Geology of the Ozarks and its Lead-Zinc Deposits

Jim Palmer

Terms

- **Mississippi Valley type deposit** (**MVT**) ores are primarily Zinc-Lead, less commonly Lead-Zinc. Southeast Missouri Bonneterre ores are uncommon as Lead-Zinc-Copper MVT deposits.

- The most common **sulfide** minerals in MVT deposits are sphalerite, galena, chalcopyrite, pyrite-marcasite.

Terms

- **Aquifers** are rocks capable of transmitting groundwater such as sandstone and porous dolomites. Many of the aquifers contain traces of ore minerals. Most **aquitards** are shaley formations that restrict groundwater flow.

- Southeast Missouri MVT ore host rocks have mostly been altered to **dolomite (CaMgCOC3)**, from limestone which are **calcite (CaCO3)**.

Summary 1

- The sequence of rocks from Precambrian to Pennsylvanian are a series of aquifers and aquitards. The principal host rocks are dolomites in the Bonneterre Formation

- The accumulation of Paleozoic sediments followed a long period of weathering and erosion of Precambrian rocks.

- During lead-zinc mineralization, metals-bearing brines flowed through porous rocks. Where ***aquitards were absent*** these brines had potential to flow upward into porous host rocks.

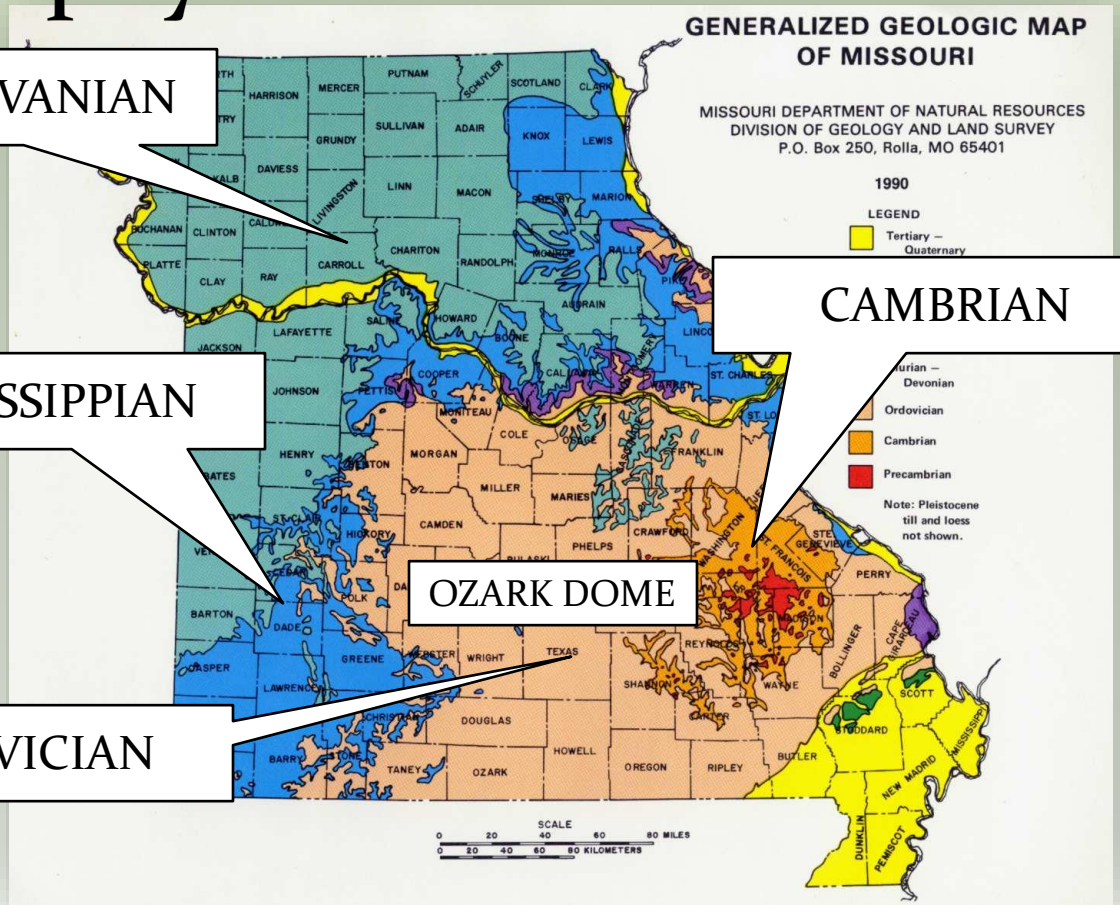
Summary 2

- In the Central and Eastern United States, mineralization followed the development of the Appalachian and Ouachita mountains and their adjacent basins.
- The fluids derived from these basins were oil field brines.
- Ores precipitated from sulfur- and metal-bearing brine into porous host rocks.

Ozarks Stratigraphy

Paleozoic formations gently dip a few degrees away from the Ozark Dome.

Cambrian and Ordovician rocks are mostly dolomites with lesser limestones. These are the most important aquifers.



Southeast Missouri Pb-Zn-Cu Host Rocks

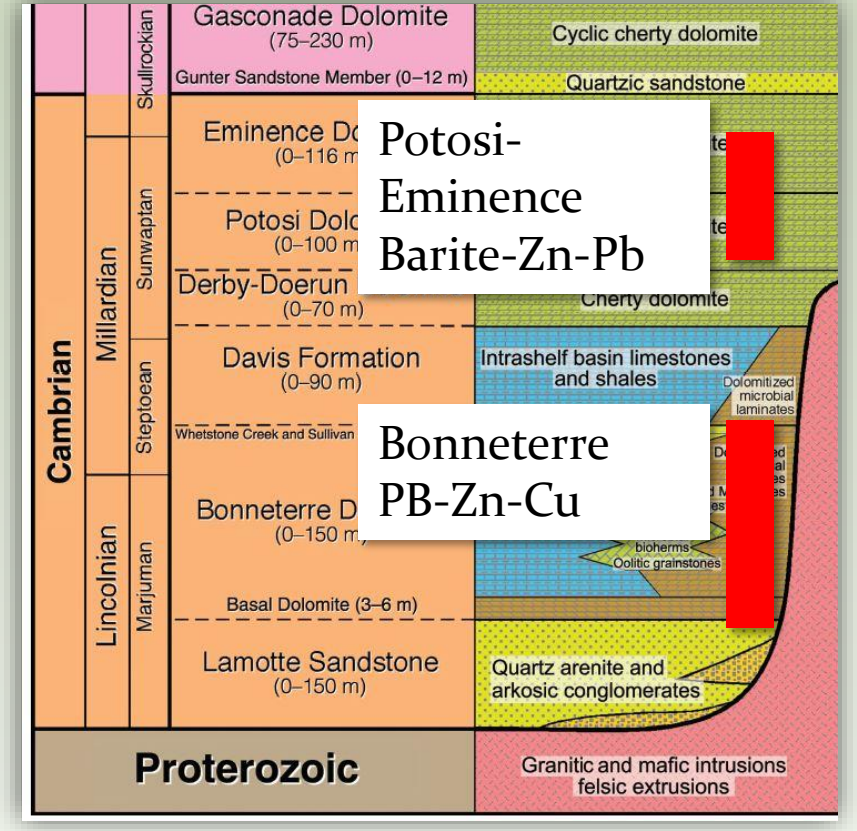
Aquifers– Potosi and Eminence (through the Gasconade Dolomite

Aquitard - Davis Formation, shales, limestone and dolomites

Bonneterre Formation, shales and limestones, and dolomites in the St. Francis Mtn. region

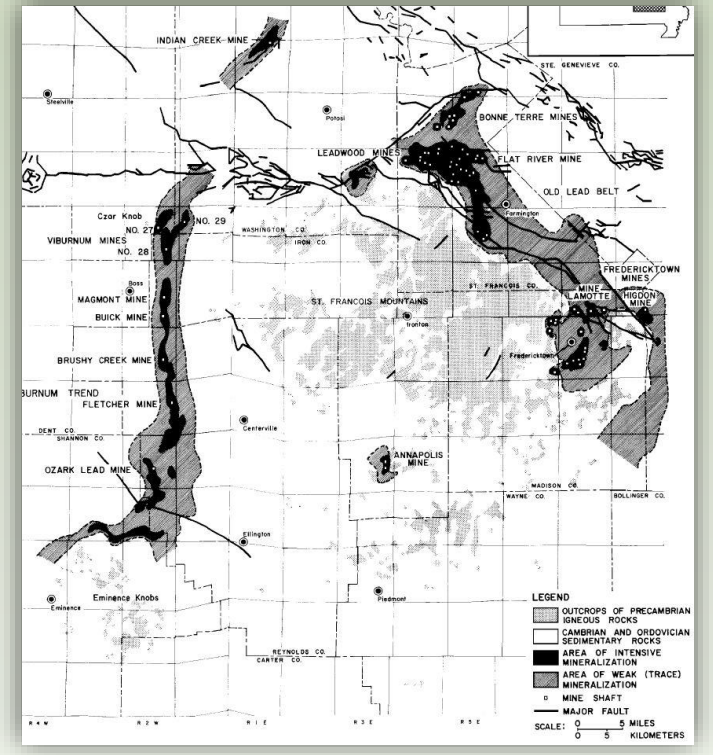
Aquifer – Lamotte Sandstone, sandstones, conglomerates

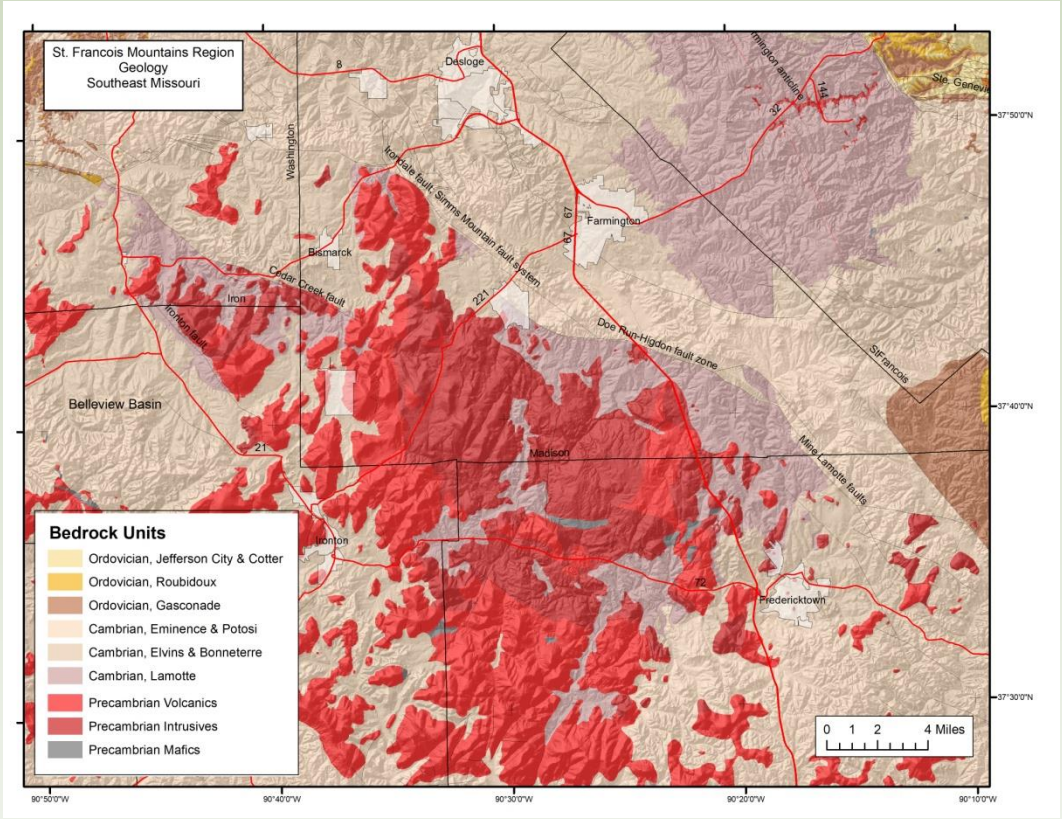
Aquitard – Precambrian volacanic rocks and granites. Iron Oxide deposits



St. Francis Mountains Area Geology

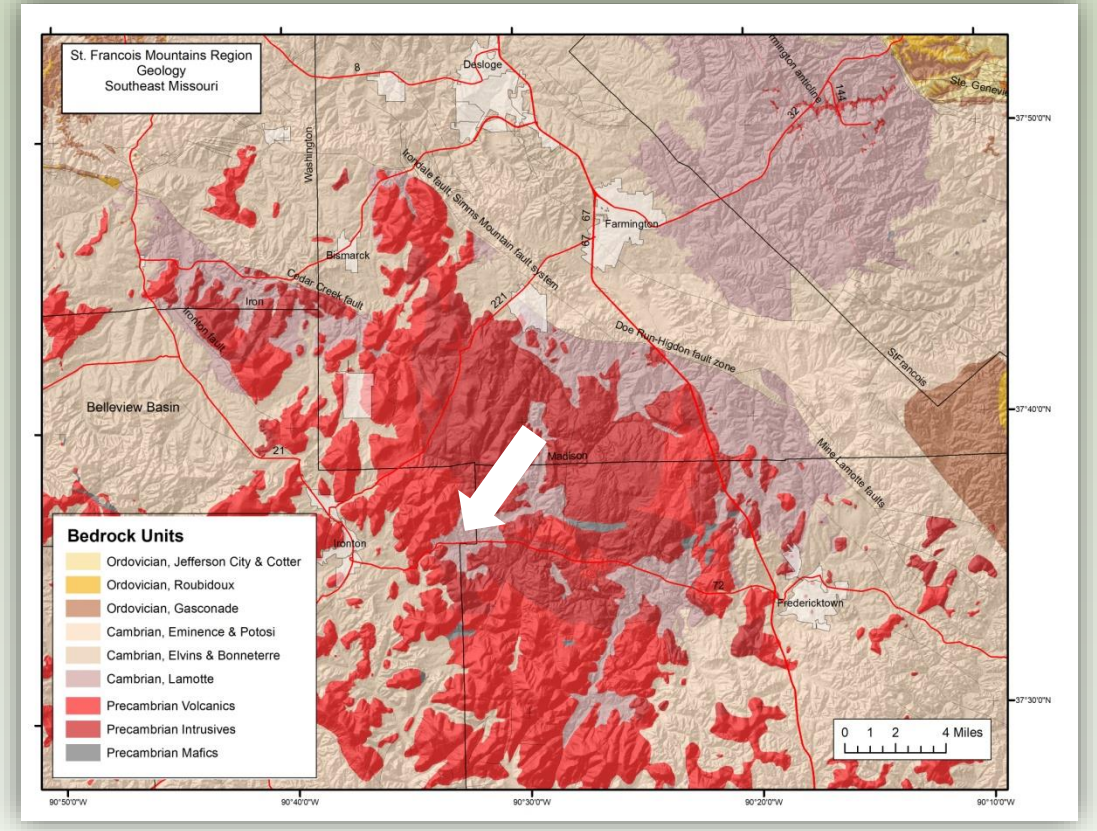
Virtual Geology Field Tour



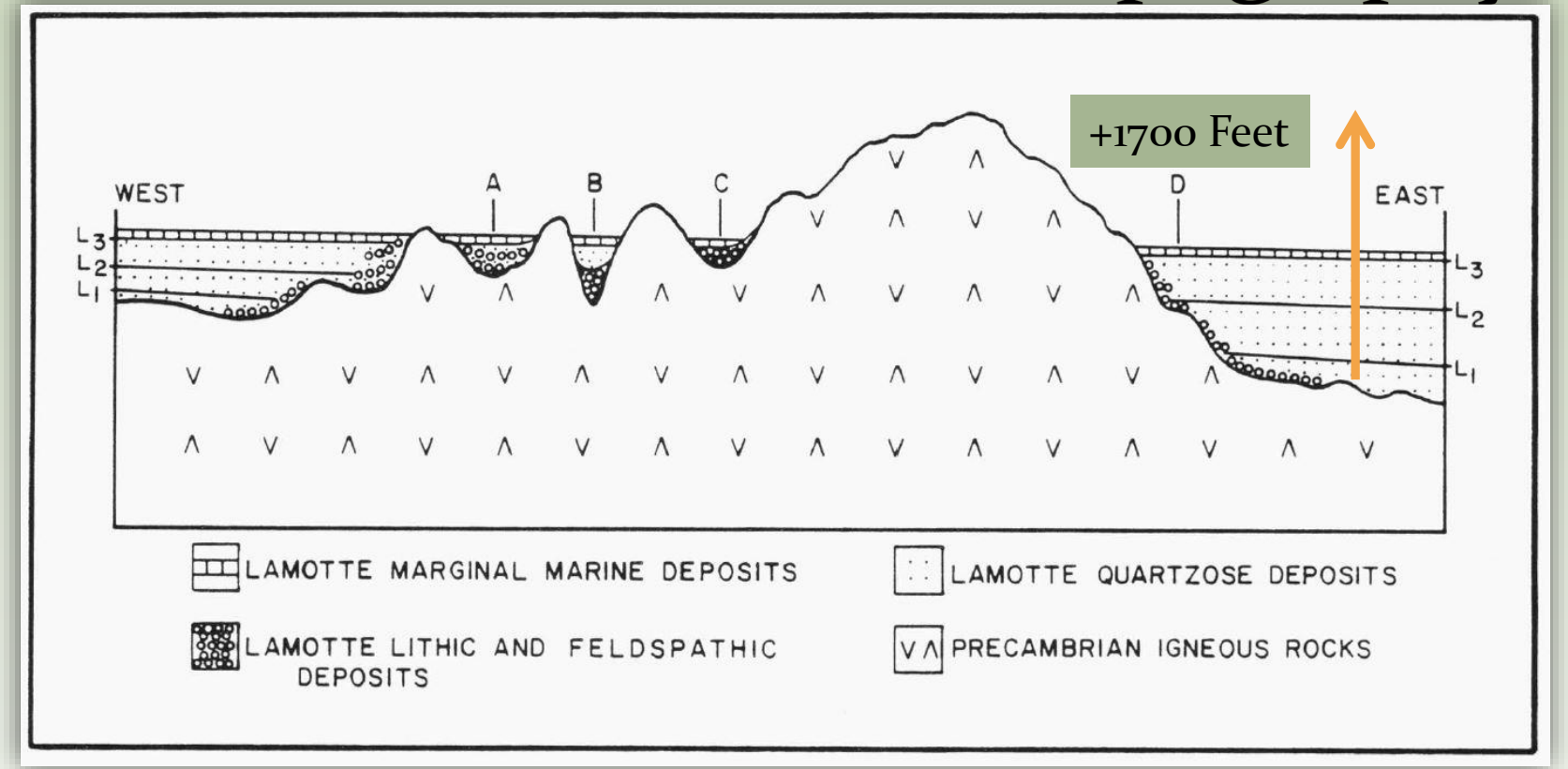


St. Francis Mountains Area Geology

Lower Lamotte Ss

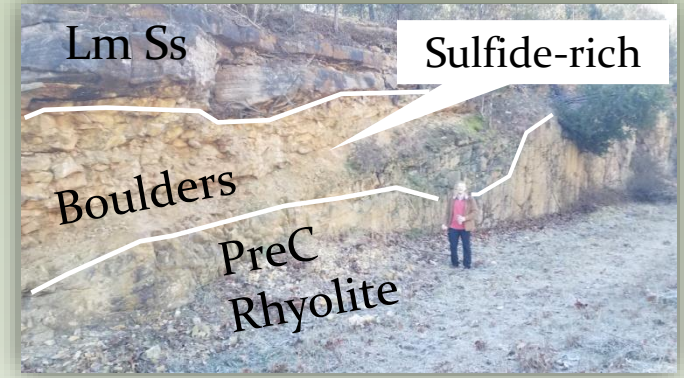


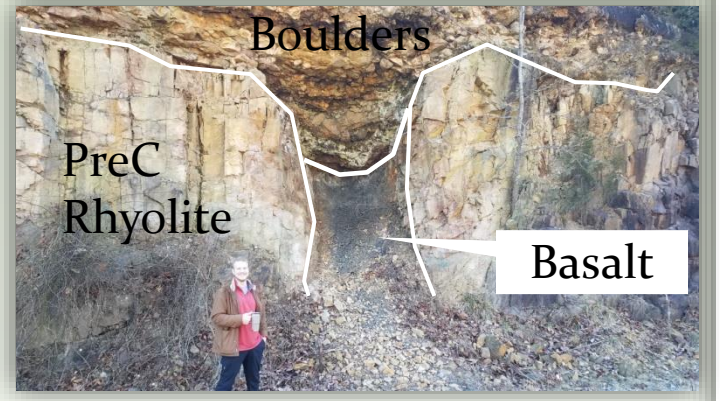
Precambrian Erosional Topography



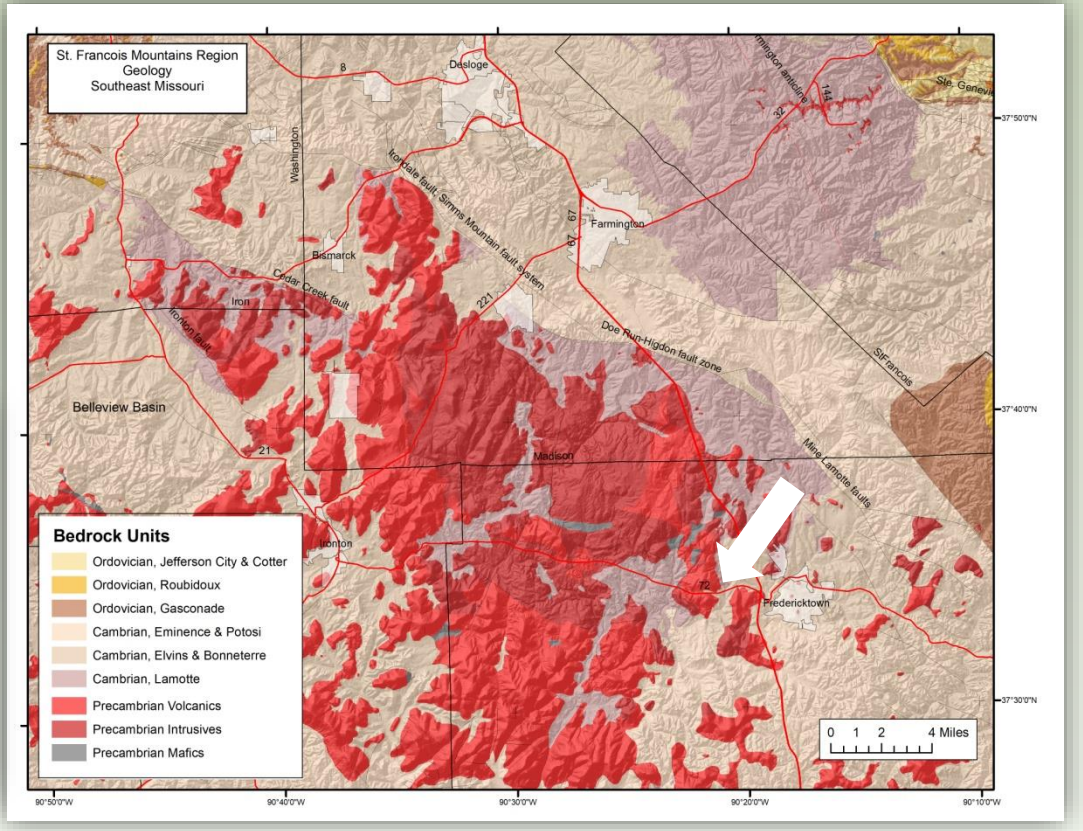
Houseknecht, 1989

St. Francis Mountains Area Geology

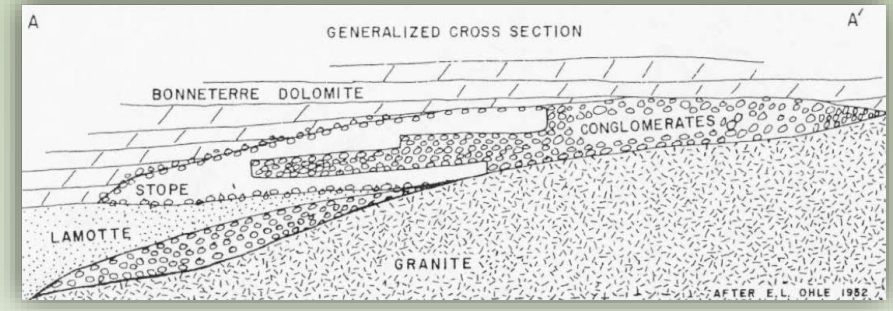




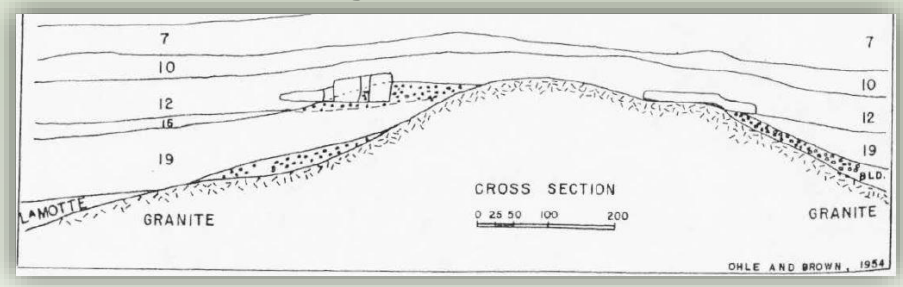
Precambrian-Lamotte Ss Contact



Lead Belt Host Rocks

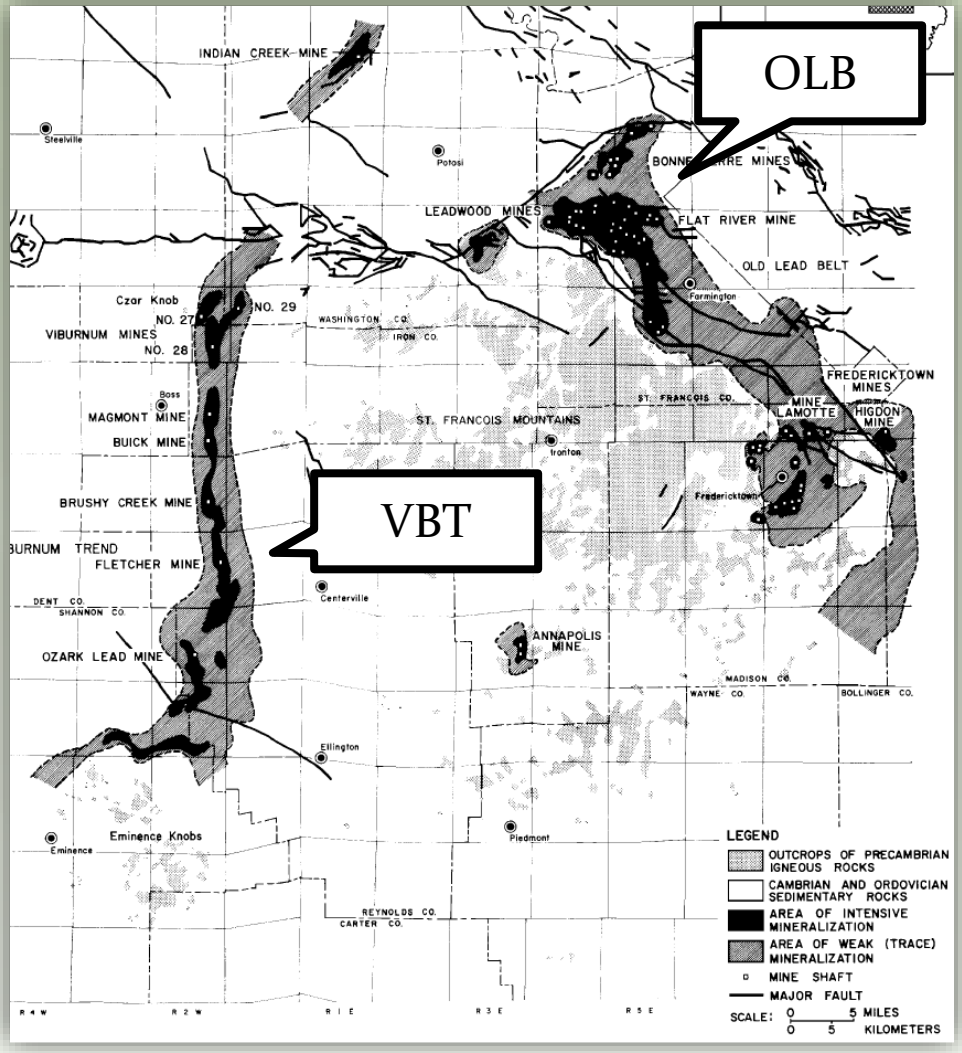


Hayden Creek Mine



Doe Run Mine, OLB

Ohle, 1952, 1954; Kisvarsanyi, 1977



Mine Lamotte

- Lead was found at what would become Mine Lamotte about 1723 by Philip Francis Renault and M. La Motte, at the head of the St. Francois River.
- Renault had left France in 1719 with 200 artificers and miners, and acquired 500 slaves in St. Domingo to work the ore deposits. Galena was mined and smelted from several diggings in the region, but in 1731 Renault lost his concessions.
- ***Mining at Mine Lamotte in bedrock ended in 1959, and had produced 325,000 tons of lead. 239 years after the initial discovery of lead mined from the soil.***

Winslow, 1984; Kiilsgard and others, 1967

Mine Lamotte

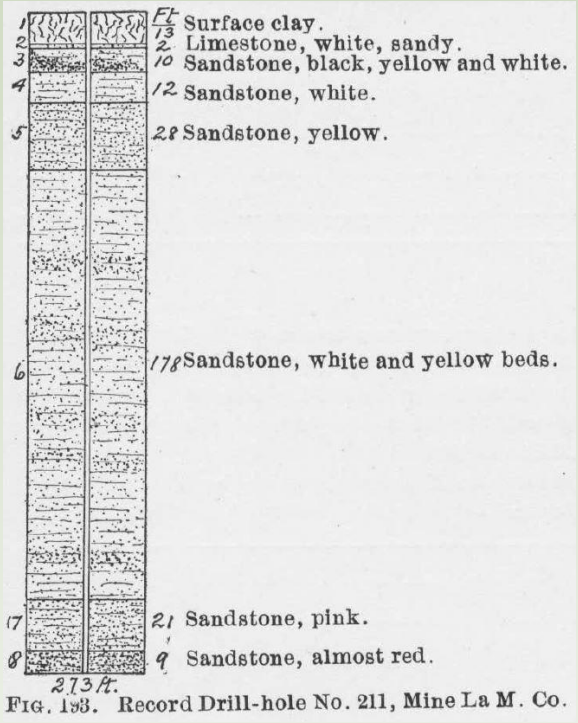


FIG. 193. Record Drill-hole No. 211, Mine La M. Co.

- By 1878 mining techniques were improved and shaft were sunk to the bottom of ore zones.
- Ore was in lower Bonneterre dolomites, lesser in sandstones
- Fine grained sulfides were common and included Cu and Co.
- In some areas, Cu-Co-Ni mineralization was below Pb ore bodies

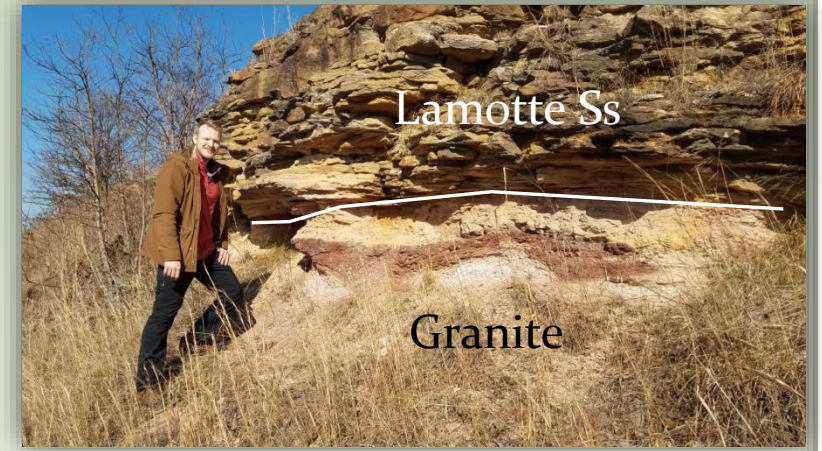
Historic Mine Lamotte Production Summary

1720 to 1790, production of lead	8,000 tons.
1800 to 1849, " "	21,485 "
1850 to 1893, " "	68,219 "
Total	97,704 "

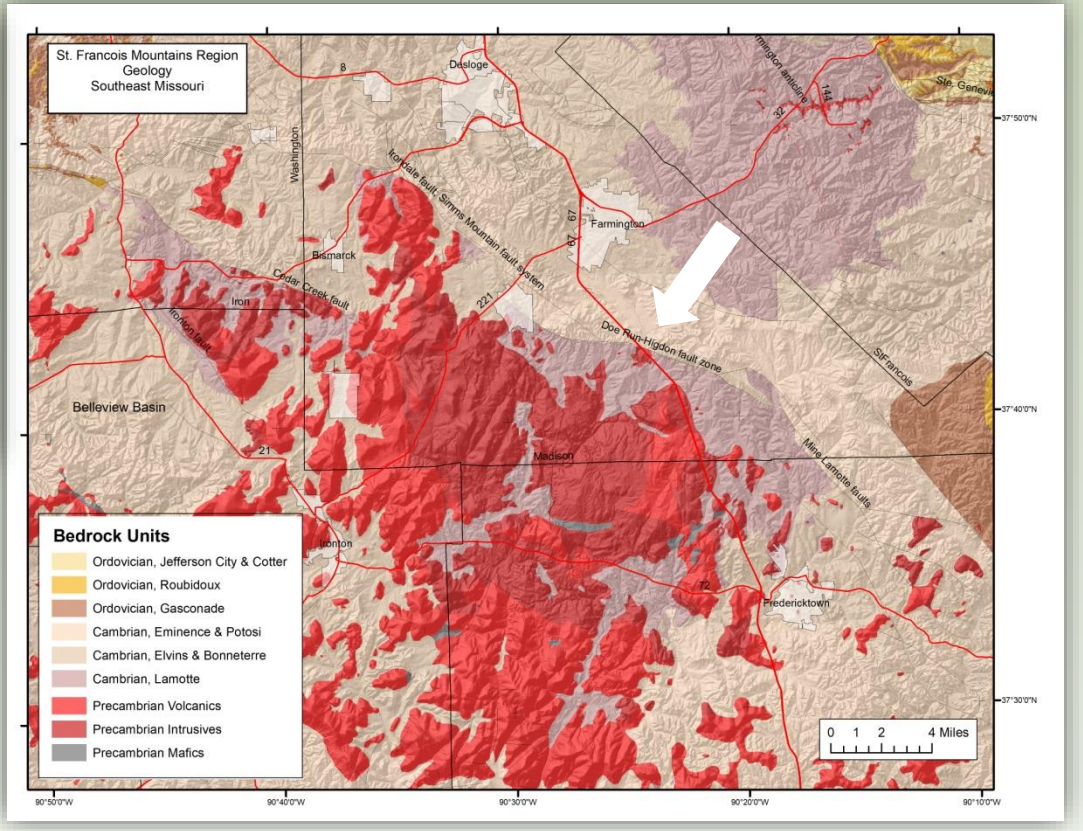
The sales of this lead at prices prevailing during the various periods must have yielded very nearly ten millions of dollars.

Winslow, 1894

St. Francis Mountains Area Geology



Precambrian Granite and Cambrian Lamotte Sandstone contact.
Granite is highly weathered for several feet below the contact. Hematite matrix, red colors, is partially leached near the base of the Lamotte.



St. Francis Mountains Area Geology

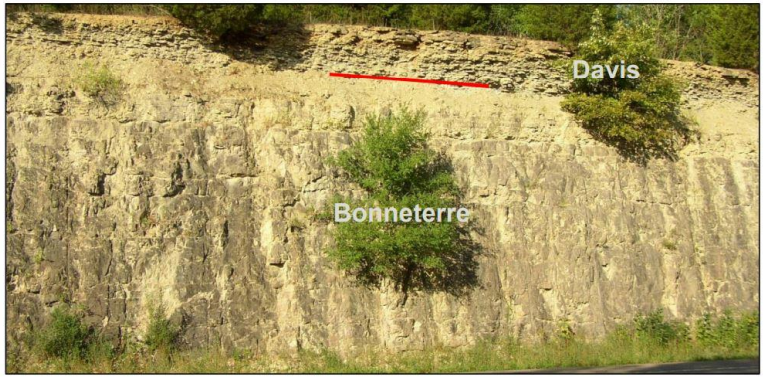
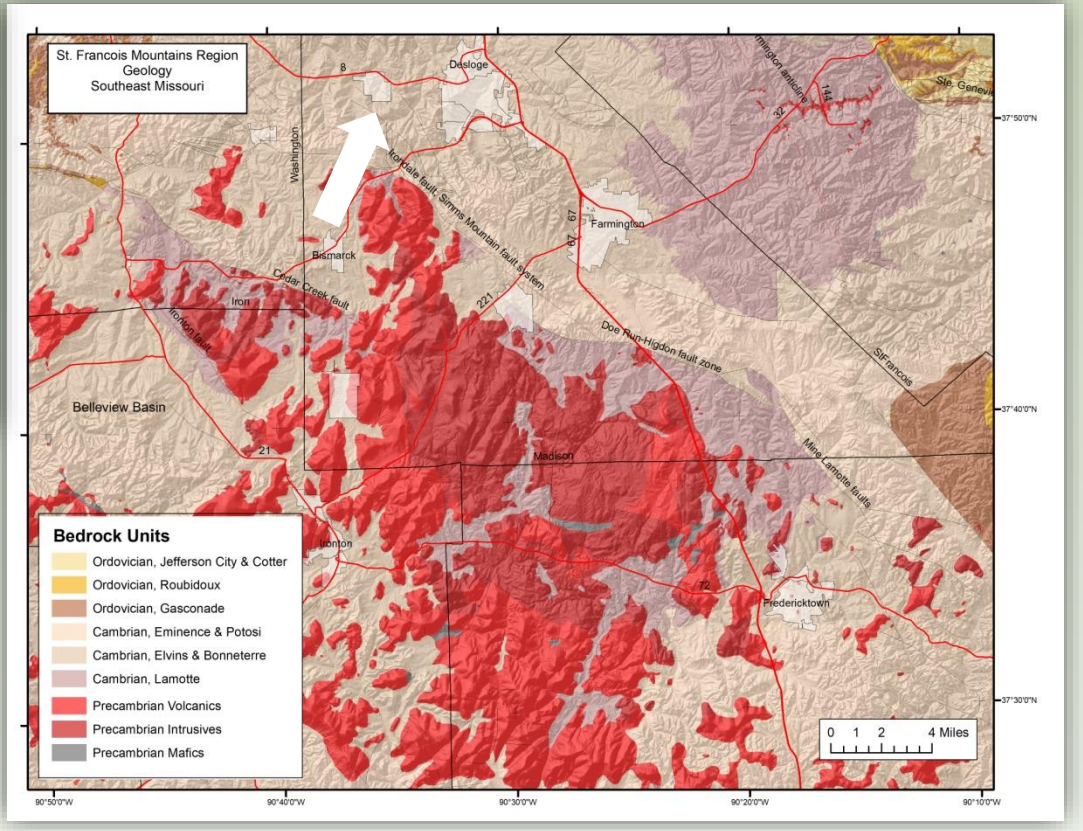
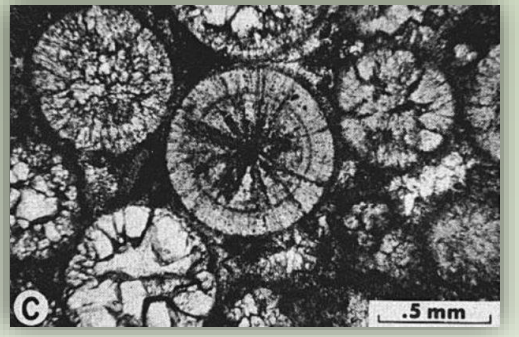
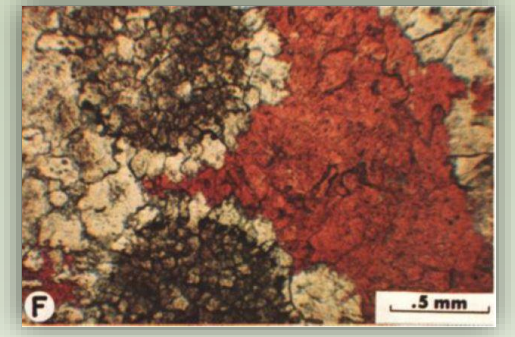


Figure 2-16. Bonneterre Formation in contact (red line) with overlying Davis Formation in cut on southwest side Missouri 8 on the northeast side of the town of Leadwood. **STOP 5** of road log.

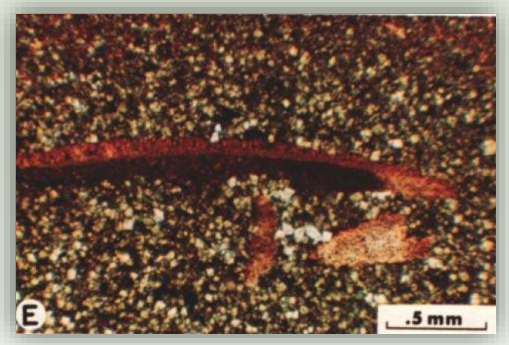


Bonneterre Dolomite Lithology





Oolites-Carbonate Sand



Fossil grain in fine dolomite

Lyle, 1977

Cambrian Davis Formation - Aquitard

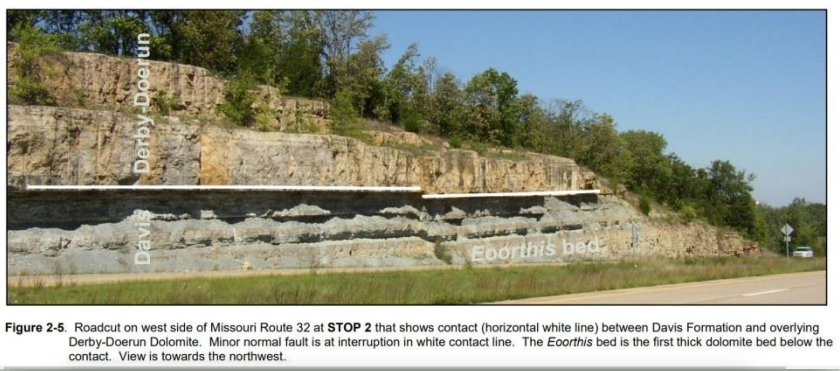


Figure 2-5. Roadcut on west side of Missouri Route 32 at **STOP 2** that shows contact (horizontal white line) between Davis Formation and overlying Derby-Doerun Dolomite. Minor normal fault is at interruption in white contact line. The *Eoorthis* bed is the first thick dolomite bed below the contact. View is towards the northwest.

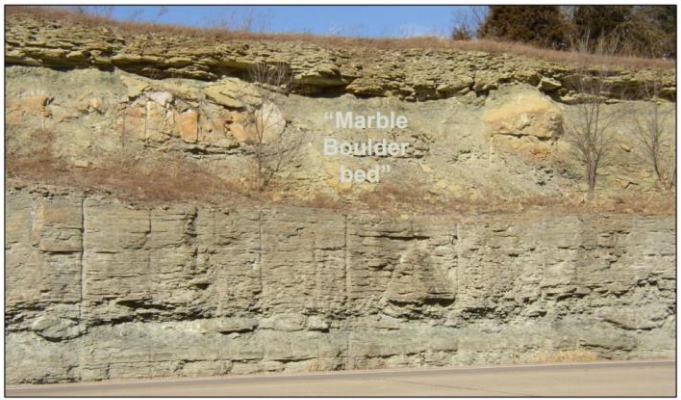
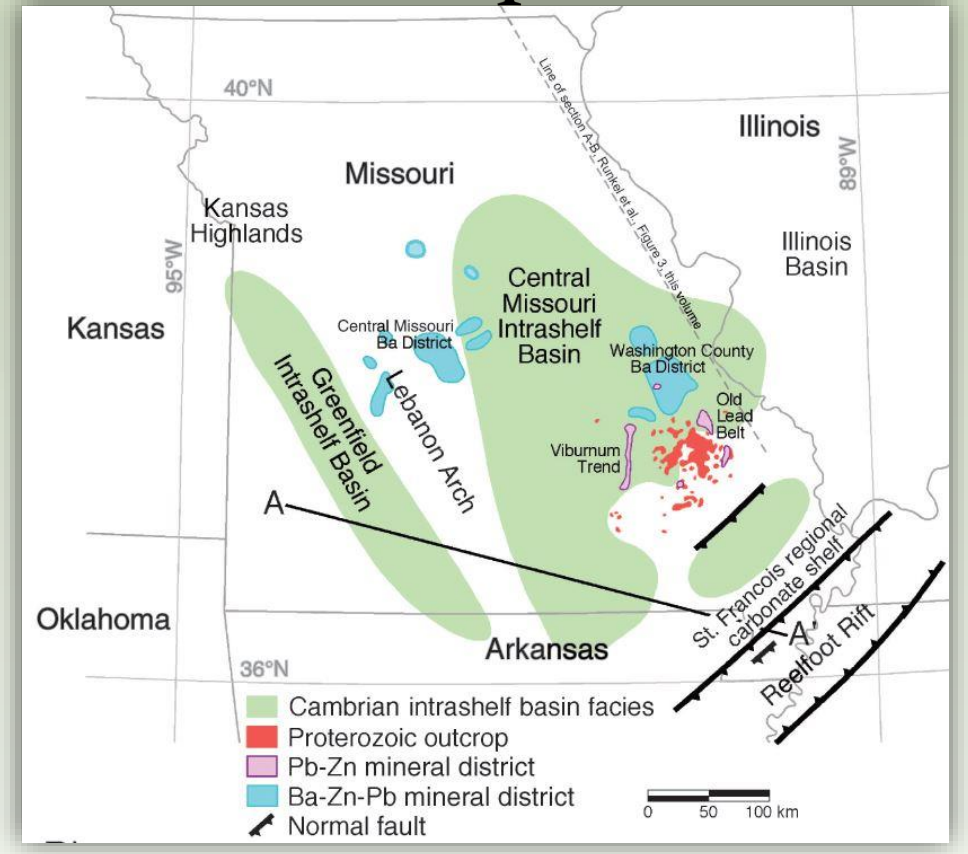
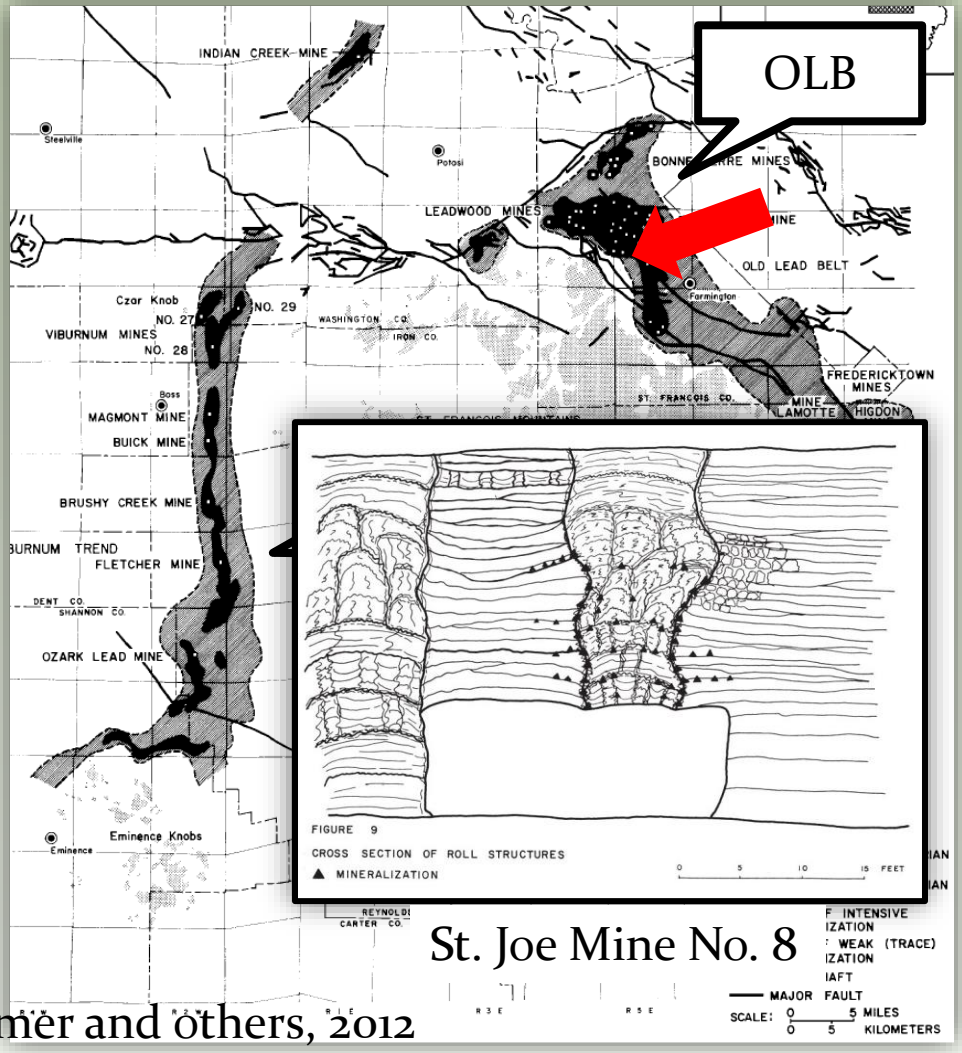


Figure 2-7. Davis Formation exposed in west side of roadcut at **STOP 3**. The "Marble Boulder bed" is a reliable marker horizon for the middle part of the Davis formation in the field trip area.



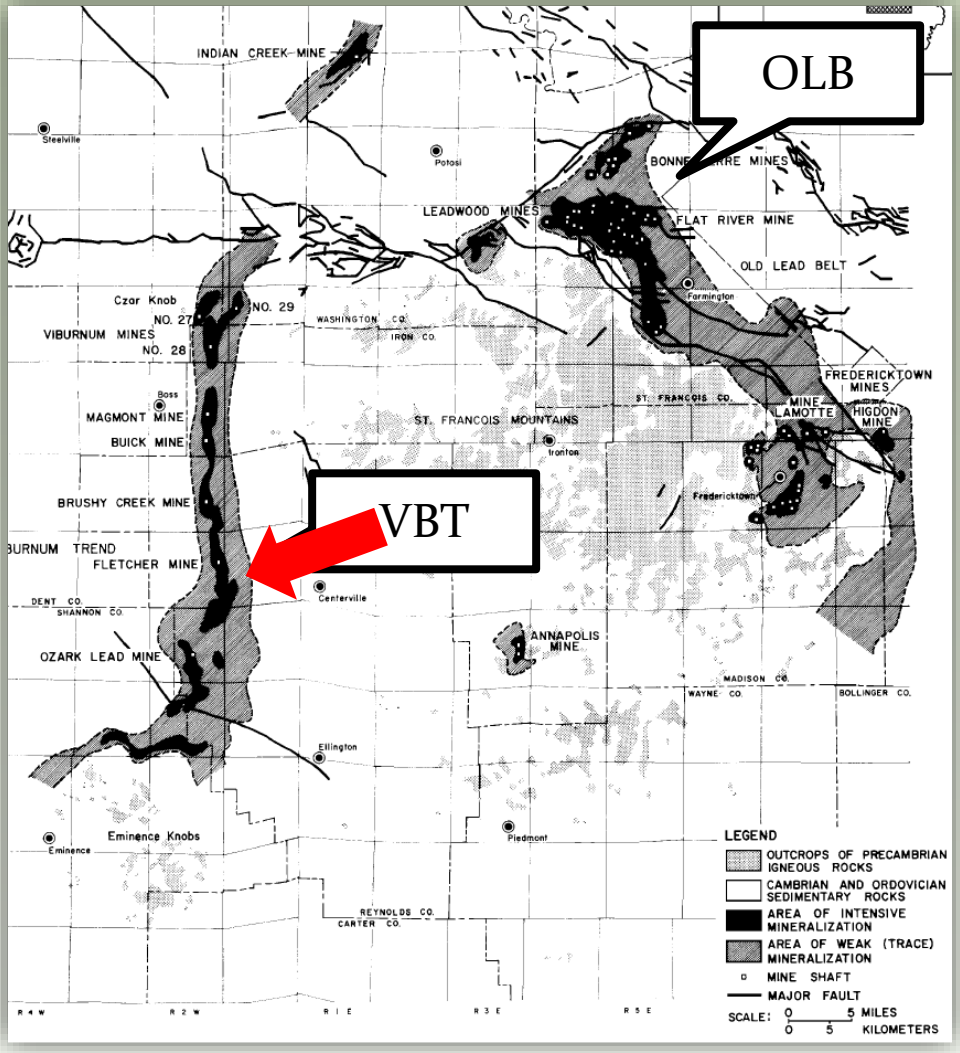
Lead Belt Host Rocks



Kisvarsanyi, 1977; Lyle, 1977; Myers, 1969; Palmer and others, 2012

VBT Host Rocks

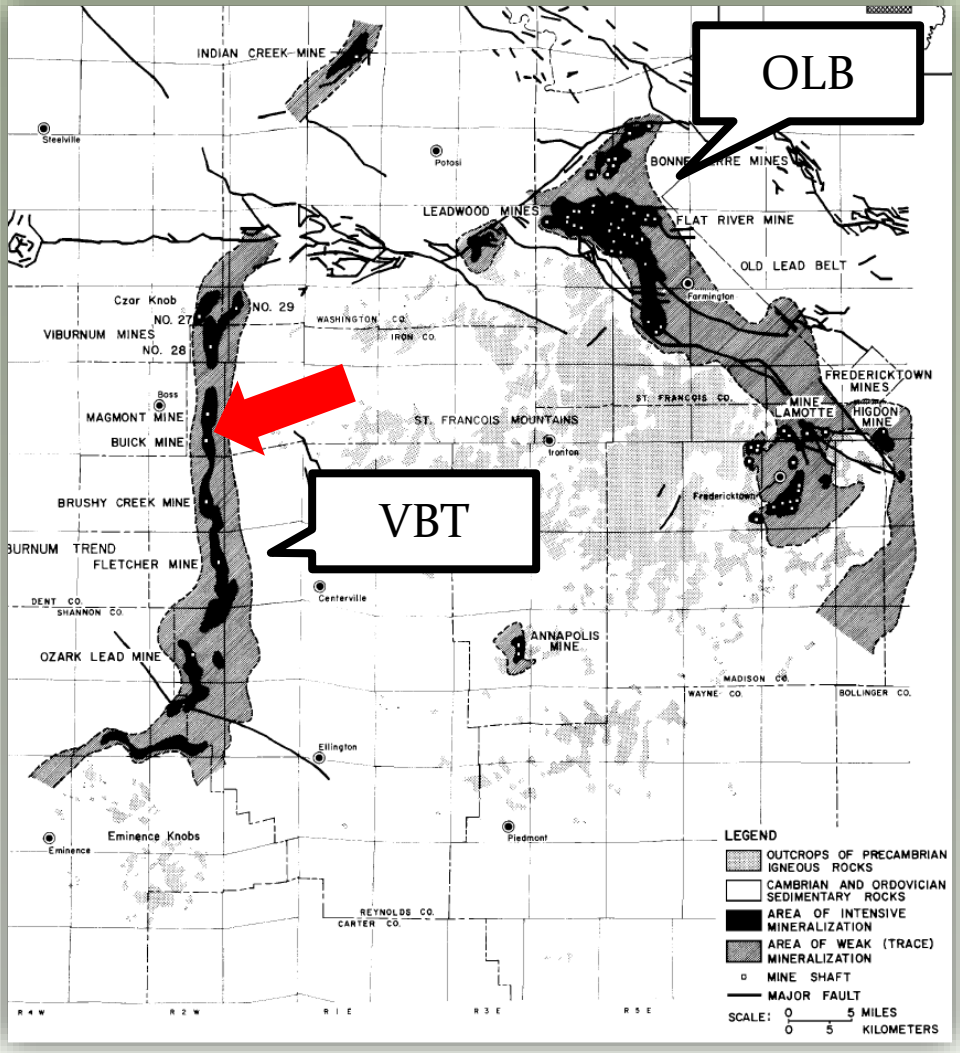
Disseminated Galena in Oolitic Dolomite



Evans, 1977; Kisvarsanyi, 1977

VBT Host Rocks

Dolomite Breccia with Galena Matrix Ore

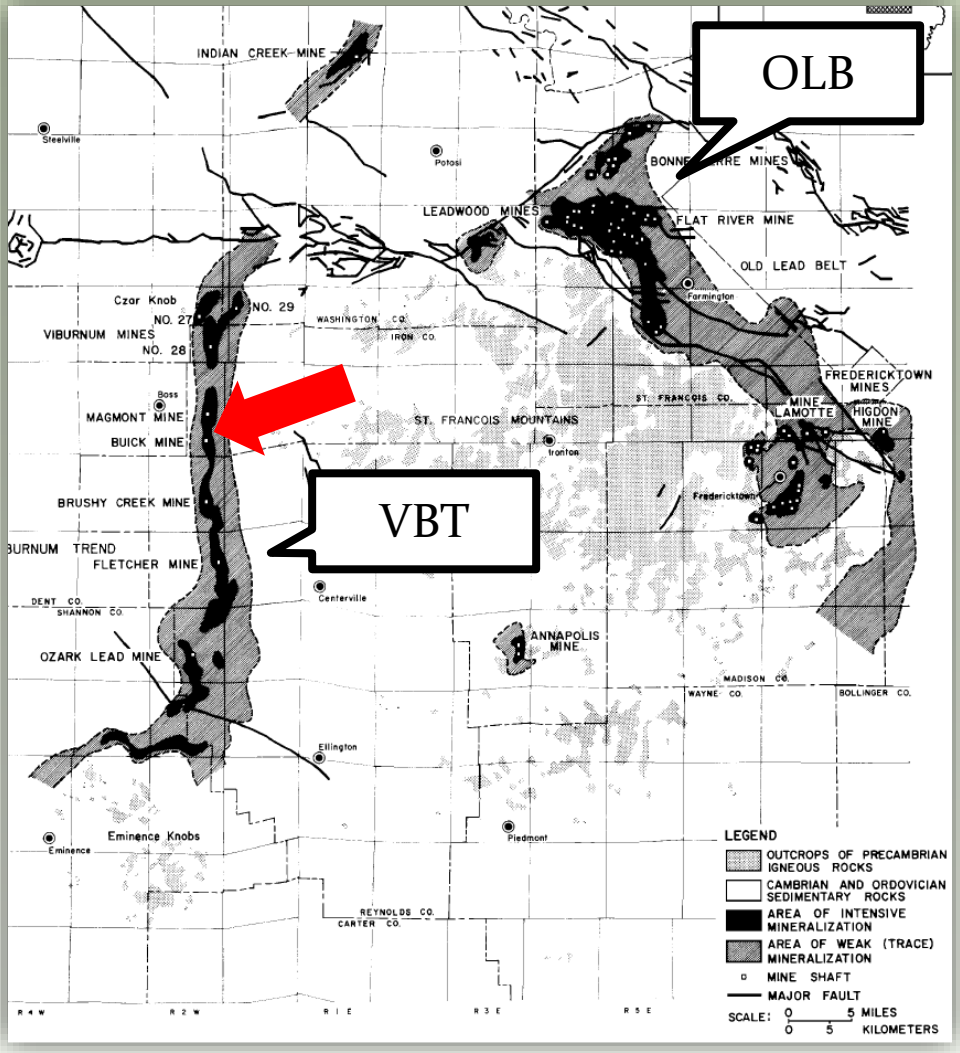


Murray Hitzman, 2011; Kisvarsanyi, 1977

VBT Host Rocks

Dolomite Breccia with Galena Matrix Ore

Davis, 1977; Kisvarsanyi, 1977



Collapse Breccias and MVT Deposits

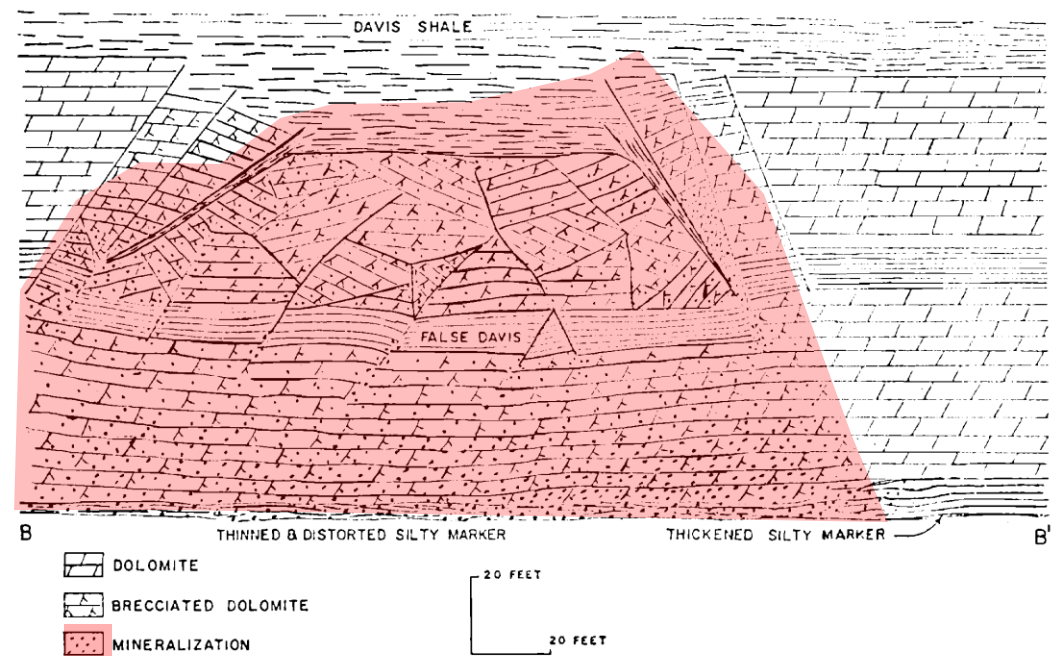


FIG. 4. Cross section B-B′ showing breccia, associated subsidence fractures, and thinned Silty Marker.

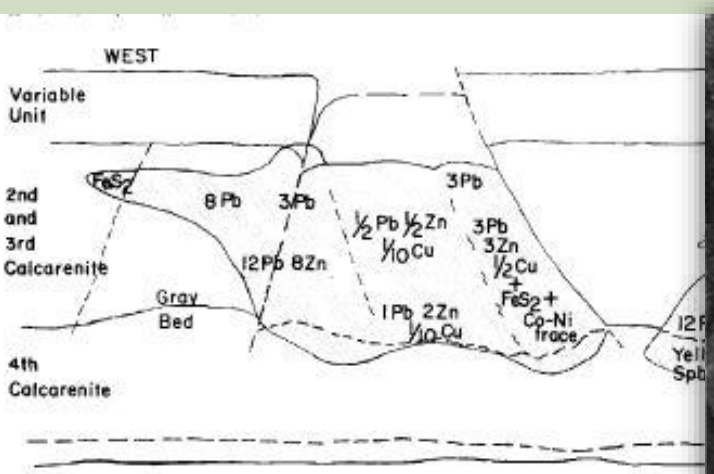
Intense dissolution of dolomite was localized, creating open voids and fracturing to develop in the overlying rocks.

Breccias are composed of rocks in the dissolution zone and down-dropped blocks from the overlying beds including the Davis Formation.

Mineralization commonly is more intense at the margins of the breccias

Sweeney, Harrison and Bradley, 1977

Collapse Breccias and MVT Deposits



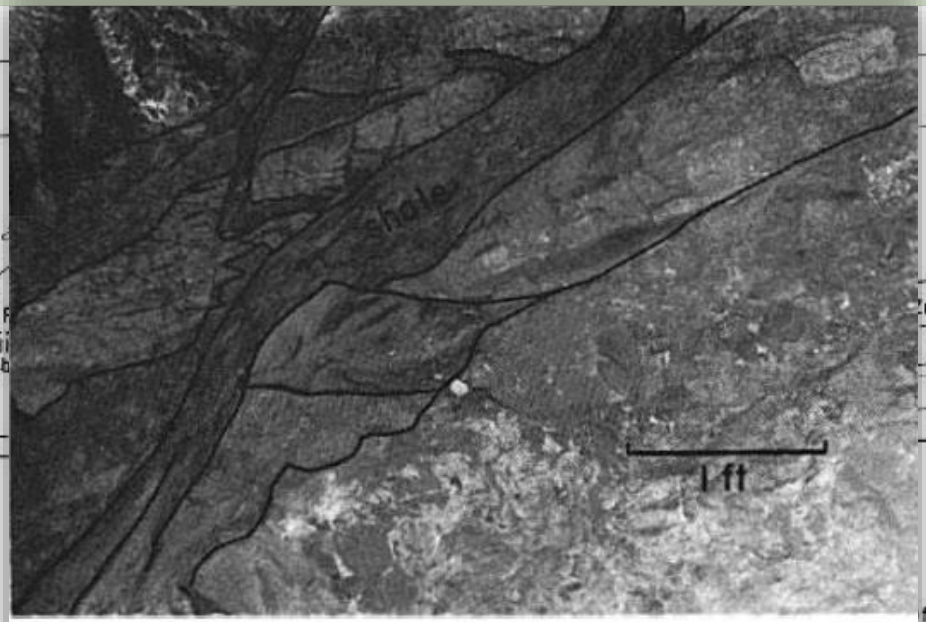


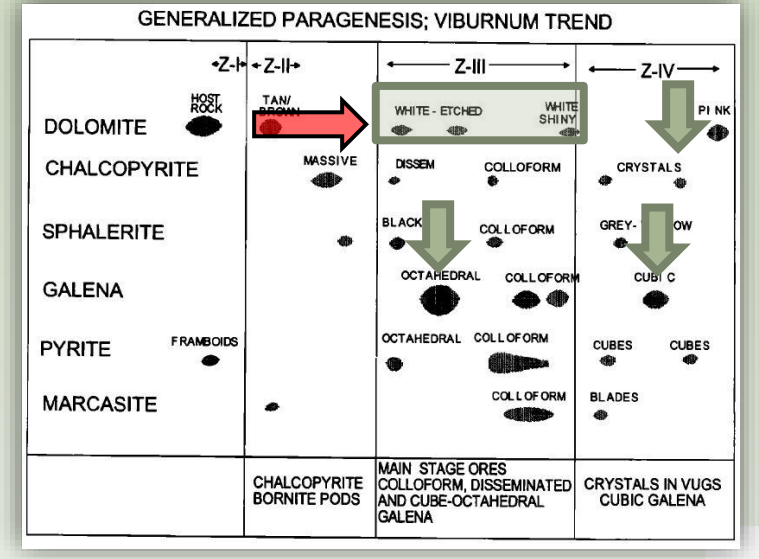
FIG. 3. Shale occupying a boundary fracture in the central ore breccia.

Rogers and Davis, 1977

Consistent Order of Minerals

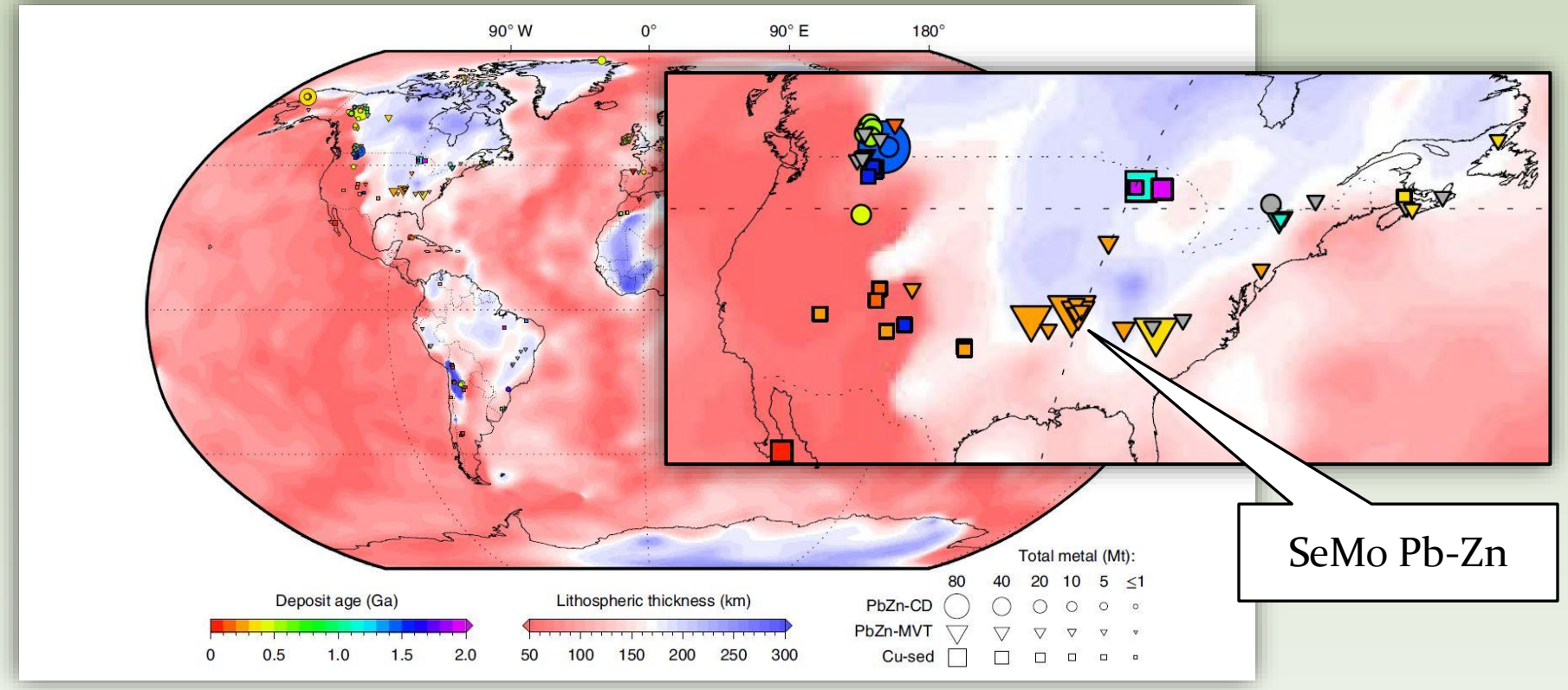
The sequence of minerals is consistent throughout the southeast Missouri Pb-Zn-Cu deposits.

Mineralization Order



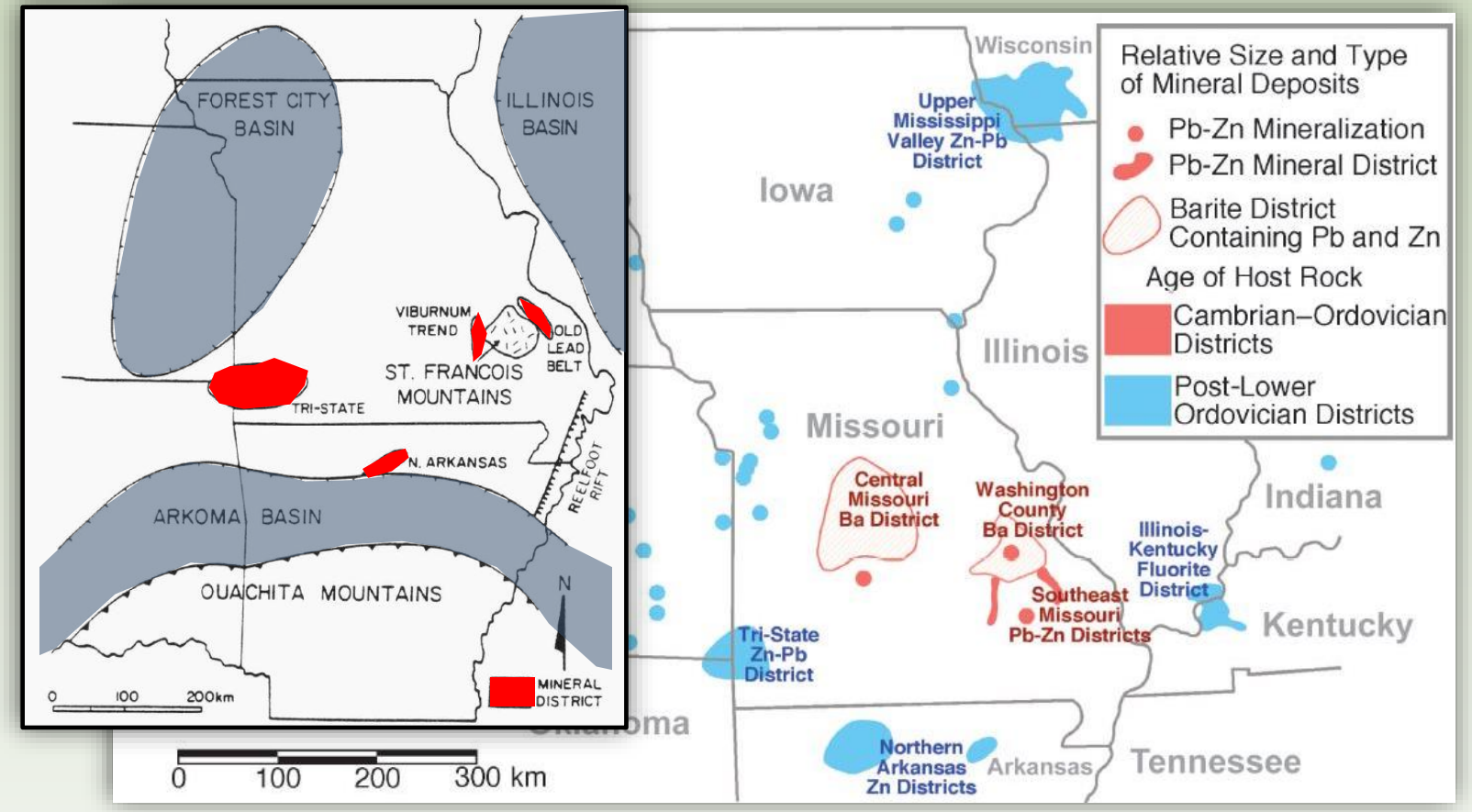
Heyl, 1983; Horrall, 1983; Voss and Hagni, 1985; Voss, Hagni, and Gregg, 1989

Lithosphere Thickness-Sediment Hosted Ore Deposits

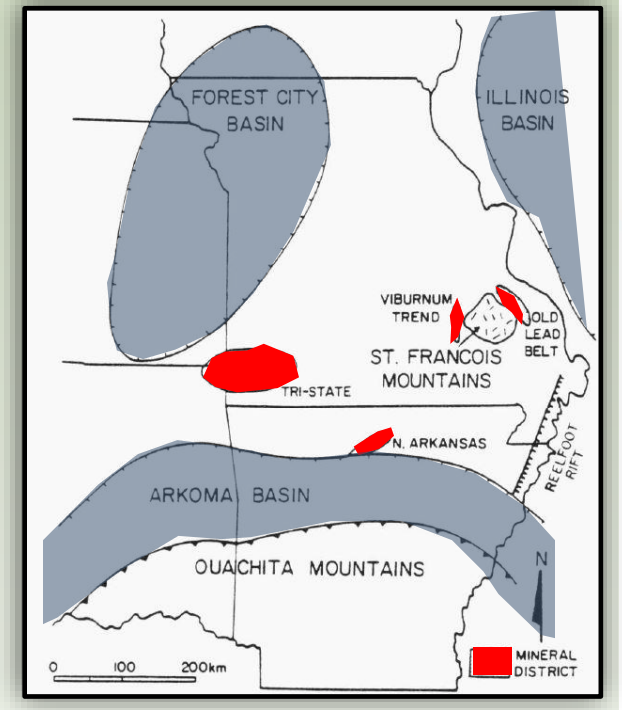


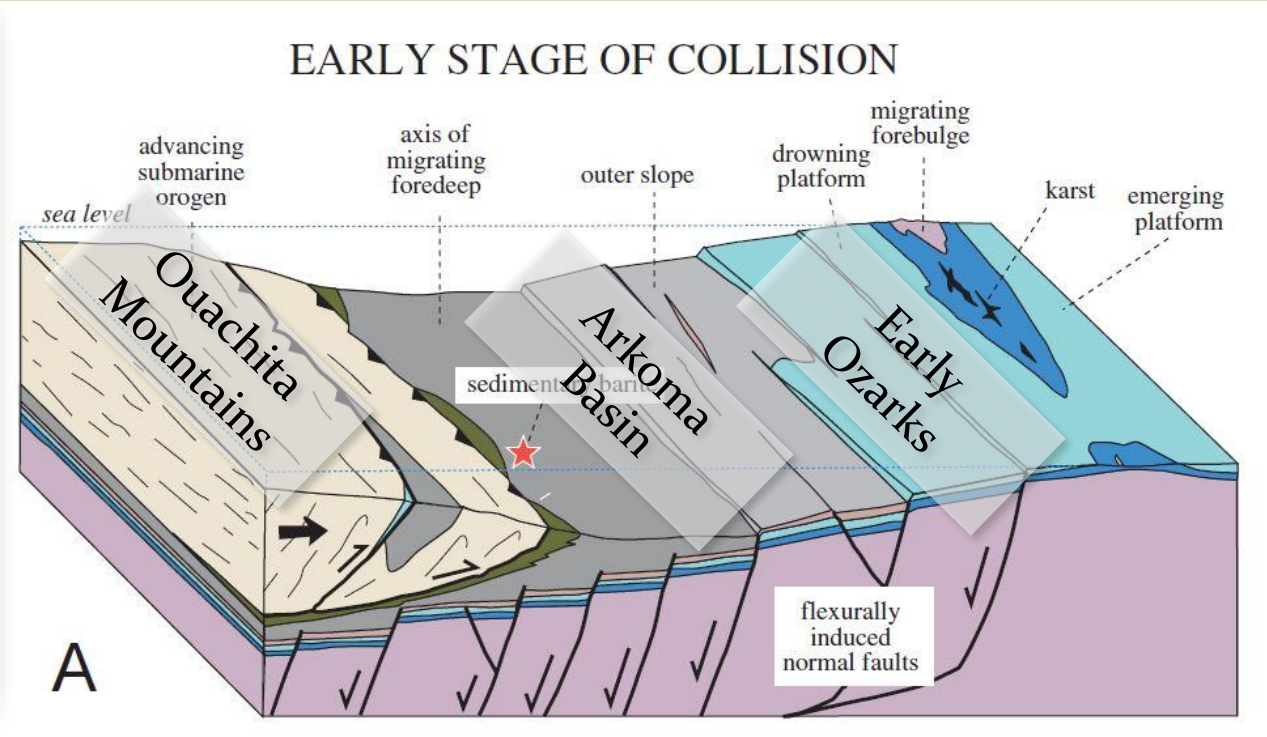
Hoggard and others, 2020

Lead and Zinc - Central United States

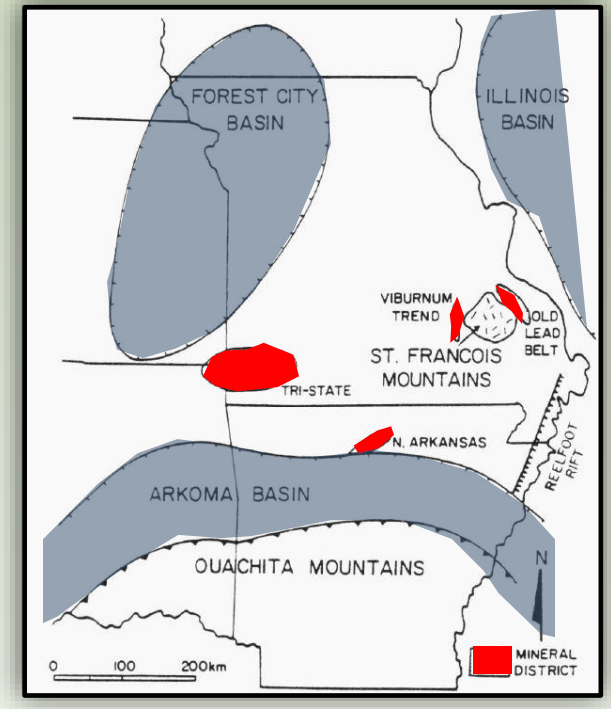


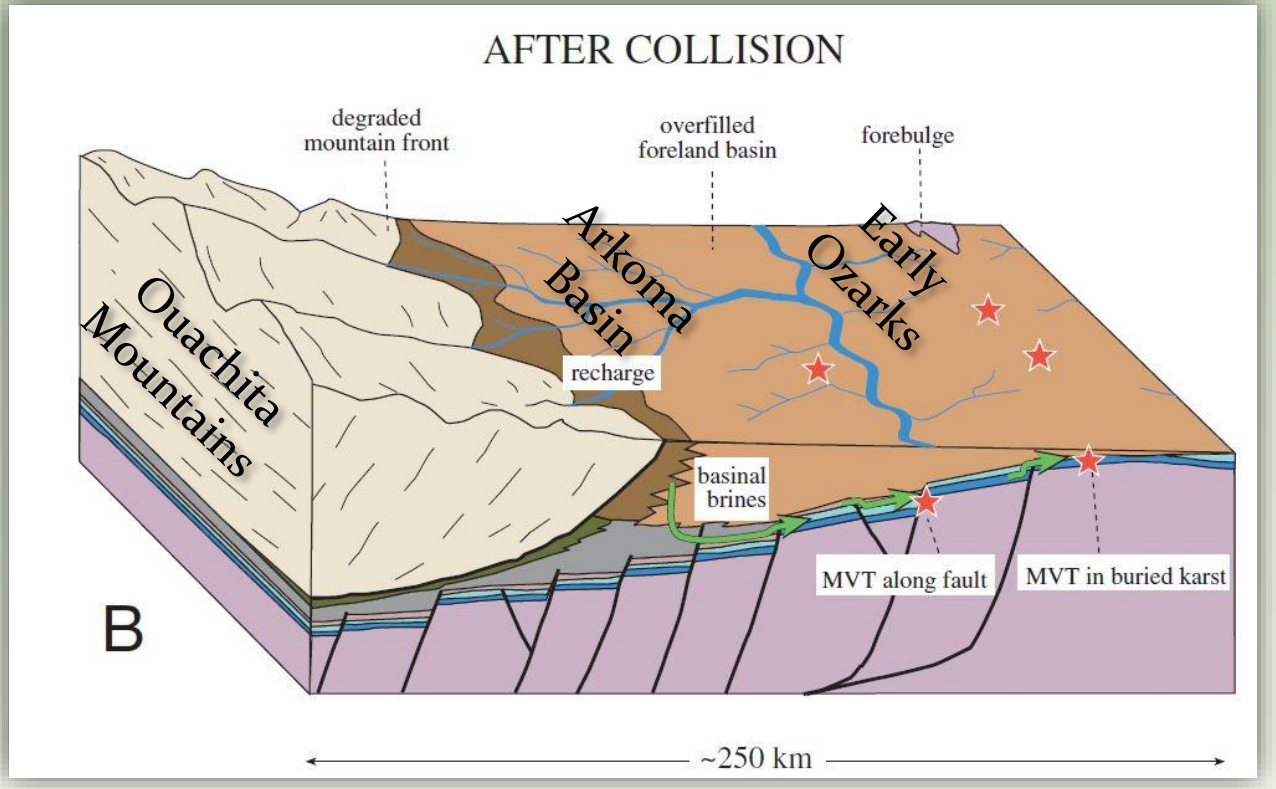
Formation of MVT Deposits





Formation of MVT Deposits





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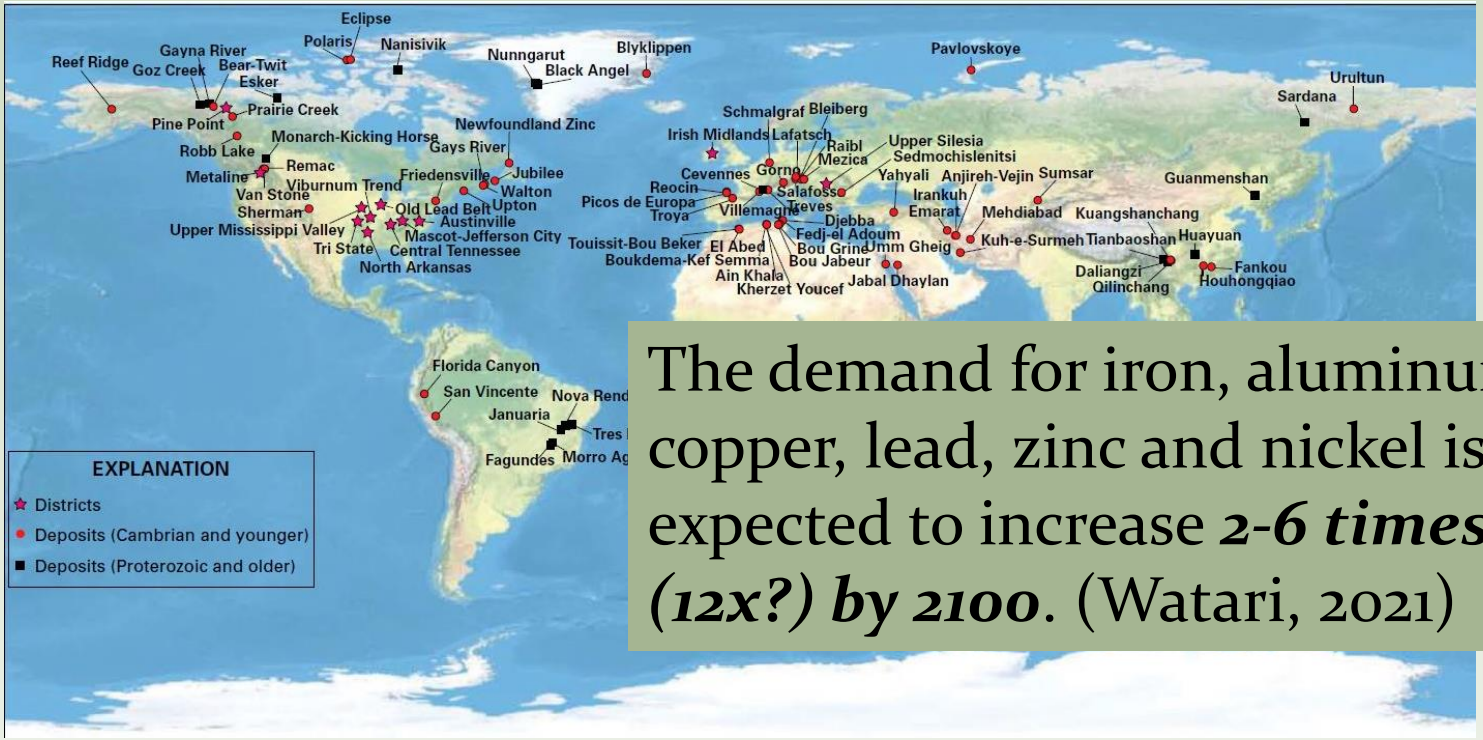
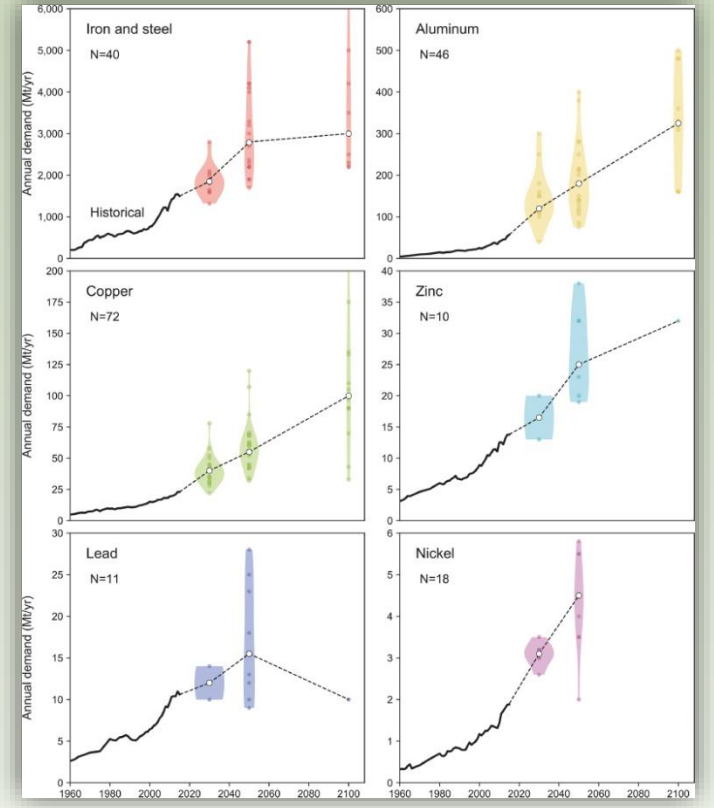
Global MVT Deposits



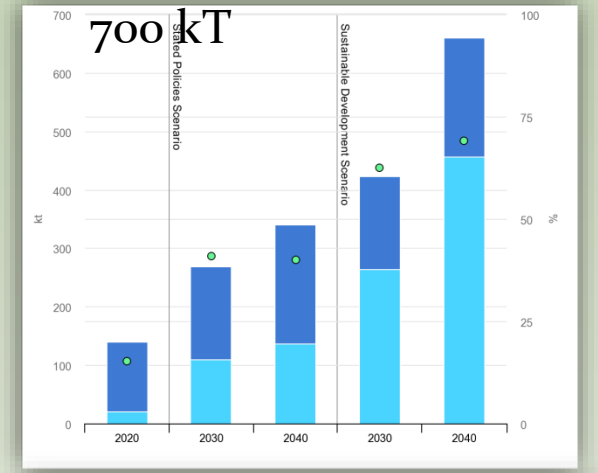
The demand for iron, aluminum, copper, lead, zinc and nickel is expected to increase ***2-6 times (12x?) by 2100***. (Watari, 2021)

Leach and others, 2010

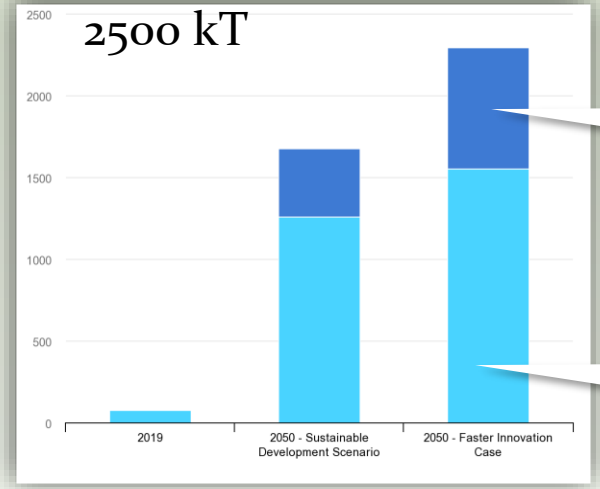
Metals Demand



IEA, 2020; Watari and others 2021



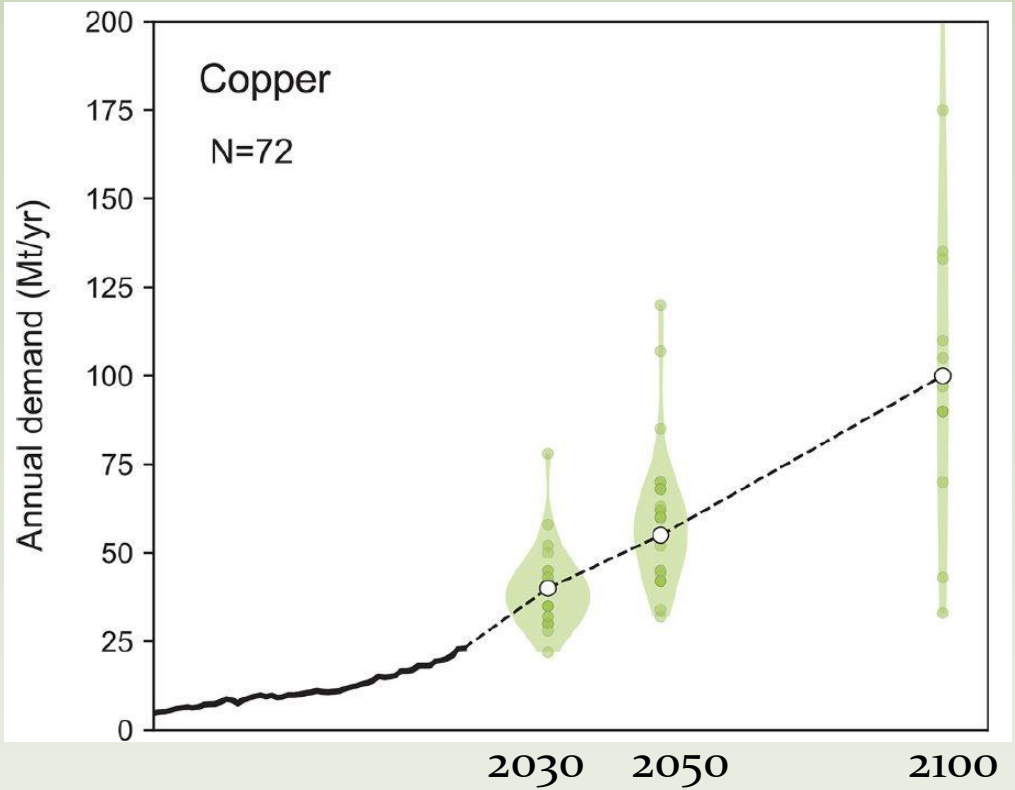
Cobalt Demand



Other Sectors

Lithium Demand

EV's and Storage

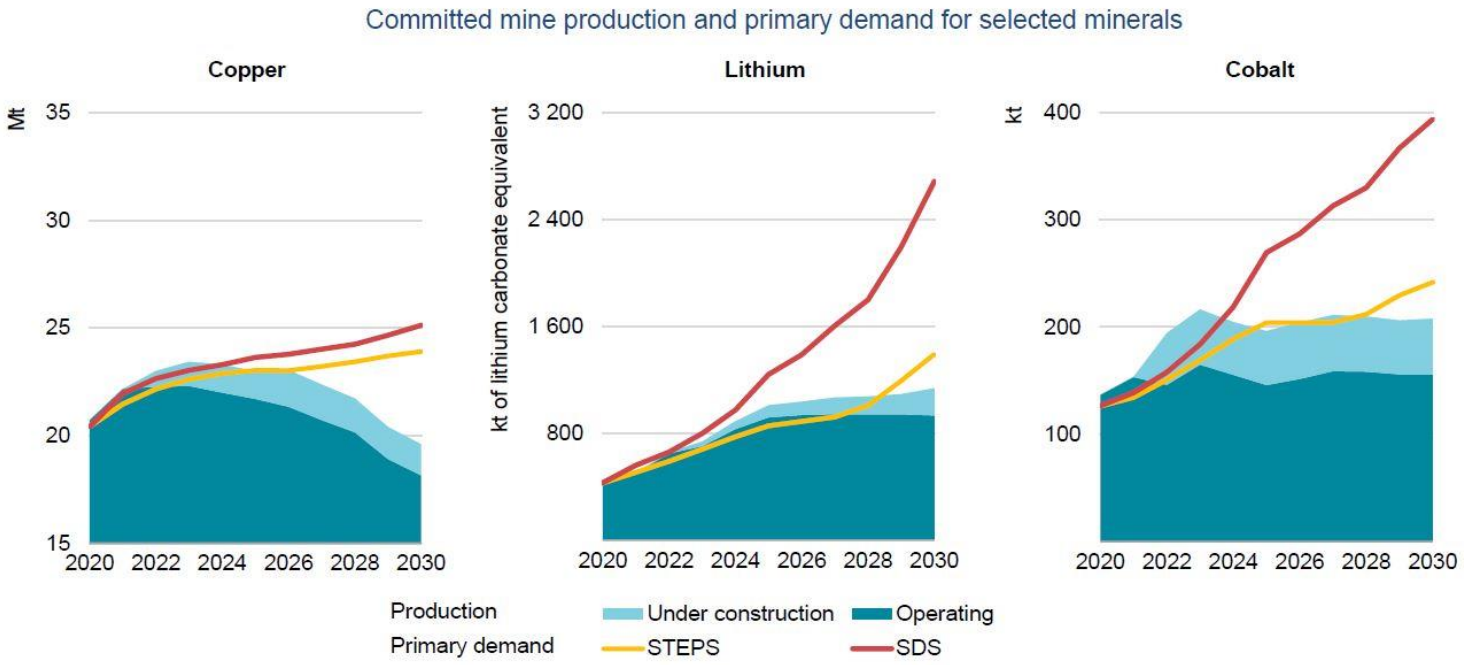


Copper Demand

- No substitute for copper
- 2.5x (+60%) by 2050
- *But*, Cu depleted mine resources by 2038
- Where will additional copper come from?

Watari and others 2021

Meeting primary demand in the SDS requires strong growth in investment to bring forward new supply sources over the next decade



IEA, 2022

Cobalt Production by Country

The Democratic Republic of the Congo is the primary producer of cobalt.

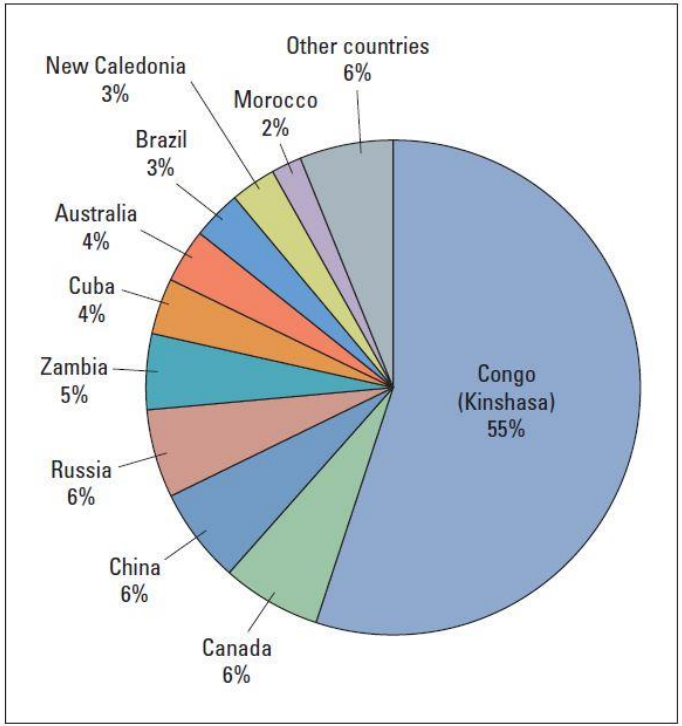
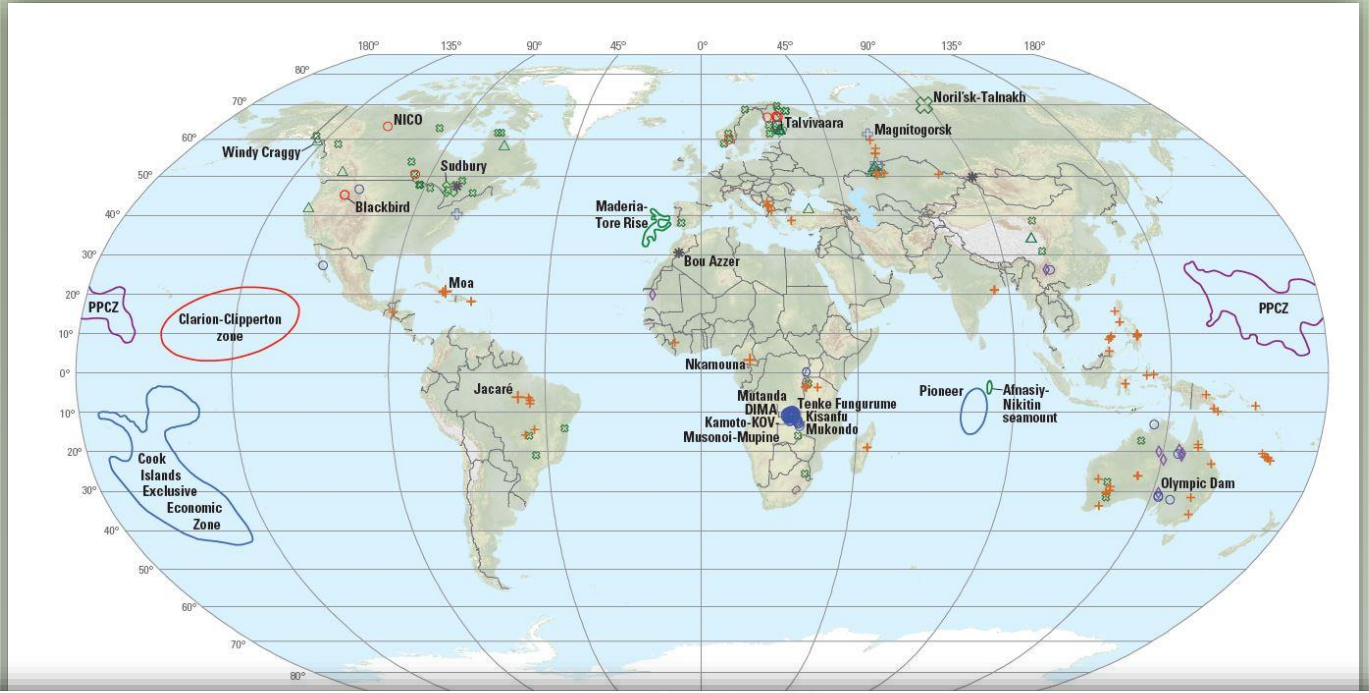


Figure F4. Pie chart showing percentage of world cobalt mine production in 2011, by country. The sources of production are cobalt, copper, nickel, platinum-group-element, and zinc operations. Data are from Shedd (2013a). Congo (Kinshasa) is a short-form name for Democratic Republic of the Congo.

Cobalt Deposits



Terrestrial (land-based) cobalt deposit types

≥1.0 Mt cobalt

- SSH Cu-Co
- Magmatic Ni-Cu (-Co-PGE) sulfide

0.5 to 0.99 Mt cobalt

- SSH Cu-Co
- Ni-Co laterite
- Magmatic Ni-Cu (-Co-PGE) sulfide

<0.5 Mt cobalt

- Fe-Cu-Co skarn and replacement
- Iron oxide-Cu-Au (-Ag-U-REE-Co-Ni)
- MSRH Co-Cu-Au
- Volcanogenic Cu(-Zn-Co-Ag-Au) massive sulfide
- SSH Cu-Co
- Ni-Co laterite
- Magmatic Ni-Cu (-Co-PGE) sulfide
- BSH Ni-Cu-Zn-Co
- Polymetallic vein

Sea-floor cobalt deposit types

>0.1 Mt cobalt

- Nodules
- Crusts
- Clarion-Clipperton zone
- Pacific prime crust zone (PPCZ)

Summary Metals Demand

- Expect up to 12x demand by 2100 for critical elements/minerals, including base metals
- Demand will outpace current mine capacity, hundreds of mines per year are needed – which is an impossible goal
- Majority of future geologically reasonable targets will be expensive and in politically unstable or environmentally sensitive areas