Epigenetic Dolomitization and Mississippi Valley-Type Mineralization in Cambro-Ordovician Carbonates of North America*

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Abstract

Middle Cambrian through Lower Ordovician carbonate rocks of North America host some of the largest Mississippi Valley-type (MVT) base-metal sulfide deposits in the world. These include the Southeast Missouri Pb-Zn-Cu district and the East Tennessee Zn-Pb district, which place the United States as one of the world's leading producers of lead and zinc. Other economic and sub-economic MVT deposits as well as minor occurrences of mineralization are found in carbonates of Cambro-Ordovician age throughout the continent.

In addition to sulfide and sulfate minerals, MVT deposits are associated with large-scale dissolution and brecciation of carbonate rocks, precipitation of large volumes of dolomite and calcite cements, epigenetic (hydrothermal) dolomitization, and recrystallization of pre-existing dolomite. Mineralizing fluids have the effect of both increasing original porosity via dissolution and brecciation as well as occluding porosity through precipitation of cements.

MVT mineralization is believed to result from saline fluids expelled from sedimentary basins, commonly associated with petroleum migration. The fluids have temperatures ranging from 60° - 250°C with most temperatures falling between 100° and 150°C. Some of the fluids originate from evaporated seawater that has interacted with sedimentary rocks and, possibly, basement rocks. A number of geochemical and hydrogeological mechanisms have been proposed for MVT deposits. However, the precise mechanisms driving fluid flow and deposition are not yet completely understood. MVT fluids are not localized but affect sedimentary rocks over large regions. It is likely that most, if not all, Cambro-Ordovician carbonate rocks in North America have undergone at least some diagenetic alteration due to exposure to these fluids, affecting the reservoir properties of carbonate rocks, even at great distances from known ore deposits.

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INTRODUCTION

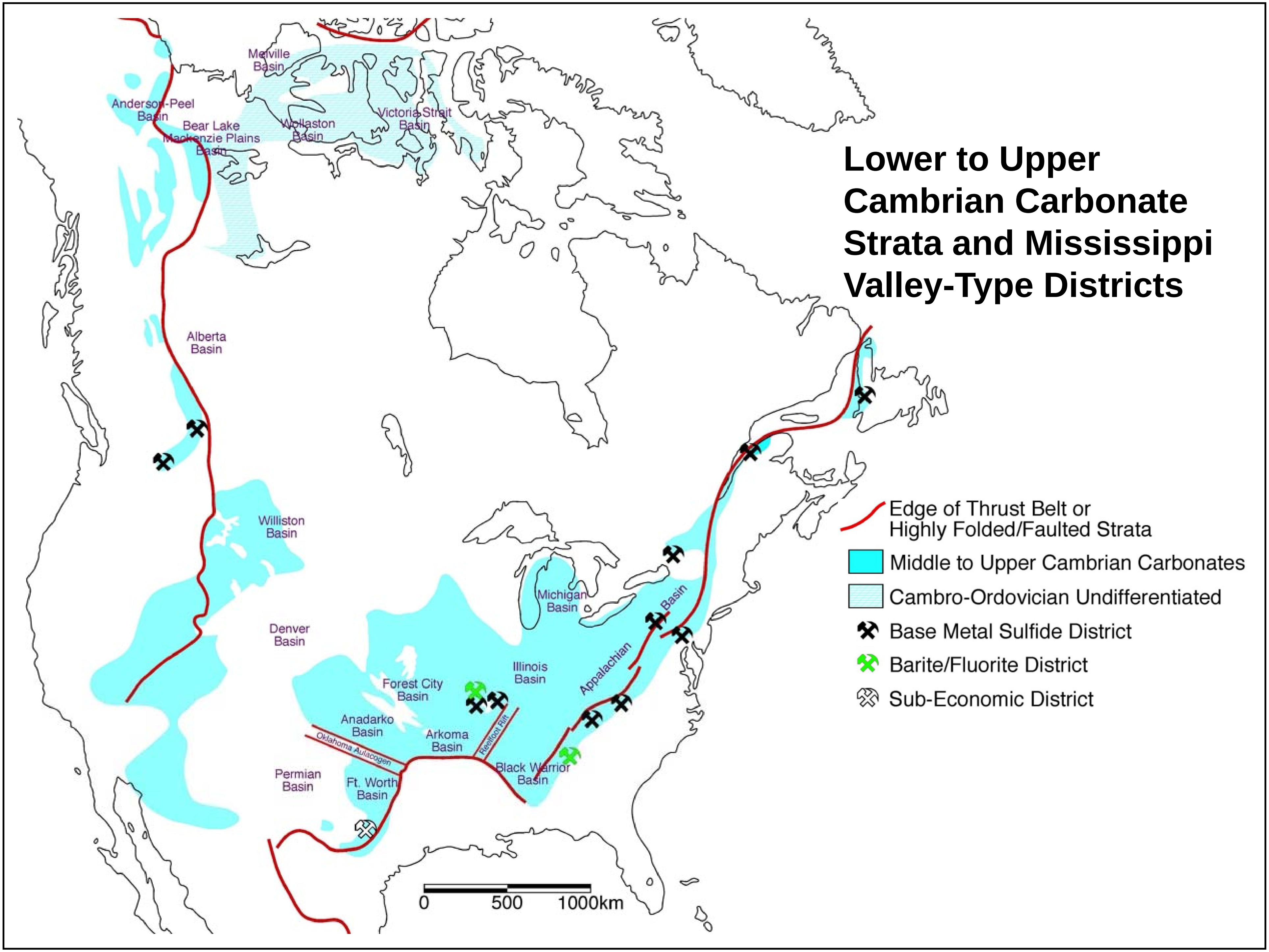
The Cambro-Ordovician “Great American Carbonate Bank” contains among the largest reserves of lead, zinc, and other base metals in the world as well as numerous minor occurrences of these metals.

This presentation will review:

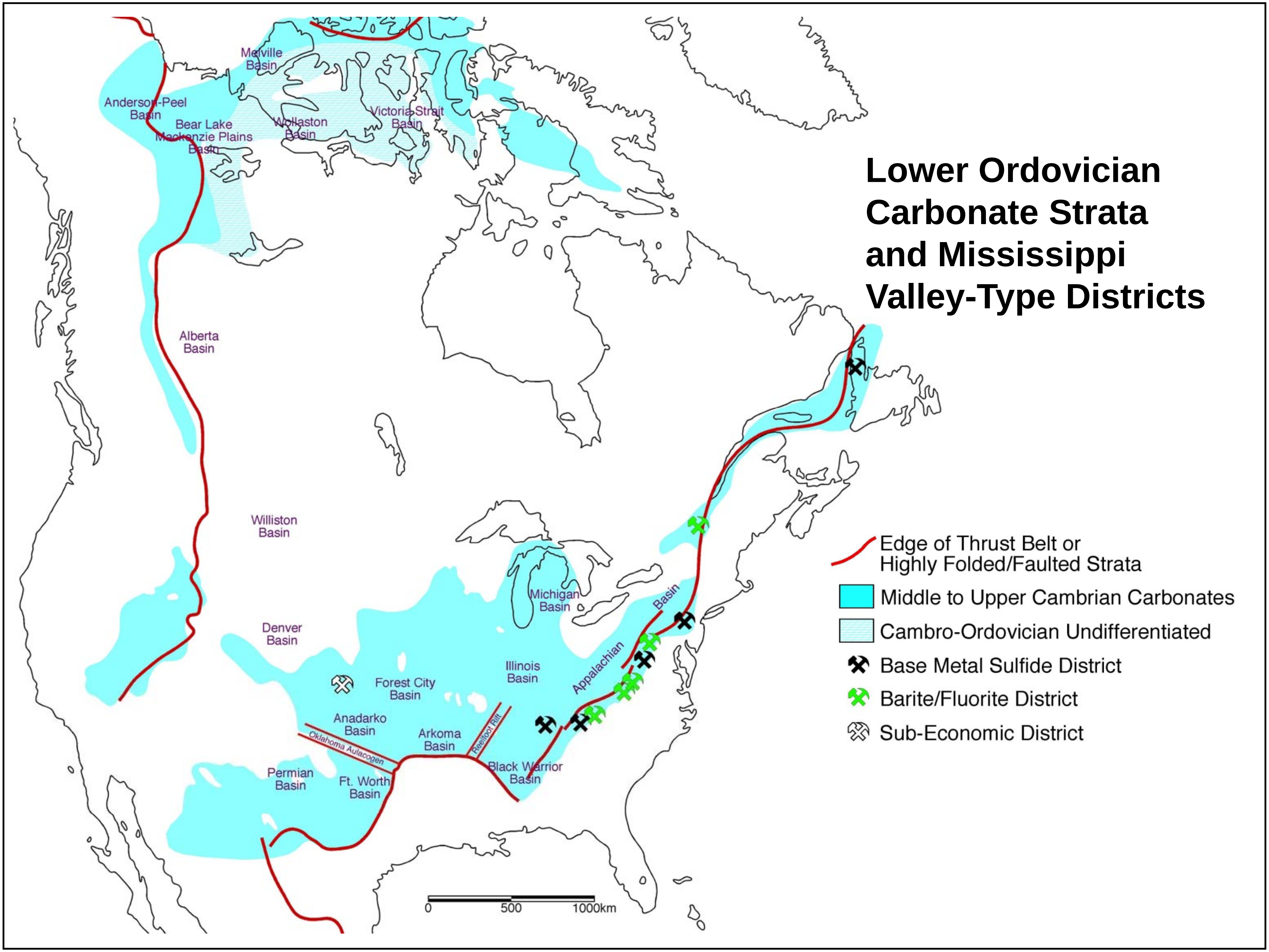
- The distribution of Cambro-Ordovician (Sauk Sequence) Mississippi Valley-type (MVT) deposits and occurrences in North America.
- The geochemistry of the fluids associated with MVT mineralization.
- The effects of mineralization on the carbonate rocks exposed to these mineralizing fluids.

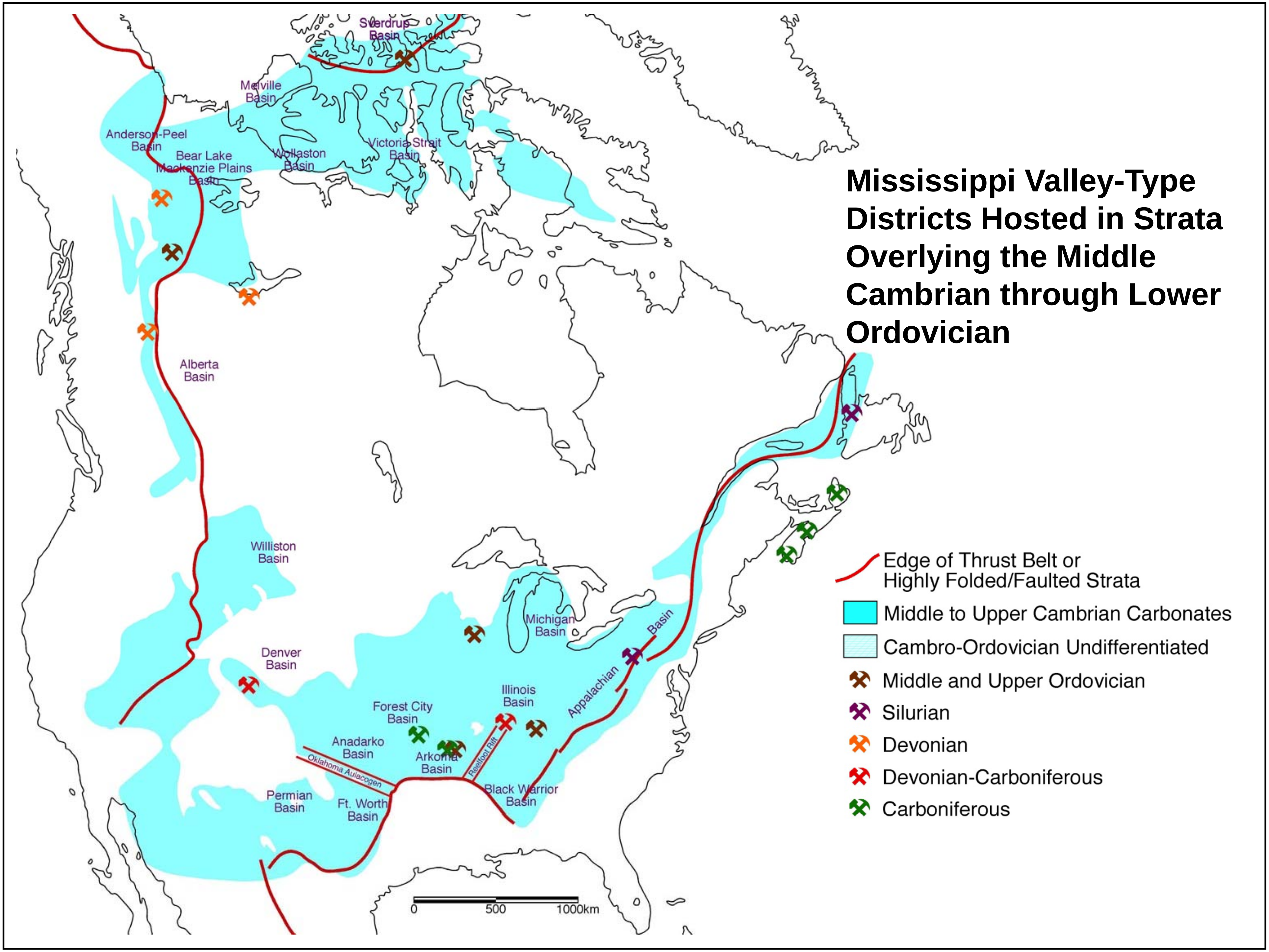
Mississippi Valley-type mineral deposits and occurrences:

- Typically **carbonate hosted** (and less frequently sandstone hosted).
- Found in almost every sedimentary basins in the world in rocks of **Archean to Cenozoic age**.
- **Epigenetic** and thought to be precipitated by basinal fluids at **relatively shallow depths**.
- May contain **lead**, **zinc**, and other base metal sulfides as well as nonsulfide minerals such as **barite** and **fluorite**.
- Almost always are associated with evidence of **hydrocarbons**.
- Precipitated with **large volumes of open-space-filling** cements such as dolomite, calcite, and quartz and are **associated with massive dolomitization** of host carbonate rock.
- Frequently associated with **large scale dissolution** of hosting carbonate rocks.


Lower to Upper Cambrian Carbonate Strata and Mississippi Valley-Type Districts
Melville Basin
Anderson-Peel Basin
Bear Lake
Mackenzie Plains Basin
Wollaston Basin
Victoria Strait Basin
Alberta Basin
Williston Basin
Denver Basin
Michigan Basin
Illinois Basin
Appalachian Basin
Forest City Basin
Anadarko Basin
Oklahoma Aulacogen
Arkoma Basin
Reelfoot Rift
Black Warrior Basin
Permian Basin
Ft. Worth Basin
0
500
1000km
Edge of Thrust Belt or Highly Folded/Faulted Strata
Middle to Upper Cambrian Carbonates
Cambro-Ordovician Undifferentiated
Base Metal Sulfide District
Barite/Fluorite District
Sub-Economic District

Lower Ordovician Carbonate Strata and Mississippi Valley-Type Districts





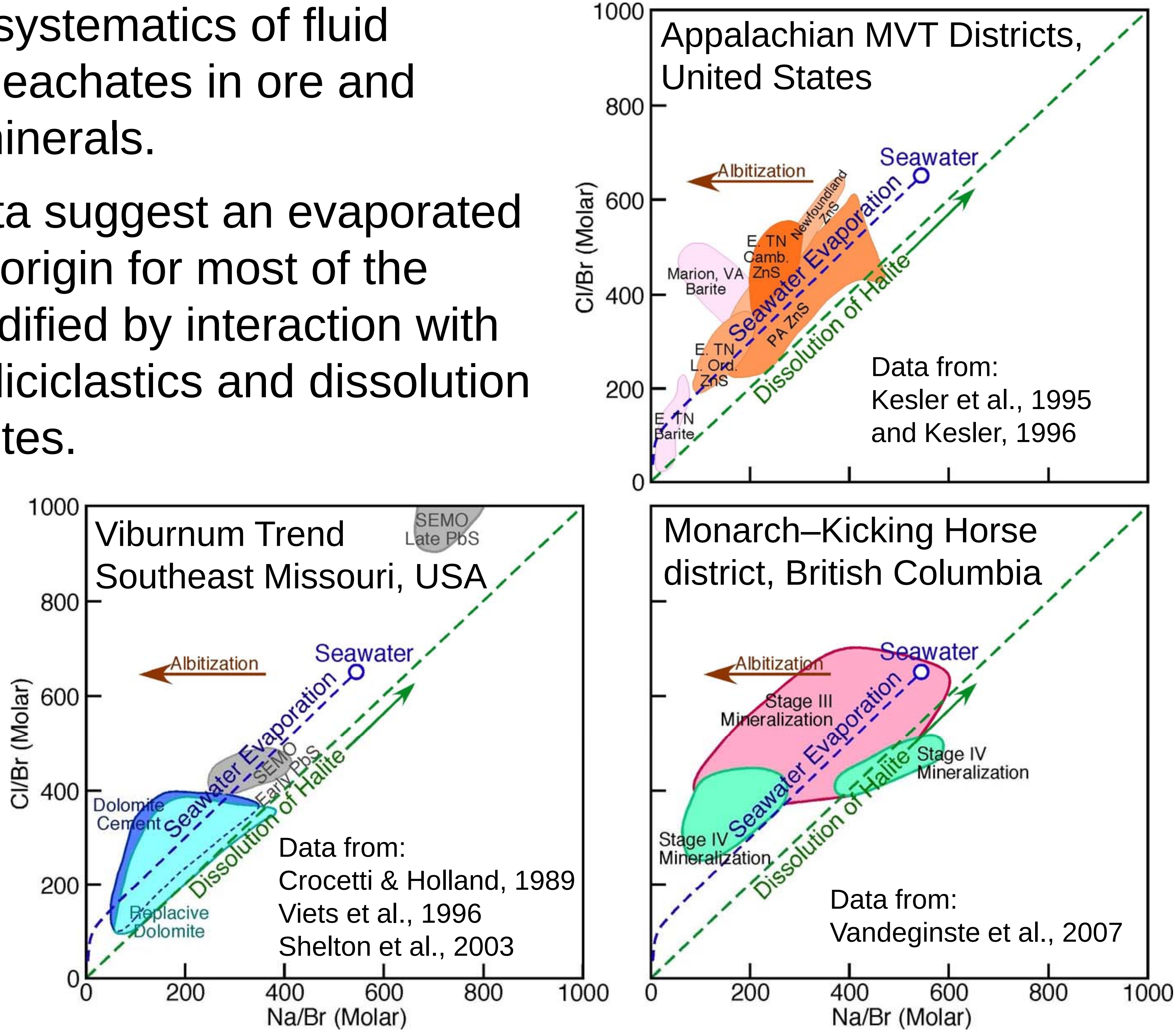
Mississippi Valley-Type Districts Hosted in Strata Overlying the Middle Cambrian through Lower Ordovician
Sverdrup Basin
Melville Basin
Anderson-Peel Basin
Bear Lake
Mackenzie Plains Basin
Wollaston Basin
Victoria Strait Basin
Alberta Basin
Williston Basin
Denver Basin
Michigan Basin
Appalachian Basin
Illinois Basin
Forest City Basin
Anadarko Basin
Arkoma Basin
Oklahoma Aulacogen
Reelfoot Rift
Black Warrior Basin
Permian Basin
Ft. Worth Basin
0
500
1000km
Edge of Thrust Belt or Highly Folded/Faulted Strata
Middle to Upper Cambrian Carbonates
Cambro-Ordovician Undifferentiated
Middle and Upper Ordovician
Silurian
Devonian
Devonian-Carboniferous
Carboniferous

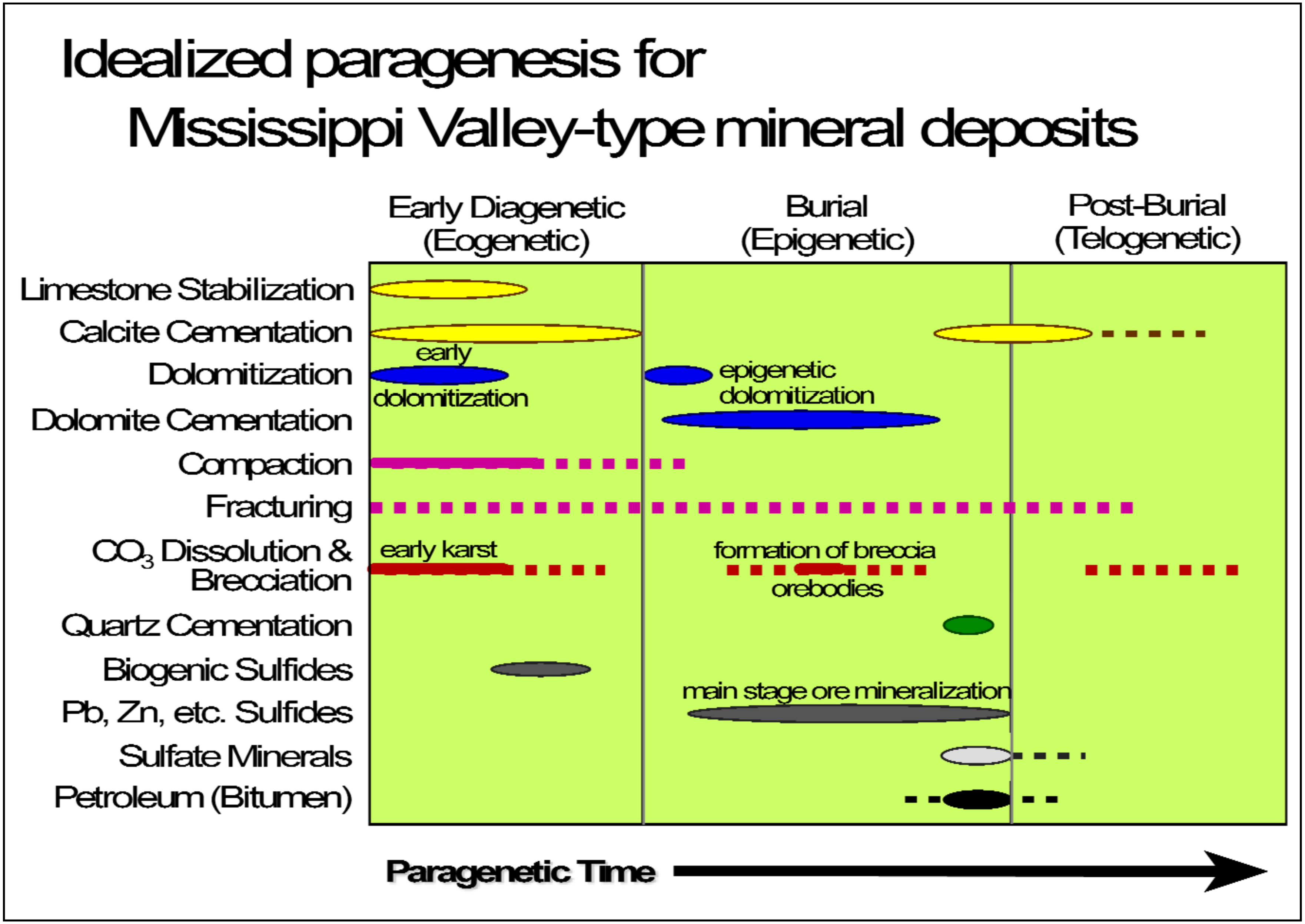
Fluid geochemistry:

- Similar in composition to oil field brines.
- Temperatures typically range from 60° to 160°C and less frequently >200°.
- Salinities typically between 10 and 30 wt. % equivalent NaCl.
- Fluid inclusion studies indicate that cooling and fluid mixing are viable ore deposition mechanisms.
- Halogen ratios indicate a seawater origin for one or more of the mixing fluids.
- $^{87}Sr/^{86}Sr$ of carbonates precipitated by these fluids indicate interaction with basement or basement derived siliciclastics.

Na-Cl-Br systematics of fluid inclusion leachates in ore and gangue minerals.

These data suggest an evaporated seawater origin for most of the fluids, modified by interaction with Na-rich siliciclastics and dissolution of evaporites.





Idealized paragenesis based on southeast Missouri and observations elsewhere. Note: early and late diagenetic dolomitization, cementation, emplacement of sulfides, and petroleum (as oil, bitumen, and/or petroleum inclusions)

The effects of mineralization on carbonate strata:

1. Dolomitization of limestone and neomorphic recrystallization of pre-existing dolomite. This typically reduces permeability due to development of nonplanar crystal textures. However, in some instances, porosity and permeability may be retained.

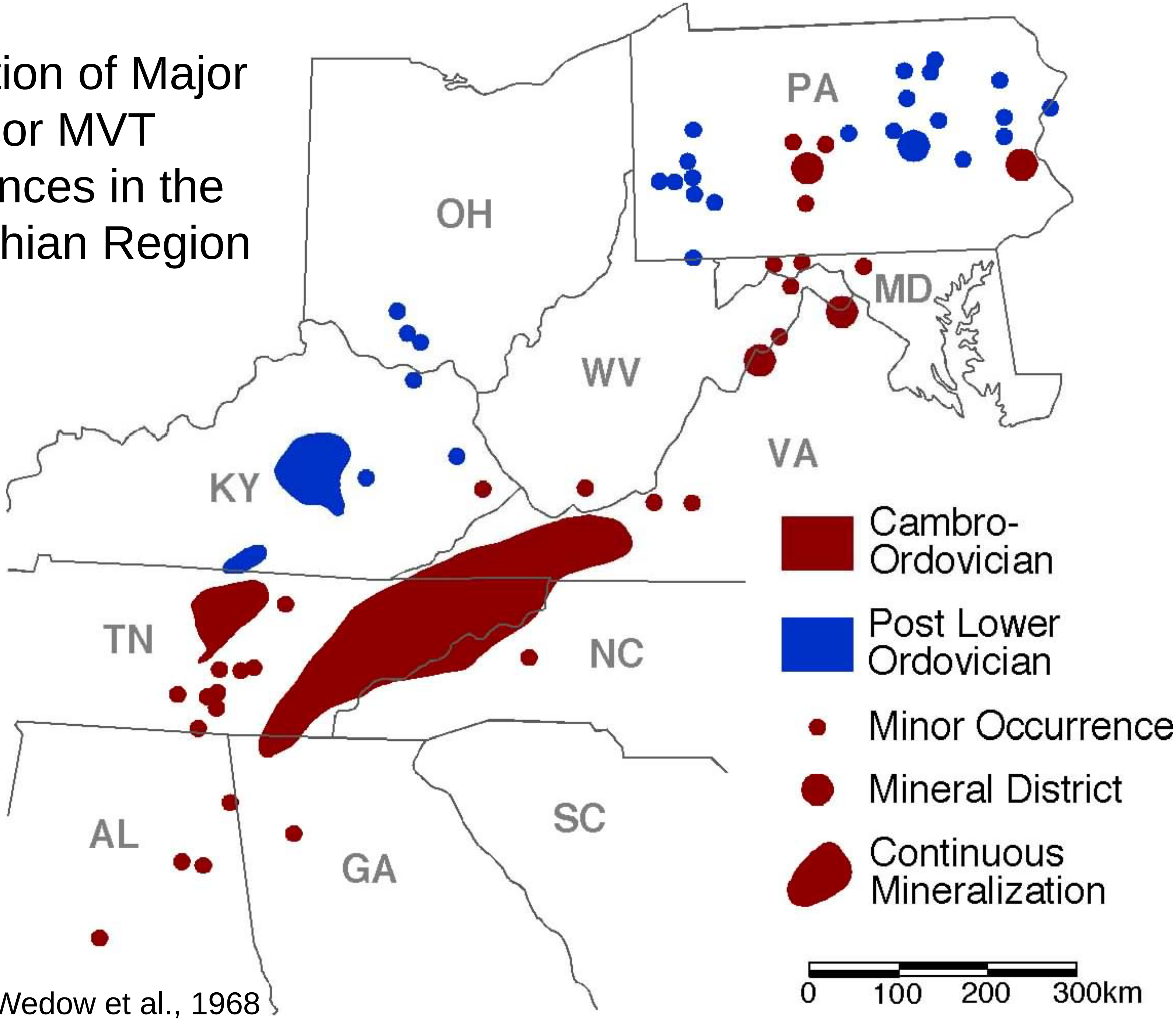
2. Precipitation of large volumes of open-space-filling cements (both ore and gangue minerals). This is particularly destructive of micro- and meso-porosity and permeability.

3. Large scale dissolution and brecciation of carbonate rocks, particularly proximal to sulfide mineralization. This creates megaporosity.

Two regions will be examined here in more detail:

- The East Tennessee Zinc-Lead district
- The Southeast Missouri Lead-Zinc district

Distribution of Major And Minor MVT Occurrences in the Appalachian Region



Modified from Wedow et al., 1968

Development of fluid conduits in Knox Group carbonate strata has been shown to be related to parasequence type.

Regressive peritidal cycles

Early diagenetic dolomite dominates →

- fine crystalline planar texture
- low porosity & permeability, poor reservoir quality

Transgressive paratidal cycles

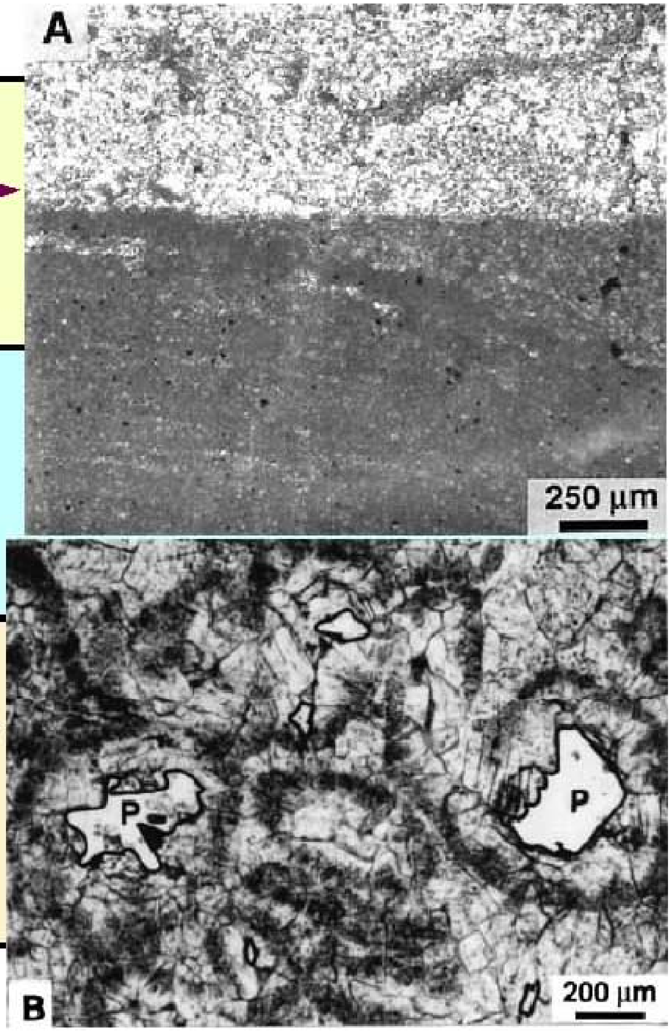
Limestone

- early diagenetic calcite cementation
- low porosity & permeability, poor reservoir qulity

Transgressive paratidal cycles

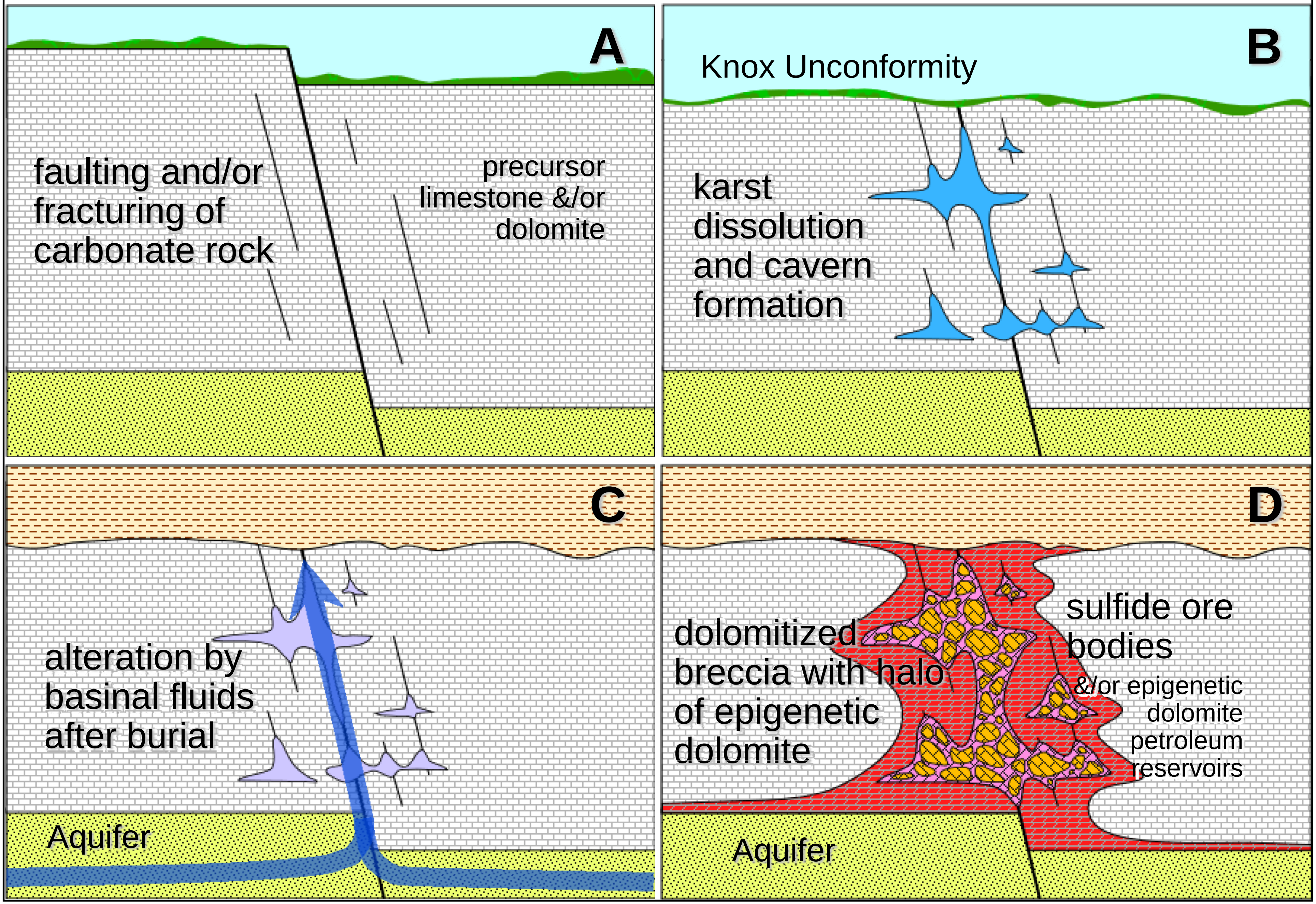
Late diagenetic dolomite →

- medium to coarse crystalline nonplanar
- high porosity & permeability
- hosts sulfide mineralization & good reservoir quality

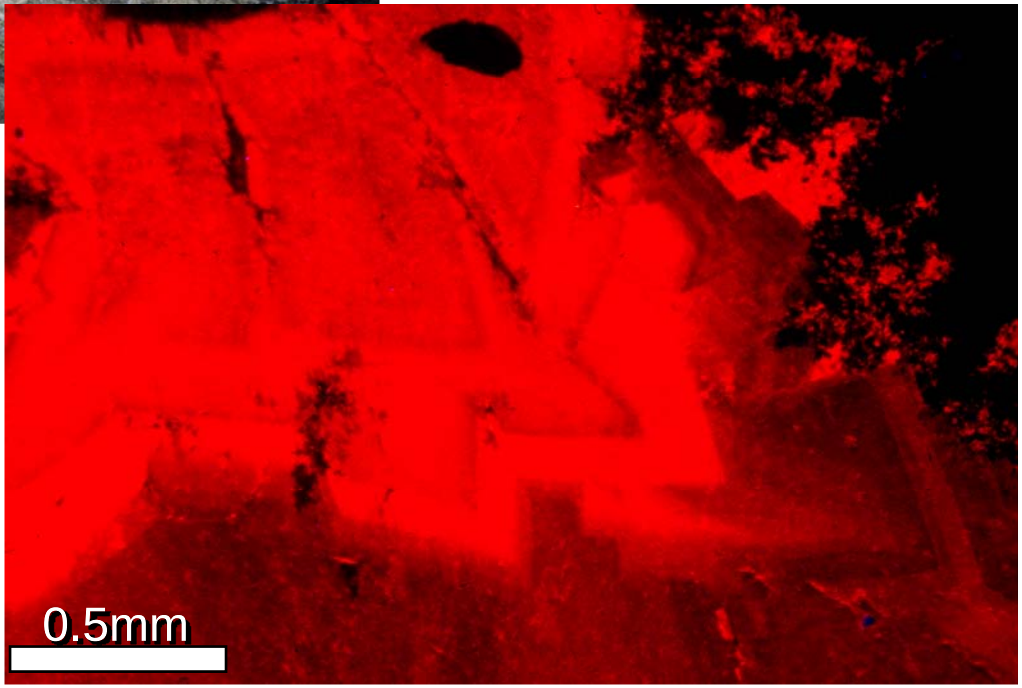


After Montañez, 1994 & 1996.

Model for formation of mineralized breccia bodies

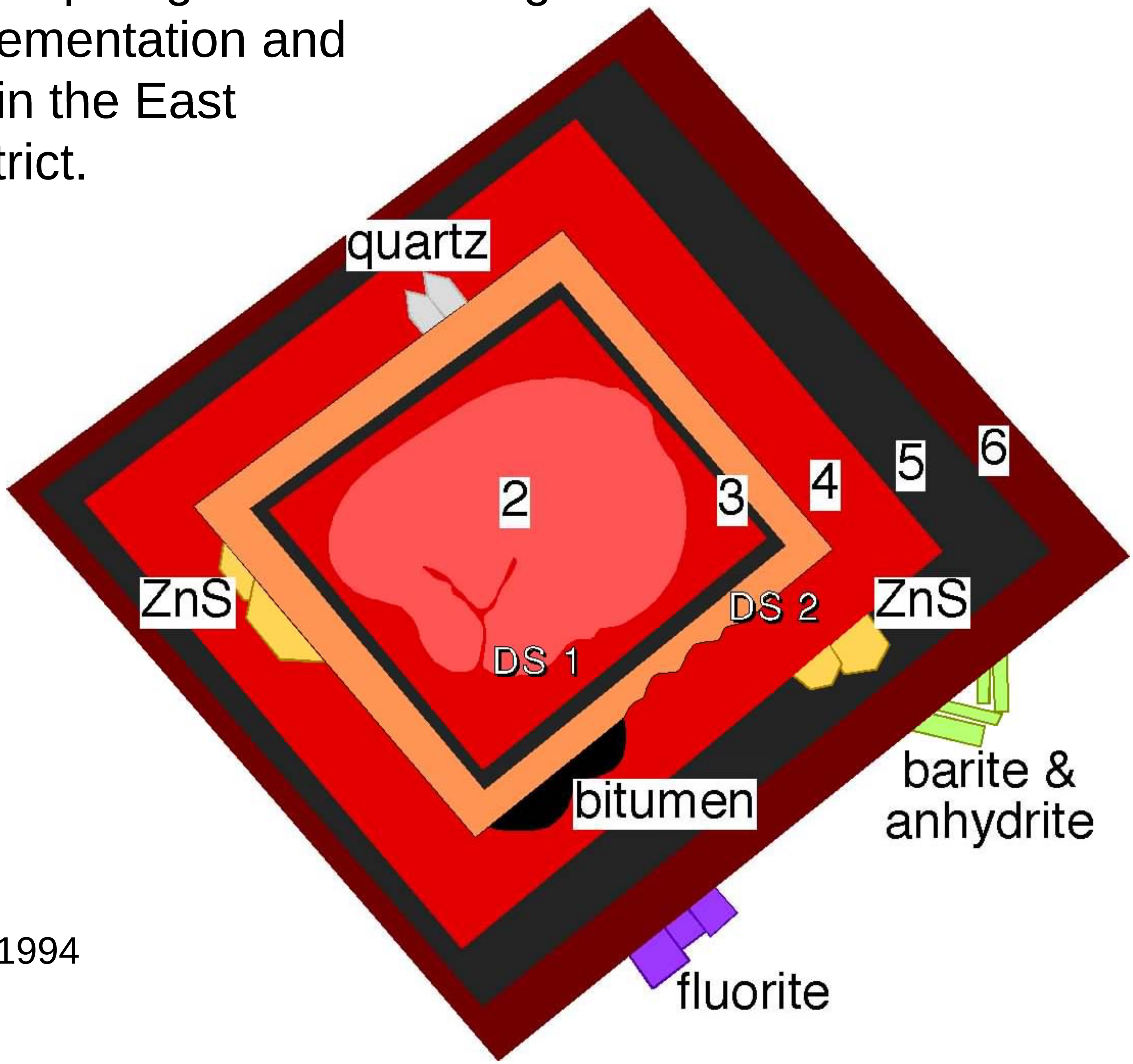


Sphalerite-mineralized breccia in Lower Ordovician of the East Tennessee district.



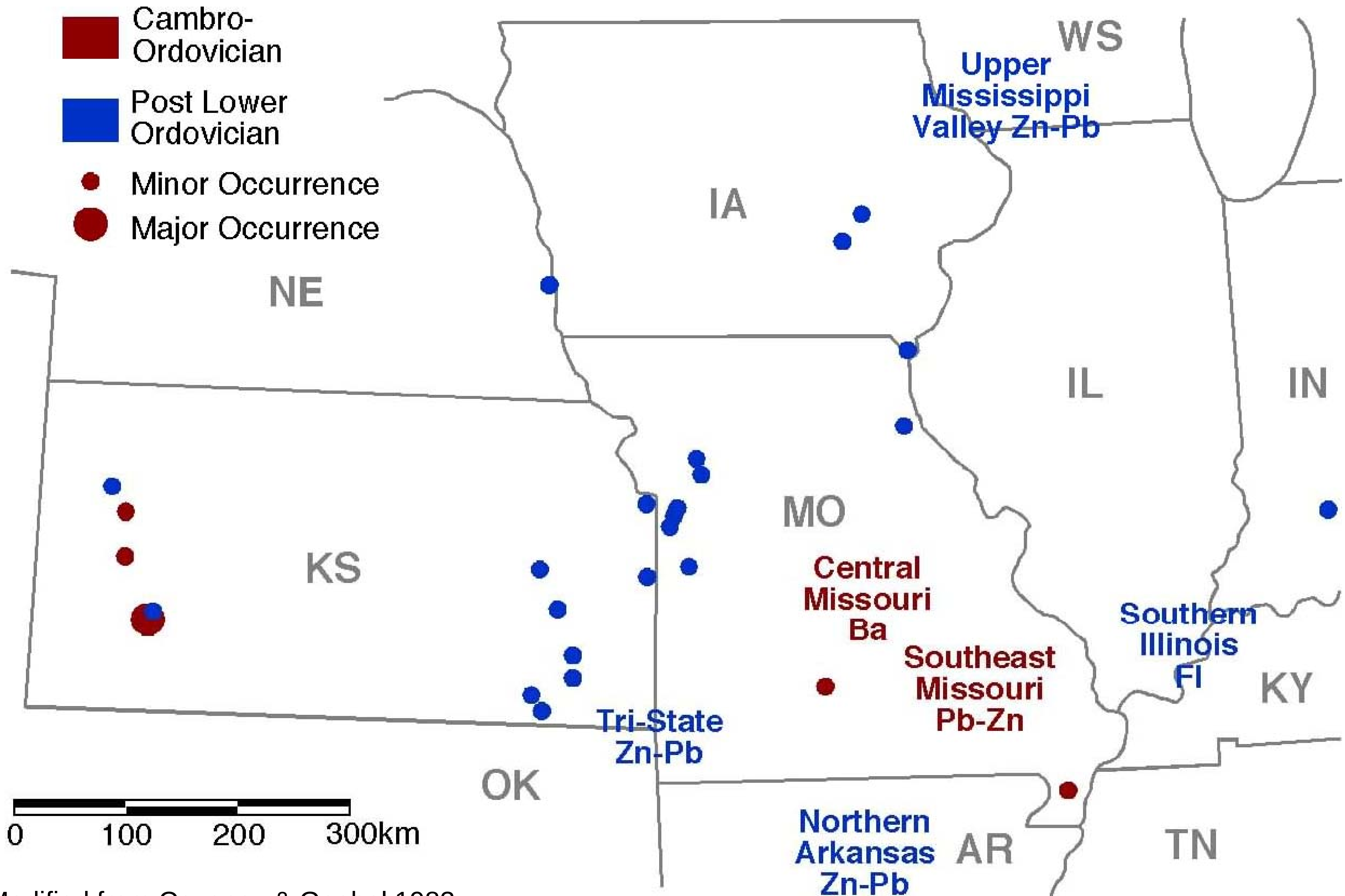
Cathodoluminescence photomicrograph of gangue dolomite cement displaying the compositional microstratigraphy typical of the the East Tennessee Zn-Pb district.

Dolomite cement paragenesis and stages of epigenetic cementation and mineralization in the East Tennessee district.



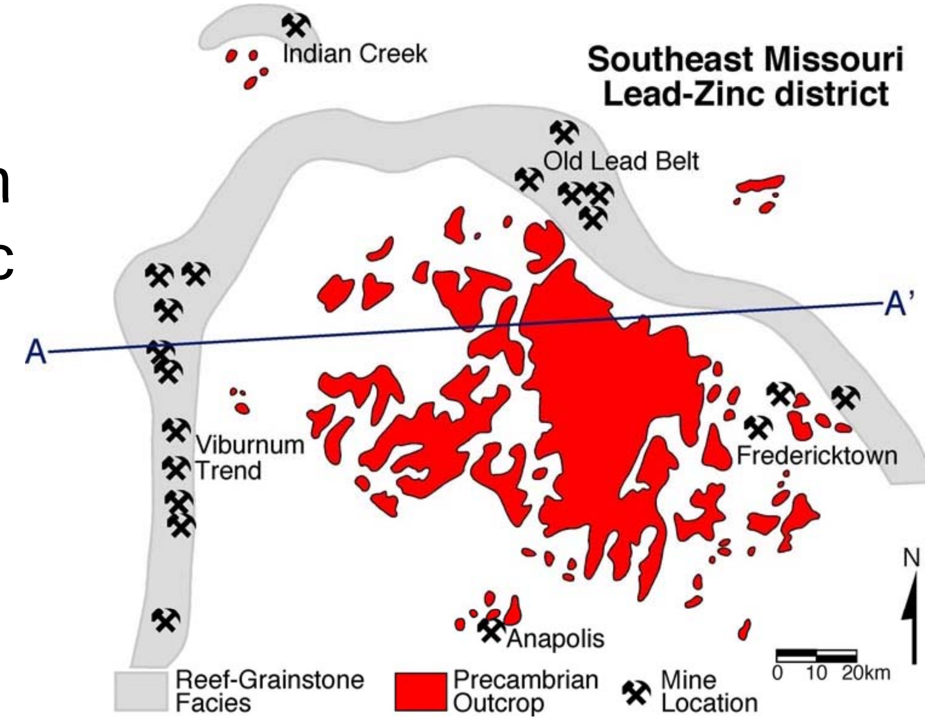
After Moñtanez, 1994

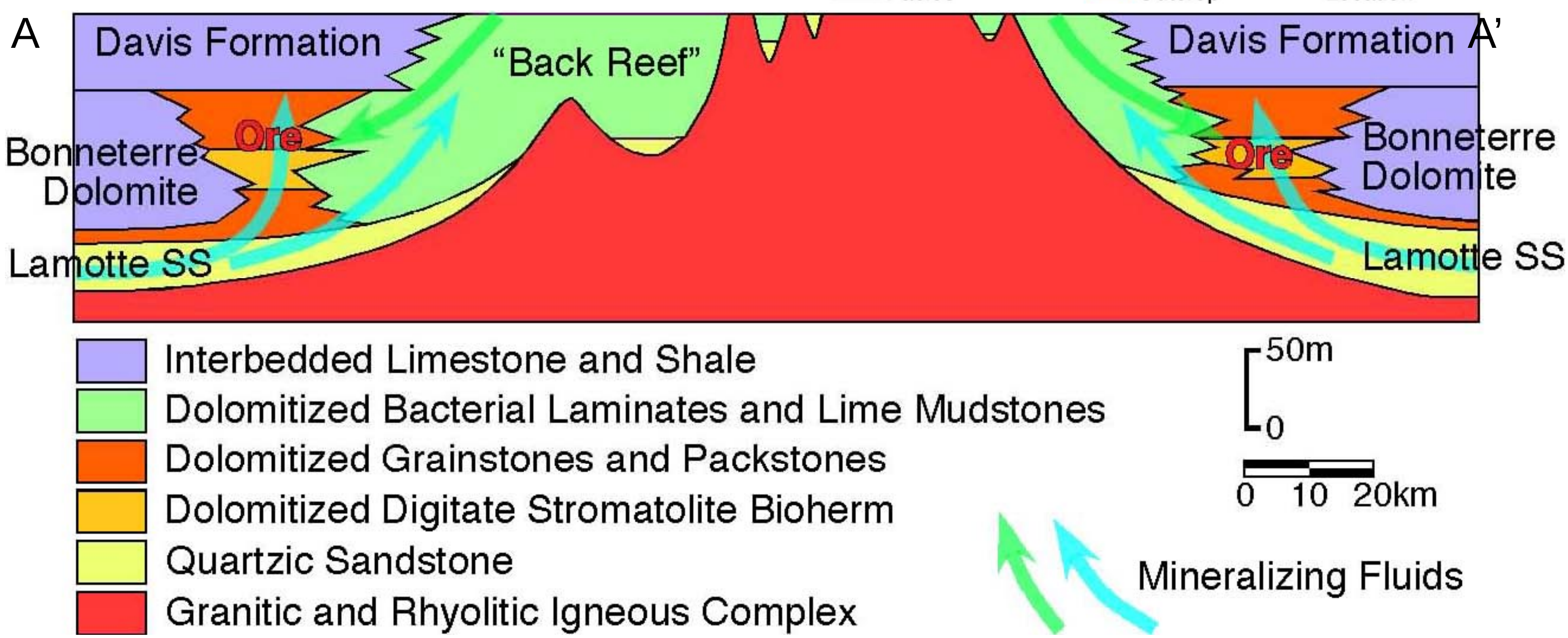
Distribution of major and minor MVT occurrences on the Midcontinent

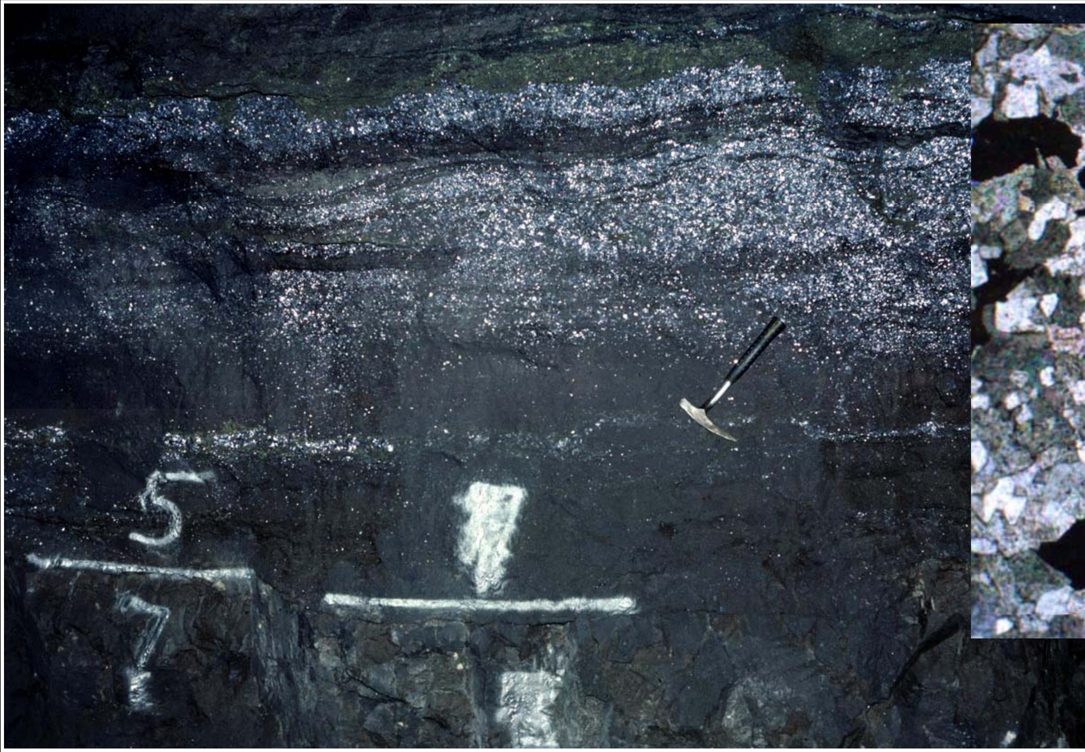


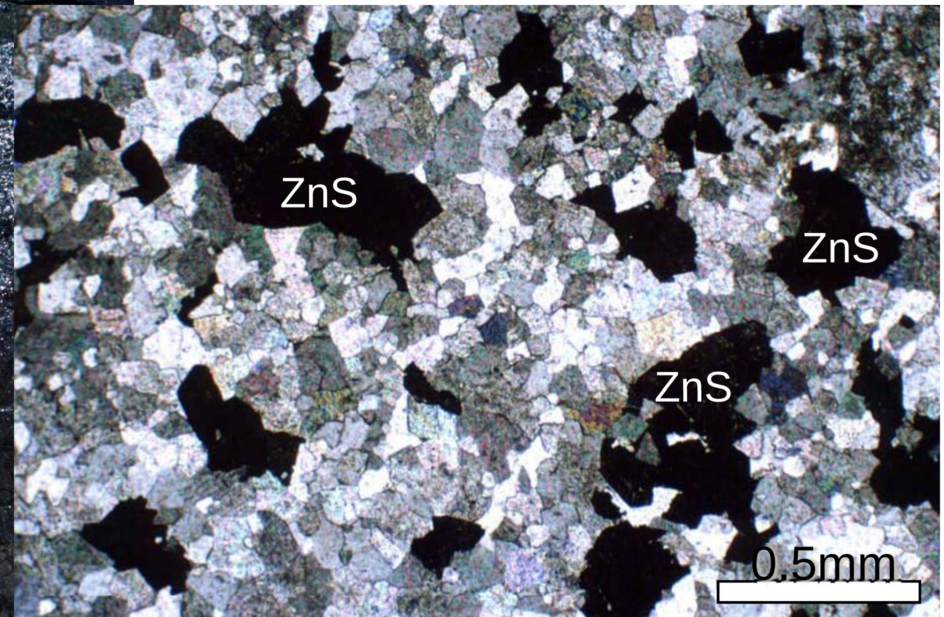
Modified from Coveney & Goebel 1983

Relationship of facies to fluid flow and sulfide mineralization in the Southeast Missouri lead-zinc district.





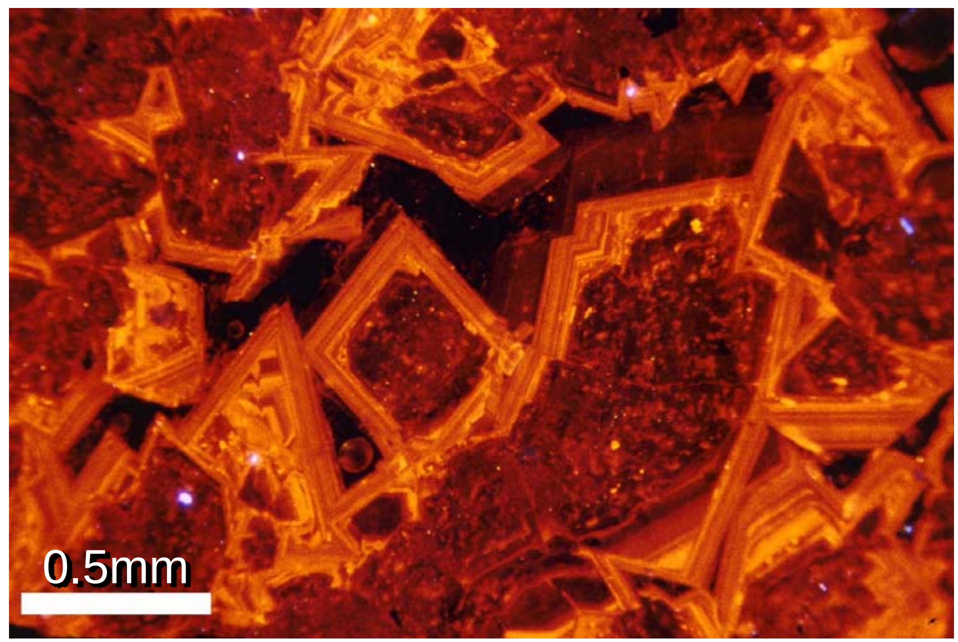




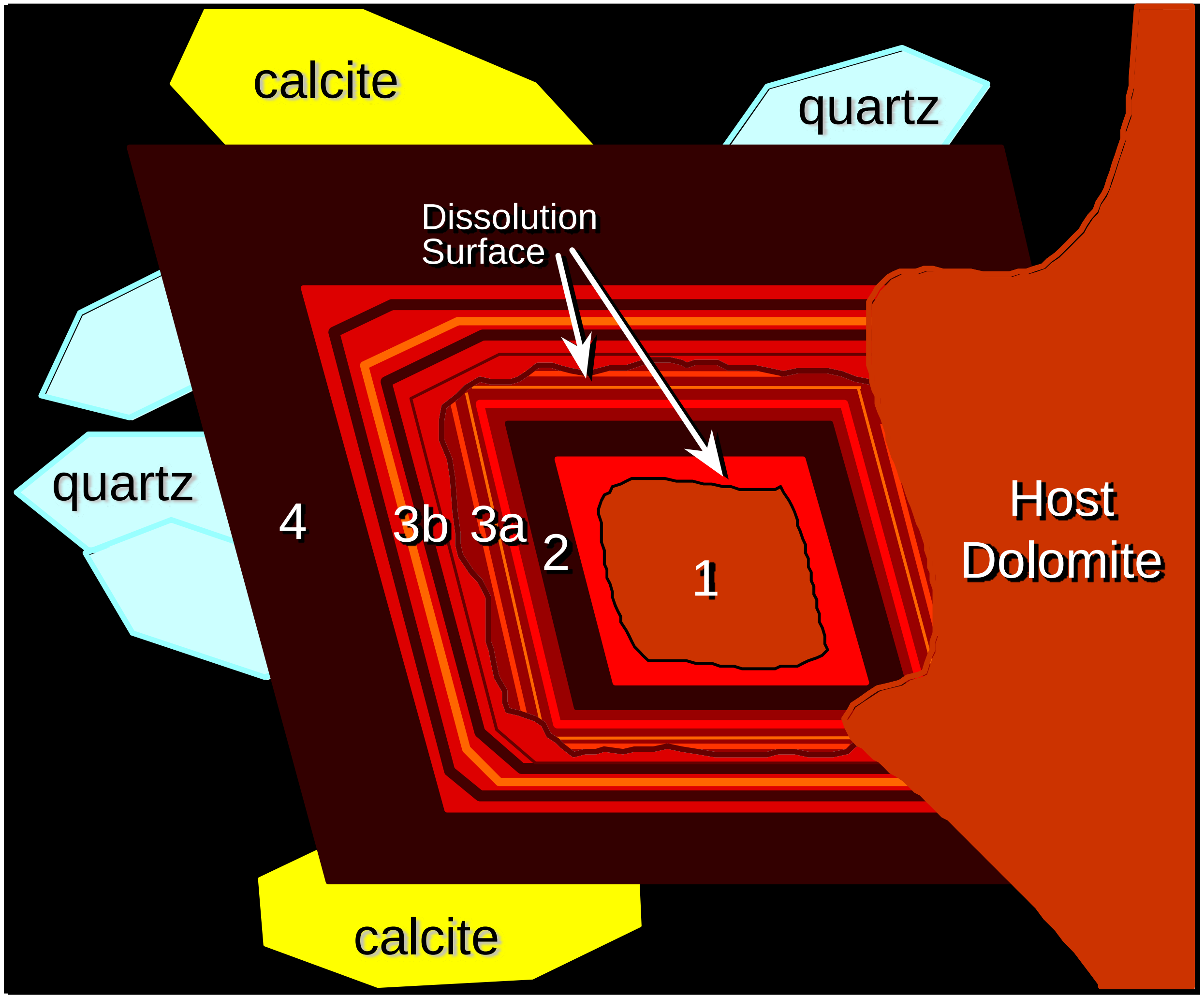
Dolomitized oolitic grainstone with ZnS filling intercrystal porosity.

A mine face with disseminated galena in the Bonneterre Dolomite, Viburnum Trend, southeast Missouri.

Cathodoluminescence photomicrograph displaying the compositional microstratigraphy typical of the southeast Missouri Mineral district.



Stages of cement growth in the Bonneterre Dolomite



Main sulfide mineralization during the 2nd stage of dissolution.

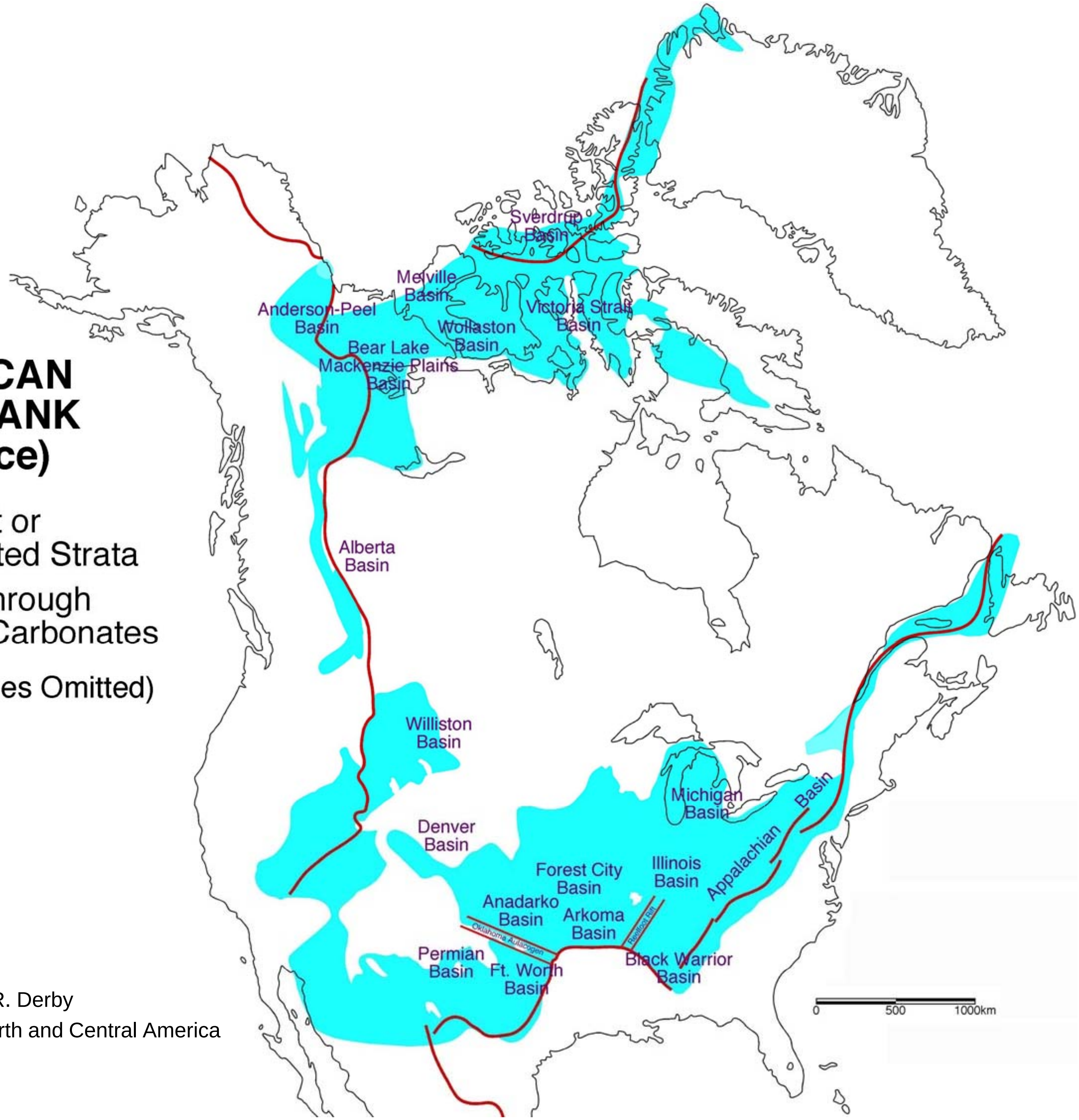
Late sulfide mineralization after zone 4 dolomite cement.

Conclusions:

1. The Cambro-Ordovician “Great American Carbonate Bank” hosts a large percentage of the worlds Mississippi Valley-type base metal sulfide deposits.
2. Most if not all of the Cambro-Ordovician carbonate section of North America likely was affected by mineralizing fluids associated with MVT mineralization.
3. Mineralizing basinal fluids have the characteristics of evolved seawater and are similar in most respects to oil field brines.
4. Effects of MVT mineralization on hosting carbonate rocks include:
   - Massive dolomitization of limestones and neomorphic recrystallization of pre-existing dolomites.
   - Precipitation of large volumes of open-space-filling carbonate and other mineral cements.
   - Large scale dissolution and brecciation of carbonate rocks.


0
10mm
20
30
40
50
60
70
80
90
100
110

Location:



GREAT AMERICAN CARBONATE BANK (Sauk Sequence)

Edge of Thrust Belt or Highly Folded/Faulted Strata

Middle Cambrian through Lower Ordovician Carbonates

(Argentina and The British Isles Omitted)

Base Map by Jay M. Gregg & James R. Derby

Based on the Stratigraphic Atlas of North and Central America By T.D. Cook and A.W. Bally

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