HighPoint RESOURCES

Evidence for Hydrothermal Systems at Hereford Field, DJ Basin, Colorado

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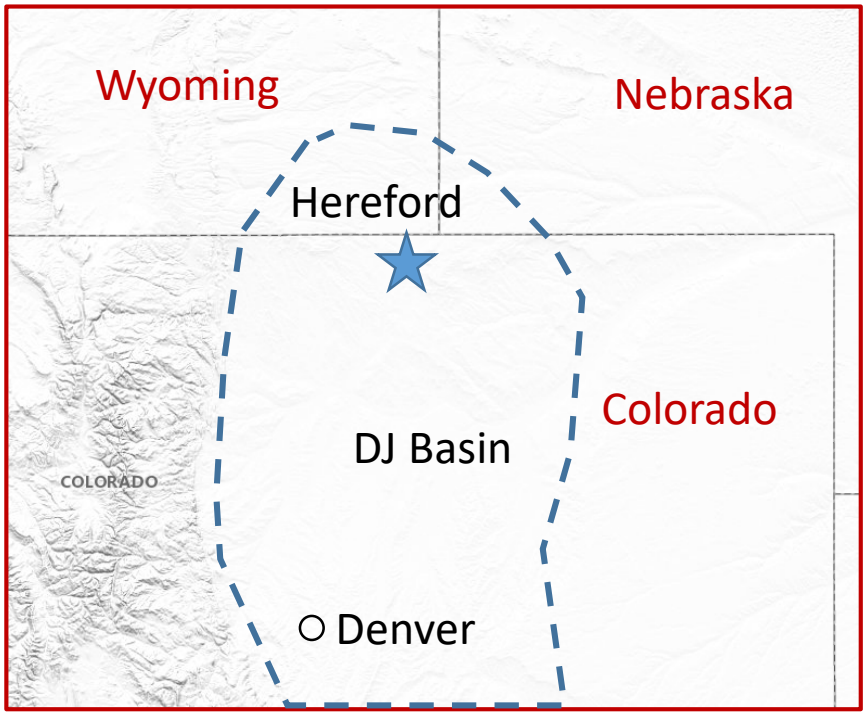
Summary & Location

- Hereford Field is in the northern DJ Basin
- Developed by:
  - Wildcats pre-2009
  - EOG 2009-2011
  - Fifth Creek 2016-early 2018
  - HighPoint mid 2018 to present
- Niobrara & Codell exploration, delineation, and development



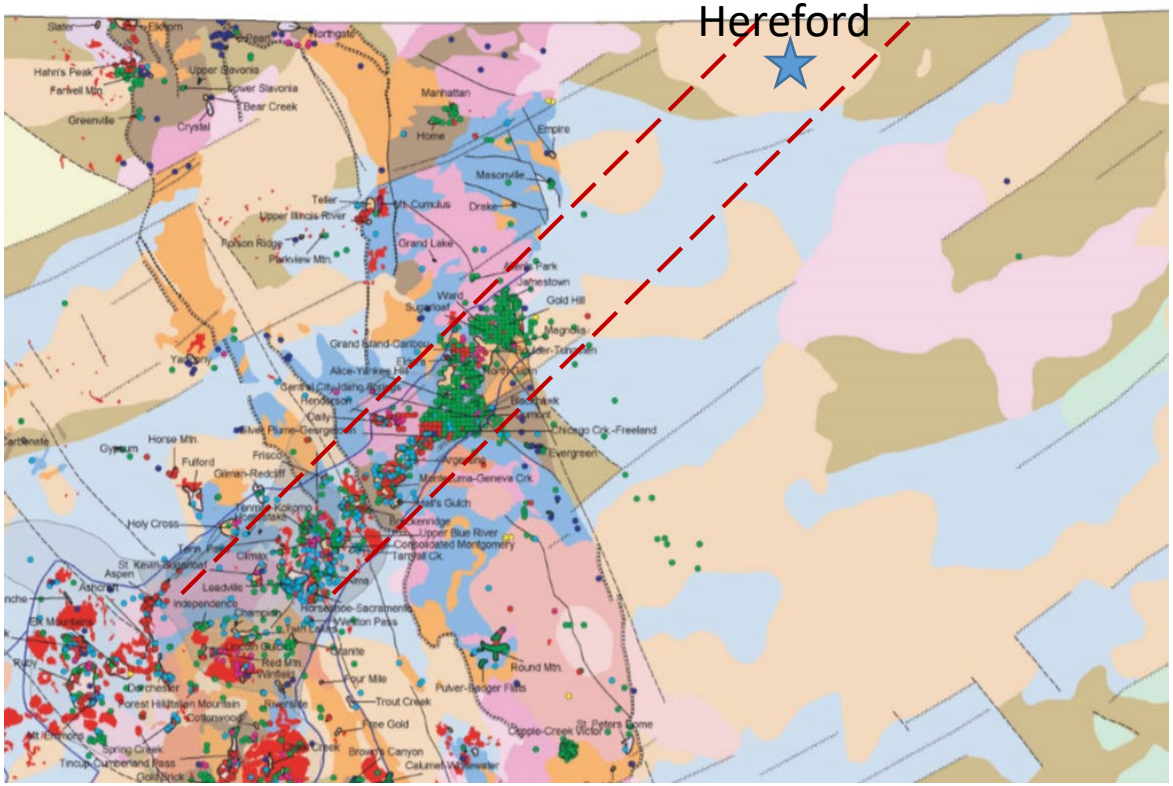
Basemap: USGS National Map

Primary Question

- Initial development hypothesis:
  - Fractures are necessary for economic development
- The null hypothesis:
  - Sufficient maturity and rock properties make the matrix a target
- Focus on maturity and rock properties
  - Diffusion?
  - Hydrothermal?
  - Both?
  - Epigenetic or diagenetic processes?

Maturity: Colorado Mineral Belt

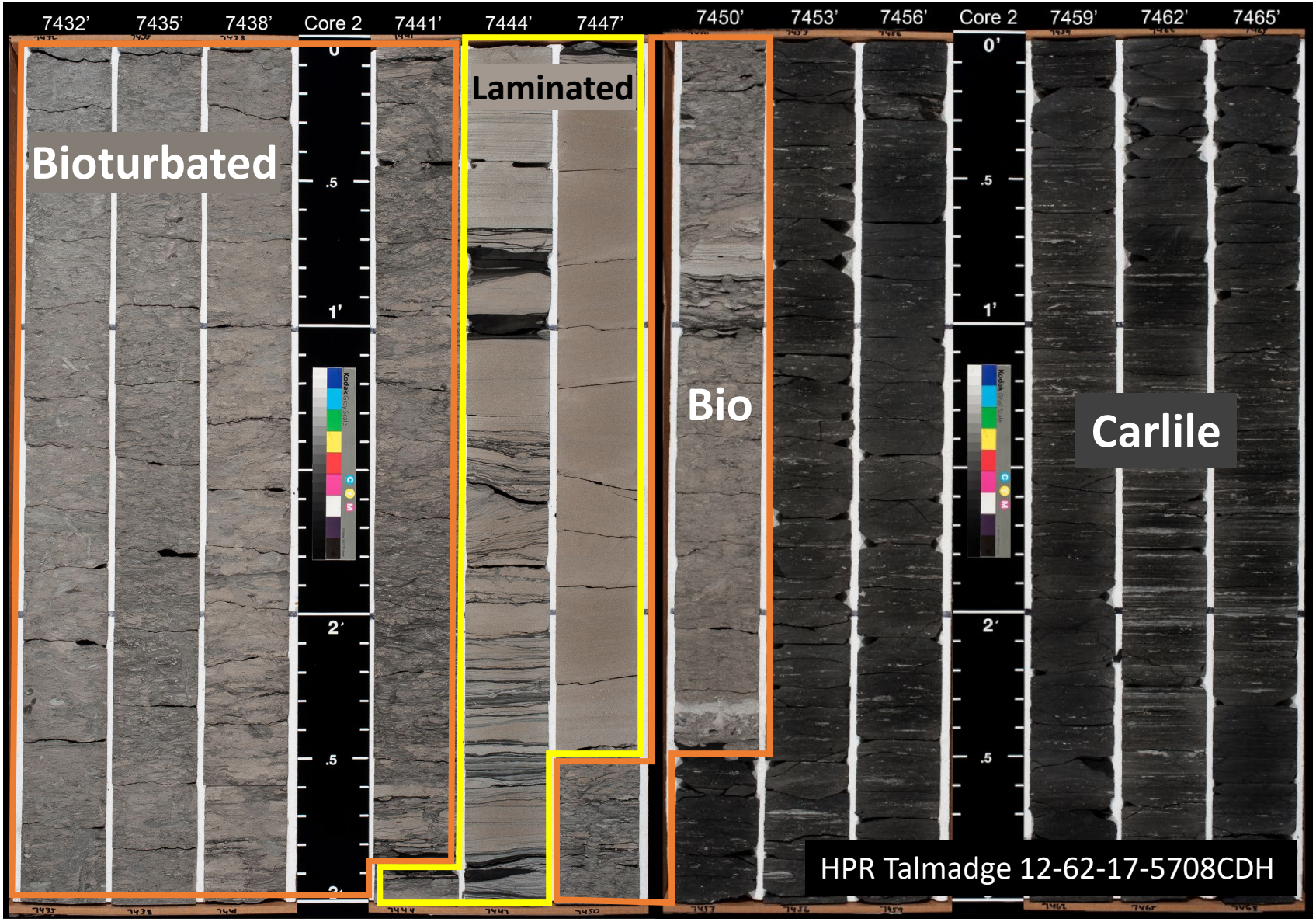
- Last event: Miocene, Oligocene time
- Precious metals in the mountains
- Maturity in the basin



Basemap from Burack and Wilson, 2003 (USGS OFR 03-046)

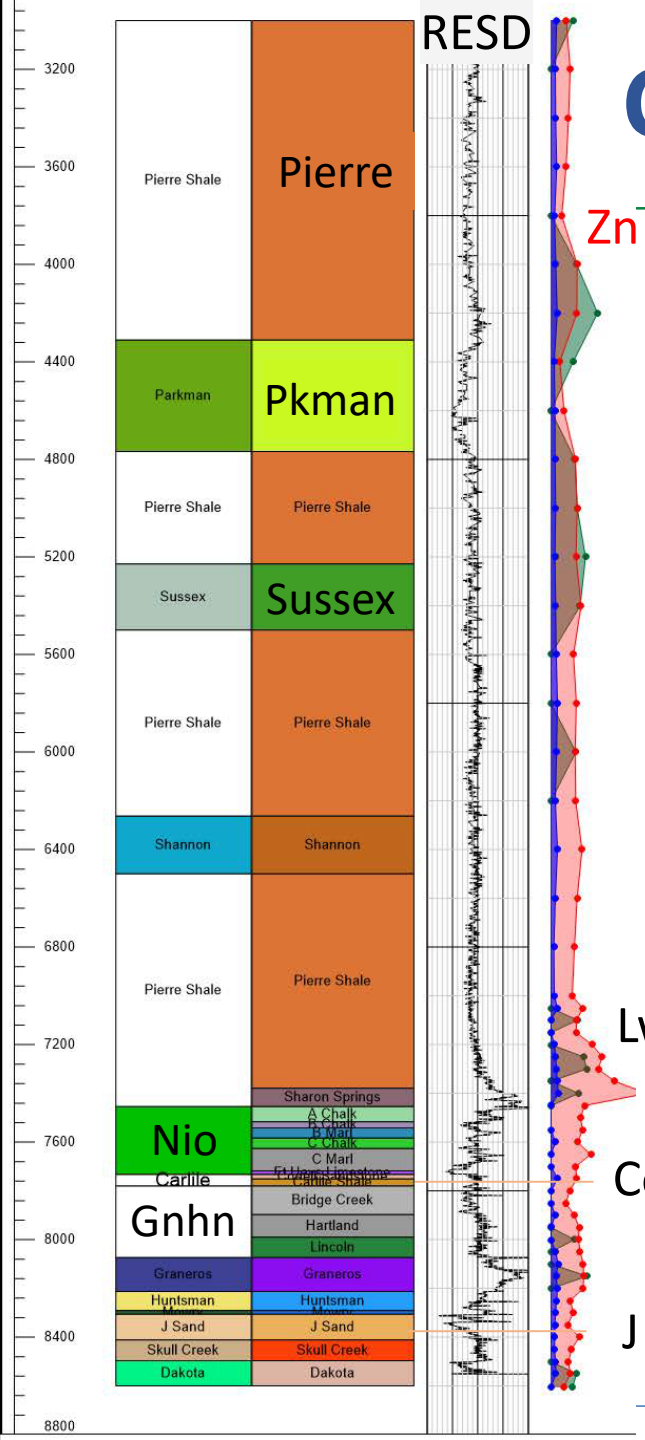
Codell at Hereford

TOP



BASE

Chemostrat Type Log



Lwr Sharon Springs

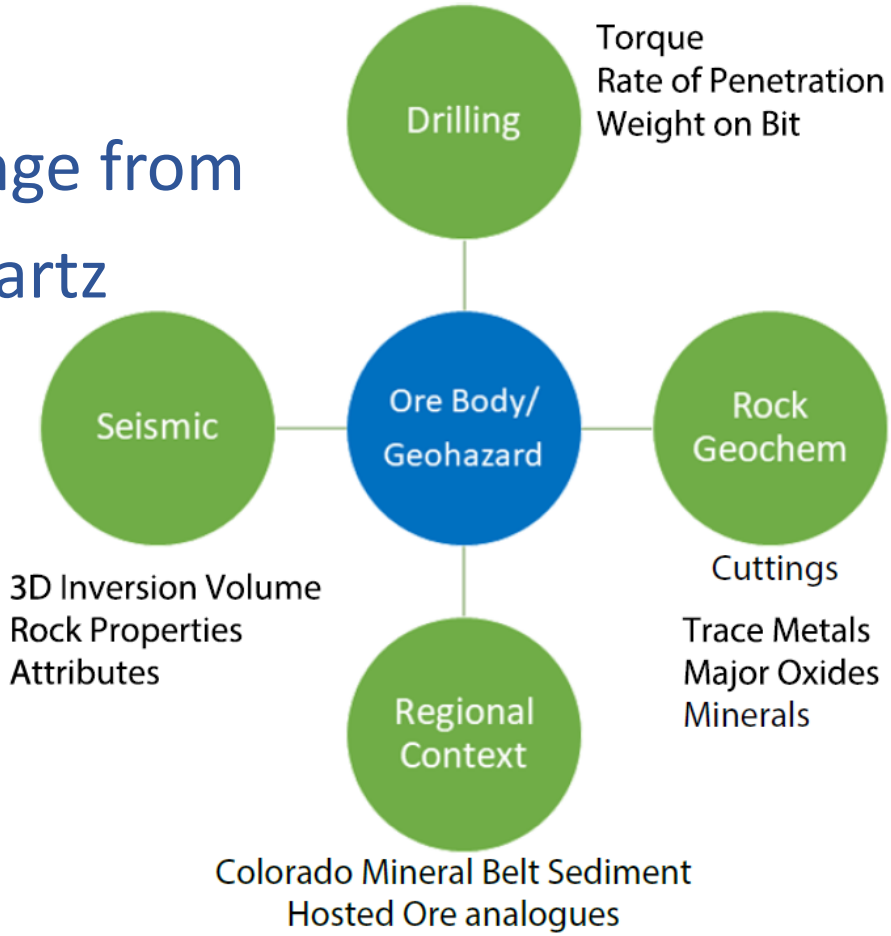
Codell

J Sand

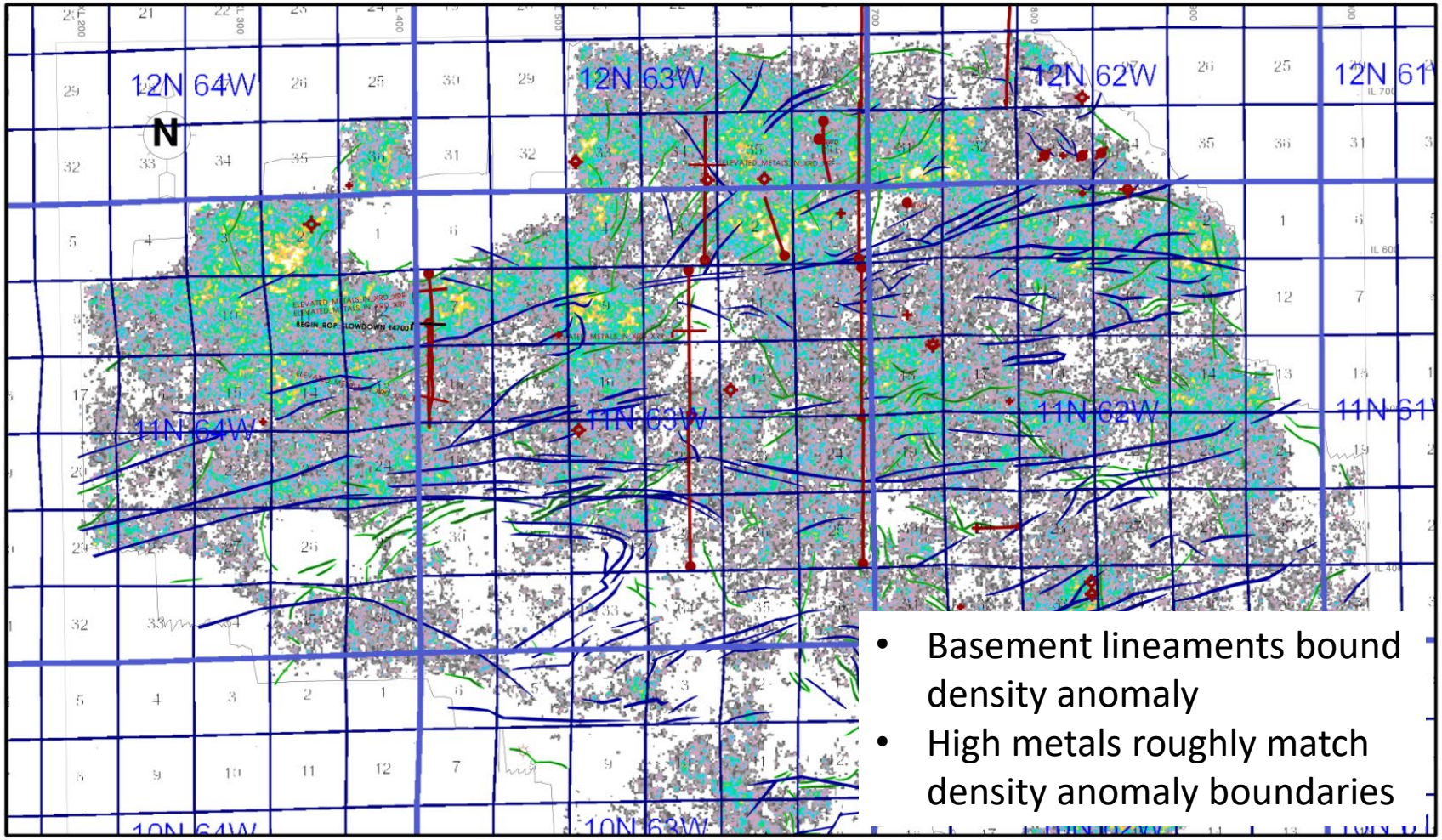
- XRD, XRF, Pyrolysis
- Chemostratigraphic log shows detail that wireline does not
- Elevated metals in key zones

Operational Challenges Yield Insight

- The 2:30 am phone call
- “Leaning the house on the bit” No ROP
- 2 sidetracks
- Density change from calcite and quartz

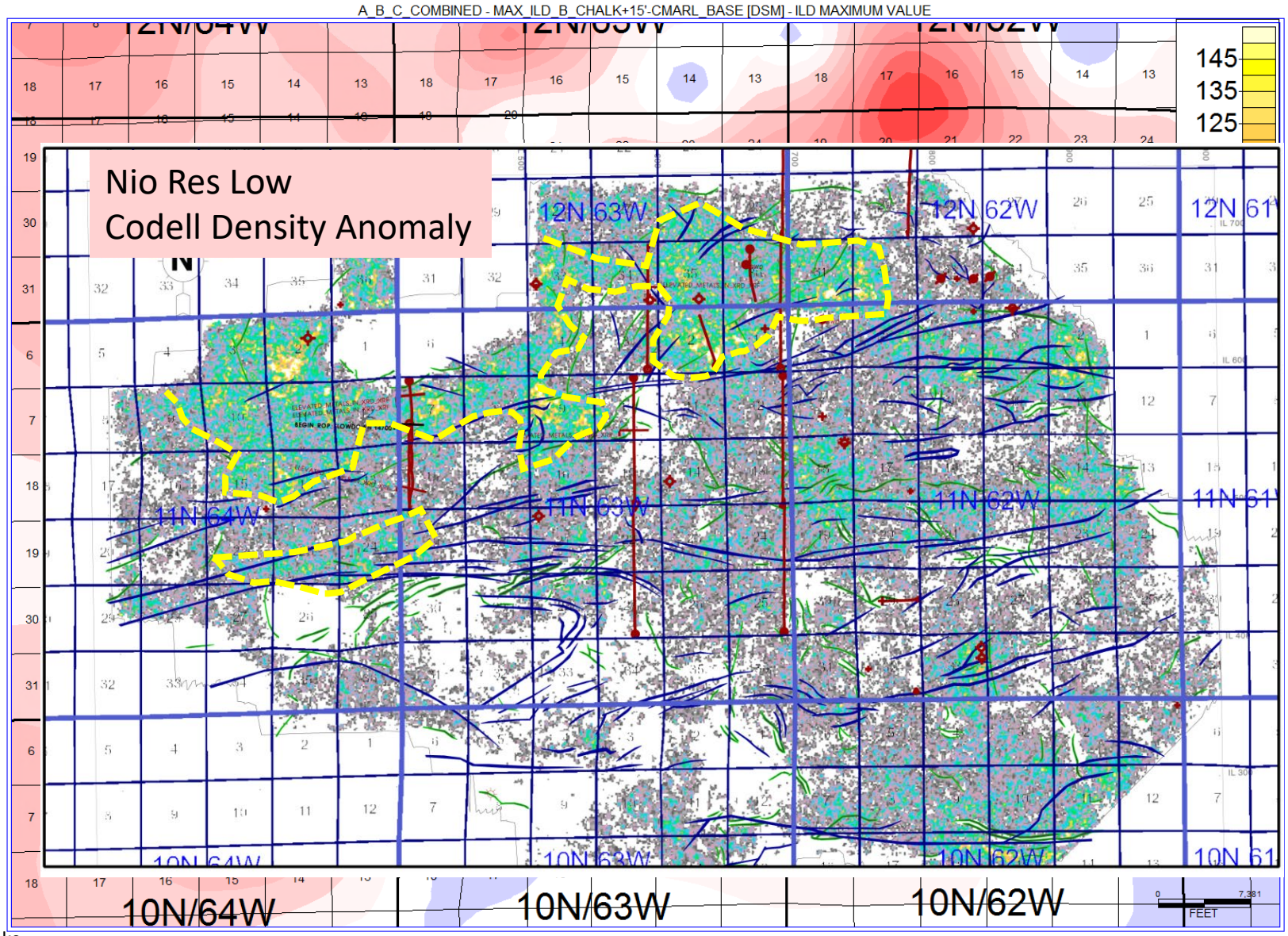


Codell Bulk Density

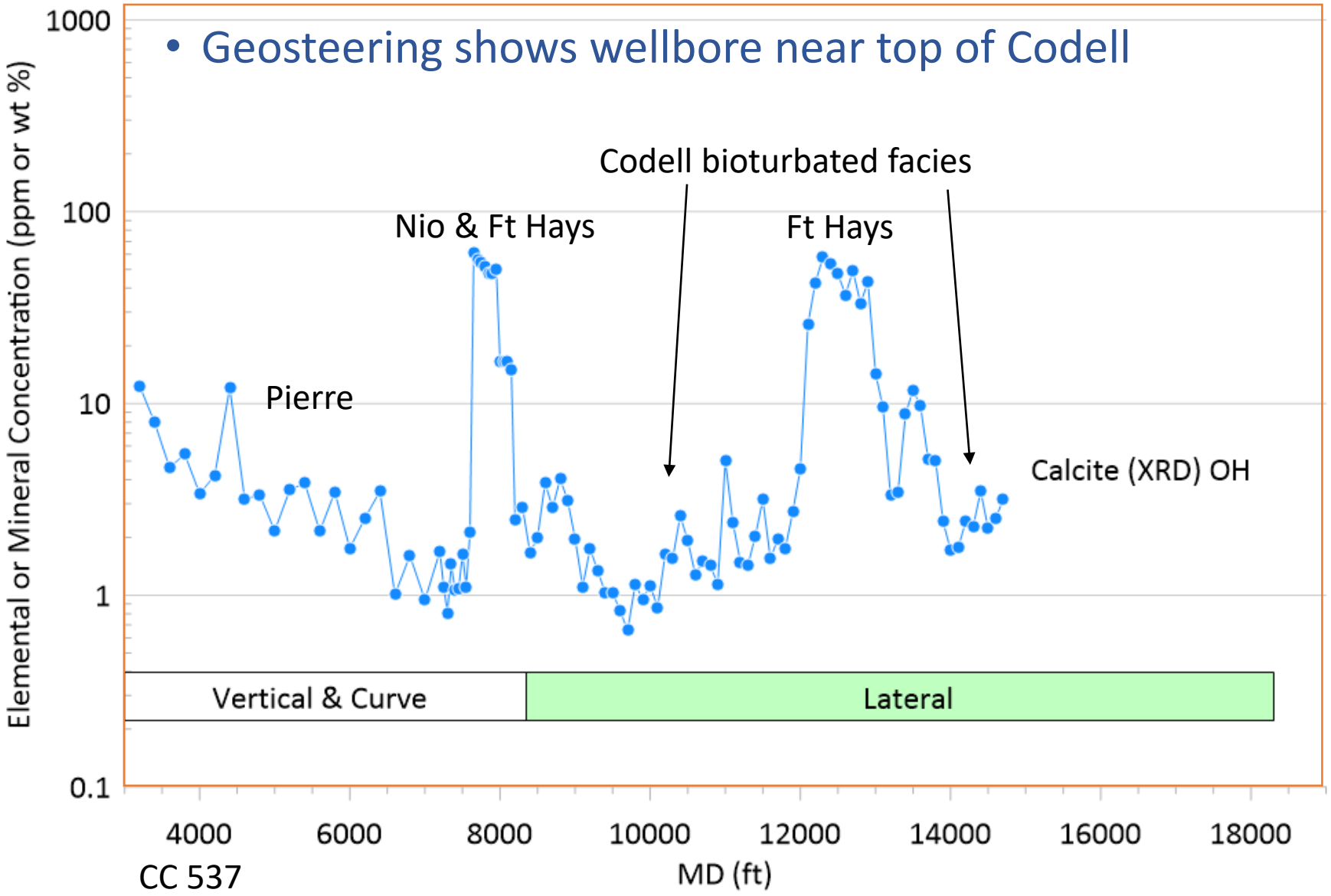


- Basement lineaments bound density anomaly
- High metals roughly match density anomaly boundaries

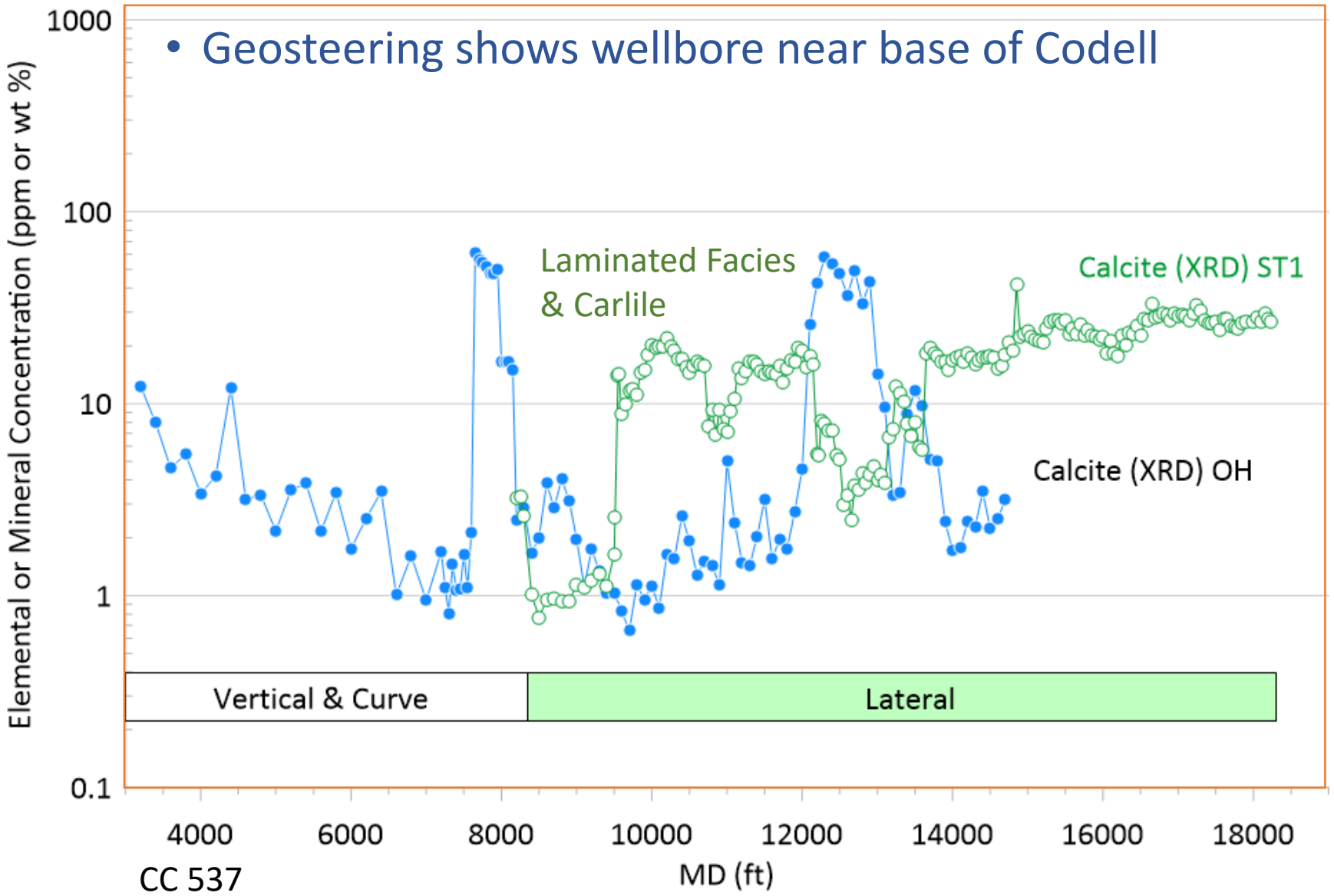
Niobrara Deep Resistivity



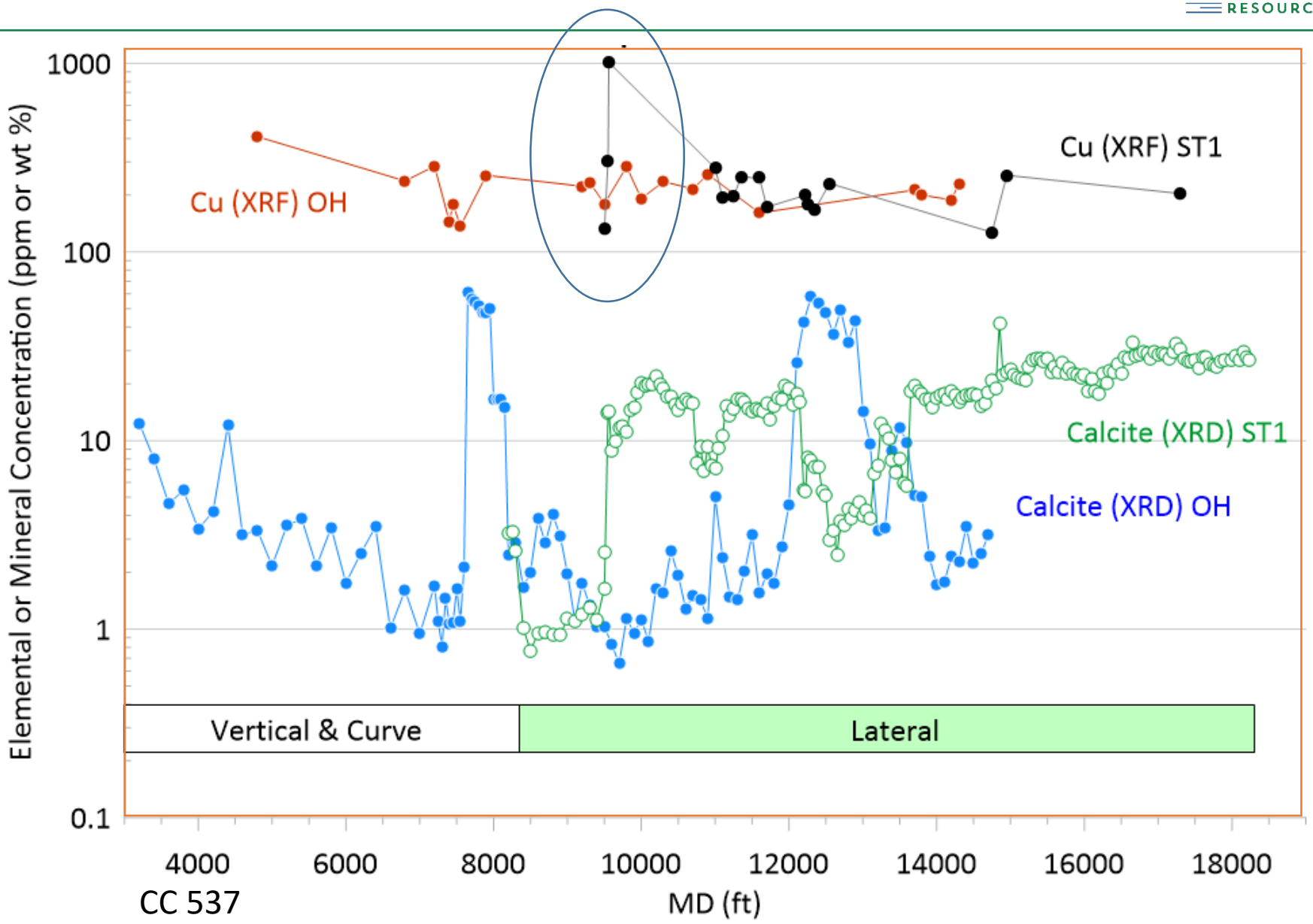
Calcite Delineates the Codell



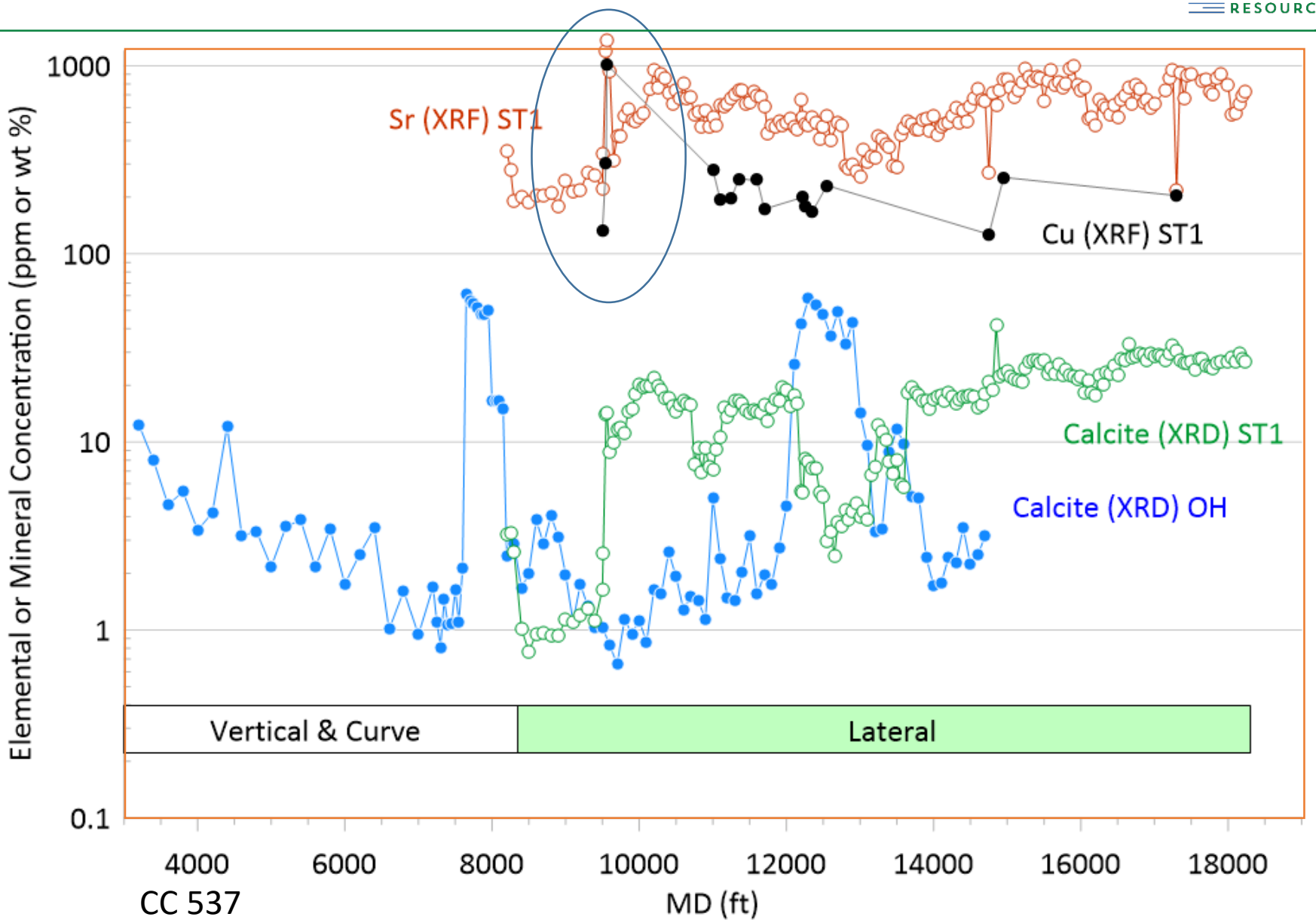
OH vs ST1: Facies Variations



Copper at the Facies Interface

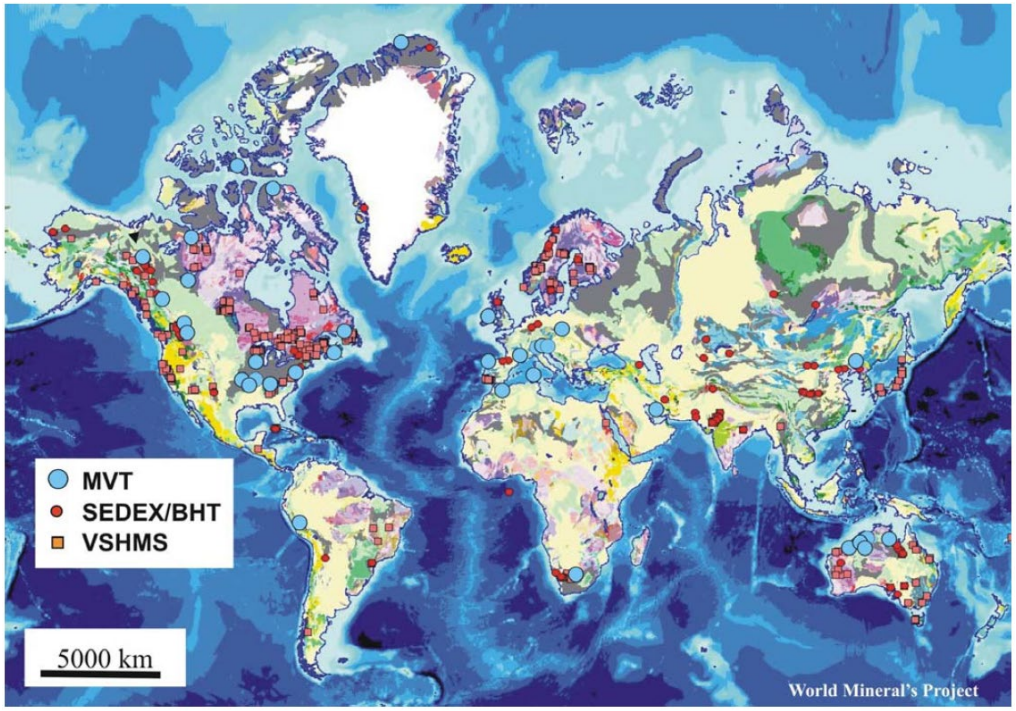


Sr at the Facies Interface



Metals in an Oil Field?

- Ores in a Sandstone??
- Mississippi Valley Type Deposits
  - Carbonate & Sandstone Hosted
  - Deposited by:
    - Changes in pressure, temperature, pH, dilution
    - Sulfur & sulfur reducing agents (e.g., methane)

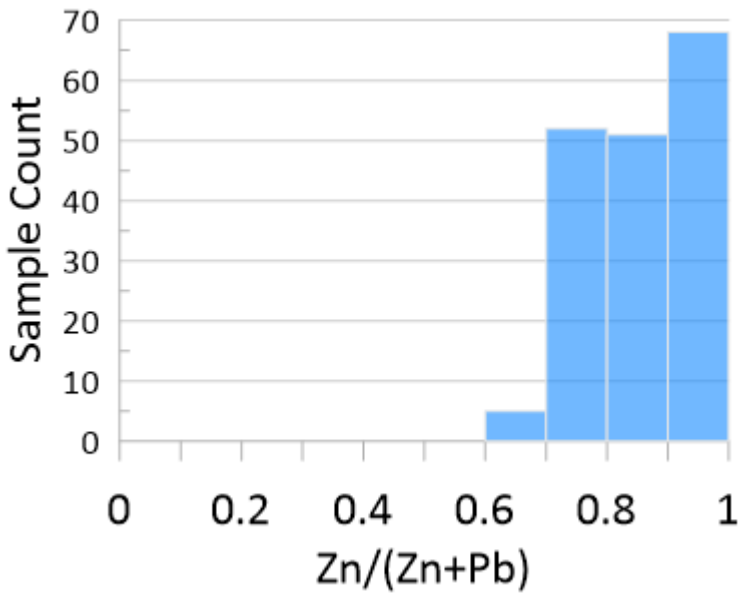


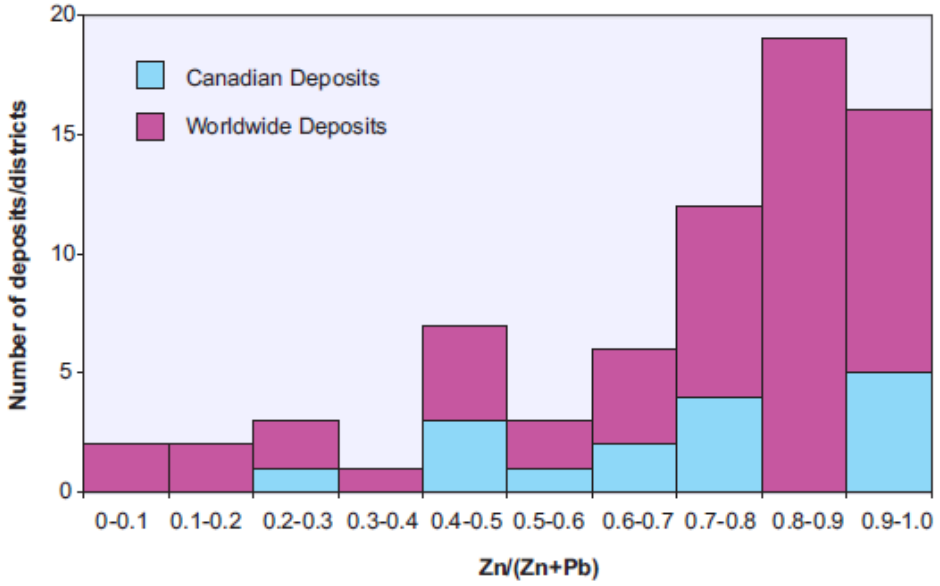
Pb & Zn at Hereford vs Wolrdwide Deposits

- Zn/(Zn+Pb) ratios compare to worldwide averages
- Concentrations are low compared to actual ores

☺ Geologic Process ✖ Ore

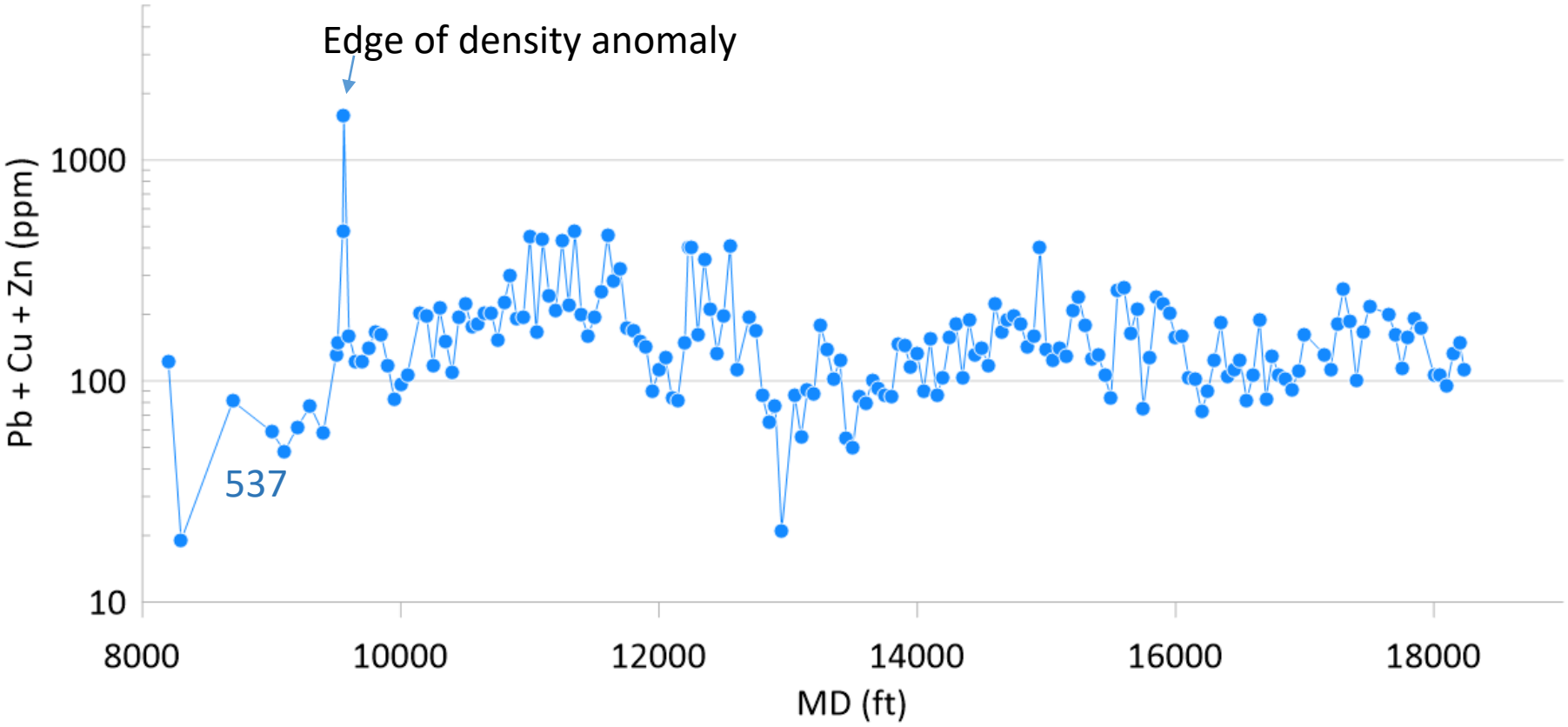
CC 537 Hereford





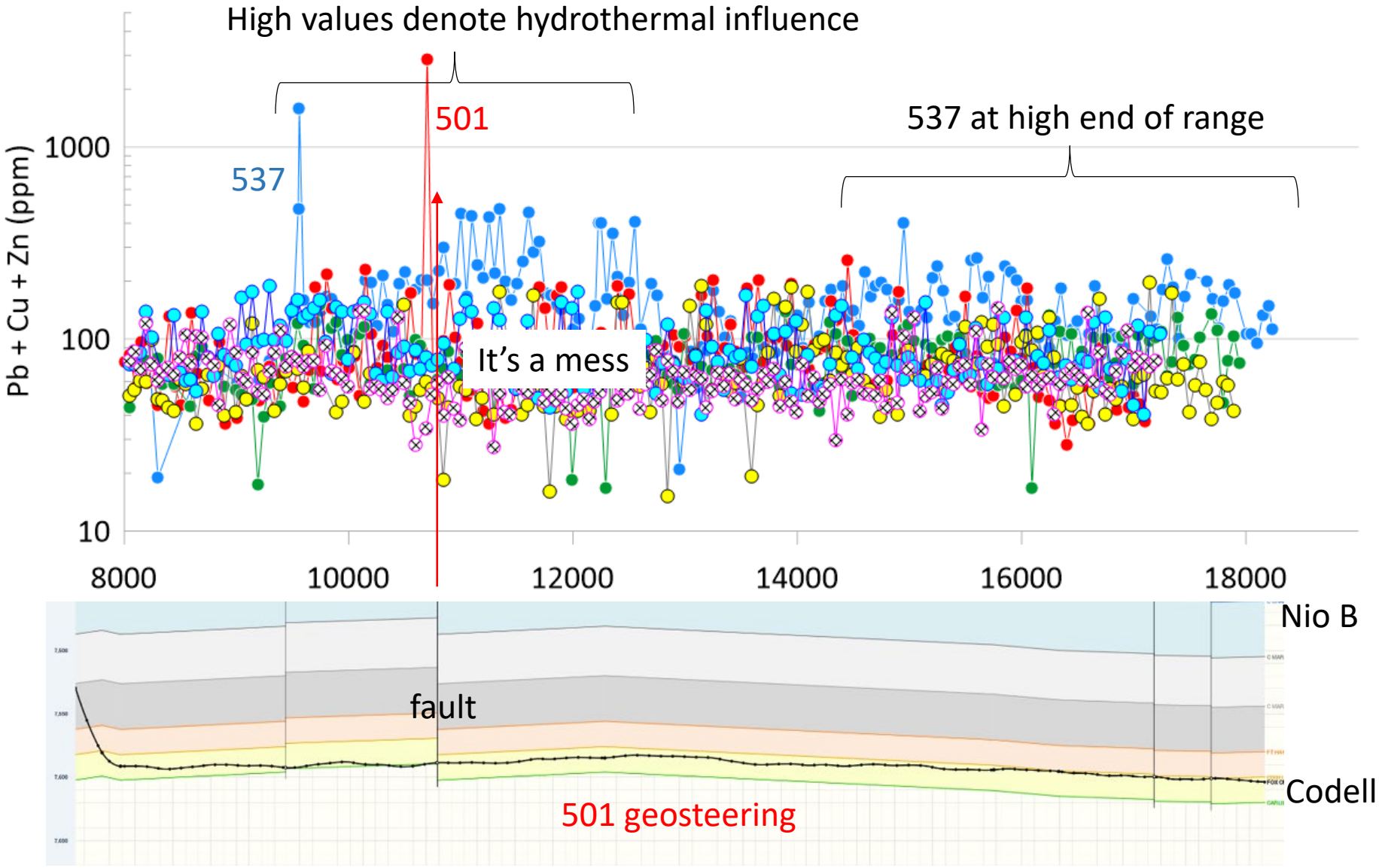
Paradis, Suzanne & Hannigan, Peter & Dewing, Keith. (2007). Mississippi Valley-type lead-zinc deposits (MVT). Mineral Deposits of Canada. 5.

Pb Zn and Cu in the CC 537

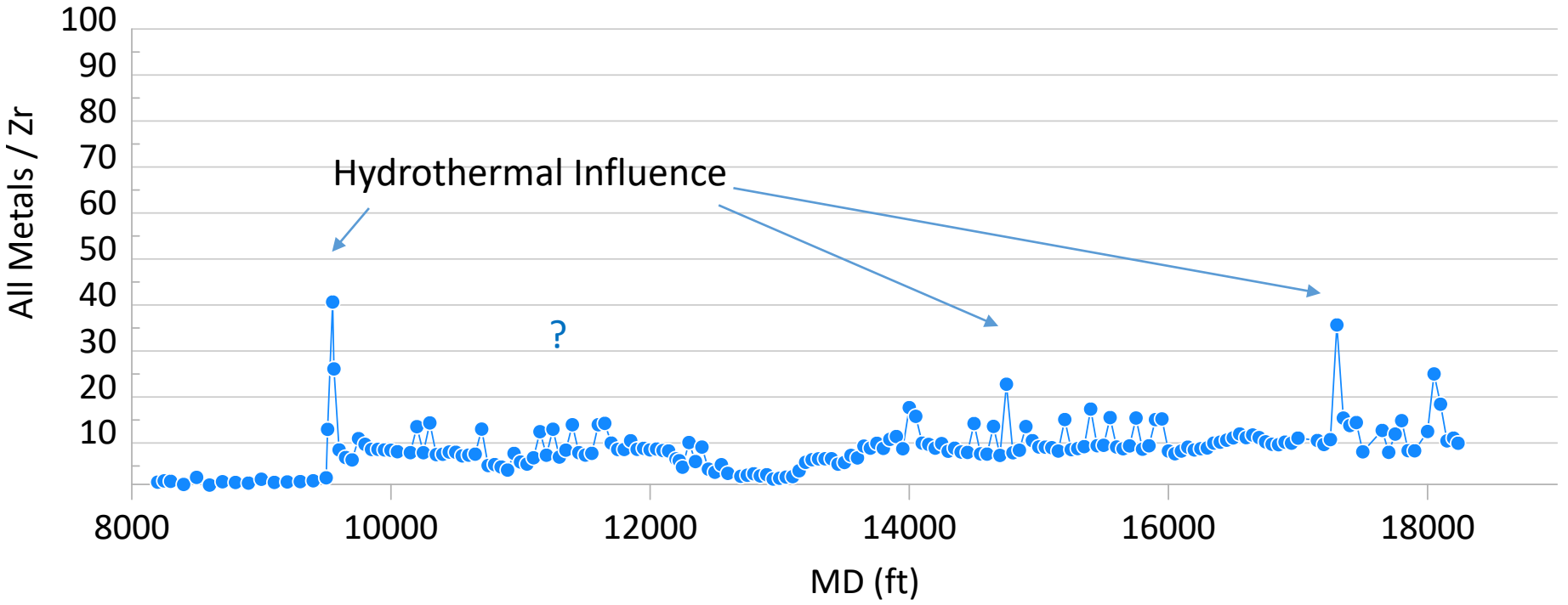


- Common mining sum (Pb+Cu+Zn) delineates edge of density anomaly

Pb Zn and Cu in other Hereford Wells

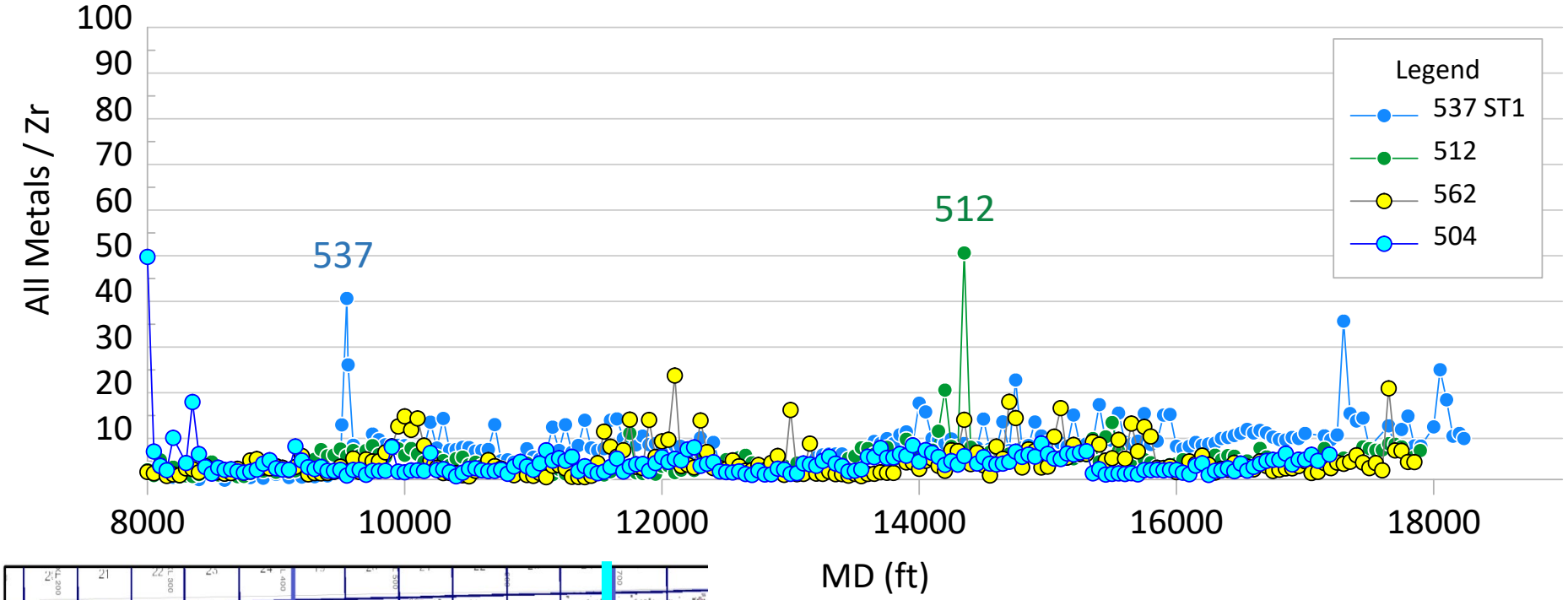


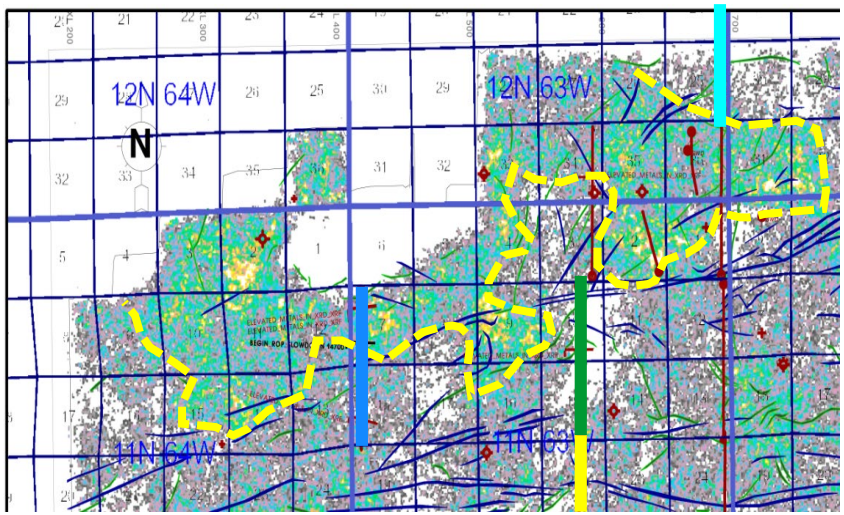
Normalized Metals in the 537



- Normalizing metals against Zr may remove stratigraphic variability
- Sum of all XRF analytes / Zr = a unitless value that accounts for variability of clastic input
- Zr is a conservative element, very difficult to chemically weather

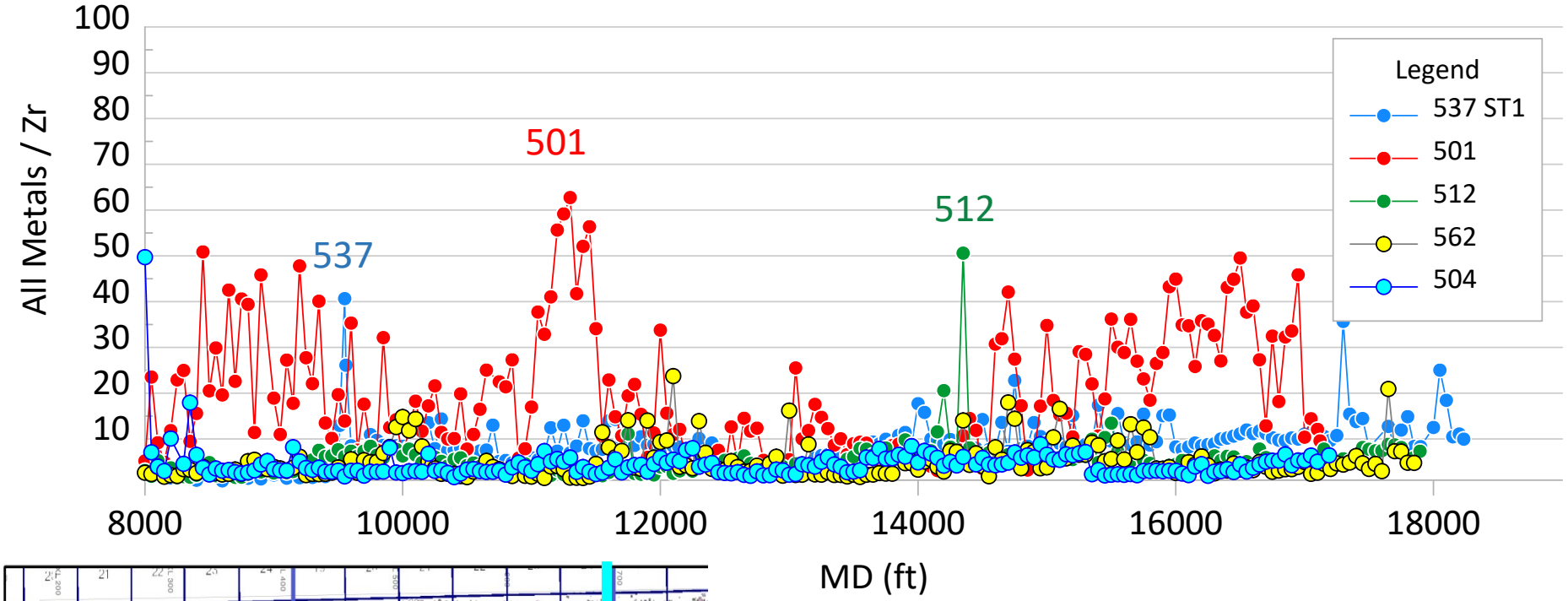
Normalized Metals in Other Codells

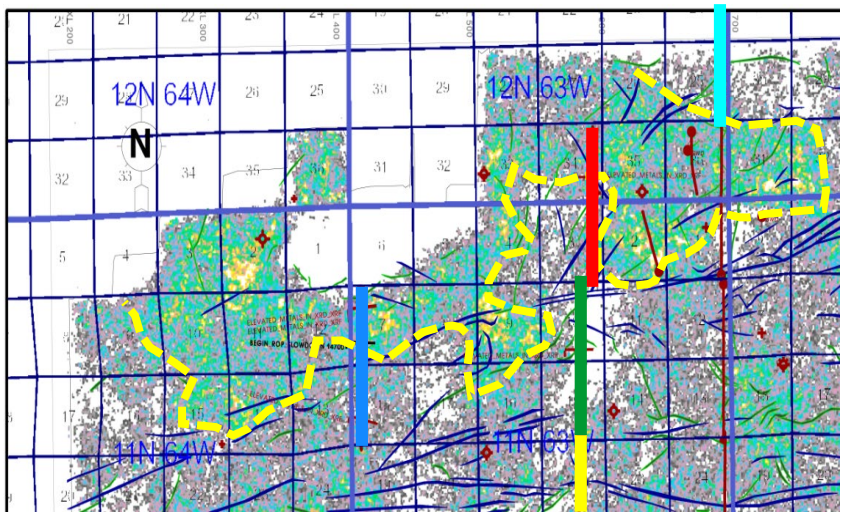




- Other wells (all in zone) set a baseline

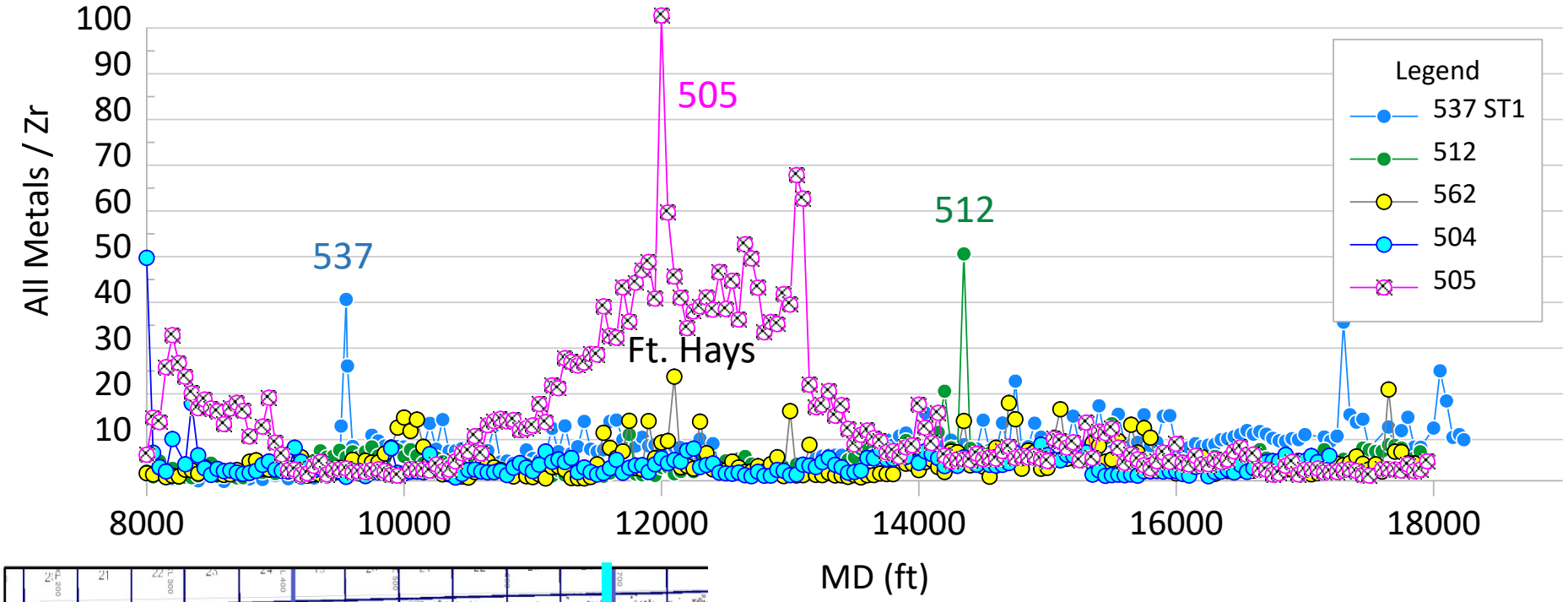
Normalized Metals in Other Codells

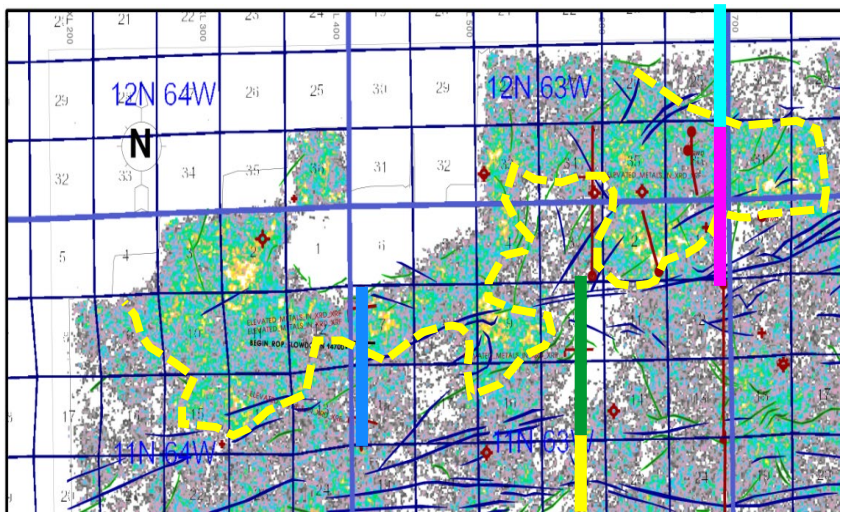




- 501 (red) has most exposure to density anomaly, and shows highest norm values

Normalized Metals in Other Codells

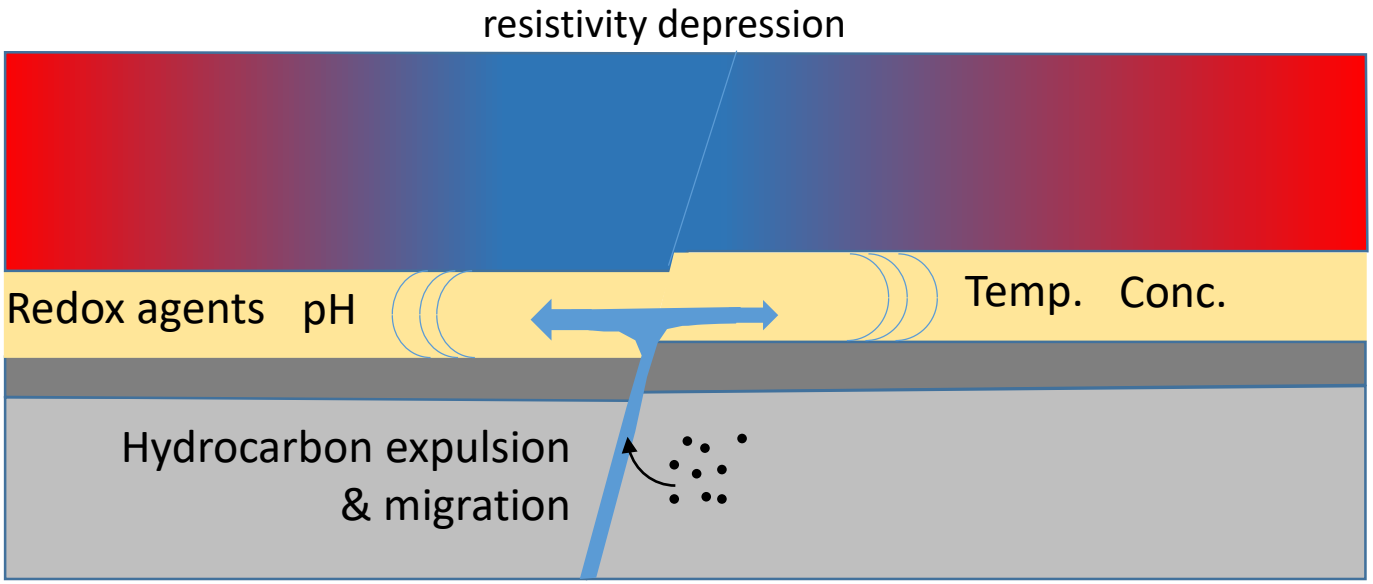




- 505 (magenta) shows the effect of carbonates on the normalized metals calculation

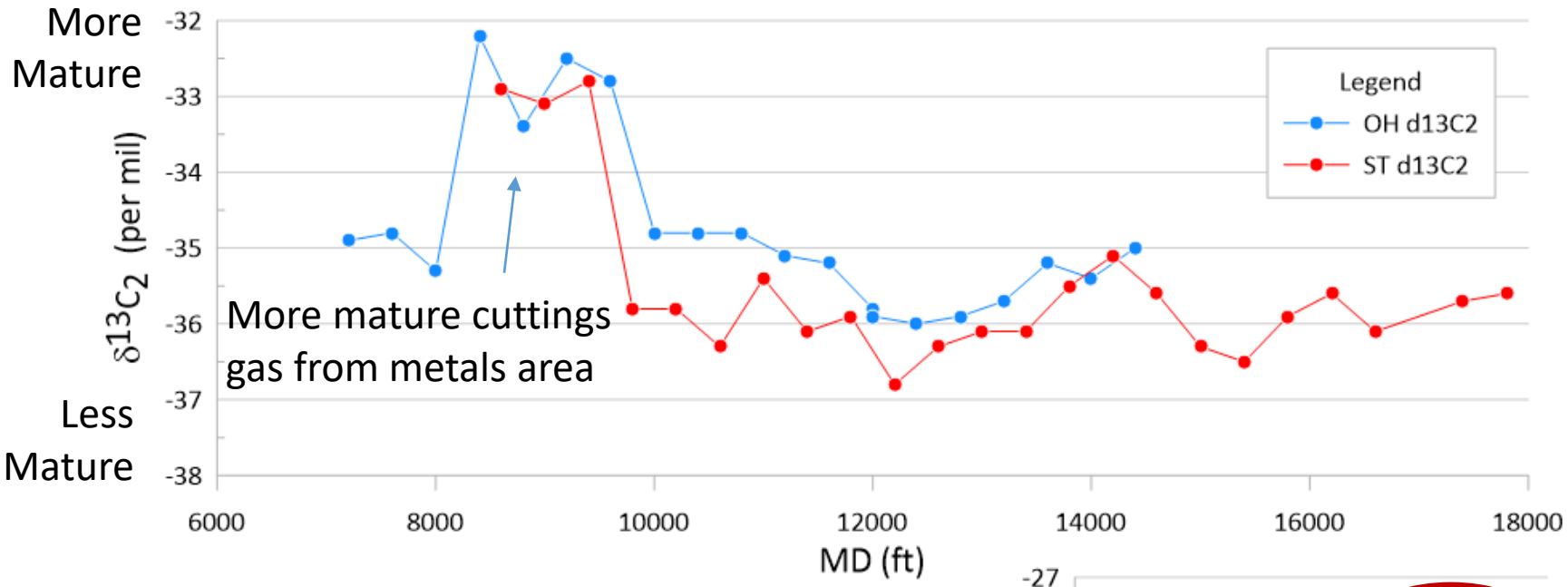
Proposed Model of Hydrothermal Process at Hereford

- Vertical movement of fluids along basement-involved faults
- Horizontal movement along high perm zones (Codell)
- Metals deposition at outer edge “roll front”
- Relative cooling of overlying zones

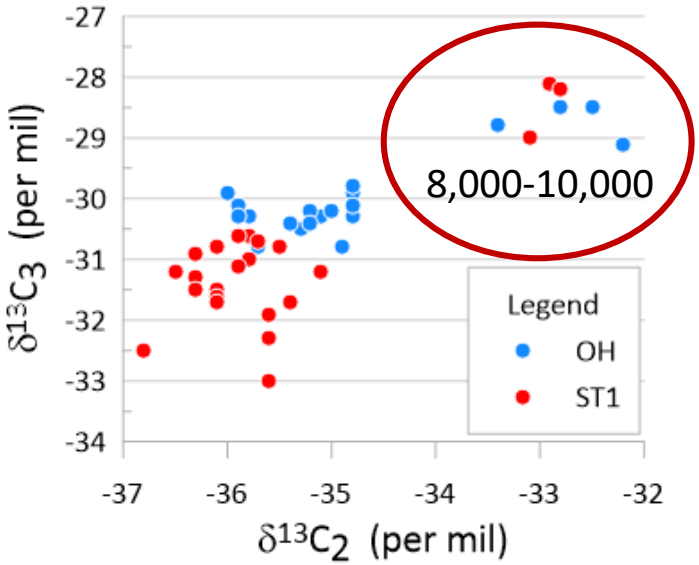


Basement-involved fault
Hydrothermal water, oil migration pathway

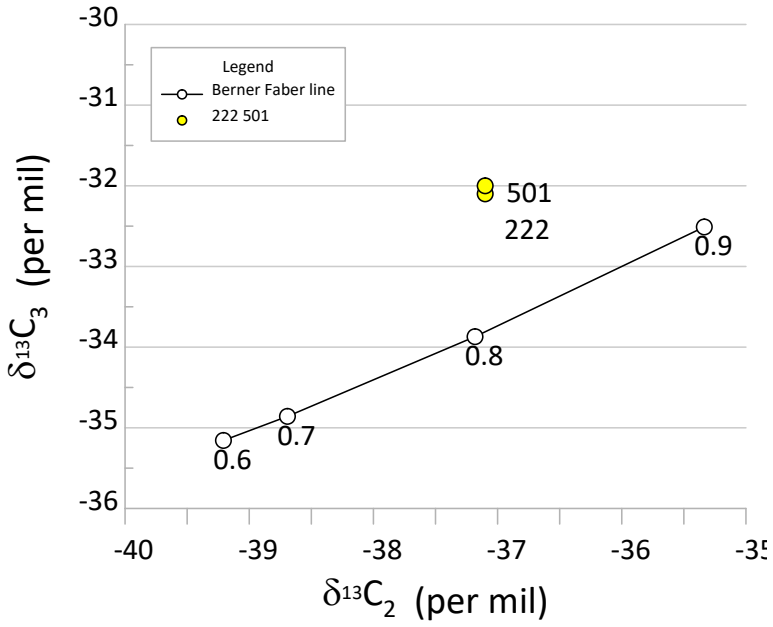
Cuttings Gas

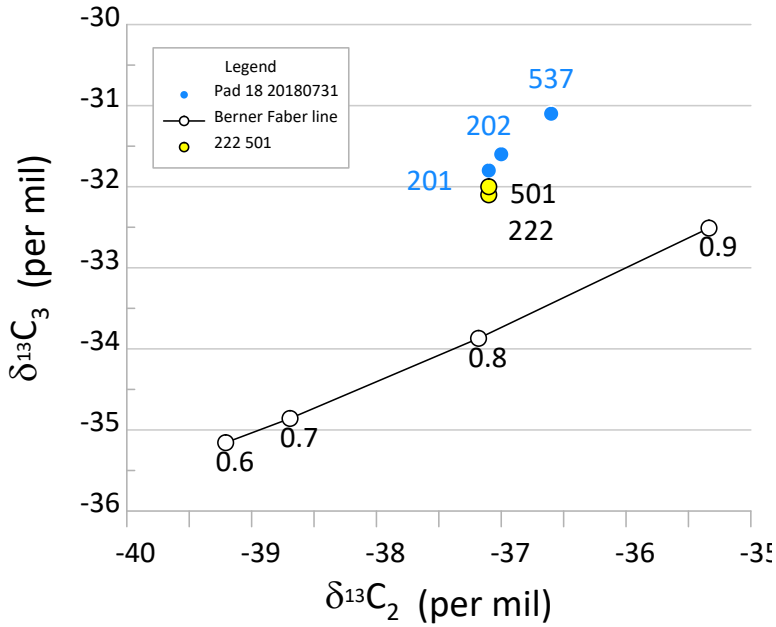


- Exsolved gas from cuttings
- Interpret that maturation follows structural/hydrothermal overprint



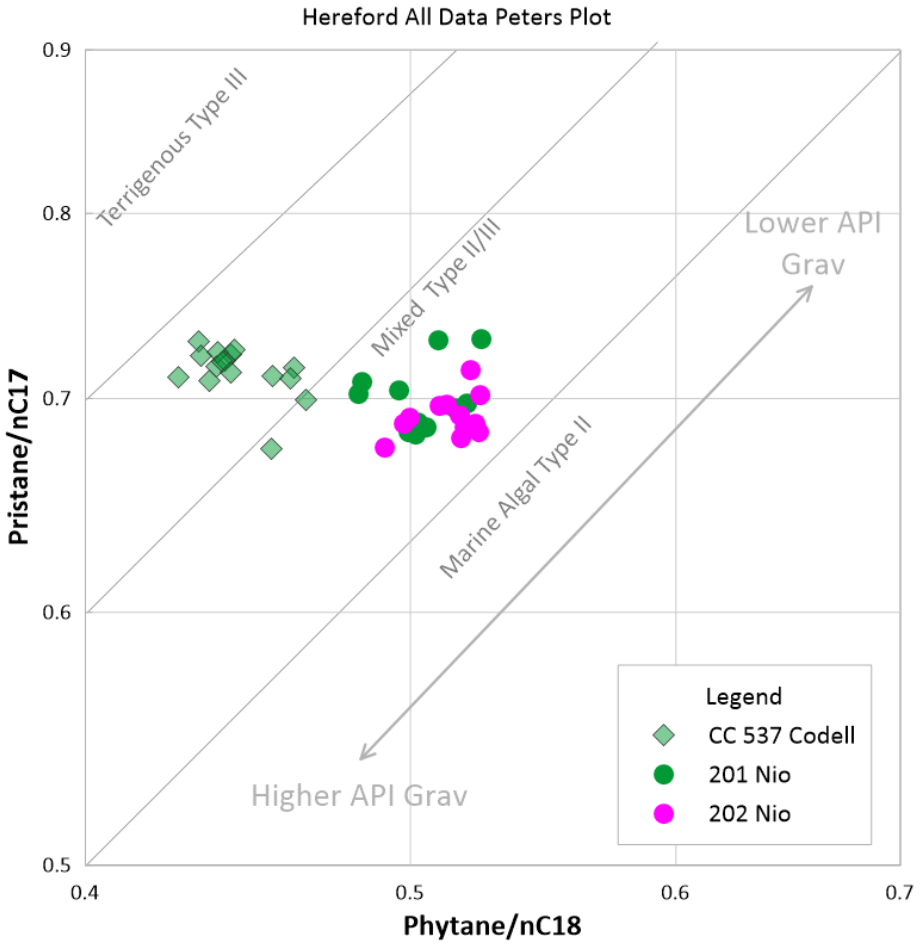
Produced Gases





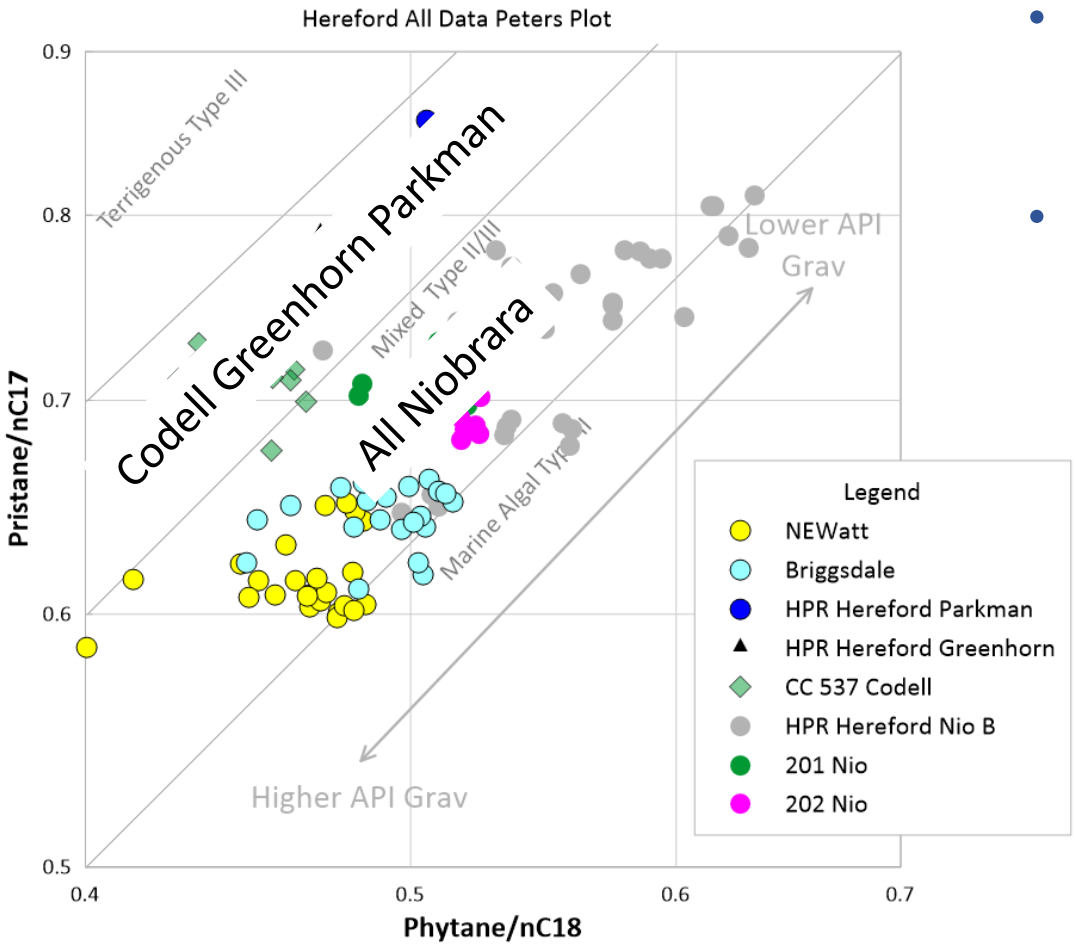
- Berner-Faber plot shows how tight Nio and Codell produced gases normally are (right)
- 201, 202, 537 show increased Codell maturity compared to others
- Is this migration from Greenhorn increasing 537 maturity? Or are Nio samples (201, 202) depressed from hydrothermal, as deep resistivity suggests?
- Choose an interpretation, and implications are important

Produced Oils



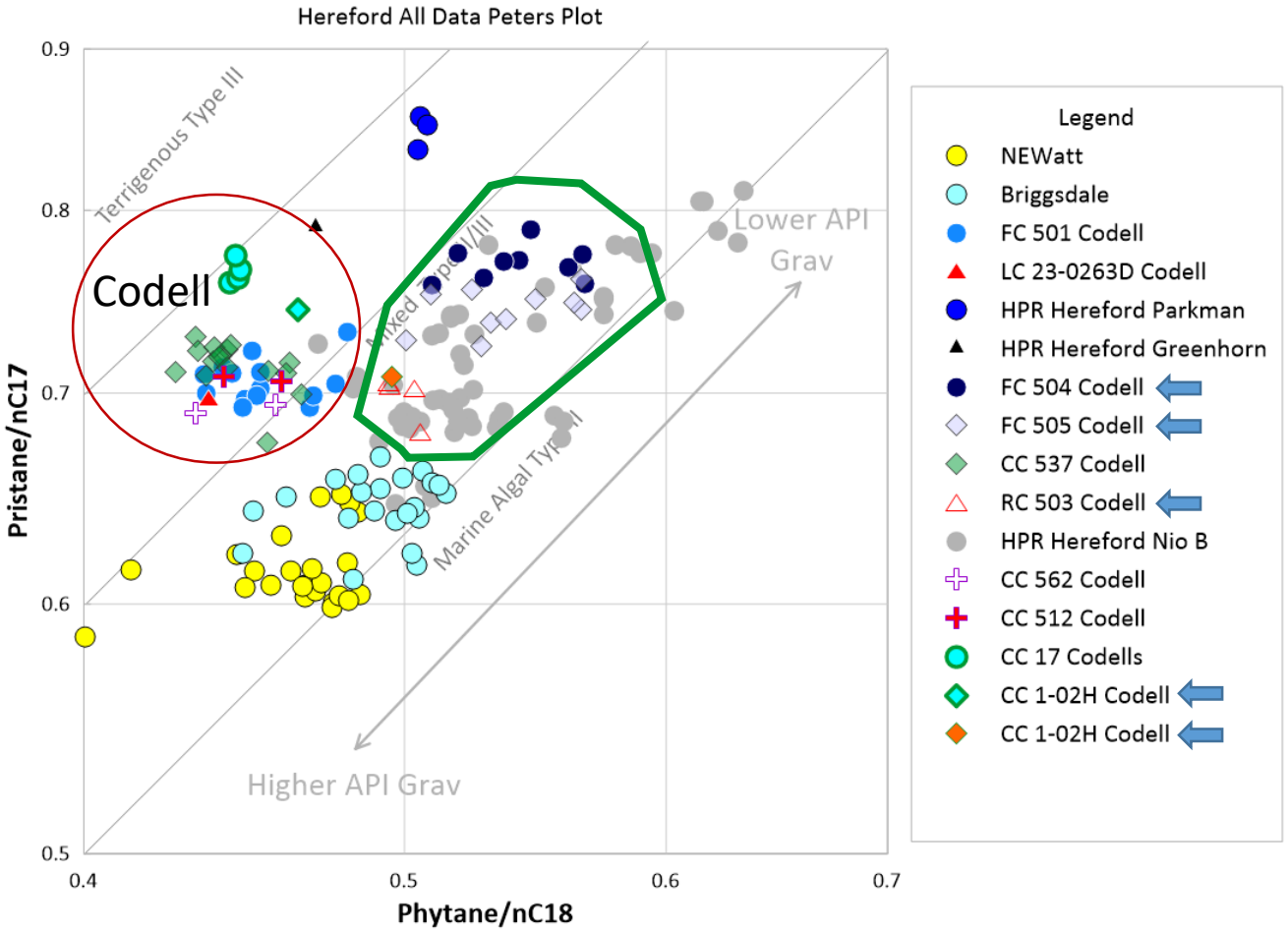
- Nio (201, 202) and Codell (537) oils plot separately
- Codell is at least partially sourced from somewhere else or Nio maturity is depressed as a result of hydrothermal processes

Produced Oils



- Nio oils from across the HPR asset base plot along the same diagonal
- Codell (537) plots on the same diagonal as Greenhorn and Parkman (!?!)
  - Parkman to Greenhorn fault transmissivity is backed up by extensive stable isotope analysis from produced waters

Produced Oils



- Codells in the "hydrothermal area" source from Greenhorn? (red circle)
- Codells in "core Hereford" source from Nio (green polygon)

Process Timing Comparison

- USGS Higley & Cox element timing chart vs Oligocene, Miocene hydrothermal timing

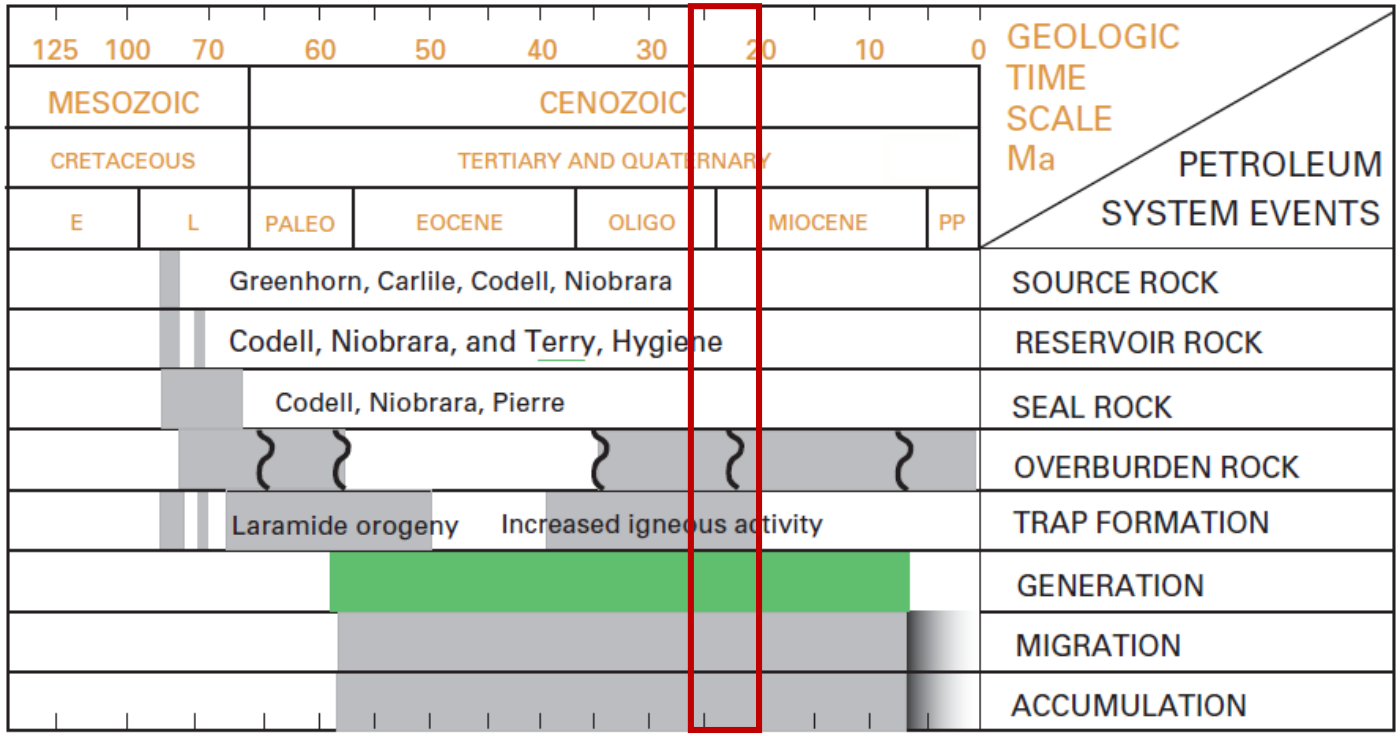
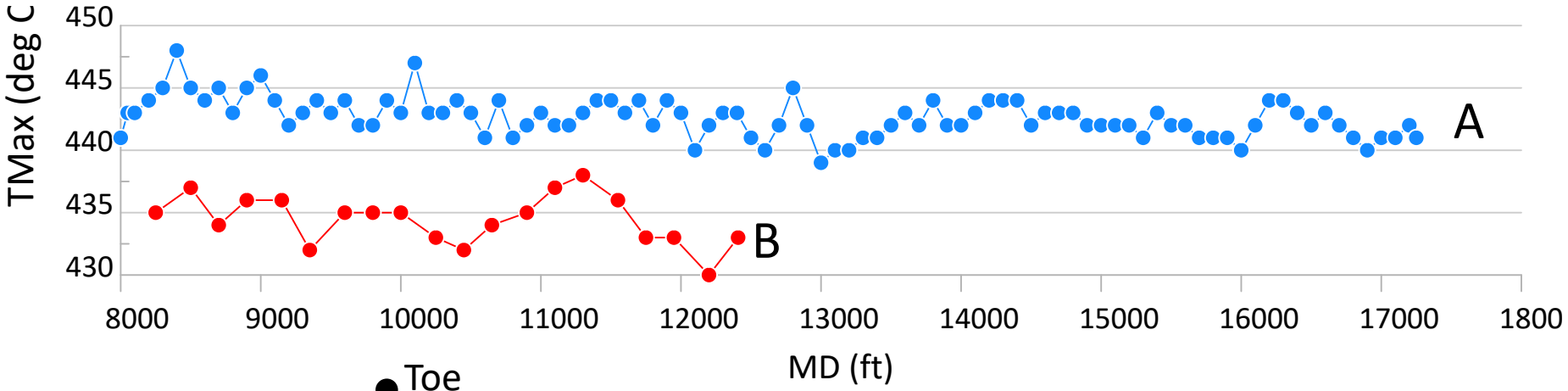
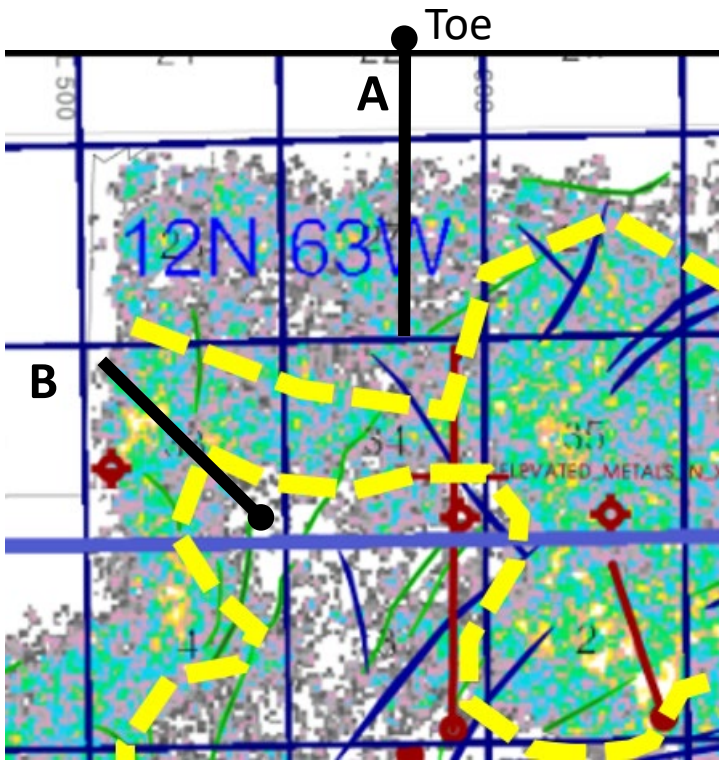


Fig 14 from Higley, D.K., Cox, D.O., 2007, Oil and gas exploration and development along the front range in the Denver Basin of Colorado, Nebraska, and Wyoming, in Higley, D.K., compiler, Petroleum systems and assessment of undiscovered oil and gas in the Denver Basin Province, Colorado, Kansas, Nebraska, South Dakota, and Wyoming—USGS Province 39: U.S. Geological Survey Digital Data Series DDS–69–P, ch. 2, 41 p.

Hydrothermal Temperatures & Maturation





- Hydrothermal system cooling effect on Niobrara
- Interpreted process behind the "Blob of Death"

Implications

- Metals deposition & calcite nodule emplacement
  - Changing the perm and porosity relationship
- 3D seismic structural analysis suggests fluid migration pathways
- Maturity retardation from cooling effect
- Epigenetic timing is critical to preservation or destruction of petroleum system
- Codell oil sourcing may be related to vertical perm pathways used by hydrothermal systems
  - Monetizing the sourcing difference

Summary

- Cuttings analysis shows elevated metals concentrations at bounds of Codell 3D seismic density anomaly
- Area of depressed Nio resistivity roughly matches area of Codell density anomaly
- Known processes of MVT metals deposition involve petroleum system processes:
  - Hydrothermal source water
  - Sulfur redox
  - Pressure, pH, and concentration changes
- Oil data suggest Codell exhibits variable sourcing
- Hydrothermal processes do not kill the petroleum system at Hereford, they are part of it!

Acknowledgements & Thank You

- This work is part of a team effort from 2017 to the present
- Tanya Inks (Geophysics)
- Aryn Rowe (Geology)
- Bryan Brown (Operations)
- Cuttings analyses by RESERVOIR GROUP
- Gas, oil analyses by dig Geochemistry for Energy
- Benefited from discussions with Terry Barrett, Steen Jurgenson, and Anna Wilson
- Figs made with Golden Software Grapher 16