Geology of the Ozarks and its Lead-Zinc Deposits

Jim Palmer
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

- 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.
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.
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 volcanic rocks and granites. Iron Oxide deposits
St. Francis Mountains Area Geology

Virtual Geology Field Tour
St. Francis Mountains Area Geology

Boulders

Lm Ss

Lower Lamotte Ss
Precambrian Erosional Topography

Houseknecht, 1989
St. Francis Mountains Area Geology

Precambrian-Lamotte Ss Contact

Lm Ss
Sulfide-rich
Boulders
Precambrian Rhyolite

Boulders
Precambrian Rhyolite
Basalt
Lead Belt Host Rocks

Hayden Creek Mine

Doe Run Mine, OLB

Ohle, 1952, 1954; Kisvarsanyi, 1977
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
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

<table>
<thead>
<tr>
<th>Period</th>
<th>Production of Lead</th>
<th>Units</th>
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<tbody>
<tr>
<td>1720 to 1790</td>
<td></td>
<td>8,000</td>
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<tr>
<td>1800 to 1849</td>
<td></td>
<td>21,485</td>
</tr>
<tr>
<td>1850 to 1893</td>
<td></td>
<td>68,219</td>
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<tr>
<td>Total</td>
<td></td>
<td>97,704</td>
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The sales of this lead at prices prevailing during the various periods must have yielded very nearly ten millions of dollars.

Winslow, 1894
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 with overlying Davis Formation in cut on southwest side Missouri 8 on the northeast side of the town of Leadwood. STOP 9 of road log.

Bedrock Units
- Ordovician, Jefferson City & Cutler
- Ordovician, Roubidoux
- Ordovician, Gasconade
- Cambrian, Eminence & Potosi
- Cambrian, Elvris & Bonneterre
- Cambrian, Lorraine
- Precambrian Volcanics
- Precambrian Intrusives
- Precambrian Metamorphic

St. Francis Mountains Region Geology
Southeast Missouri

[Map of St. Francis Mountains Region Geology showing various geological units and locations like Bonneterre, Davis, etc.]
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 Oebritts-Dorosin Dolomite. Minor normal fault is at interruption in white contact line. The Oebritts bed is the first thick dolomite bed below the contact. View is towards the northwest.

Figure 3-1. Davis Formation exposed in west side of roadcut at STOP 1. 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
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
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.

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

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

Lithosphere Thickness-Sediment Hosted Ore Deposits

Hoggard and others, 2020
Lead and Zinc - Central United States
Formation of MVT Deposits
Formation of MVT Deposits
Summary 1

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Leach and others, 2010

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

Cobalt Demand

2500 kT

Other Sectors

Lithium Demand

EV’s and Storage

IEA, 2020; Watari and others 2021
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.
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)
  - Magmatic Ni-Cu (-Co-PGE) sulfide
  - MSRH Co-Cu-Au
  - Volcanogenic Cu(-Zn-Co-Ag-Au) massive sulfide

Sea-floor cobalt deposit types

- >0.1 Mt cobalt
  - SSH Cu-Co
  - Ni-Co laterite
  - Magmatic Ni-Cu (-Co-PGE) sulfide
  - BSH Ni-Cu-Zn-Co
  - Polymetallic vein
  - 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