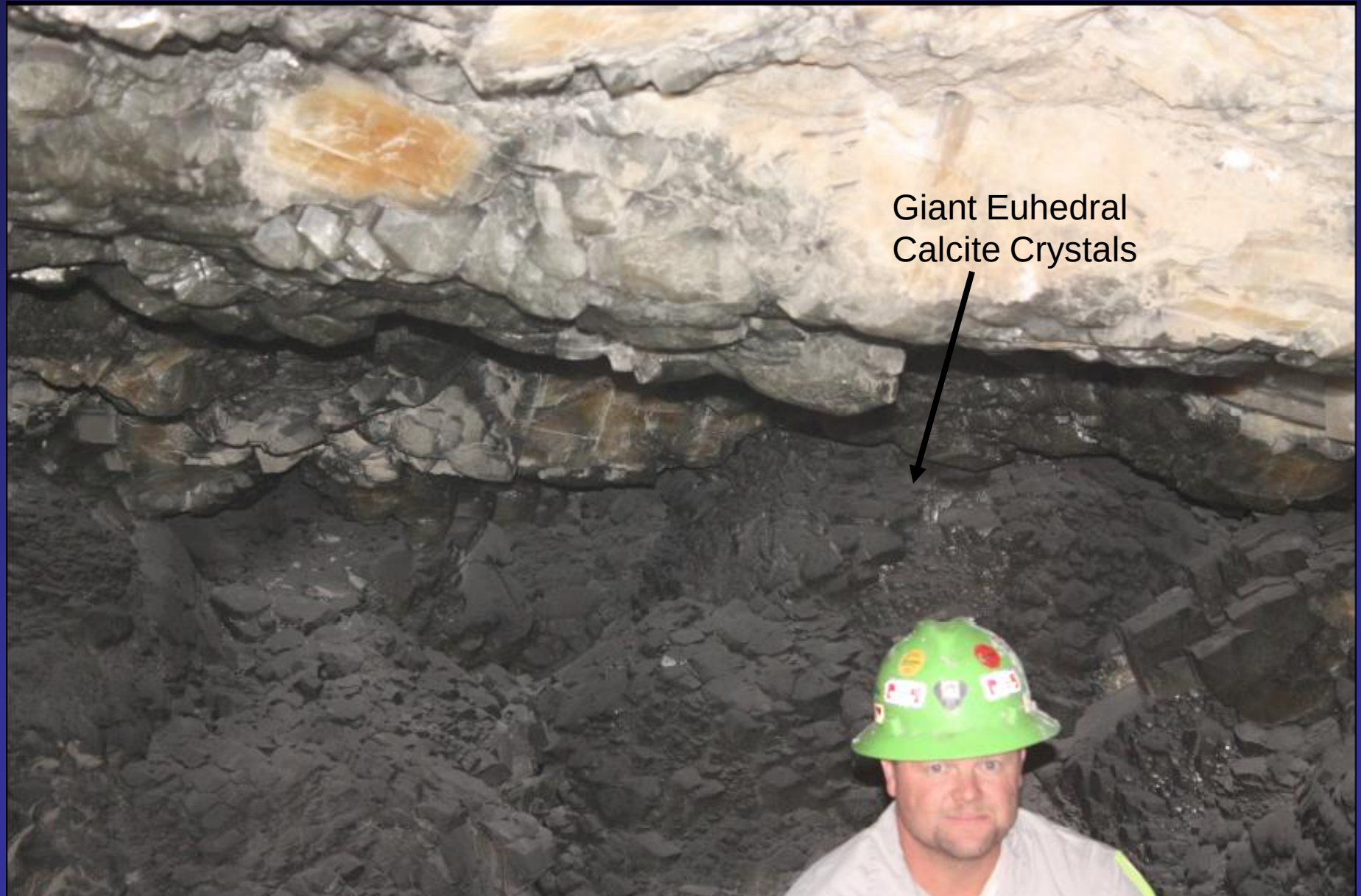
- Fracture and…
- Facies control where fluids migrate

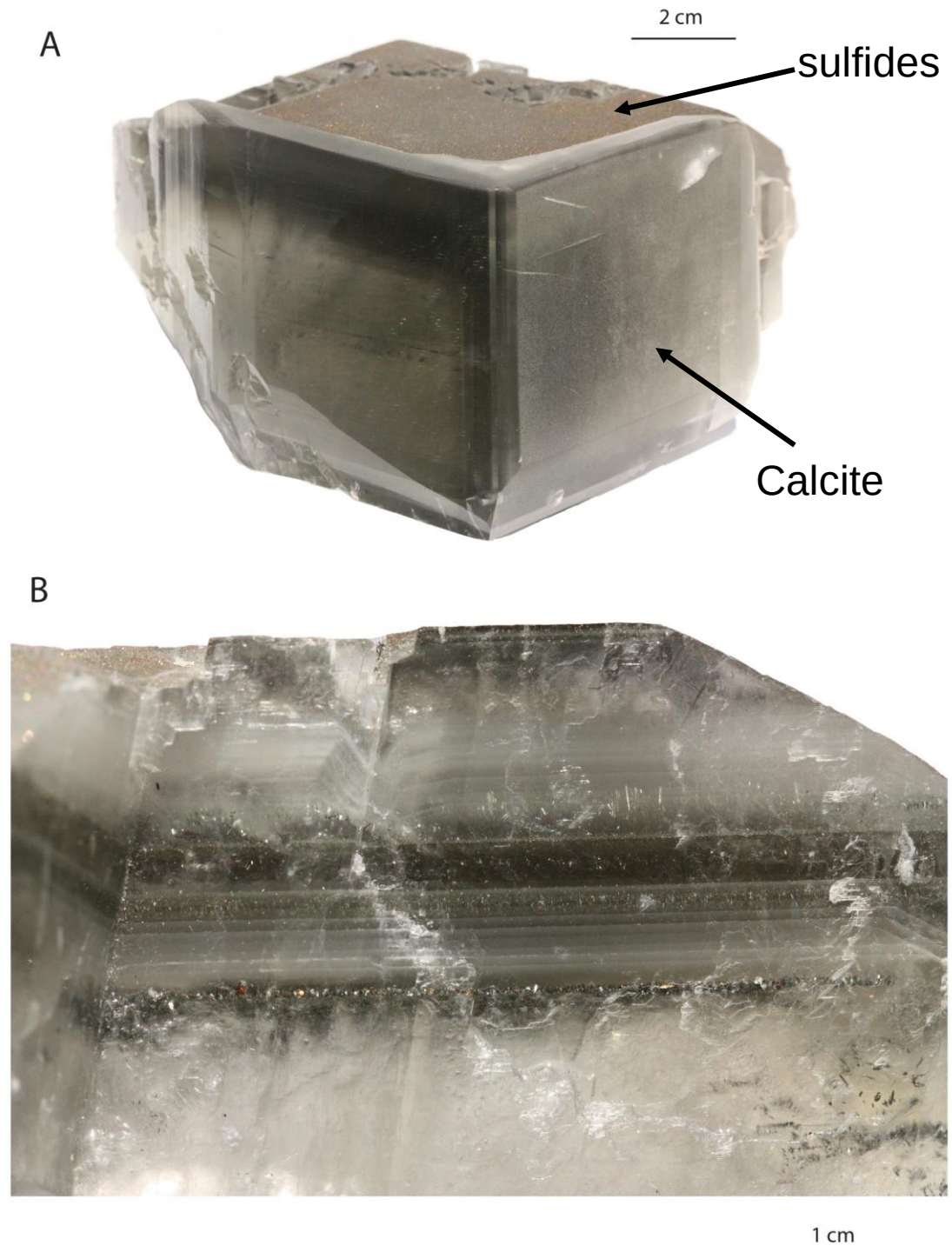
(Modified from Davies and Smith, 2006)

Solution Cavity



Cavity Cements





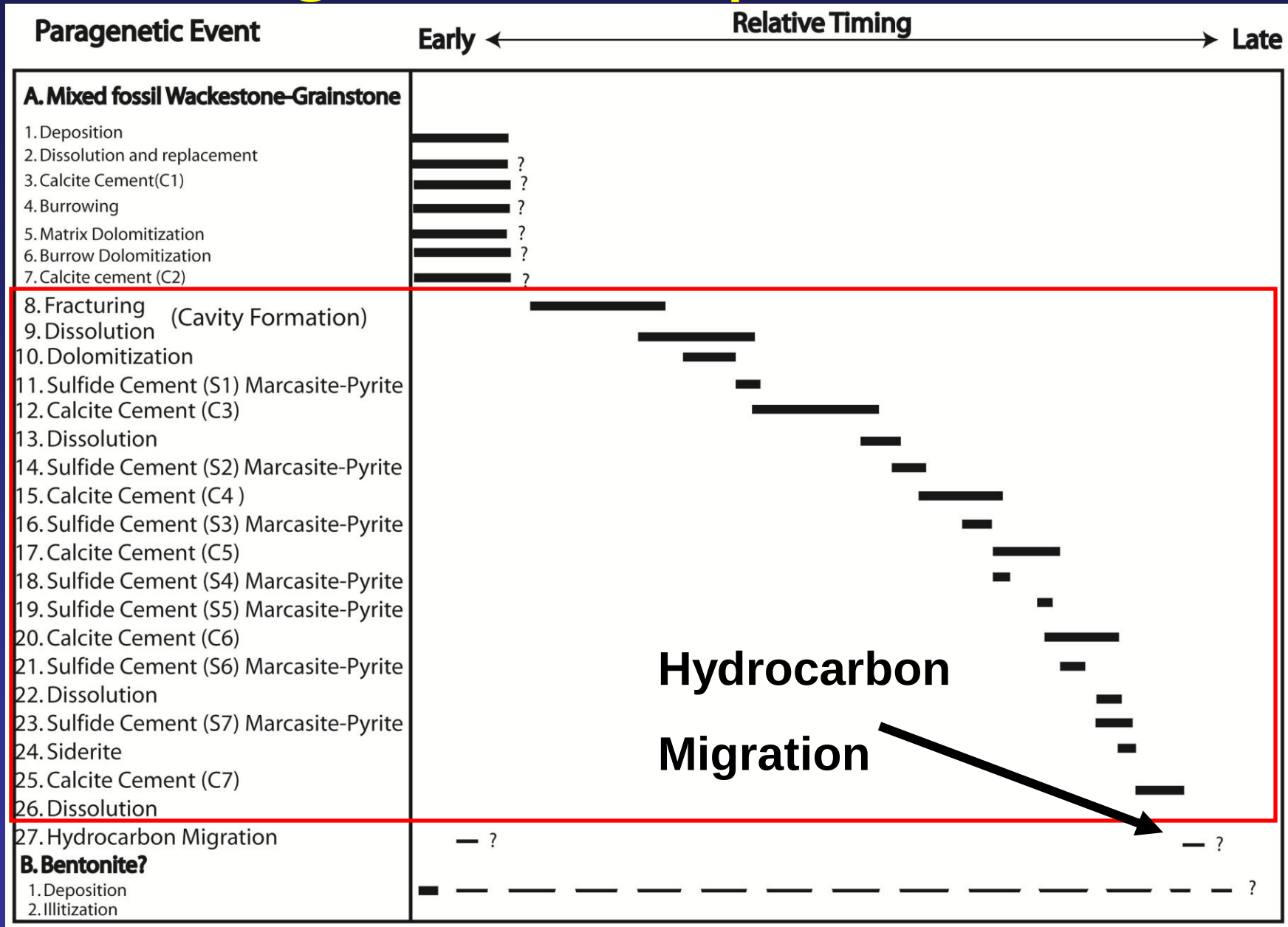
Cavity Cements

- Calcite concentrically zoned with sulfides
- Suggests changes in fluid composition with respect to time

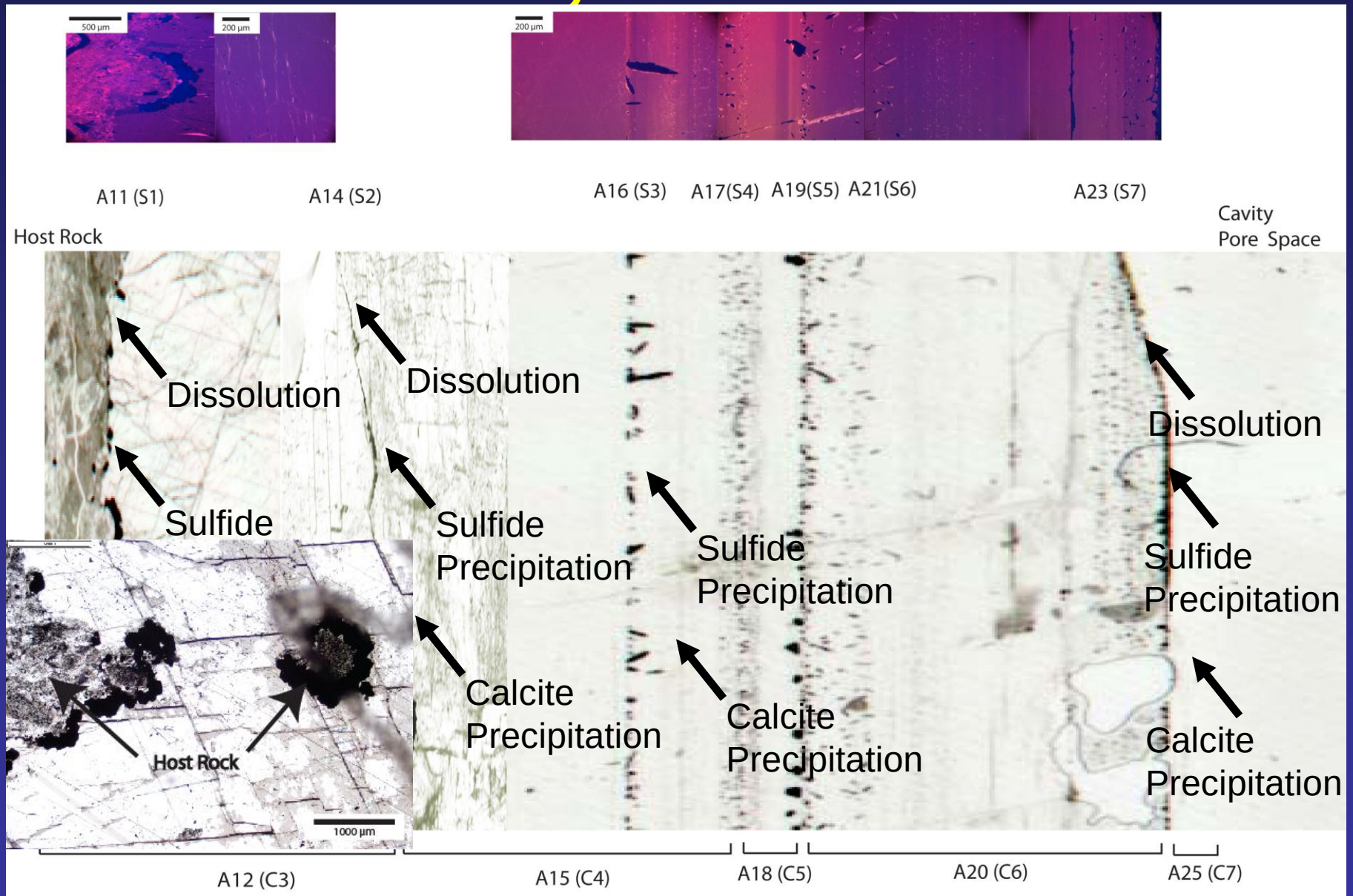
Hypothesis

Diagenetic events within solution cavities reflect multi-sourced diagenetic waters responsible for porosity development and destruction.

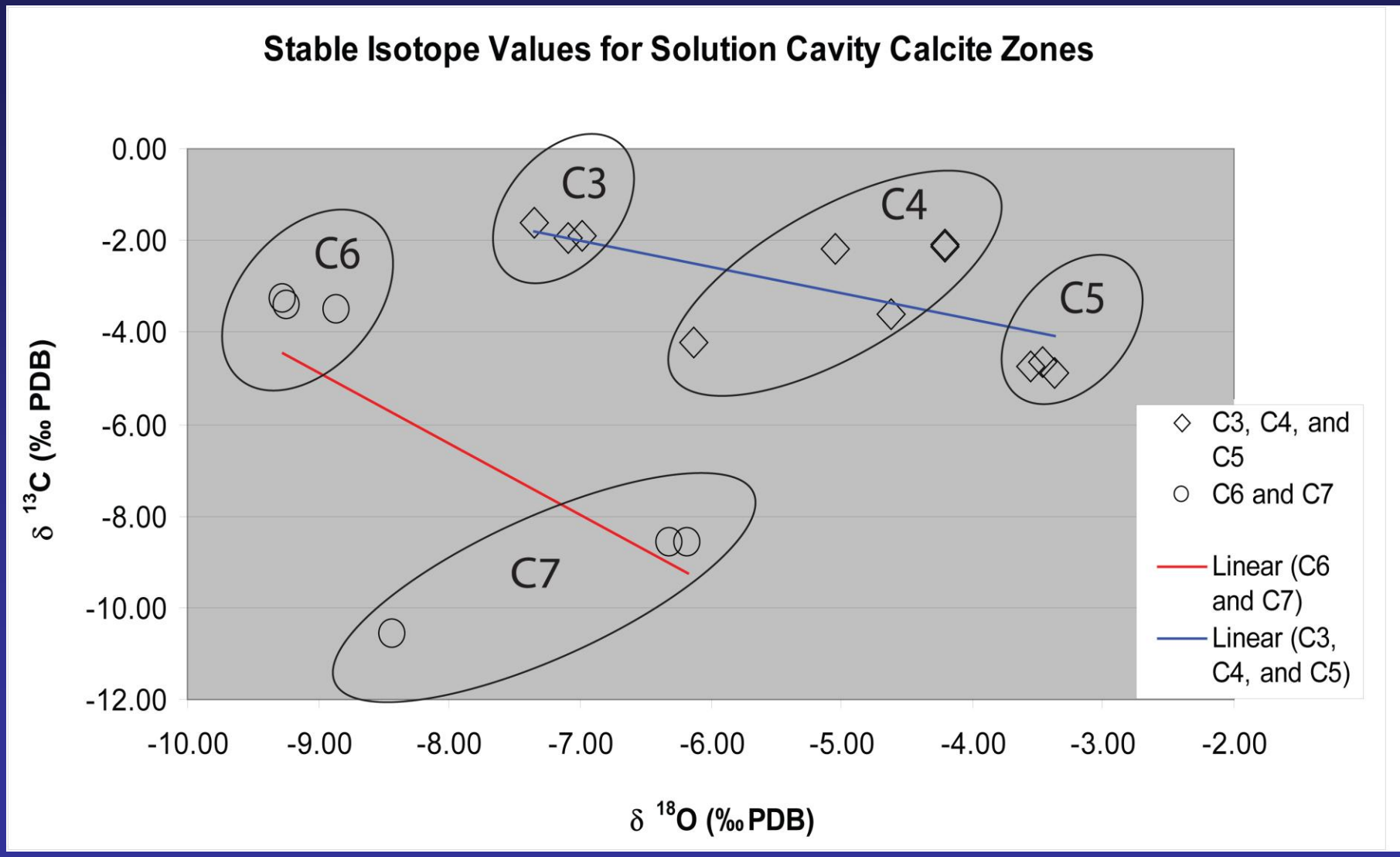
Paragenetic Sequence



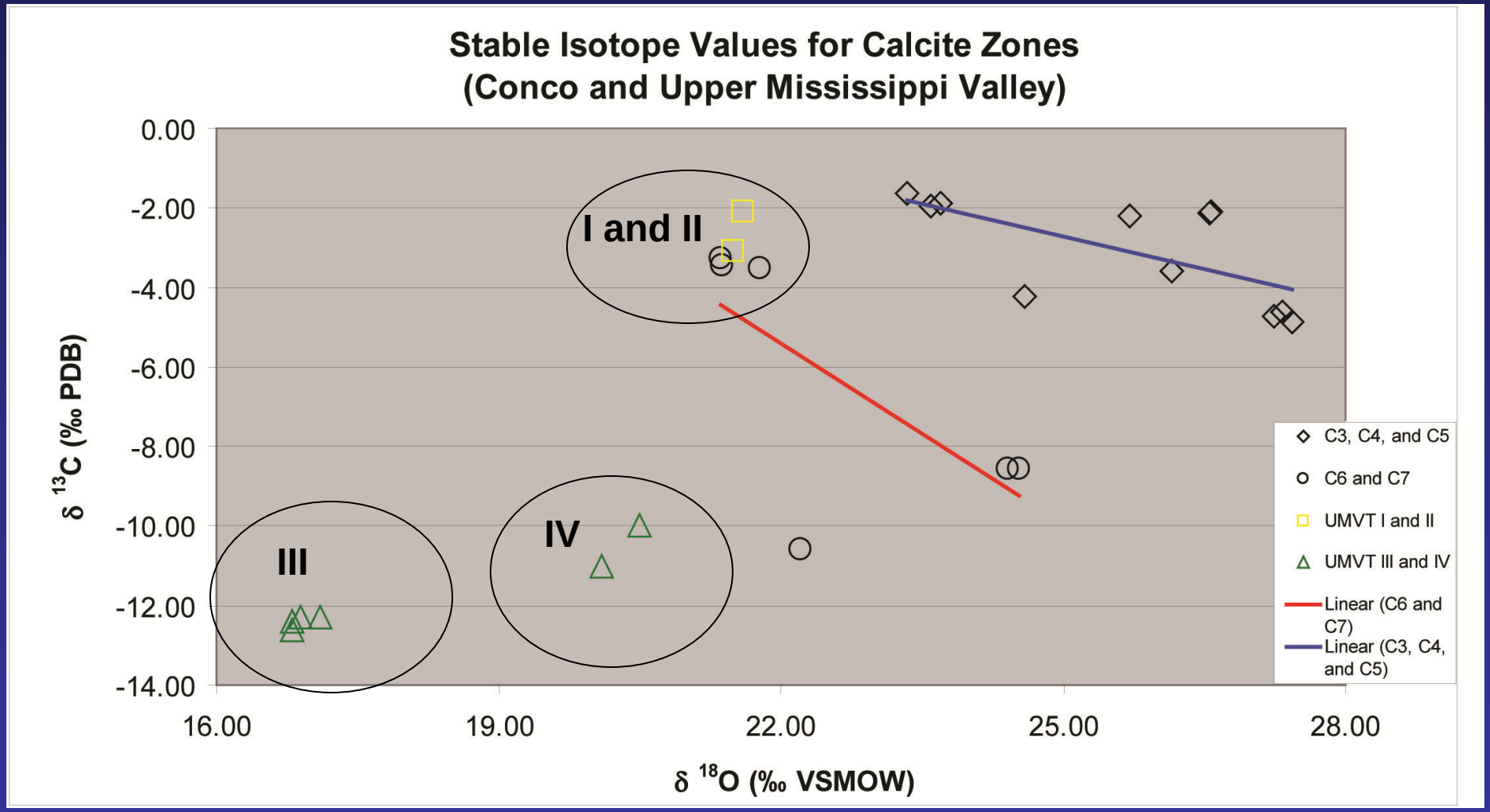
PL and CL cross-section through cavity cements



Calcite $\delta^{13}C$ and $\delta^{18}O$



Calcite $\delta^{13}C$ and $\delta^{18}O$



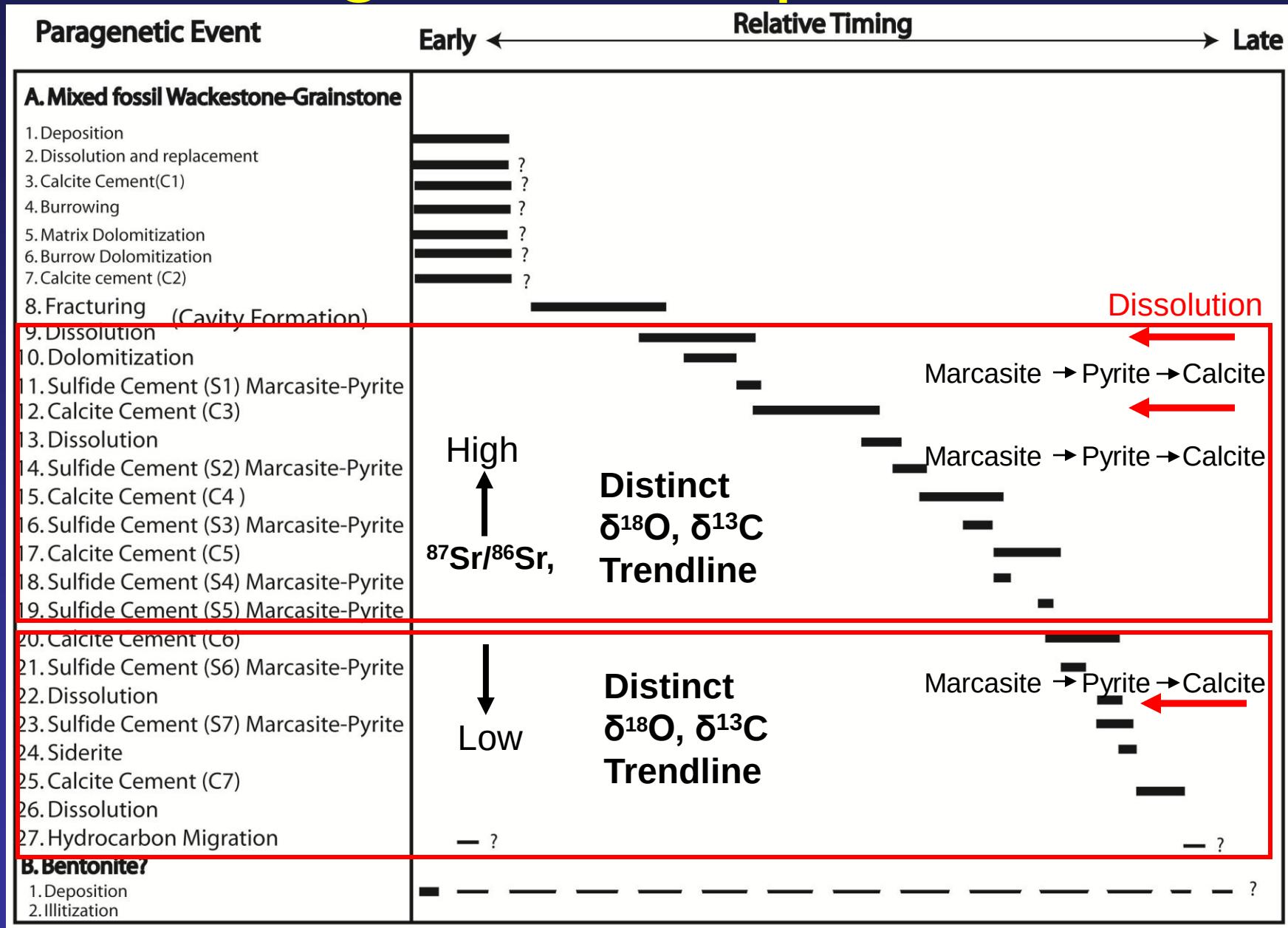
UMV data from McLimans, 1977

Geochemistry

Paragenetic Sequence (Cavity Calcite)		Ca (mol %)	Na (ppm)	Sr (ppm)	Fe (ppm)	Mg (ppm)	Mn (ppm)	$^{87}Sr/^{86}Sr$ (Standard SRM976)
A12 (C3)	Older	40.7	47	164	355	1113	238	na
A15 (C4)	↕	40.0	52	150	77	1615	566	0.71015
A15 (C4')		40.5	44	196	242	395	372	na
A17 (C5)		40.6	64	23	bd	490	451	na
A20 (C6)		40.4	43	155	146	375	203	0.70980
A25 (C7)	Younger	41.0	147	249	bd	526	158	0.70898

- Older Calcite has high radiogenic $^{87}Sr/^{86}Sr$, high Fe, high Mg)
- Younger calcite has lower radiogenic $^{87}Sr/^{86}Sr$, low Fe, low Mg)

Paragenetic Sequence



Conclusions

- Cavernous porosity development and later mineralization formed when basinal fluids migrated up fractures in the Galena (Trenton)
- Facies such as impermeable clay zones act as internal aquitards
- Cyclical diagenetic events represent temporal changes in the fluid composition and suggest multiple sources of fluid
- Negative values of $\delta^{13}C$ for later calcites may be attributed to oxidation of organic compounds

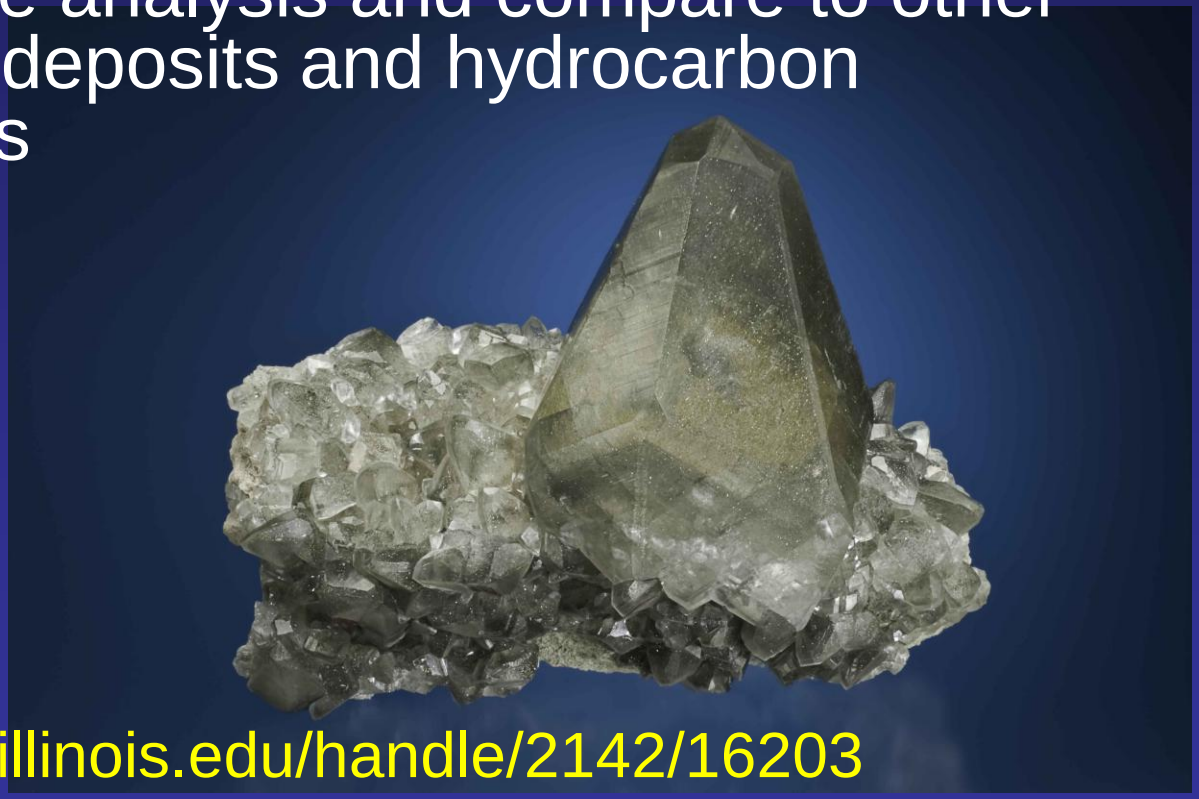
- An overlap of calcite stable isotope values from Conco and the Upper Mississippi Valley Zn-Pb district imply a genetic relationship.

- The geographic location of the Conco mine implies some fluids responsible for cavernous porosity development were sourced from the Michigan Basin. However, the Illinois and Appalachian Basins can't yet be ruled out

- Cavernous porosity development may be more widespread throughout midcontinent basins such as the Michigan Basin

Current Work

- Fluid inclusion analysis
- Further isotope analysis and compare to other regional MVT deposits and hydrocarbon reservoir cores
- Date minerals



Publication

https://www.ideals.illinois.edu/handle/2142/16203