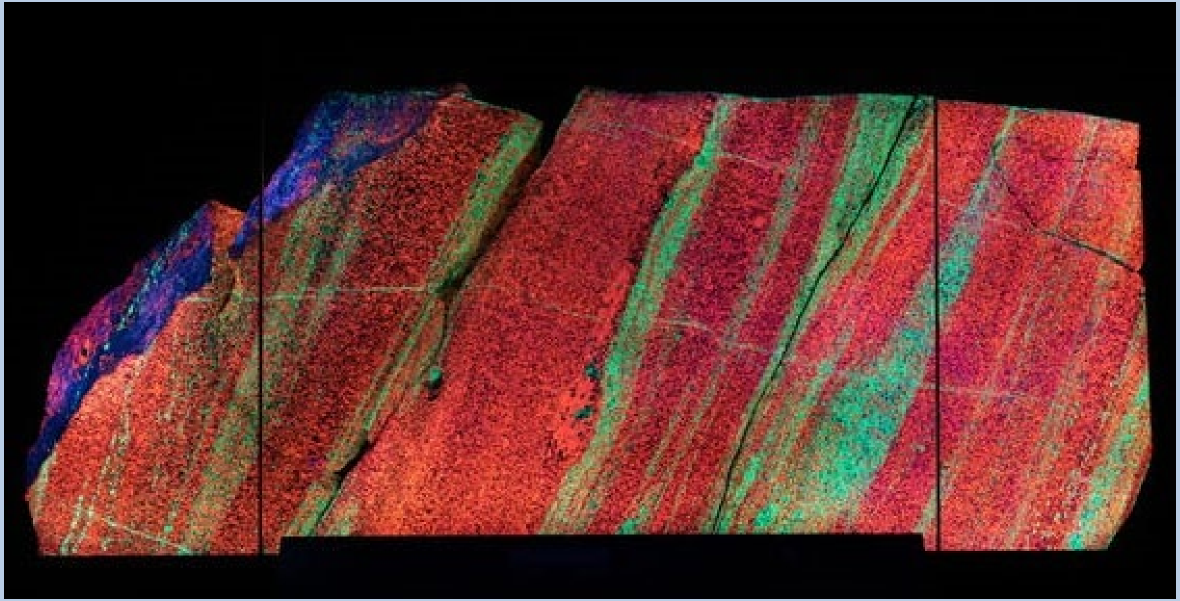
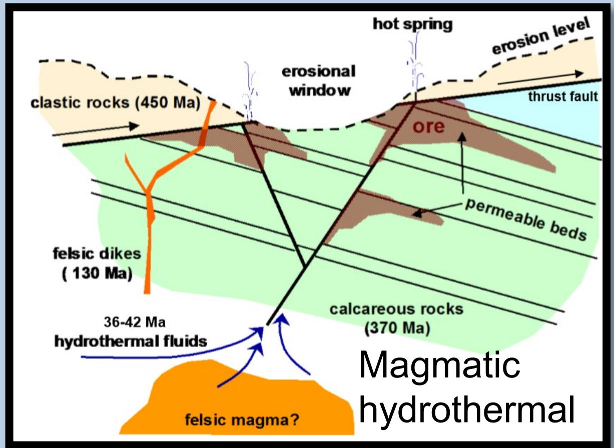
Zinc Isotope Constraints on the Formation of Sedimentary Exhalative (SEDEX) Ore Deposits: New Evidence from the Franklin, NJ Mining District.

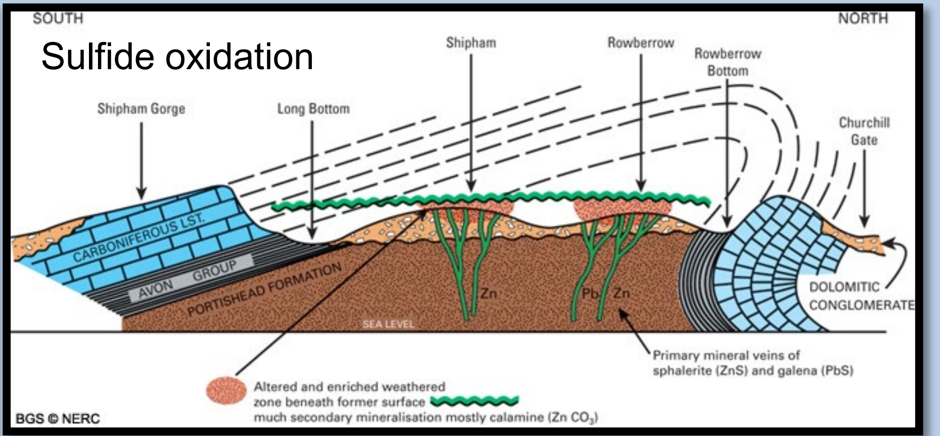


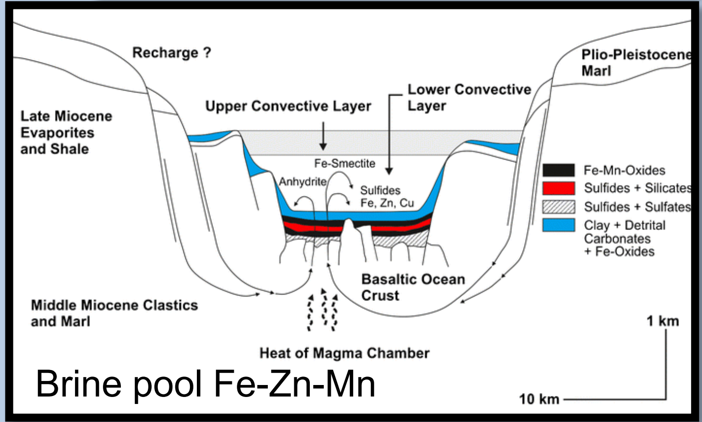
Slab of fluorescent rock on display at American Museum of Natural History, NYC. Field of view ~6 m. Samples for our study were taken just above the position of this slab after its removal from the open pit at Sterling Hill mine.

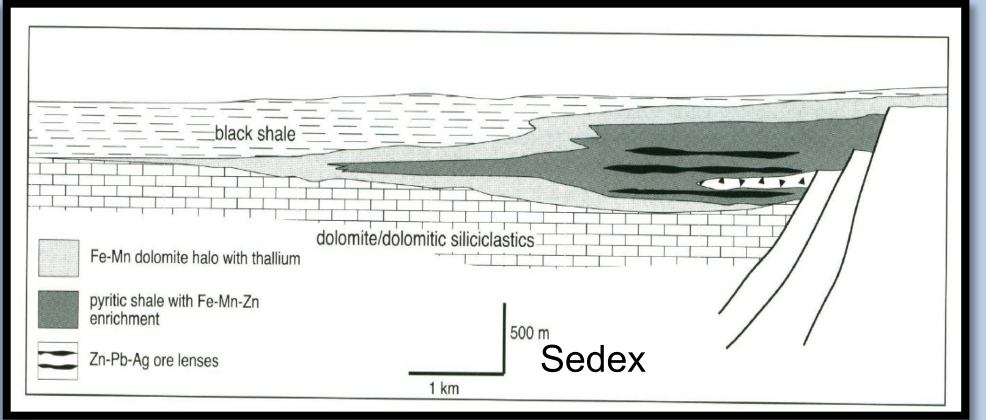
Peter Matt, Pratt Institute, Brooklyn, NY
William Peck, Colgate University, Hamilton, NY
Ryan Mathur, Juniata College, Juniata PA
Mary Hurtgen, MP Materials, Las Vegas, NV
Linda Godfrey, Rutgers University, New Brunswick, NJ

Deposit Models/Research Goal

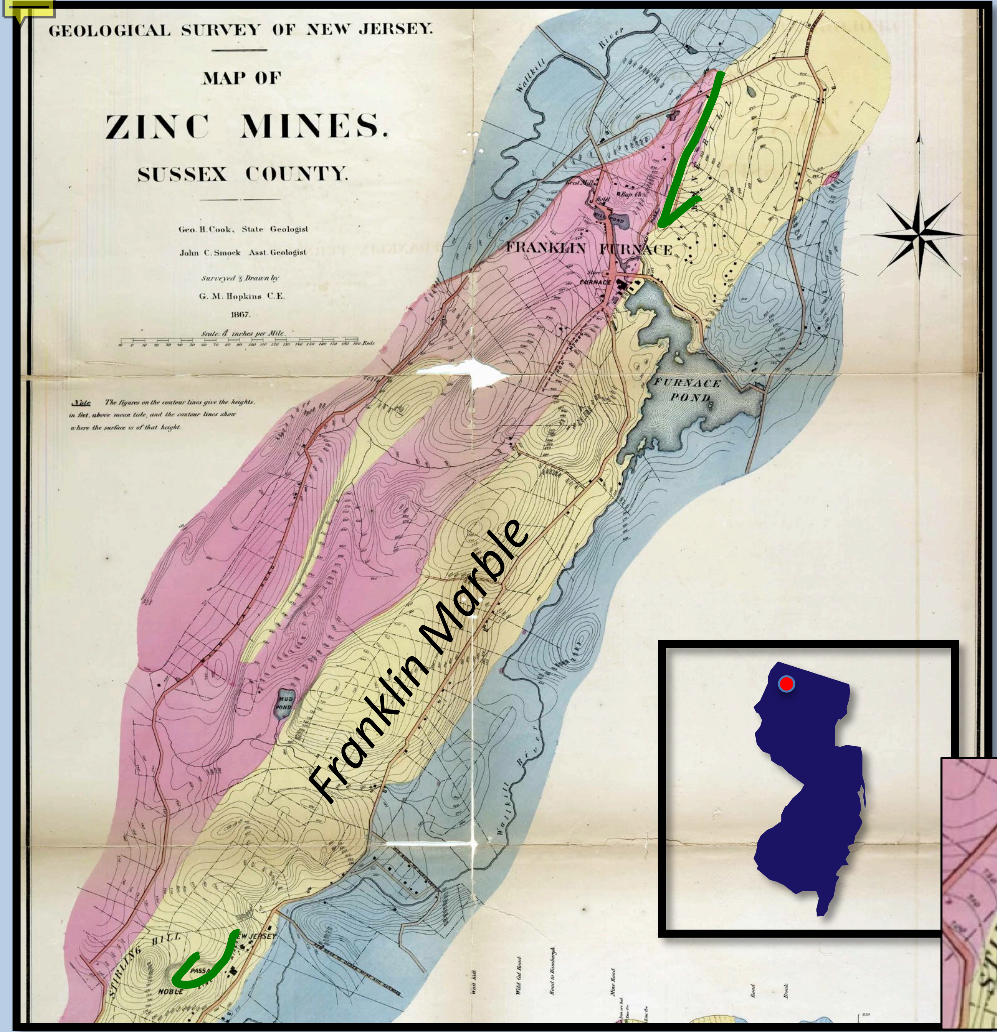




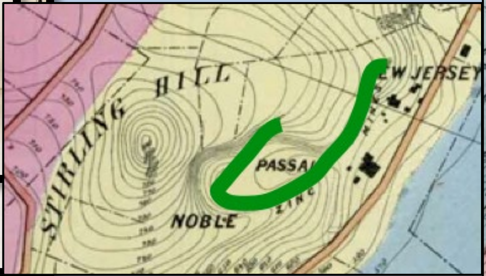




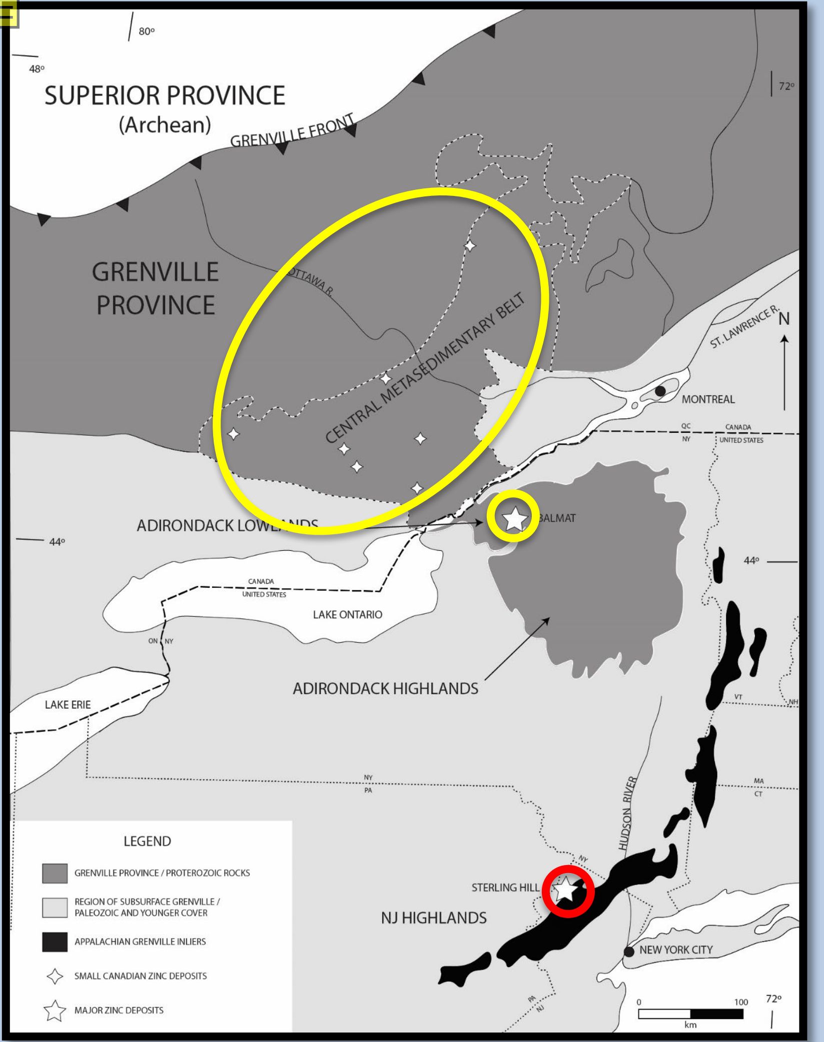
Historic Mining District

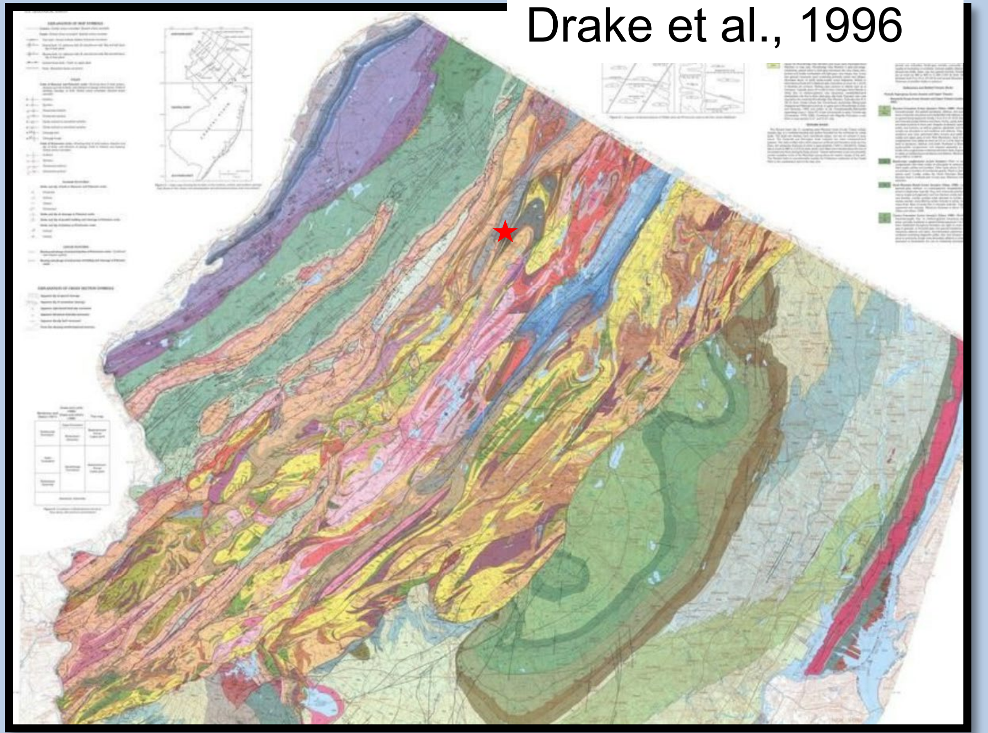


- Two mines, Franklin Furnace and Sterling Hill, both started ~1898
- Franklin closed in mid-1950’s, Sterling Hill closed in 1986
- ~33 Mt of >20% Zn ore total
- Mines about 2 miles apart



NJ Highlands-Grenville Inlier

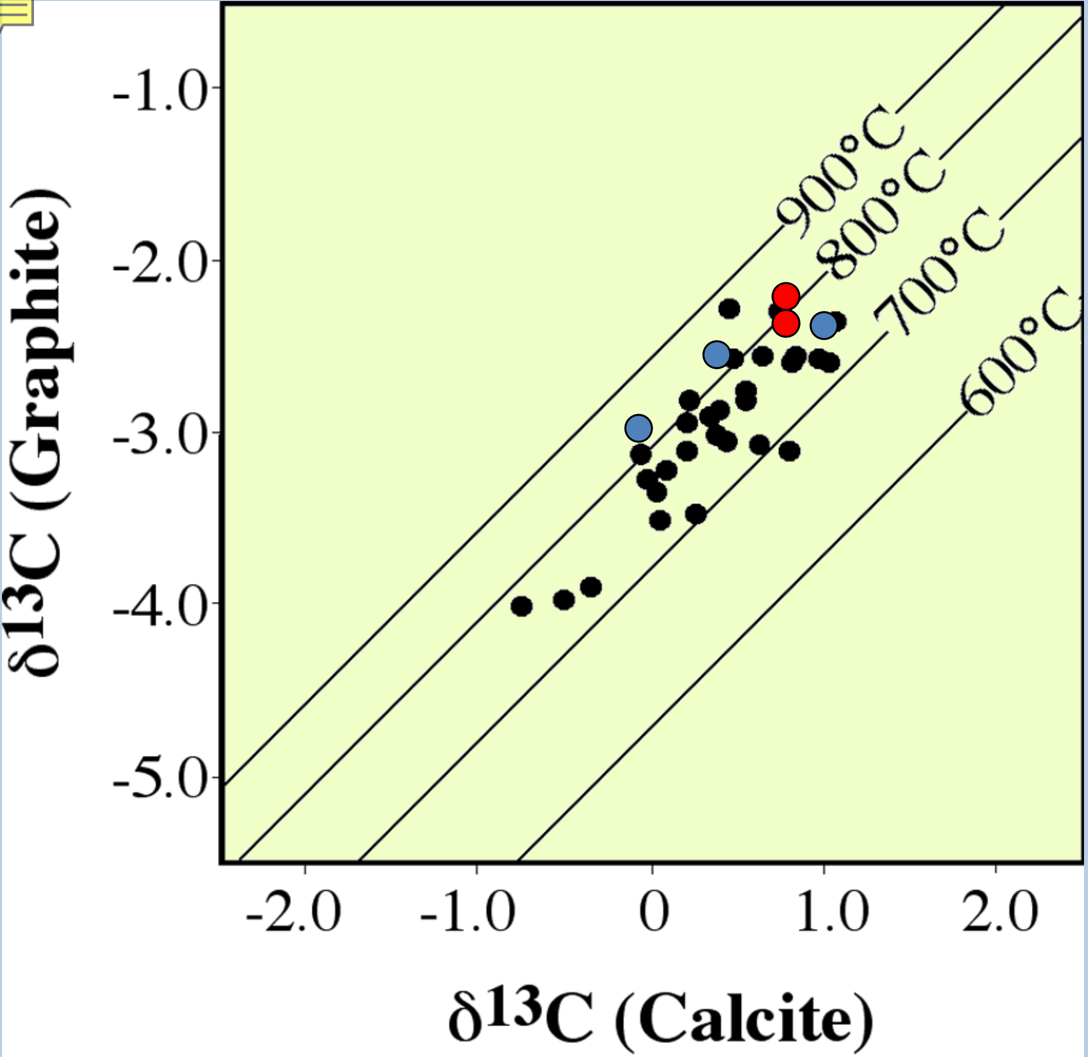




Drake et al., 1996

Calcite-Graphite Thermometry of the Franklin Marble

Peck et al. J Geol 2006



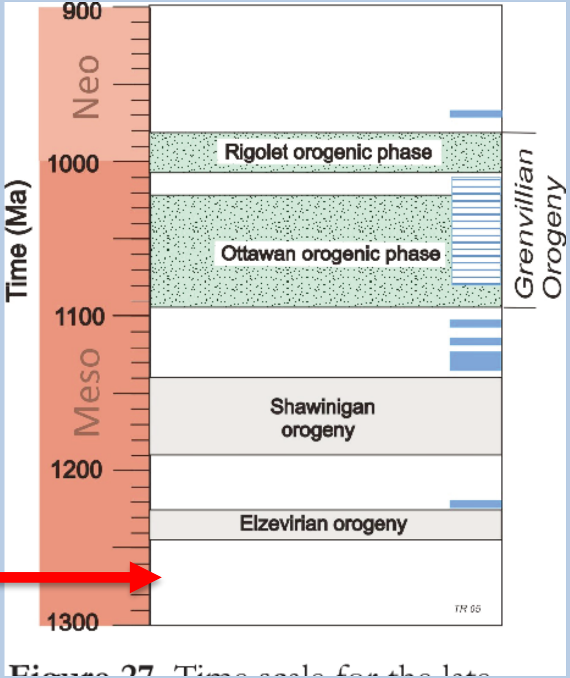
Fluorescent samples

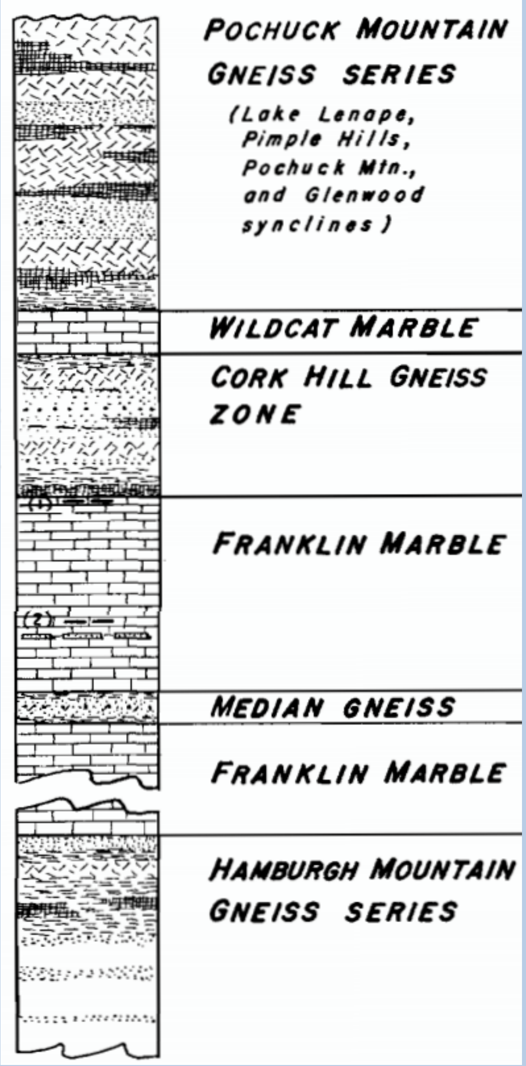
Near ore deposits

Highlands metamorphic peak T 769 ±43° C, (Peck at al. 2006), 4-5 kbar (Volkert, 2004)

Timing Constraints on Deposition

Protolith deposition, pre-Elzeverian (Rivers, 2015)





1259 ± 7 Ma

1299 ± 5 Ma

Franklin Mine

Sterling Hill Mine

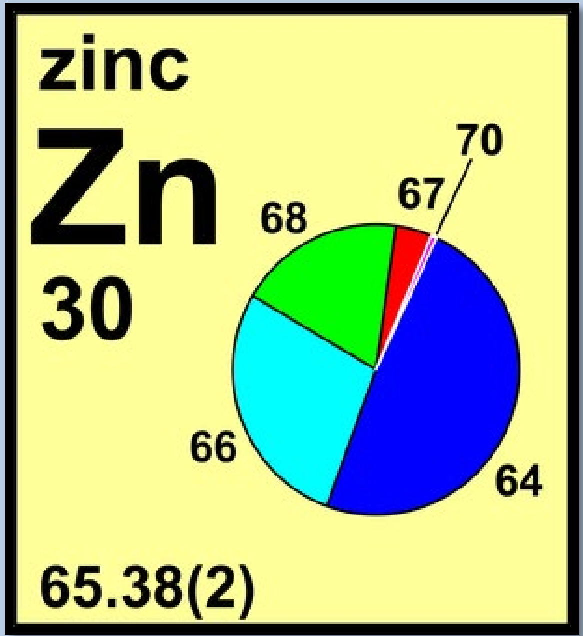
1294 ± 8 Ma

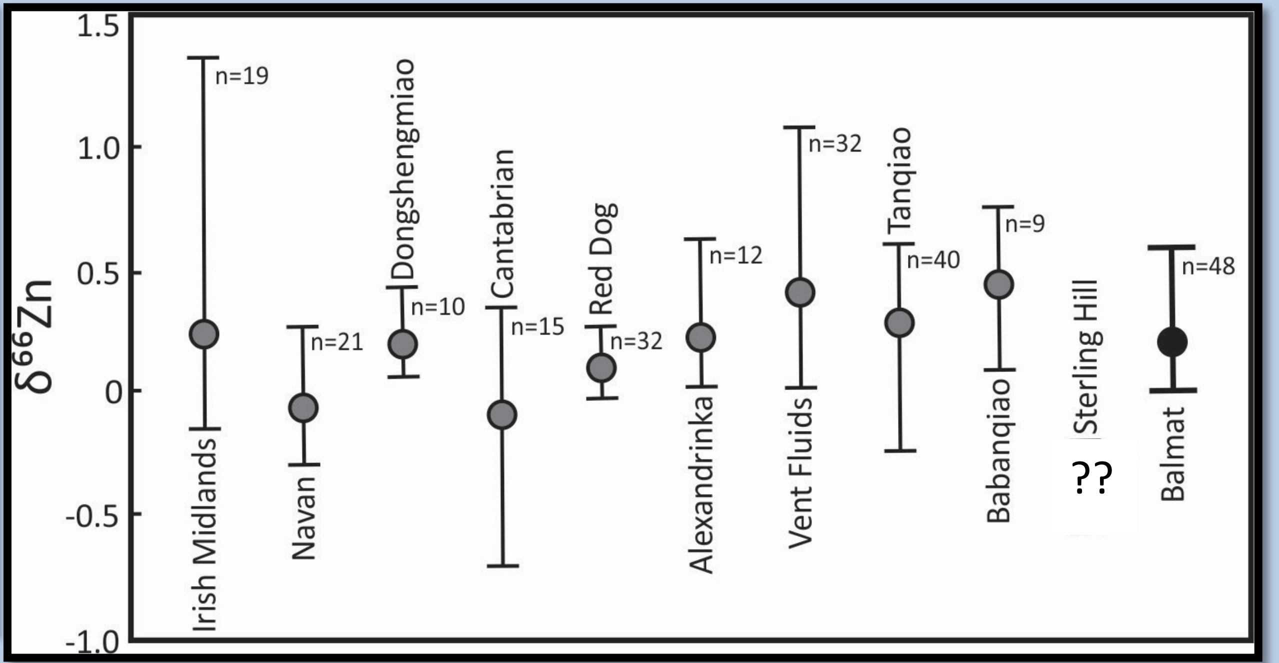
Hague et al., 1956
Volkert et al., 2010

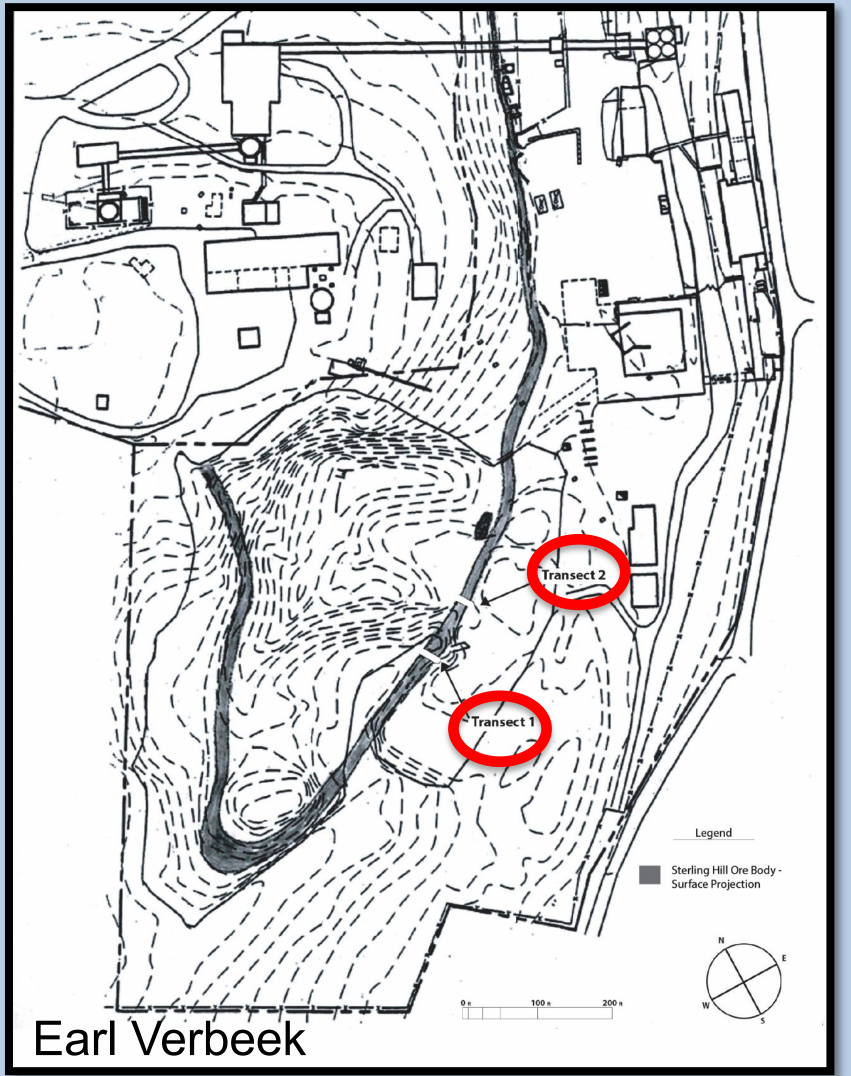
Stable Isotope Geochemistry of Zinc

Standard isotope notation

$$\delta^{66}Zn = [(^{66}Zn/^{64}Zn)_{sample}/(^{66}Zn/^{64}Zn)_{standard} - 1] \times 1000$$

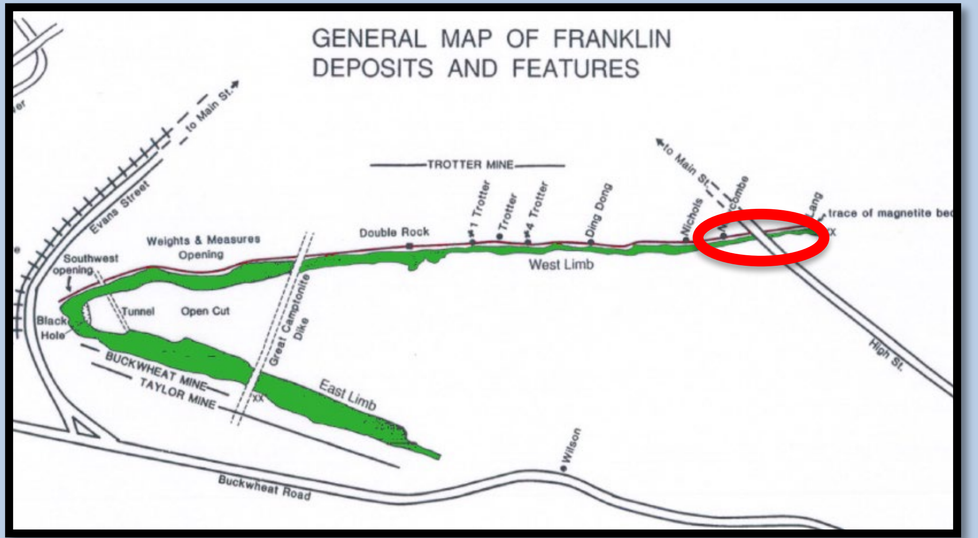




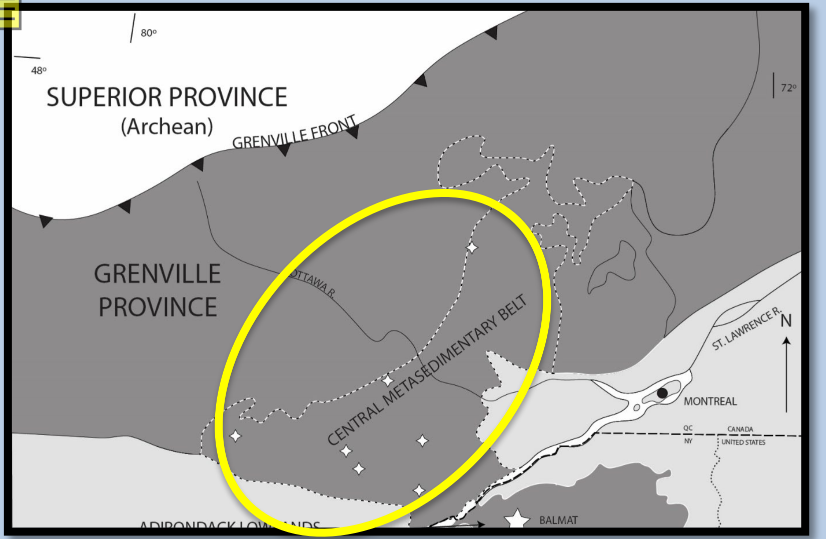


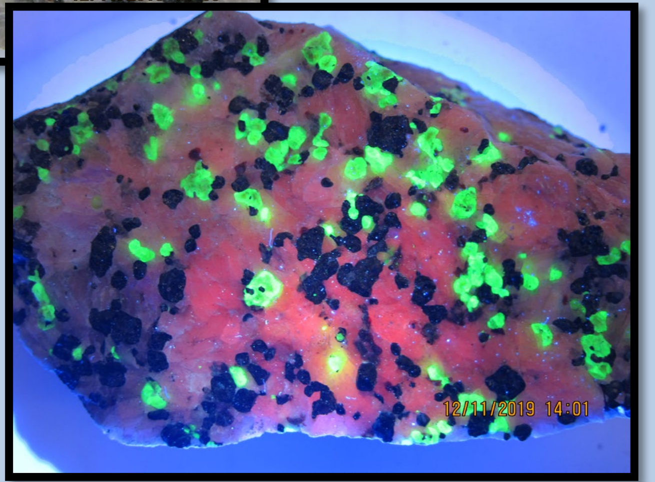
Our Study

- Sterling Hill transect 1-19 samples
- Sterling Hill transect 2-7 samples
- Trotter mine-4 samples
- Total mineral separates-38 Zn-bearing, 30 calcite



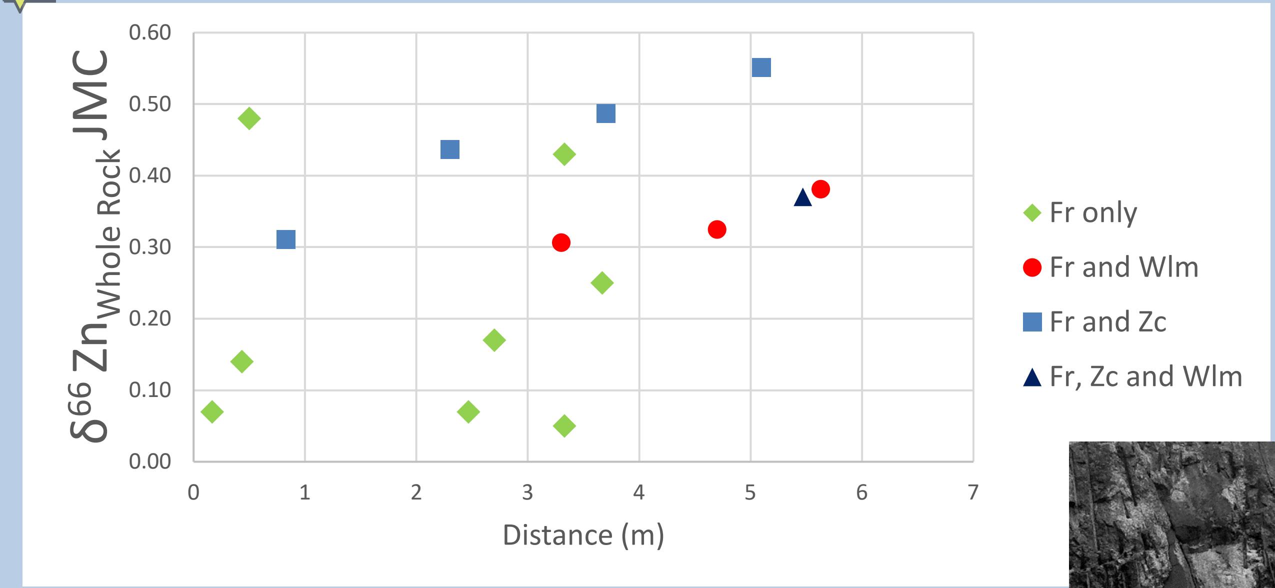
Our Study





- $\delta^{66}Zn$ of franklinite ($Zn^{2+}Fe^{3+}_2O_4$), willemite (Zn_2SiO_4) and zincite (ZnO) from Sterling Hill (n=32) and Franklin (n-4)
- $\delta^{66}Zn$ of sphalerite from Canadian deposits (n=31)
- $\delta^{18}O$ and $\delta^{13}C$ of calcite from all samples (n=67)

Results

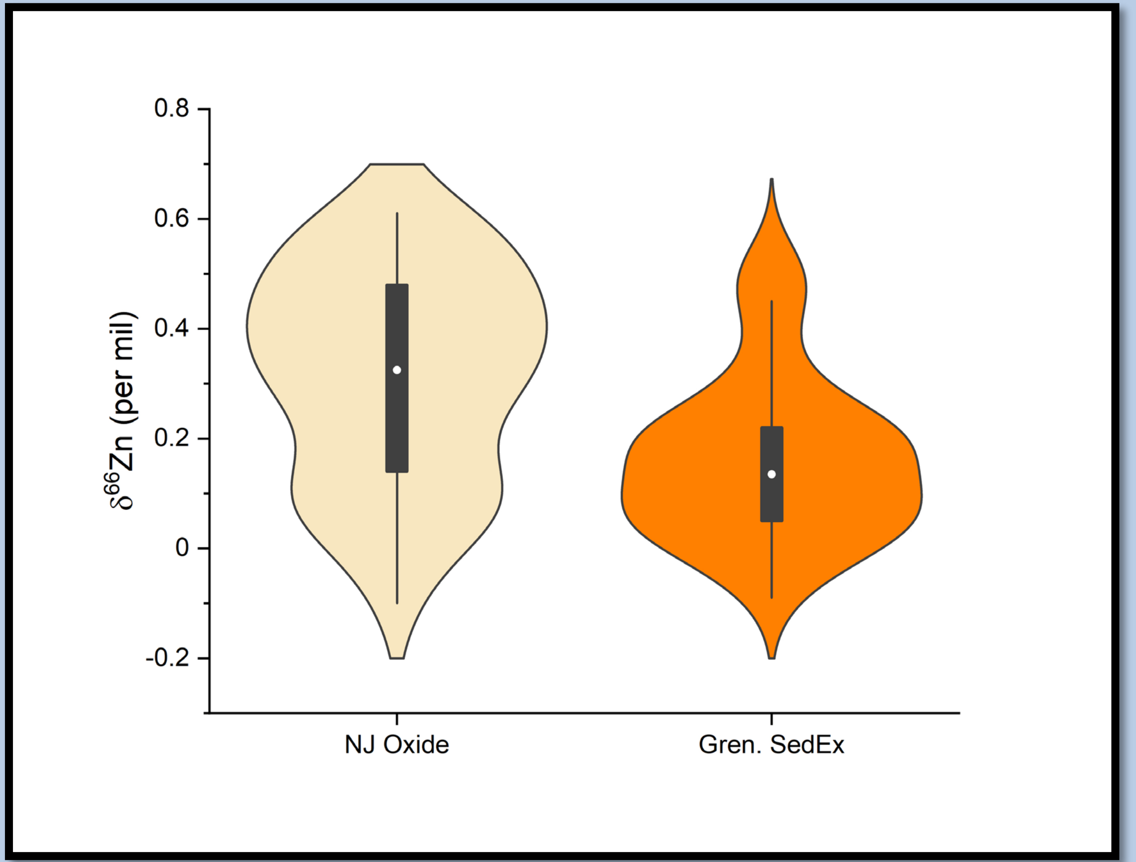


$\delta^{66}Zn_{Fr}$ mean 0.20 ± 0.17 ‰ n=22

$\delta^{66}Zn_{Wm}$ mean 0.37 ± 0.09 ‰ n=7

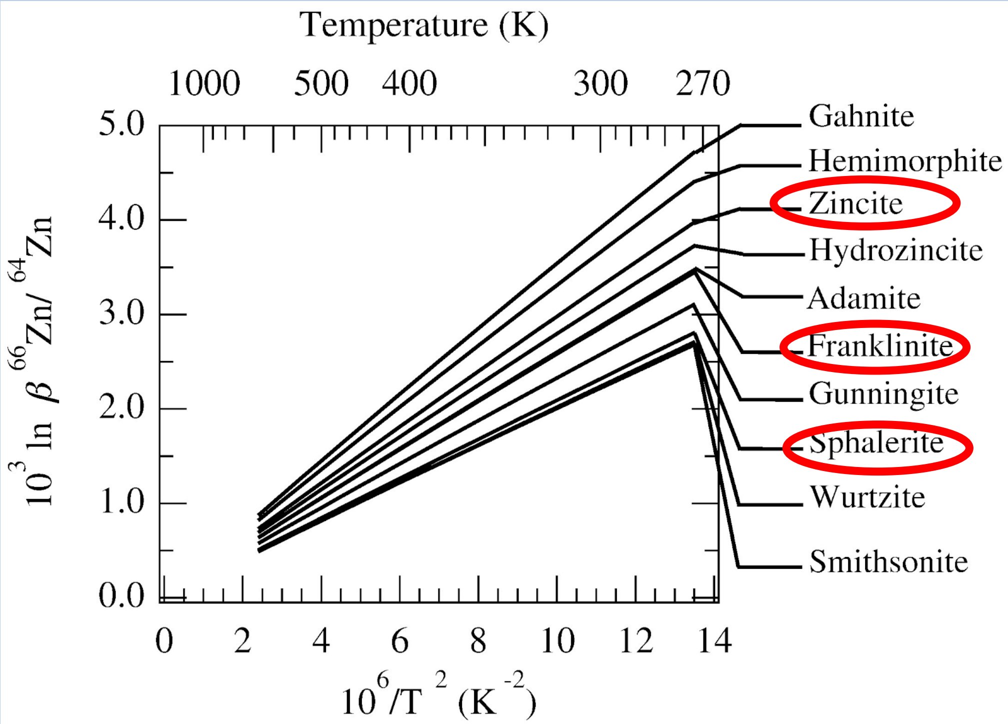
$\delta^{66}Zn_{Zc}$ mean 0.47 ± 0.12 ‰ n=9

Violin Plots



- NJ oxides and silicates mean $\delta^{66}Zn$ 0.30 ±0.19 ‰
- Canadian and Balmat sulfides (sphalerite) mean $\delta^{66}Zn$ 0.15 ±0.14 ‰
- Difference is nearly 8x experimental error
- Very statistically significant ($p=0.0011$)

Results Consistent With Modeling



Ducher et al., 2016

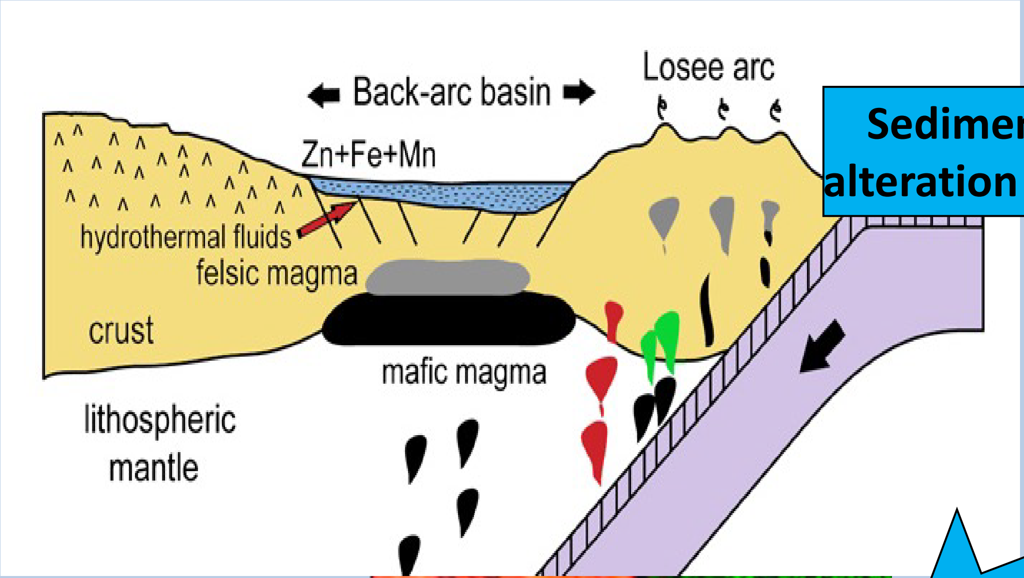
Average $\delta^{66}Zn$ zincite 0.47

Average $\delta^{66}Zn$ willemite 0.37

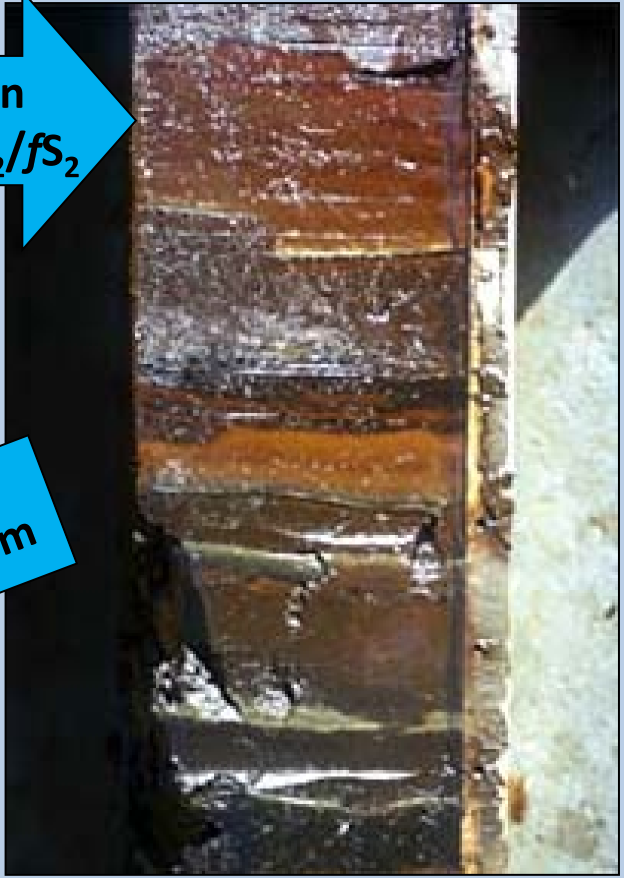
Average $\delta^{66}Zn$ franklinite 0.20

World average sphalerite $\delta^{66}Zn$ 0.12
n = 206

Data Supports Syngenetic Model

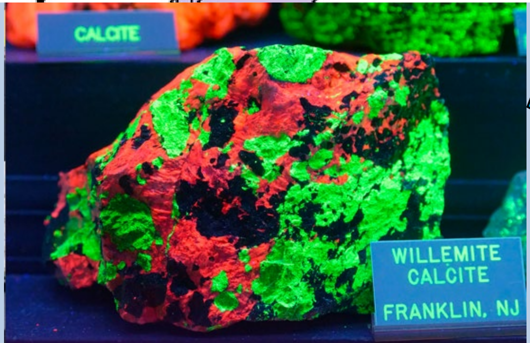


Sedimentation then alteration @ high fO_2/fS_2

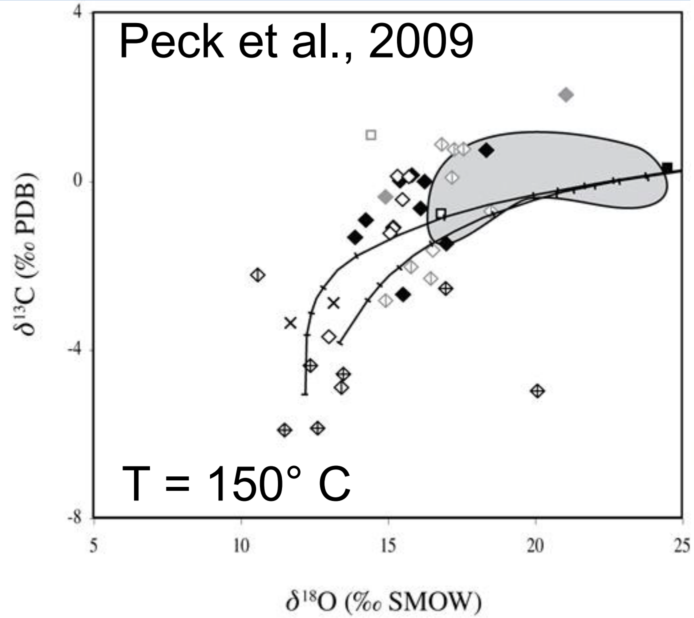


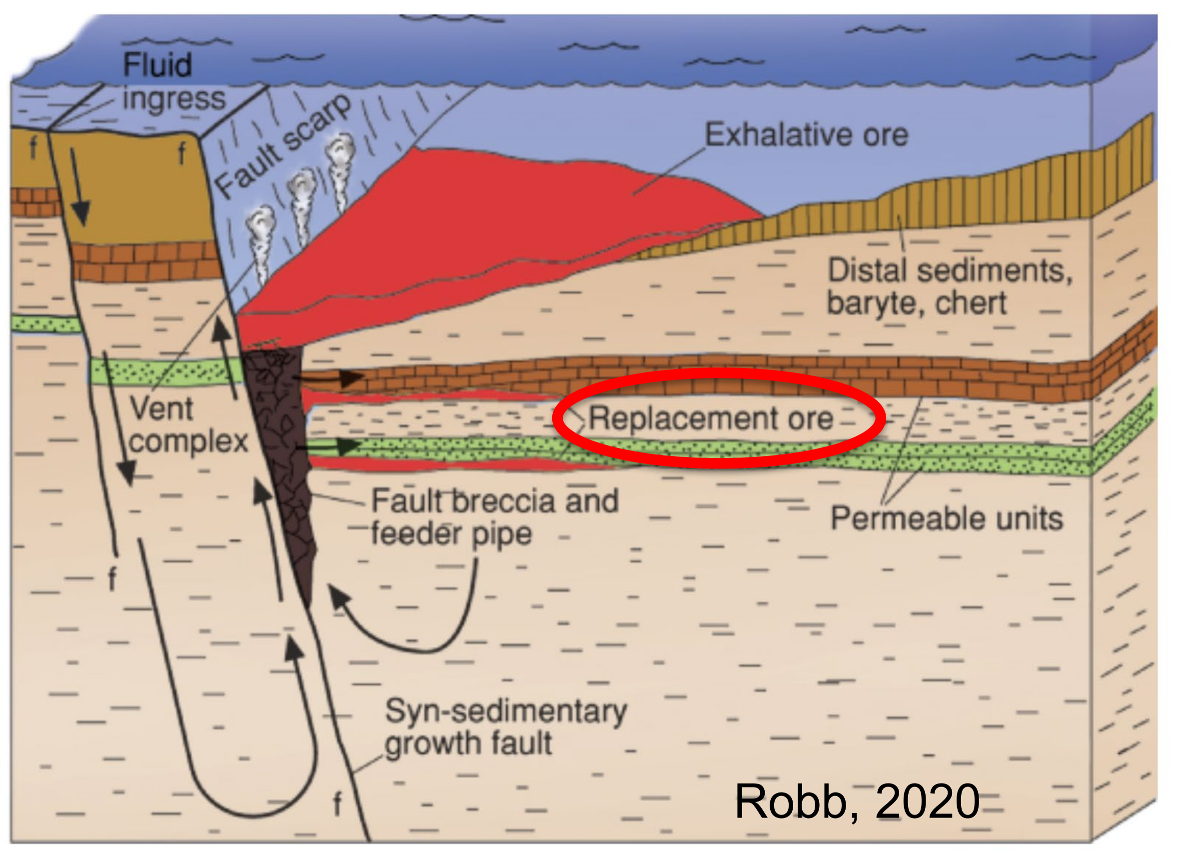
750°C Metamorphism

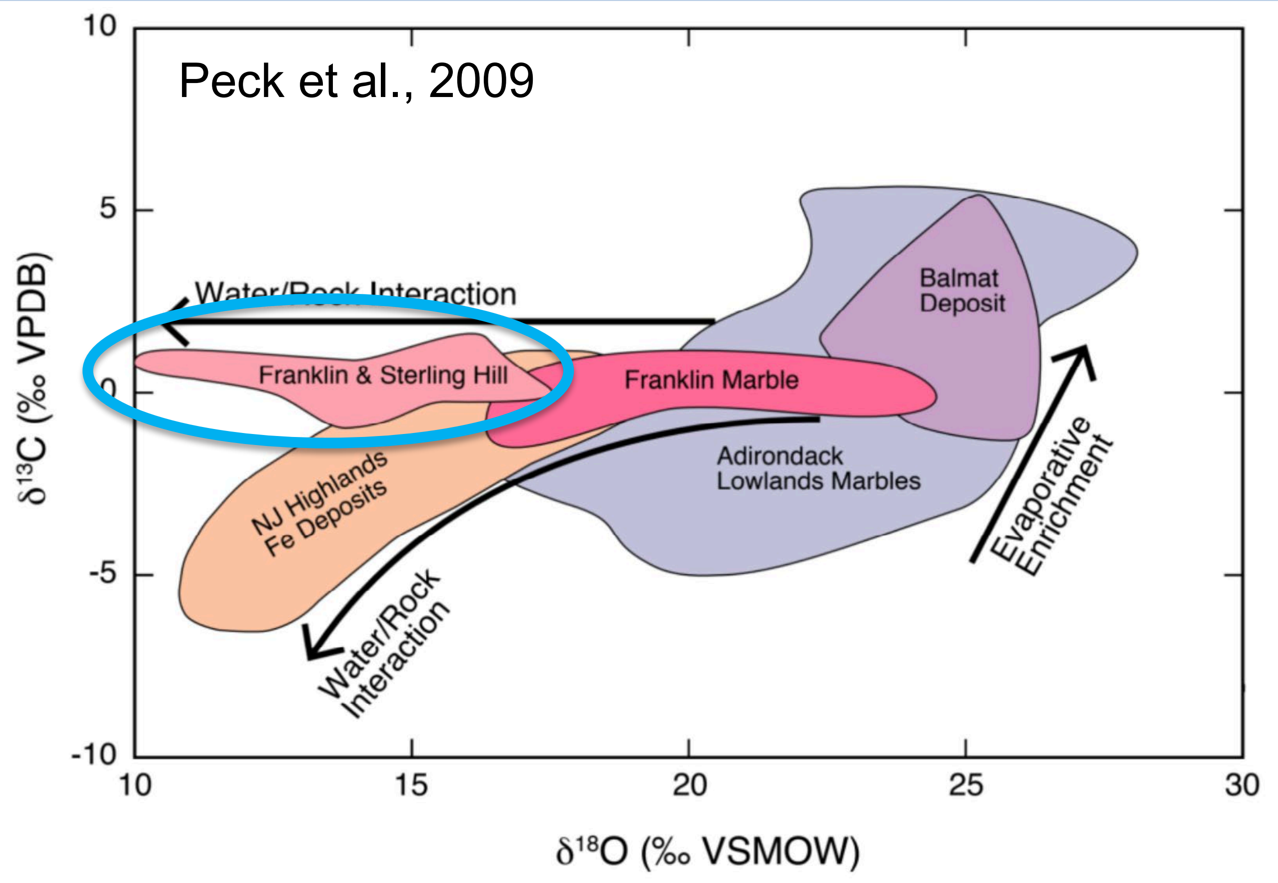
Zinc silicates and oxides



Exhalative vs. Replacement SEDEX







Variation in Water/Rock Interaction

- $\delta^{13}C$ is decoupled from $\delta^{18}O$ in Zn-mineralized Franklin marble
- Fluid carbon buffered by dissolving calcite?

Conclusions/Acknowledgements

- $\delta^{66}Zn$ of Franklin district oxides and silicates are on average ~0.15 ‰ higher than world average for sphalerite
- Results consistent with first principles calculations
- Data suggests that $\delta^{66}Zn_{Zc} > \delta^{66}Zn_{Wm} > \delta^{66}Zn_{Fr}$
- Results support sub-surface replacement at high fO_2/fS_2 for deposit genesis (pre-metamorphic)

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