Core to Local Scale Assessment of REE and Critical Minerals in Sedimentary Rocks from the Powder River Basin

Scott N. Montross

Research Geologist

Geological Society of America Connects 2023

Oct. 18, 2023

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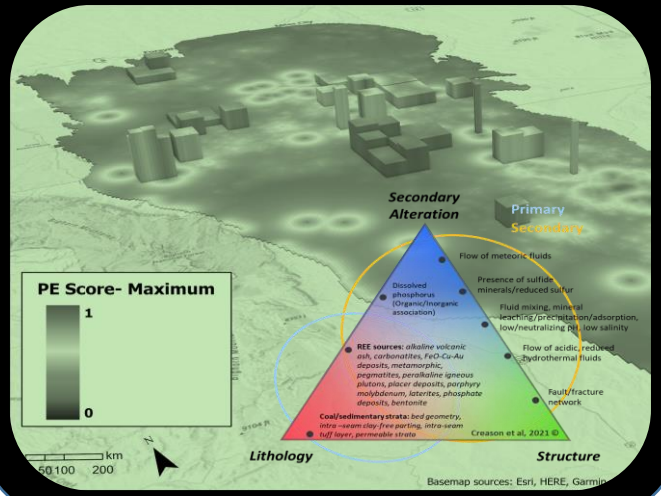
Authors

Scott Montross[1,2]; Sophia O'Barr[1,2]; Grant Hazle[3]; Sebastian Skipwith[3]; Christopher Creason[1]; Burt R. Thomas[1]; Kelly Rose[1]

[1] National Energy Technology Laboratory, 1450 Queen Avenue SW, Albany, OR 97321, USA
[2]NETL Support Contractor, 1450 Queen Avenue SW, Albany, OR 97321, USA
[3]Ramaco Carbon Resources, 74 Kleenburn Road, Ranchester, WY 82839, USA

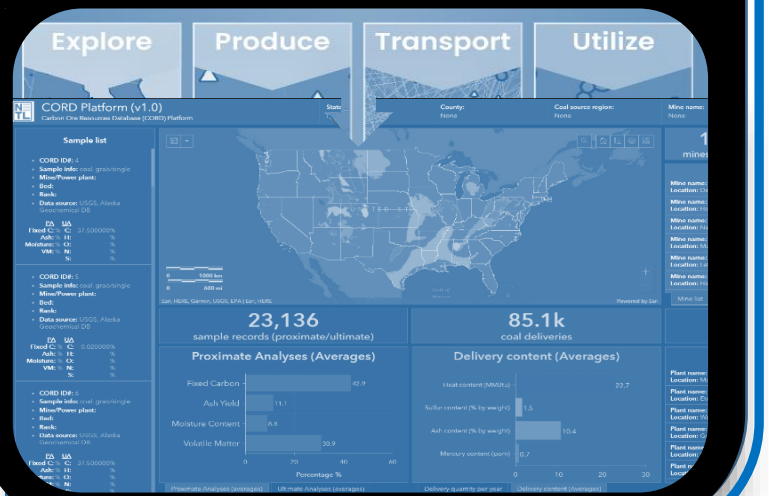
NETL REE/CM Geo-data Science Research and Development

Unconventional REE/CM Resource Assessment



Systematic Methods & Data to Constrain REE/CM

Data & Digitalization for REE-CM Supply Chain & Waste Beneficiation



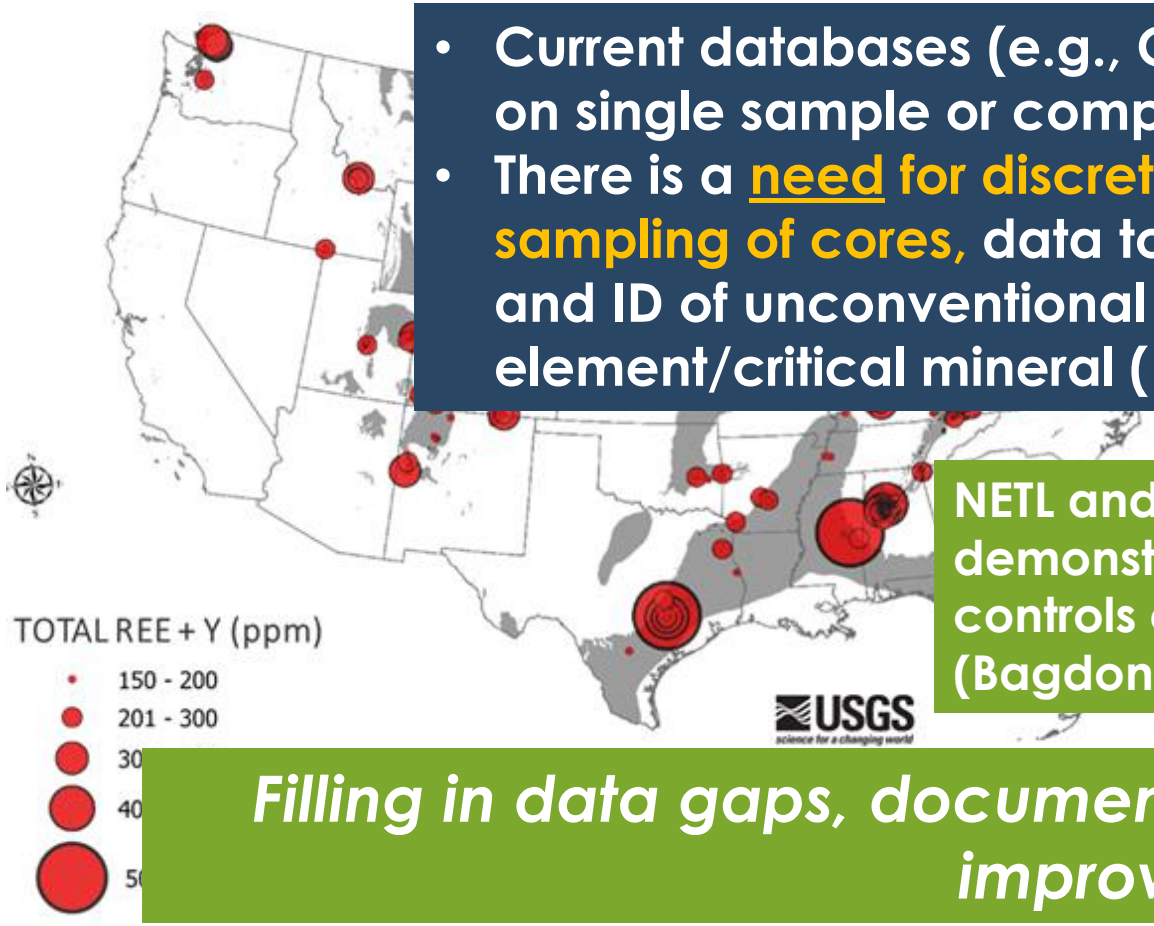
[A Multi-scale, Geo-Data Science Method For Assessing Unconventional CM Resources](), Session T9. Wednesday, 18 October 2023, 2:20pm

[EDX ClaiMM: A Virtual Common Operating Platform and Interactive Tools Supporting Critical Minerals Resource Development](), Session T7. Tuesday, 17 October 2023, 8:35am

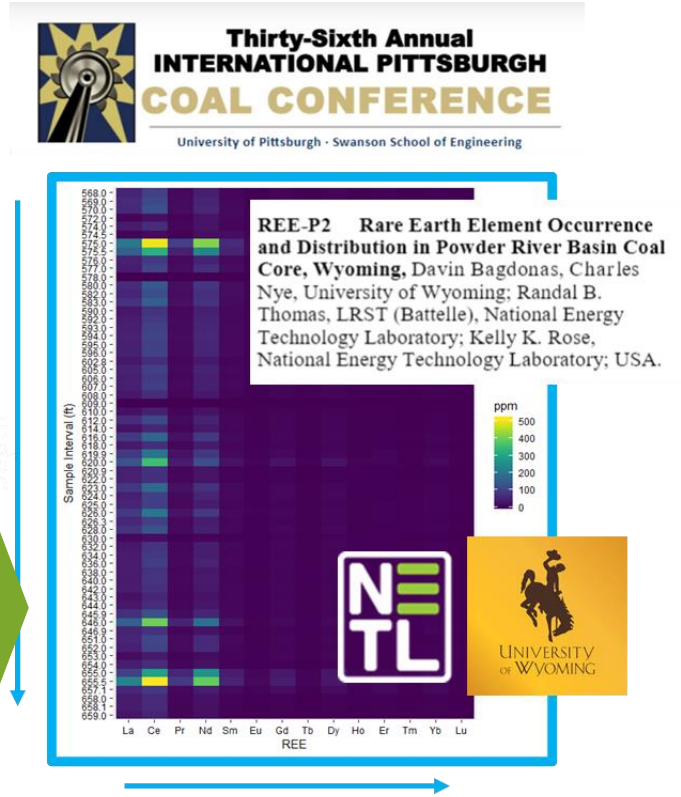
Data Scarcity and Lack of Systematic Data Collection Methods for REE/CM Evaluation

REE Data for Domestic Deposits

- Current databases (e.g., CoalQual) are based on single sample or composite measurements
- There is a need for discrete, finer-scale sampling of cores, data to improve prospecting and ID of unconventional ore quality rare earth element/critical mineral (REE/CM) deposits



NETL and U of Wyoming study demonstrated vertical, lithologic controls on REE/CM occurrence (Bagdonas et al., 2019)



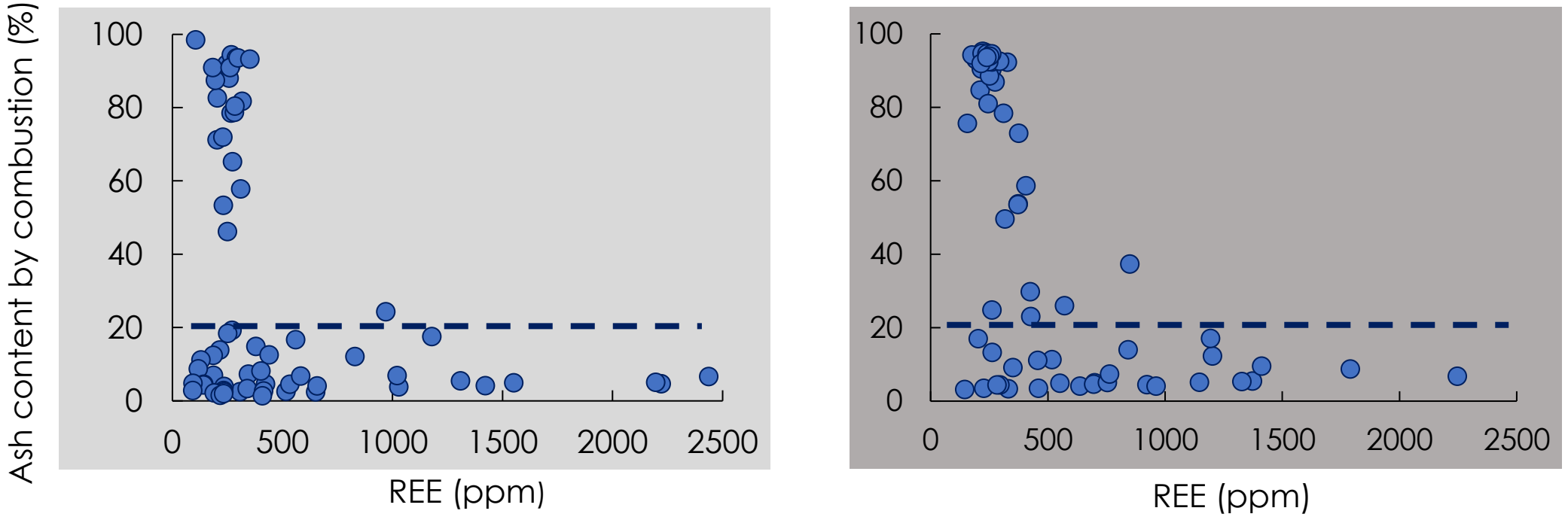
Filling in data gaps, documenting high-concentration deposits, and improving predictions

Bagdonas, D., Nye, C., Thomas, R., and Rose, K., 2019, Rare Earth Element Occurrence and Distribution in Powder River Basin Coal Core, Wyoming, 2019 Thirty Sixth Proceedings of the International Pittsburgh Coal Conference, September 3 - 6, 2019, 13 pgs.

REE in Powder River Basin Rock

Brook Mine, Sheridan Wyoming

Brook Mine Cores (2019 and 2021)

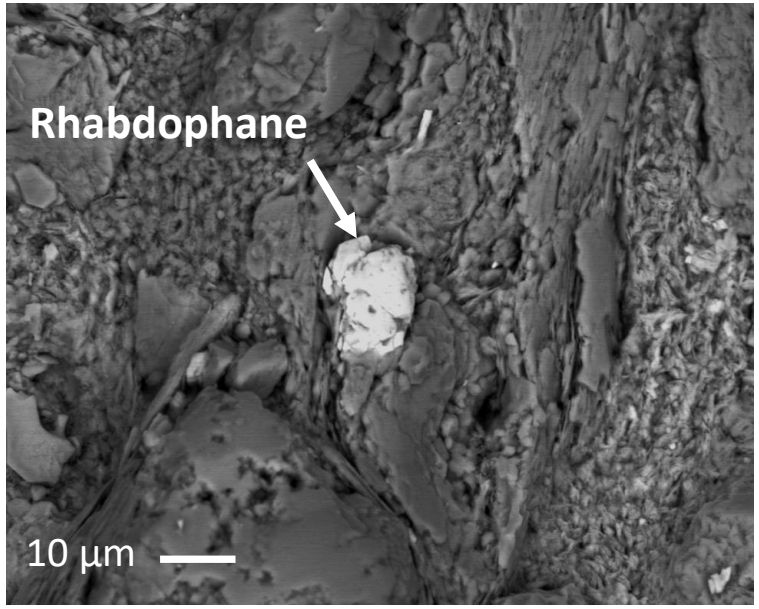


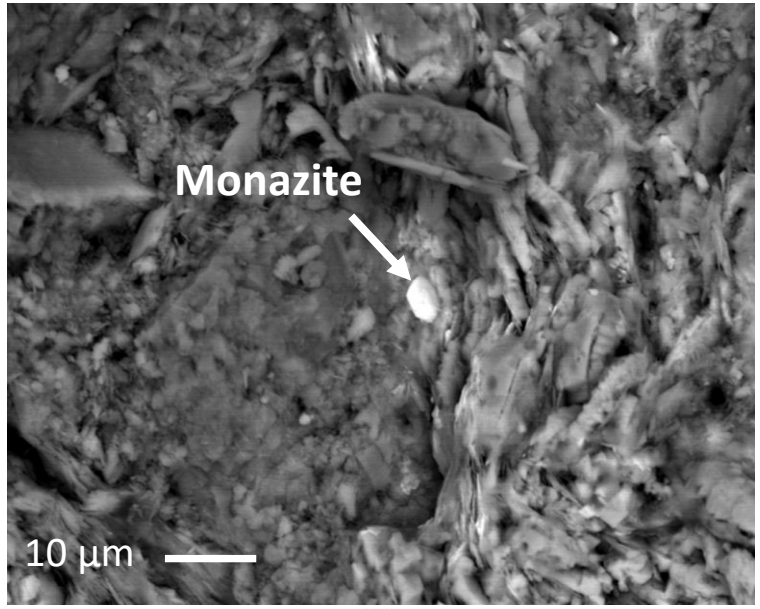
Trend of high REE in carbon ore compared to other lithotypes (e.g., clay or sandstone)

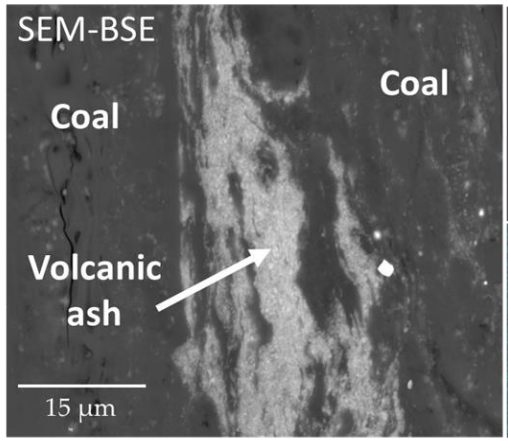
Microanalysis of Coal Bearing Minerals

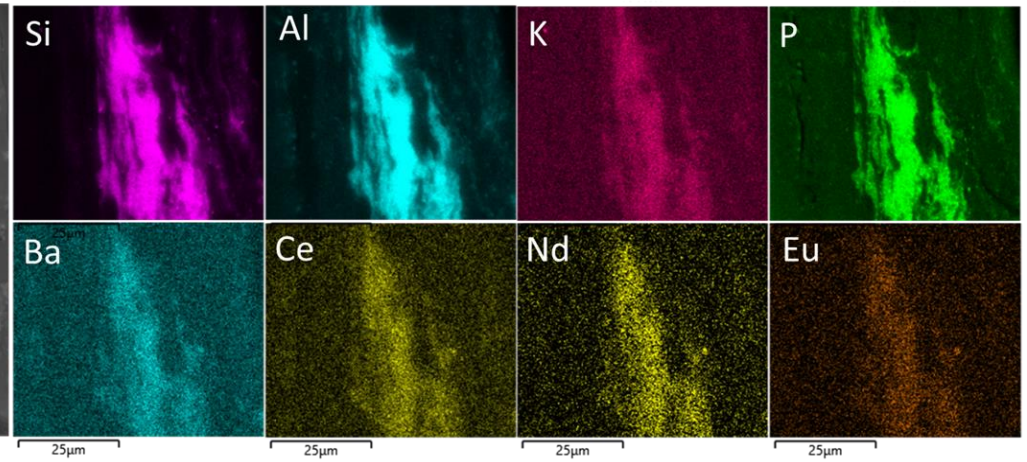
Core Chip or Thin Section Analysis

- Collected single field or large area images and element maps
- Presence and distribution of mineral phases
- Evidence of diagenesis or mineralization (e.g., pyritic zones or large grains of zircon, monazite, xenotime)





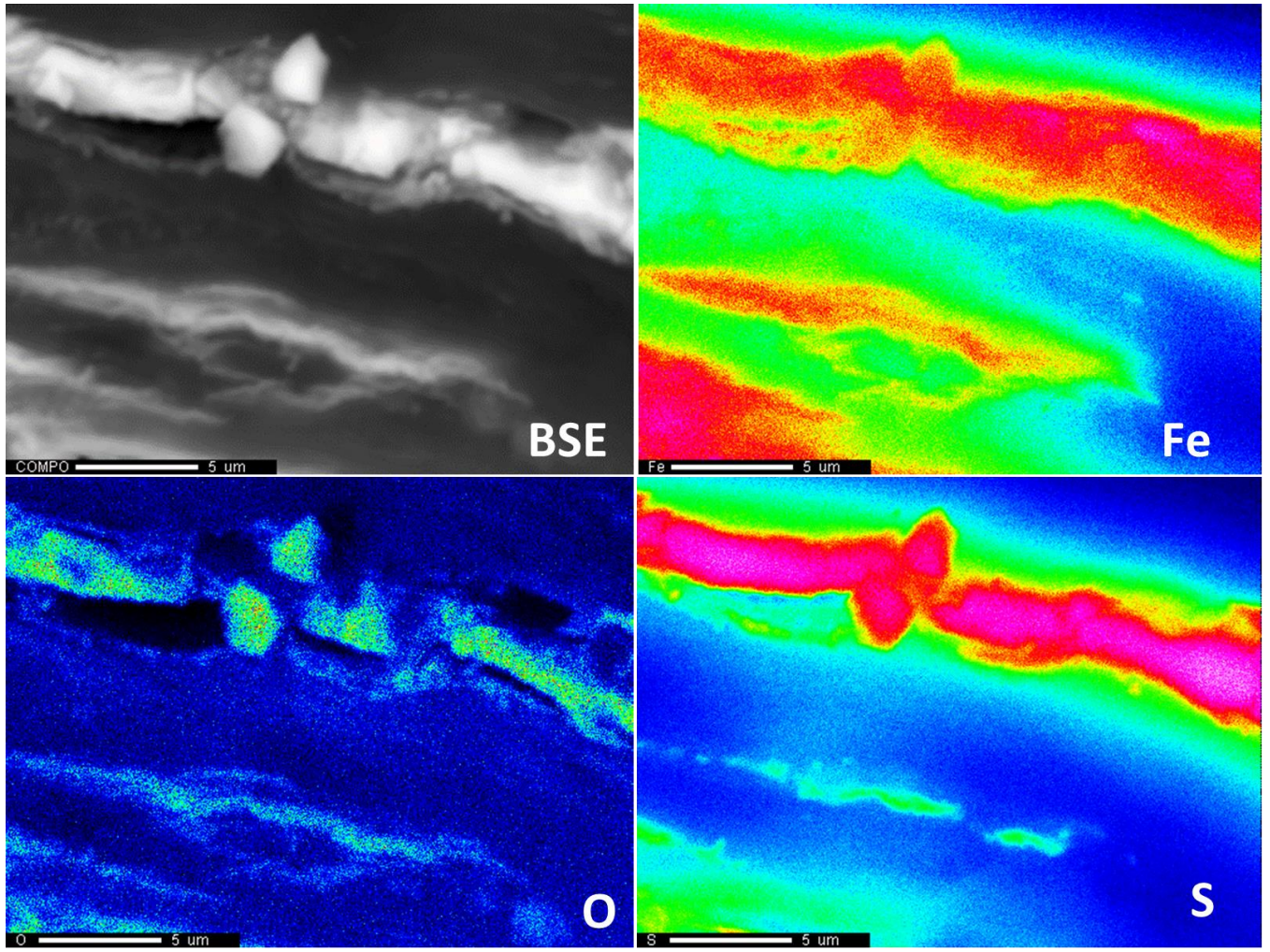




Microscopy and Microanalysis of Coal Bearing Minerals

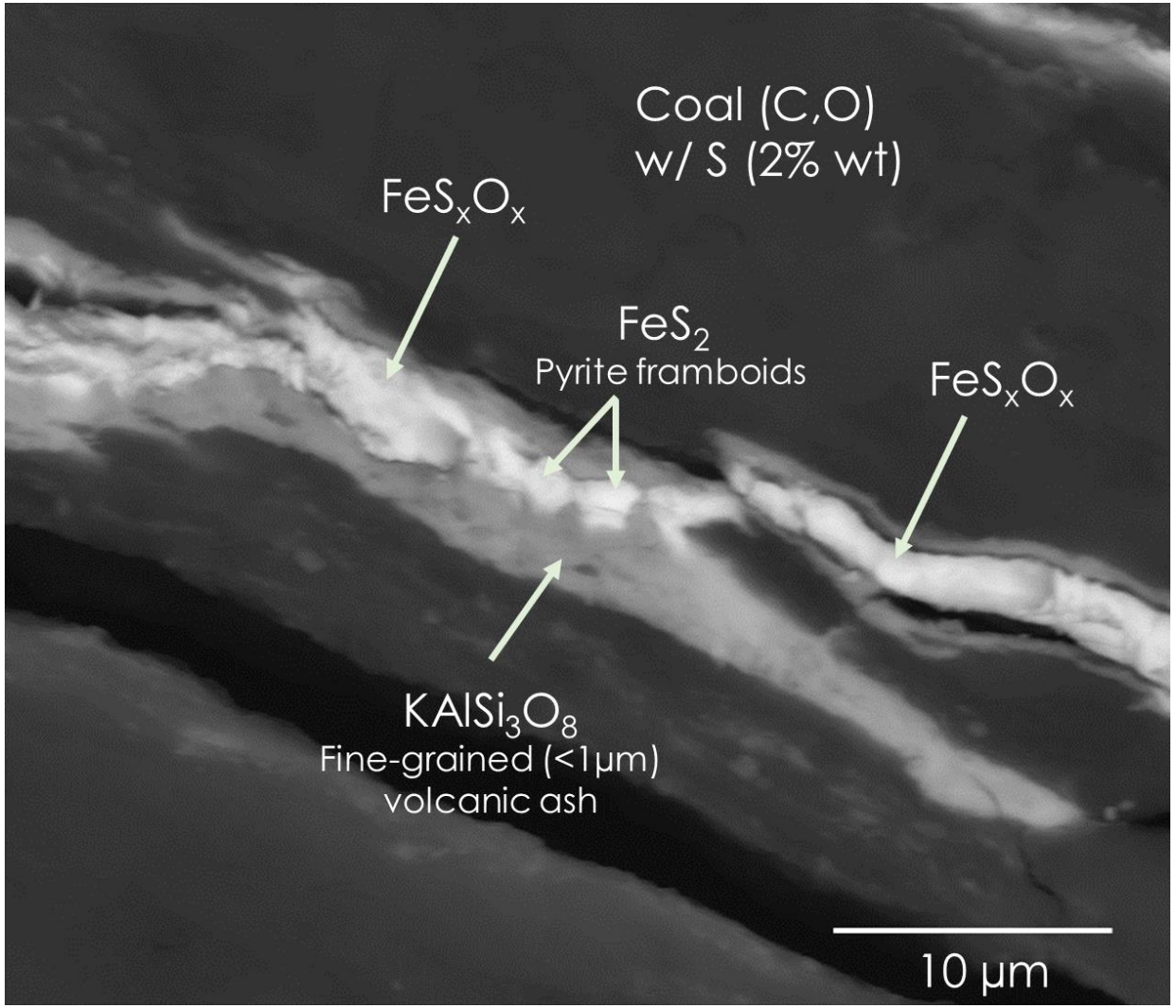
Fe Mineral Phases

- Dissolution of volcanic ash grains and oxygen replacement in Fe-sulfide minerals present in coal
- Due to introduction of oxygenated epithermal water into fractures and pore spaces within parent material



Microscopy and Microanalysis

Fe-S-O Mineral Assemblage

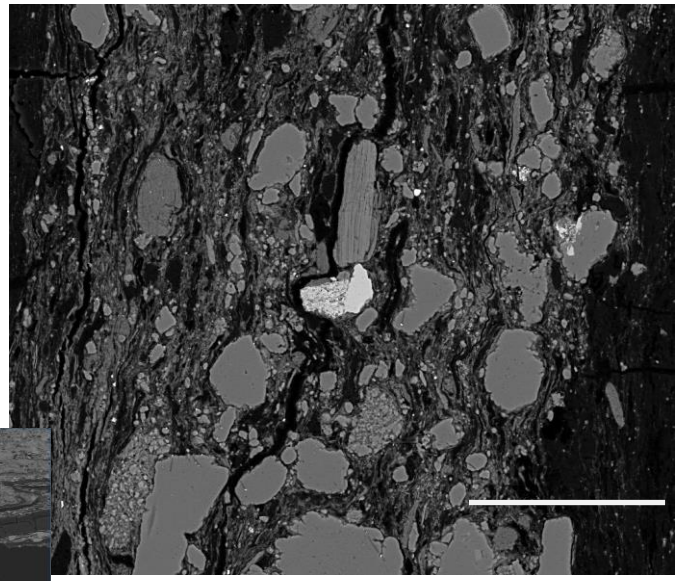


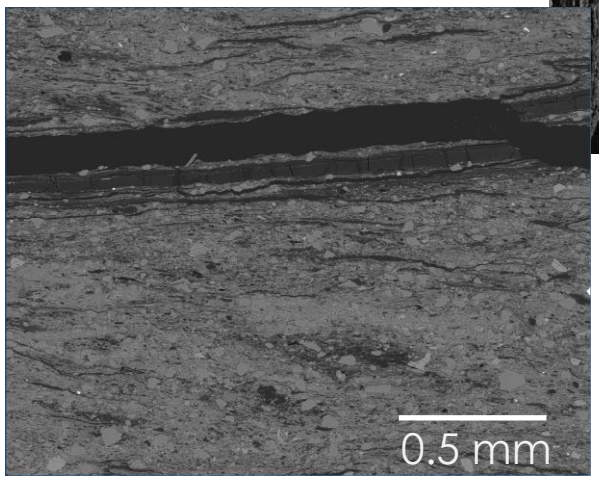
- Changes in mineral phases present due to dissolution and replacement
- Sulfide oxidation via oxygenated water
- Acidity generated by pyrite oxidation leads to:
  - Weathering of mineral phases and mobilization of REE
  - Dissolution and breakdown of coal matrix

Evidence for Mobilization and Fractionation of REE at Coal-Clay Boundary

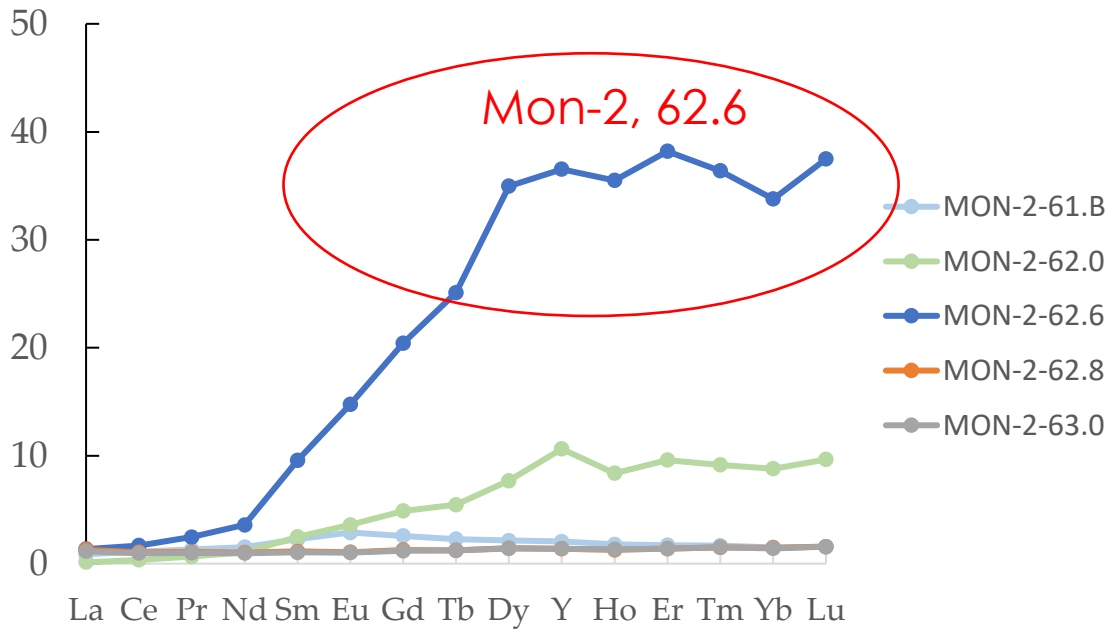
Mon-2, 62.6, ΣREE=1551 ppm; Ash = 4.9%; Coutl = 4.8; Heavy Rare Earth Element Ore

Base of coal and lower clay





Monazite, xenotime (REE-PO_4)
Quartz, kaolinite, pyrite, Ti, and FeO, zircon Clay matrix kaolinite and illite

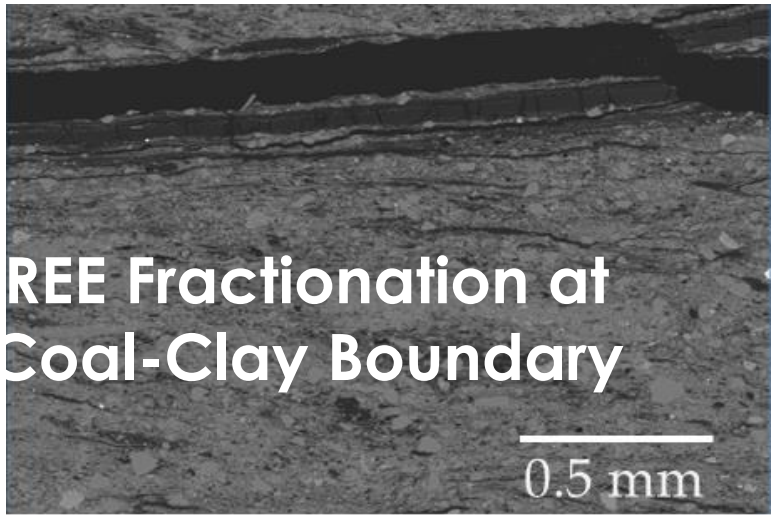


- No Eu anomalies in zone (61.8-63.0')
- H-type ore, highly enriched in HREE

Evidence for Mobilization and Fractionation of REE at Coal-Clay Boundary

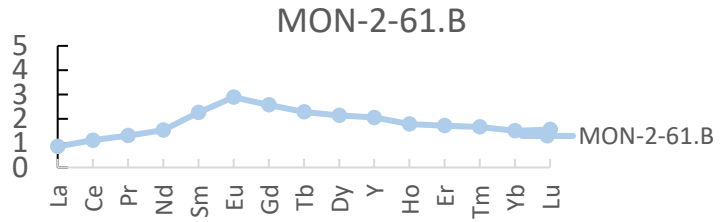
REE Type at Lithologic Boundary

Coal above (62.8), low ash 4%, M/HREE enrichment at 62.6, 4.9% ash, high outlook coefficient (Coutl)

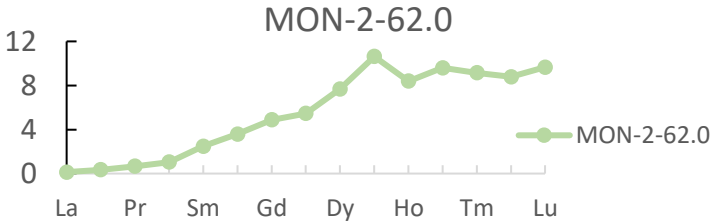


Clay layer below (62.8), high ash % (87%), UCC like, low C_{outl} and REE rel def.

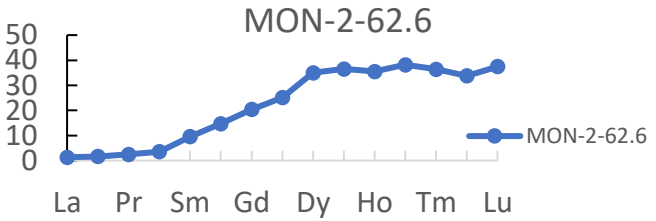
REE = 232 ppm
Ash = 1.92
Coutl = 1.2, REE rel def = 43



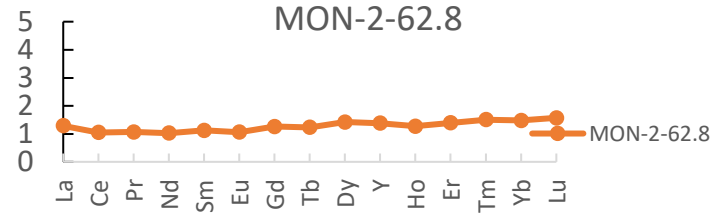
REE = 409 ppm
Ash = 1.36
Coutl = 5.8, REE rel def = 77



REE = 1551 ppm
Ash = 4.92
Coutl = 4.8, REE rel def = 73

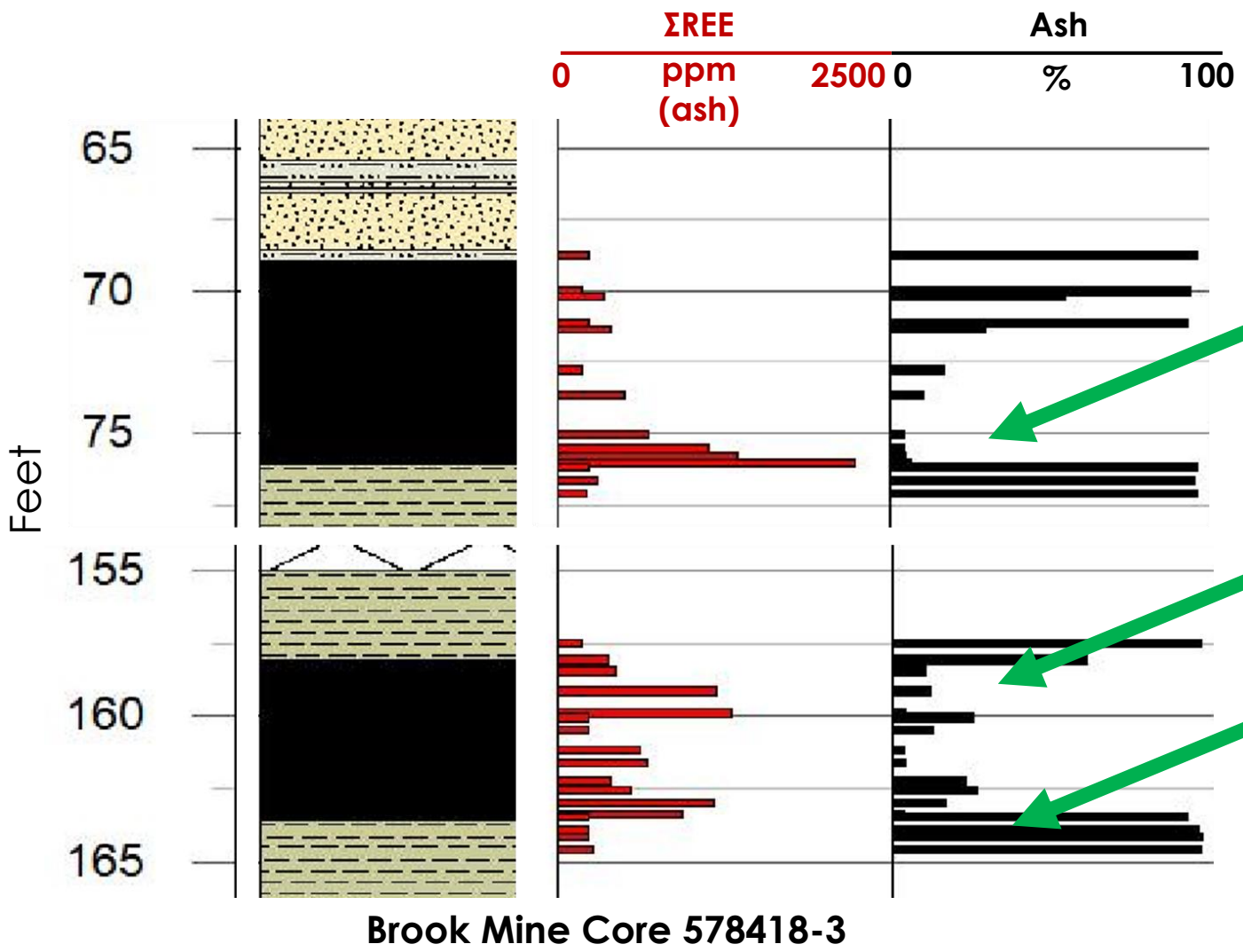


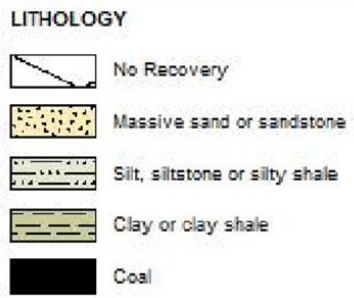
REE = 196 ppm
Ash = 87.4
Coutl = 0.9, REE rel def = 34



Enrichment by Deposition or Mobilization

Intraseam Variation





Brook Mine Core 578418-3

Enrichment up to 2500 ppm, HREE type at base of ~7 ft seam

Enrichment up to 1500 ppm, HREE type at top and base of ~5 ft seam

Provided key data on vertical distribution of REE (both concentration and type)

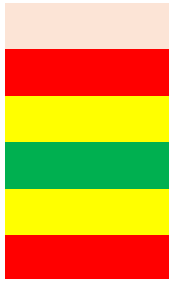
Optimization of Method for Core Scanning

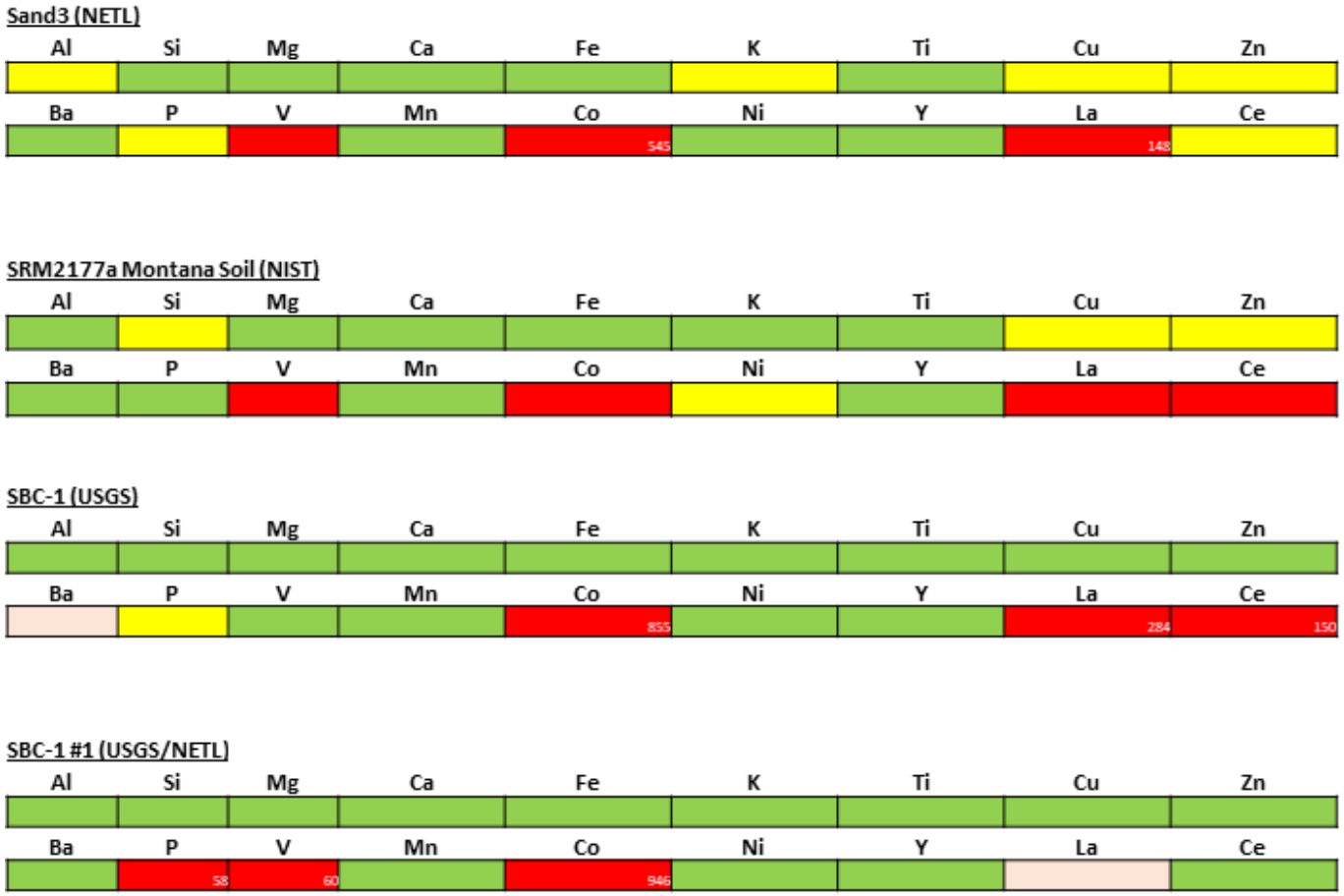
pXRF Data Optimization

- pXRF calibrated for REE (Ce, La, Nd, and Y) and major and trace elements using standard reference materials
- Experiments to optimize beam time, X-ray voltage, and spot location
- Identified confidence level for element analysis in different matrices

KEY

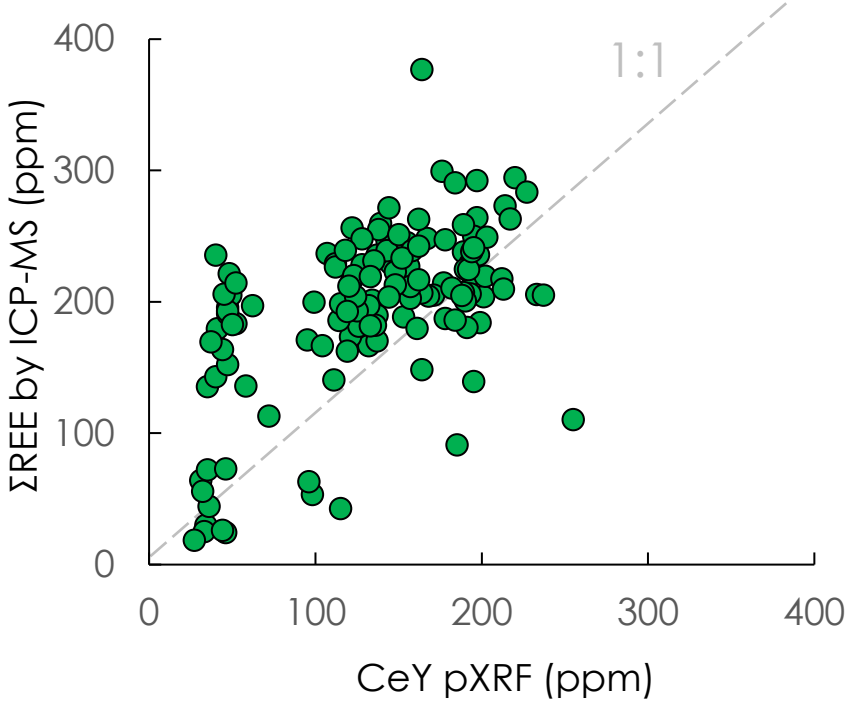
Below Detection Levels
TOO LOW
LOW, close to acceptable: 60%-80%
Acceptable range: 80%-120%
HIGH, close to acceptable: 120%-140%
TOO HIGH

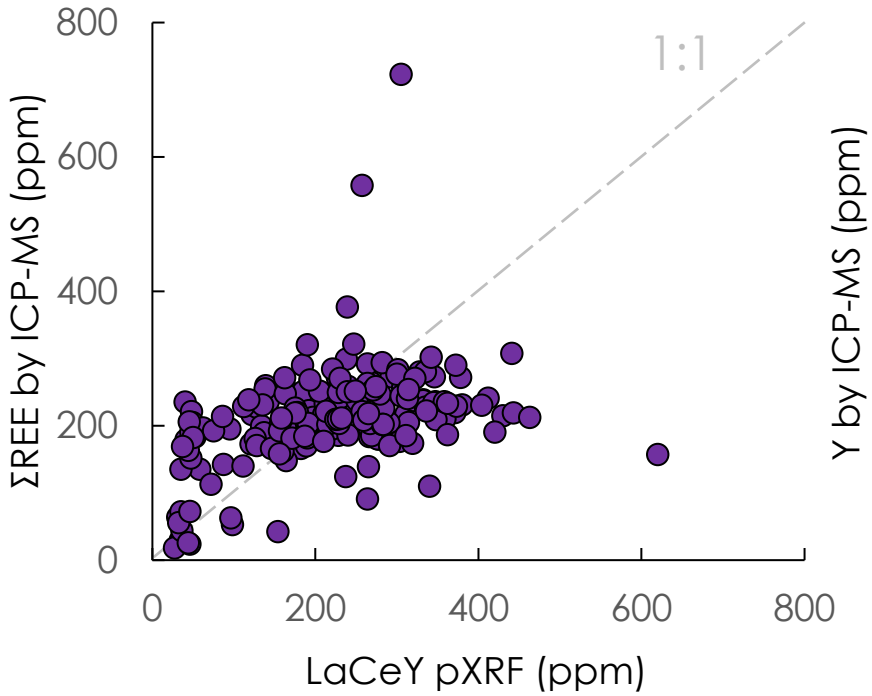


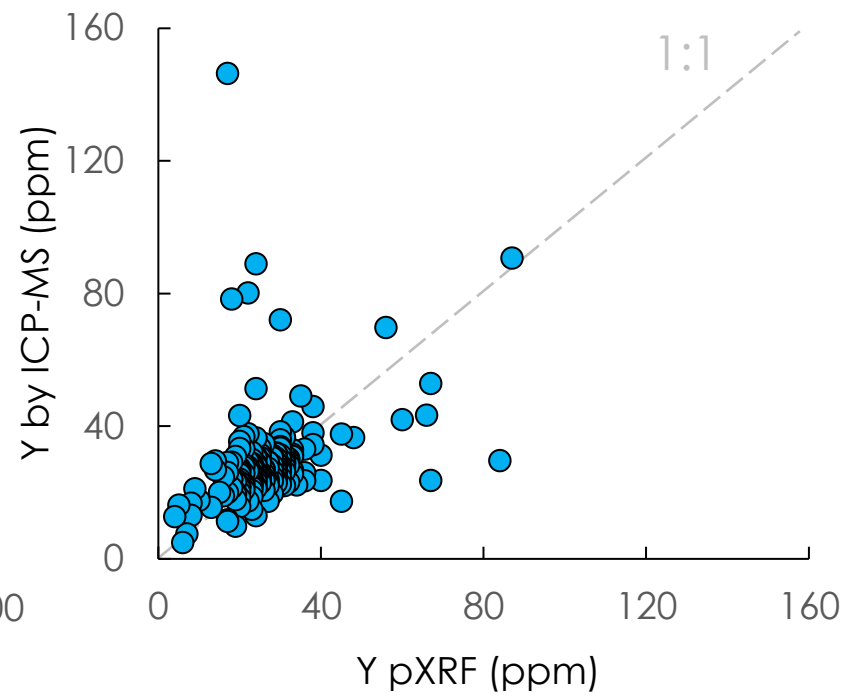


Correlations between ICP-MS and pXRF

LaCeY by pXRF and ΣREE by ICP-MS from Core Samples





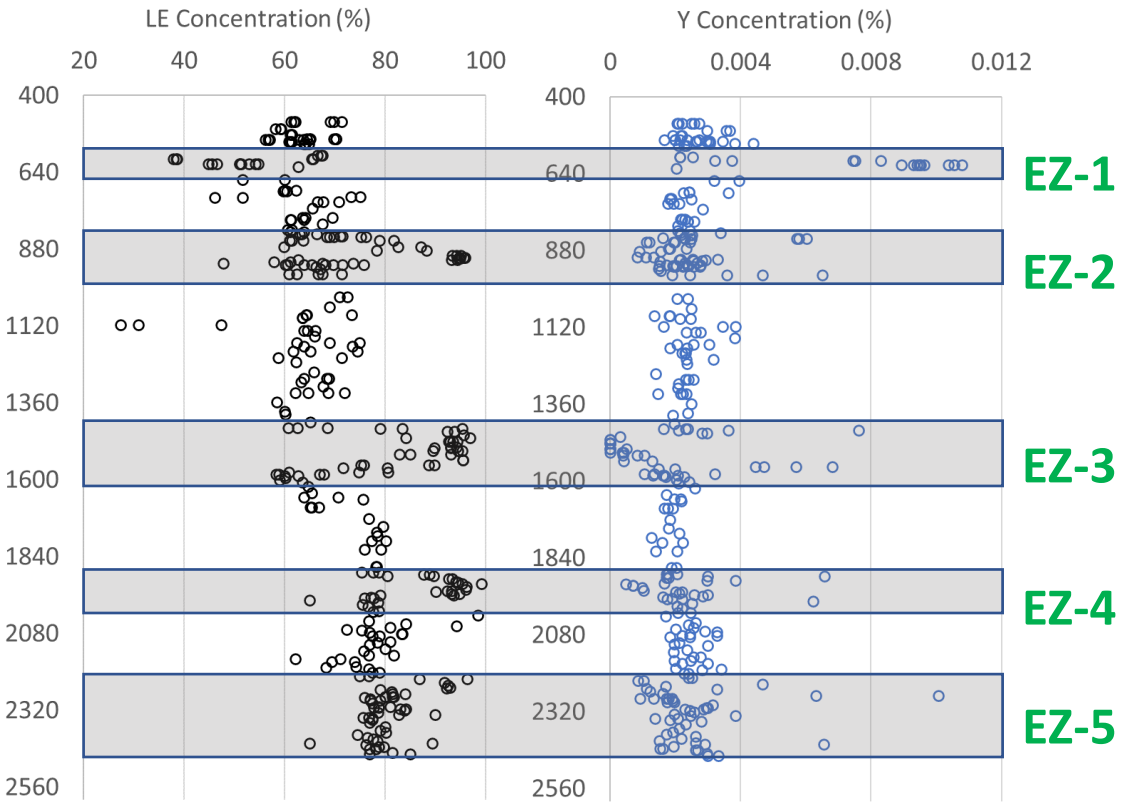


- Correlation between pXRF La, Ce, and Y with total REE measured by ICP-MS
- Confirms use of pXRF for measuring and tracking REE in received core samples

Identification of Enrichment Zones

Core Scale Logging

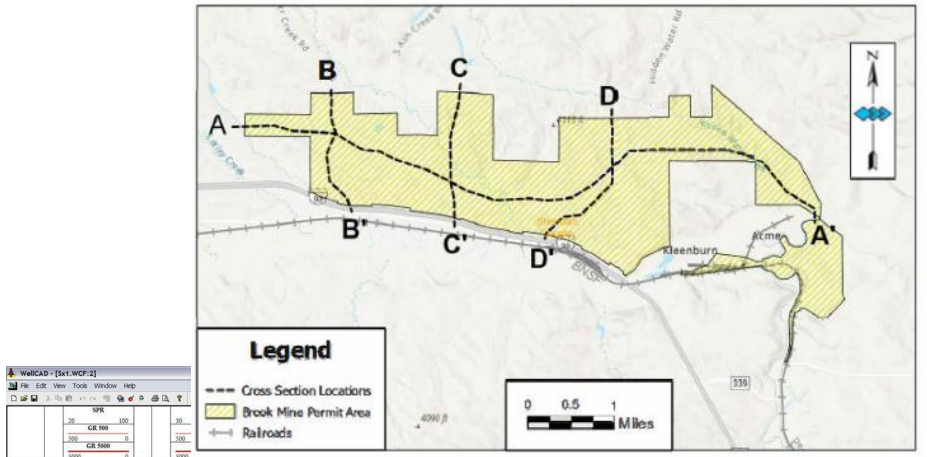
- Enrichment zones (EZ) identified with pXRF and correlated spatially with lithology and stratigraphy from other cores collected
- RockWare WellCAD Modules for creating digital logs of physical, chemical, and geophysical data

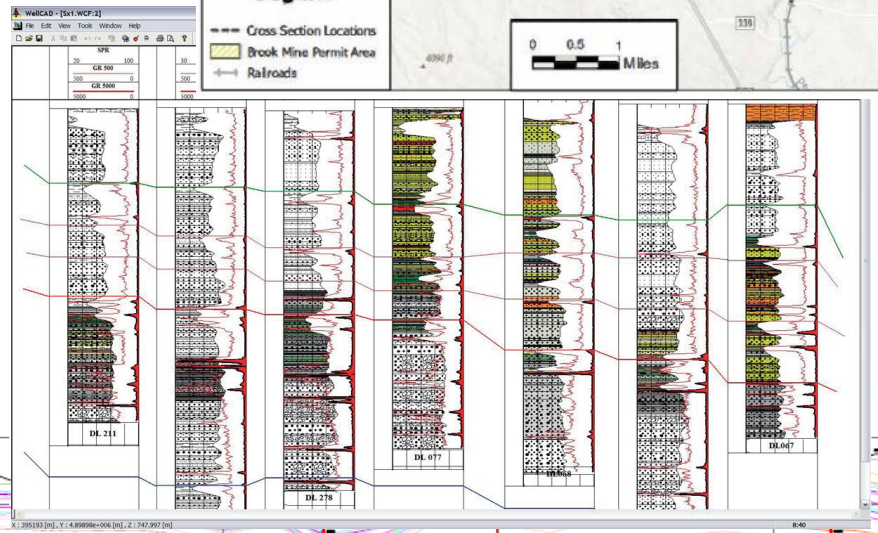


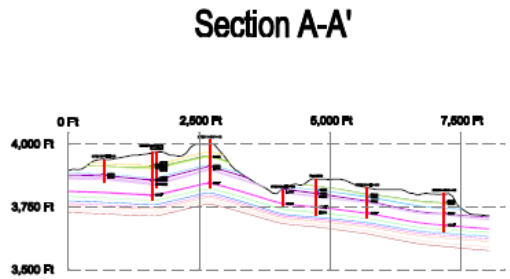
Core to Mine Scale

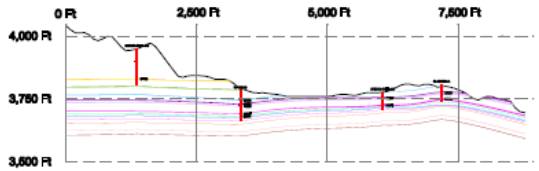
Data Collection, Visualization, and Modeling

- Data collected using NETL core characterization workflow (Montross et al., 2020) is used for correlation and modeling
- Seam to formation scale trends in resource occurrence are used to develop mining plans



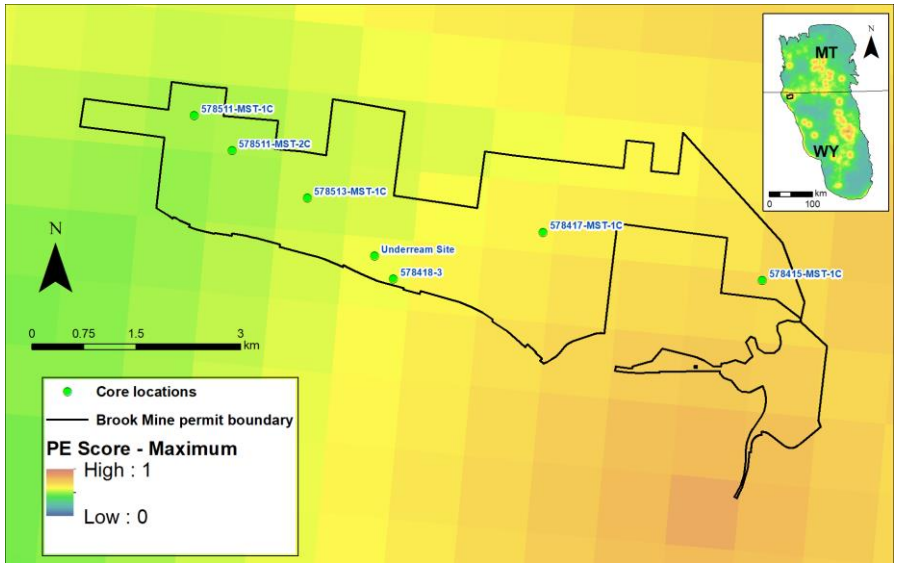






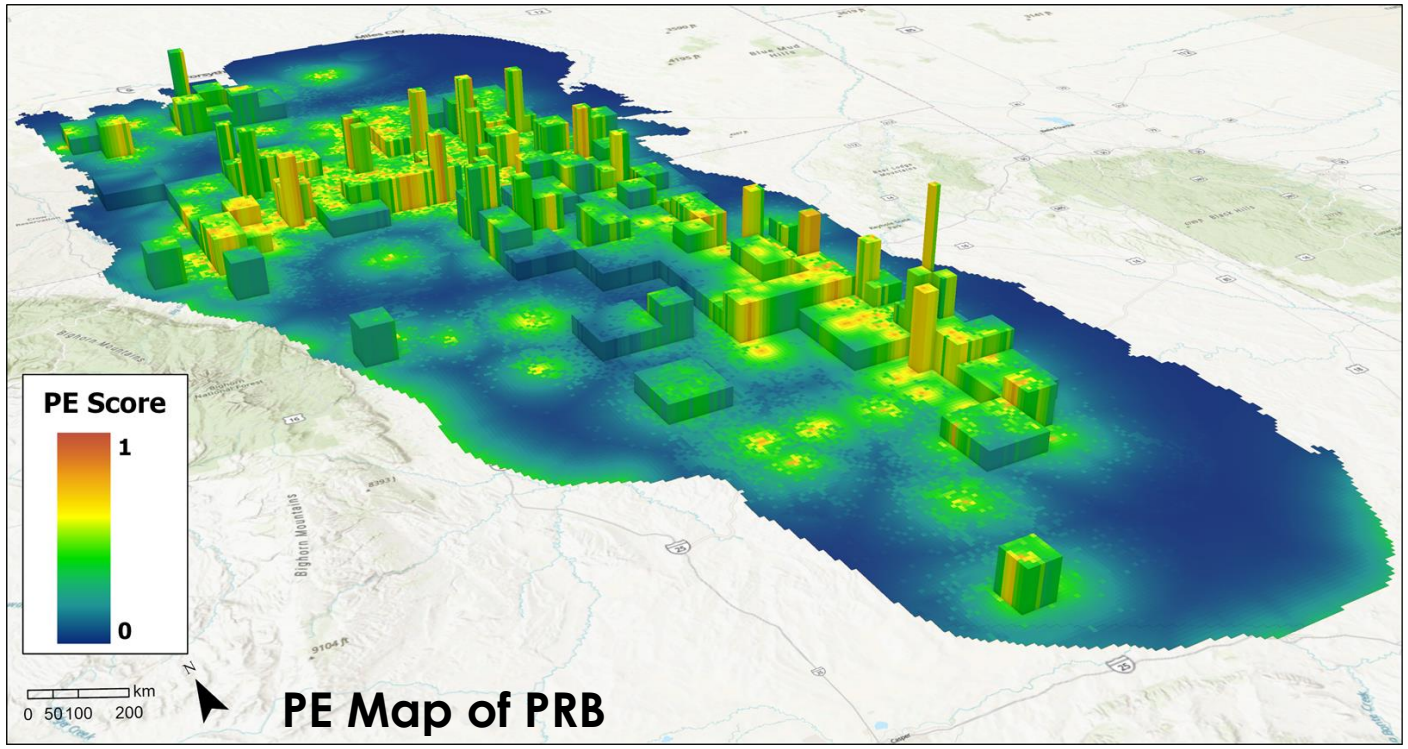
Core to Basin Scale

NETL-Unconventional Resource Assessment Tool



Potential Enrichment (PE) score map, based on geologic and hydrologic data, depicts areas where conditions are favorable for the enrichment of REE

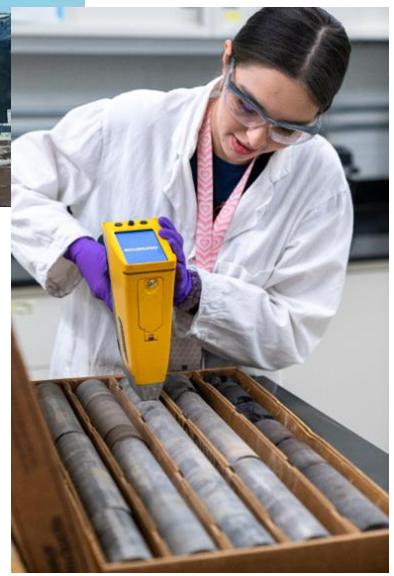
Higher PE score means higher likelihood for presence of resource



From Creason et al. (2023)

Acknowledgments

NETL CM/REE Geo-Data Science Team:
Kelly Rose*, Gabe Creason, Devin Justman, Mackenzie Mark-Moser, Michael Sabbatino, Burt Thomas, Patrick Wingo, Sophia O'Barr, Sophia Bauer, and Rachel Yesenchak



The work was performed in support of the National Energy Technology Laboratory's (NETL) ongoing research under the Rare Earth Element Field Work Proposal by NETL's Research and Innovation Center.

This research was supported in part by an appointment to the U.S. Department of Energy (DOE) Postgraduate Research Program at the National Energy Technology Laboratory (NETL) administered by the Oak Ridge Institute for Science and Education (ORISE).

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Scott Montross, Scott.Montross@netl.doe.gov
Sophia O'Barr, Sophia.Obarr@netl.doe.gov
Gabe Creason, Christopher.Creason@netl.doe.gov
Burt Thomas (NETL CM TPL), Burt.Thomas@netl.doe.gov