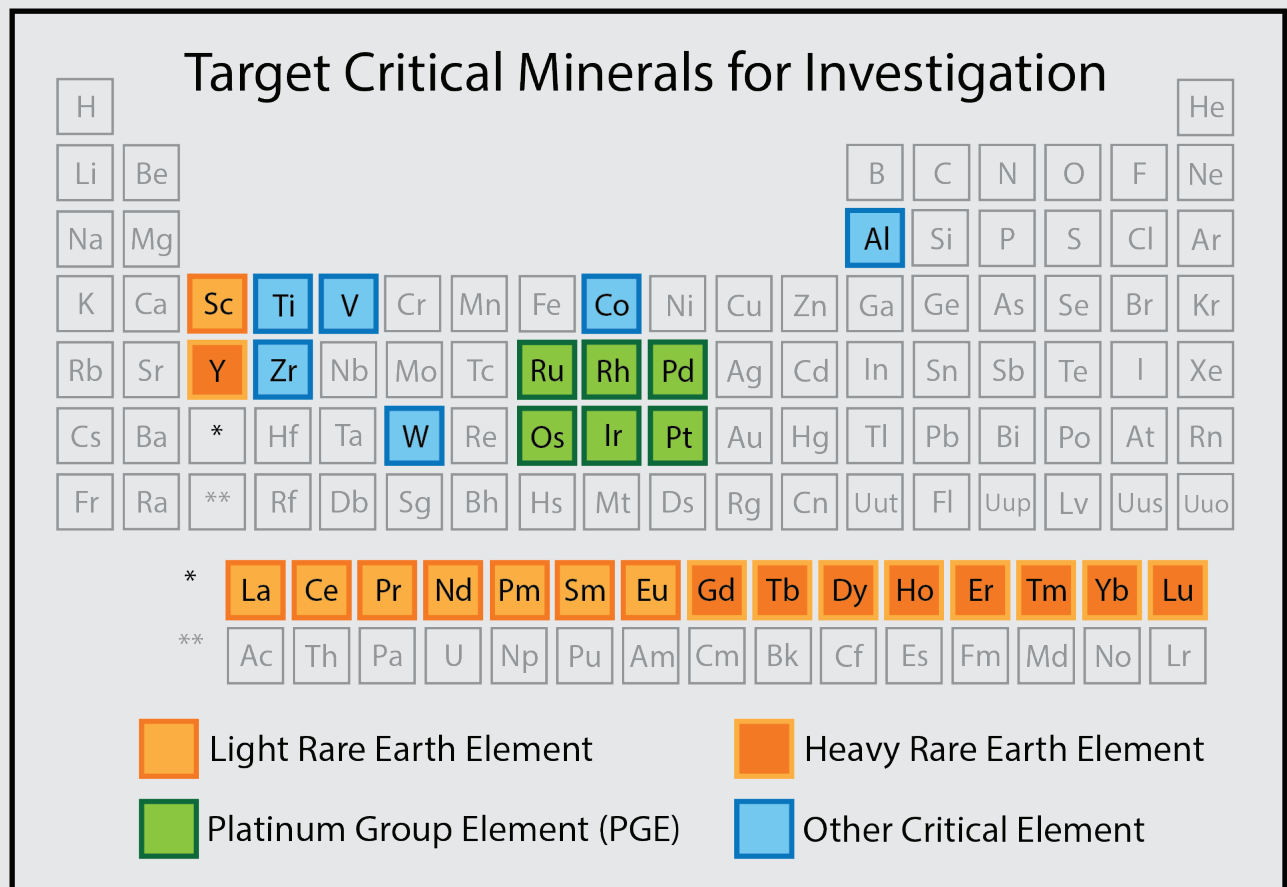


## 1. Why Study REE and CM?

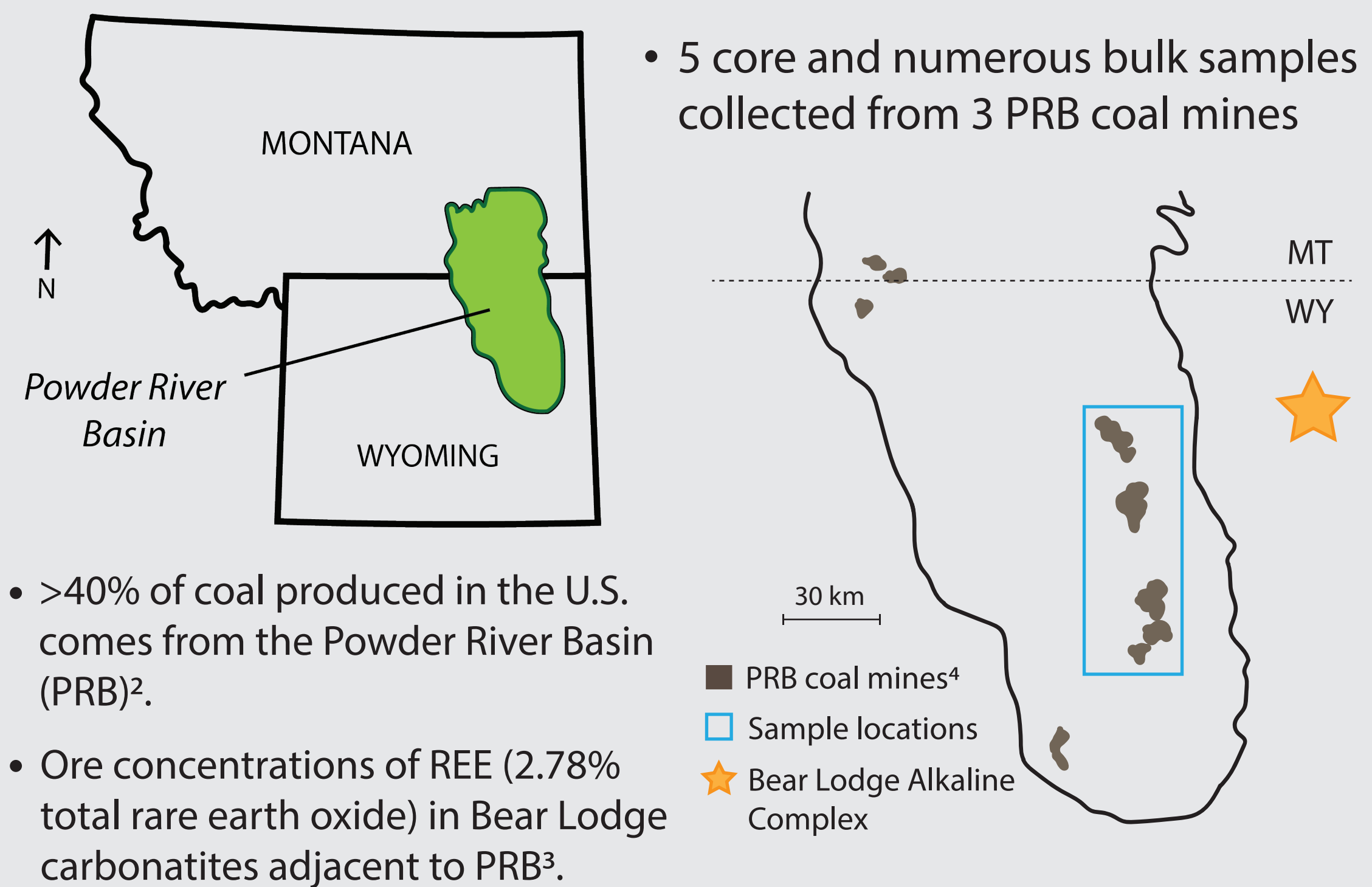
Rare earth elements (REE) and critical minerals (CM) are essential for energy transition technologies including:

- wind turbines
- solar cells
- electric motors and batteries

Coal and coal byproducts may be an unconventional source of domestic REE and CM<sup>1</sup>.

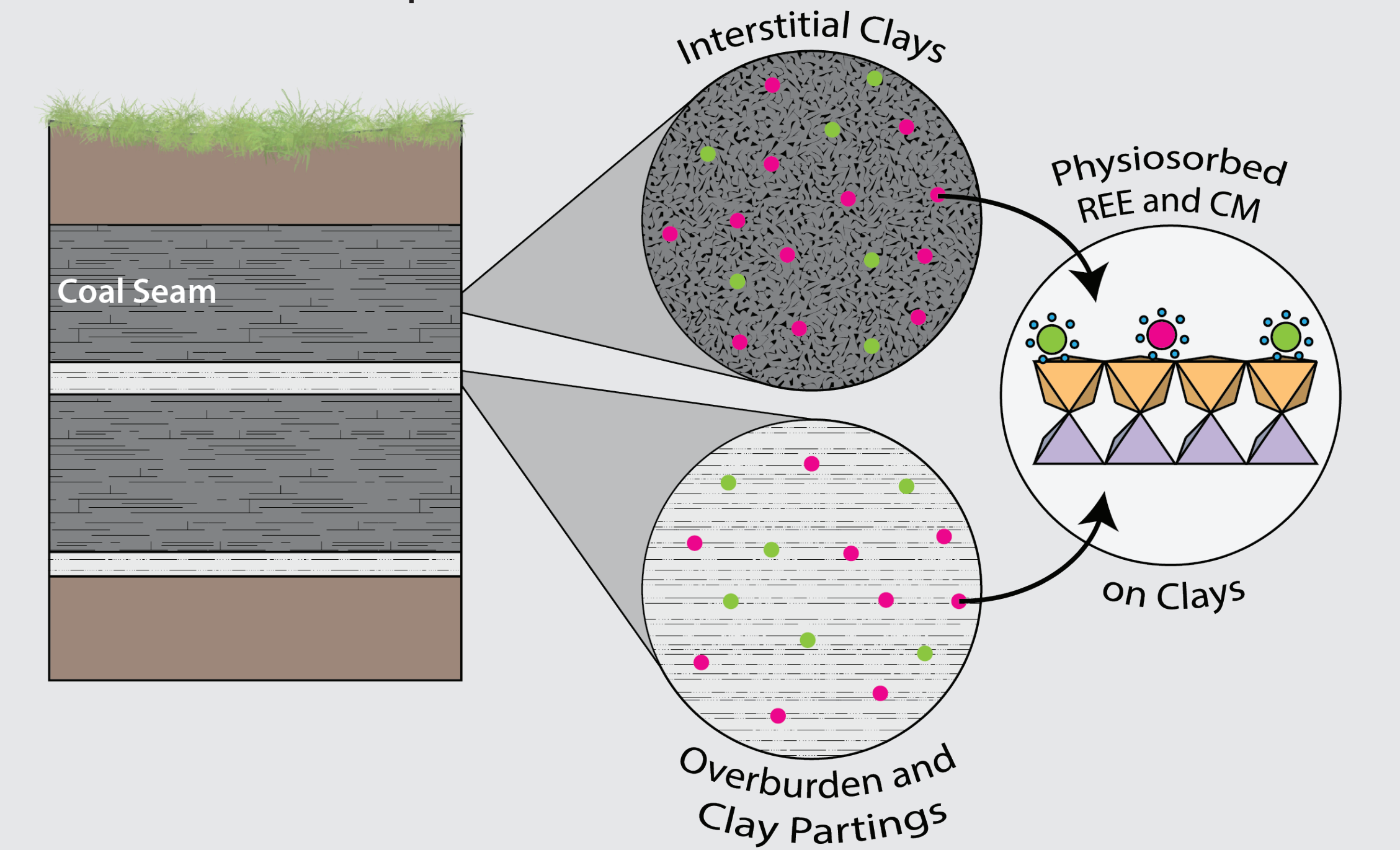


## 2. Location and Sampling



## 3. Coal-hosted Clay Minerals

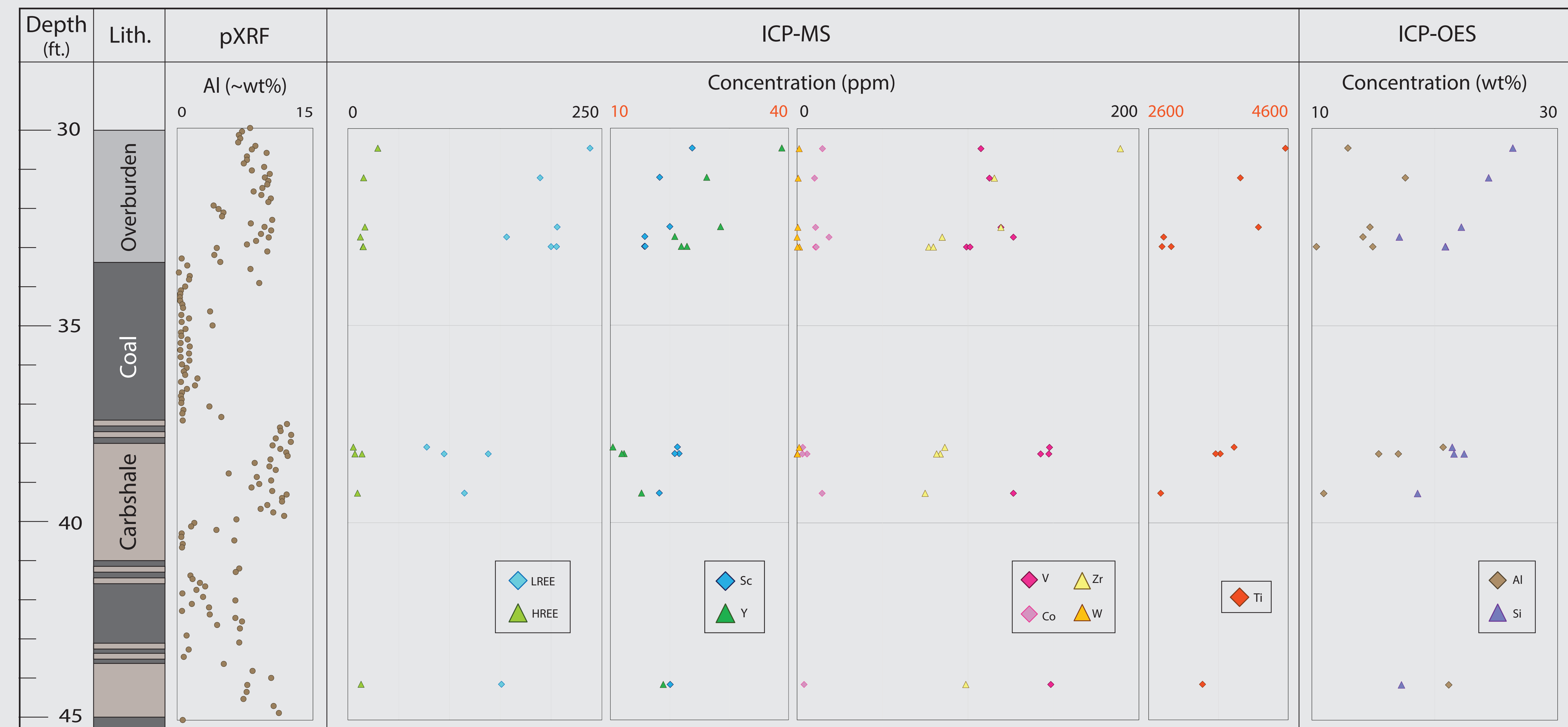
How do REE and CM fractionate into clay minerals within PRB coal deposits?



Hypothesis: REE and CM (pink and green) will preferentially sorb to the surfaces of clay minerals (aluminosilicates) (orange and purple) in clay-rich sections of the coal deposit.

## 4a. Geochemistry\*

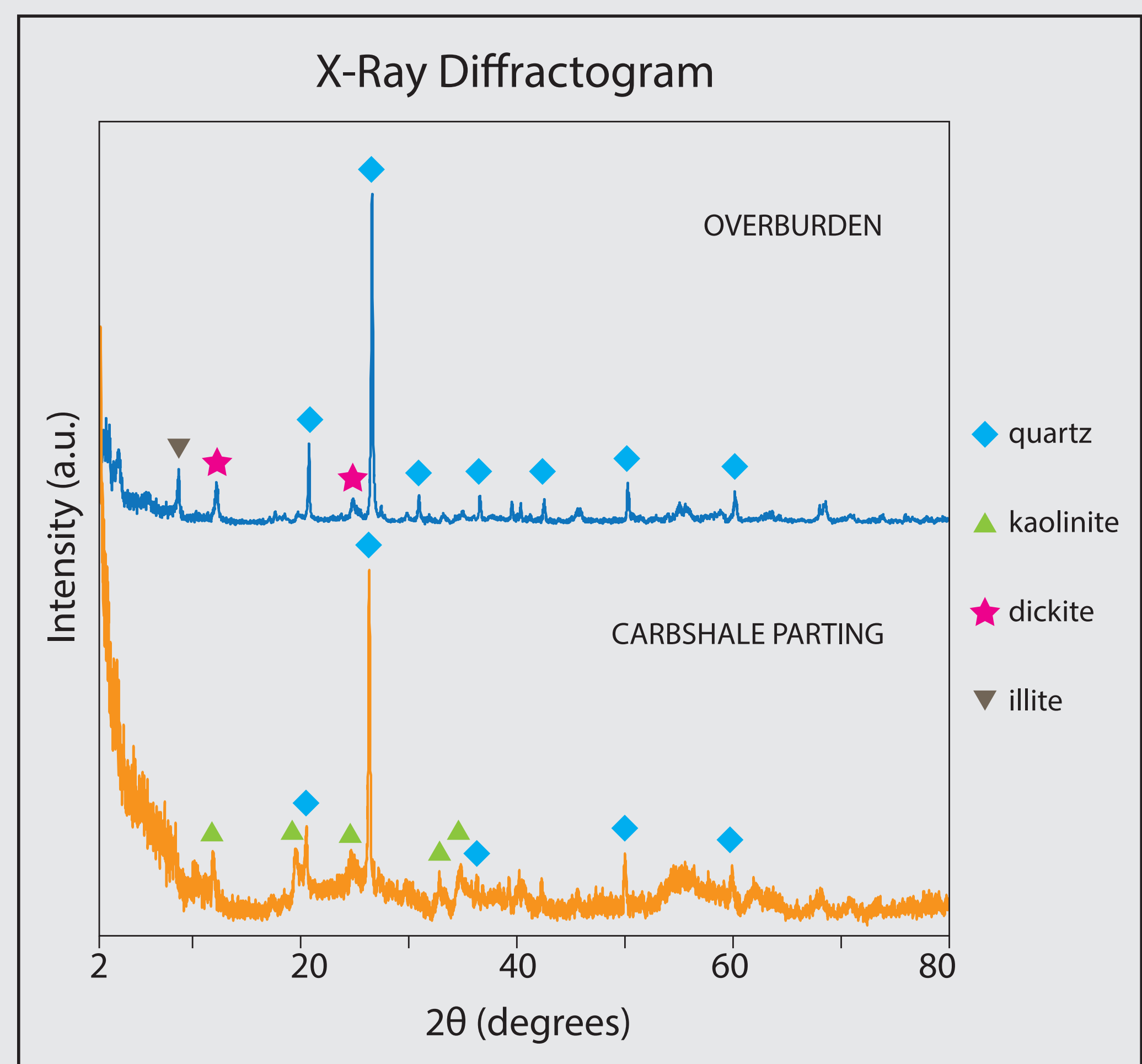
Range of total REE 120 - 330 ppm (n=11); PGEs negligible



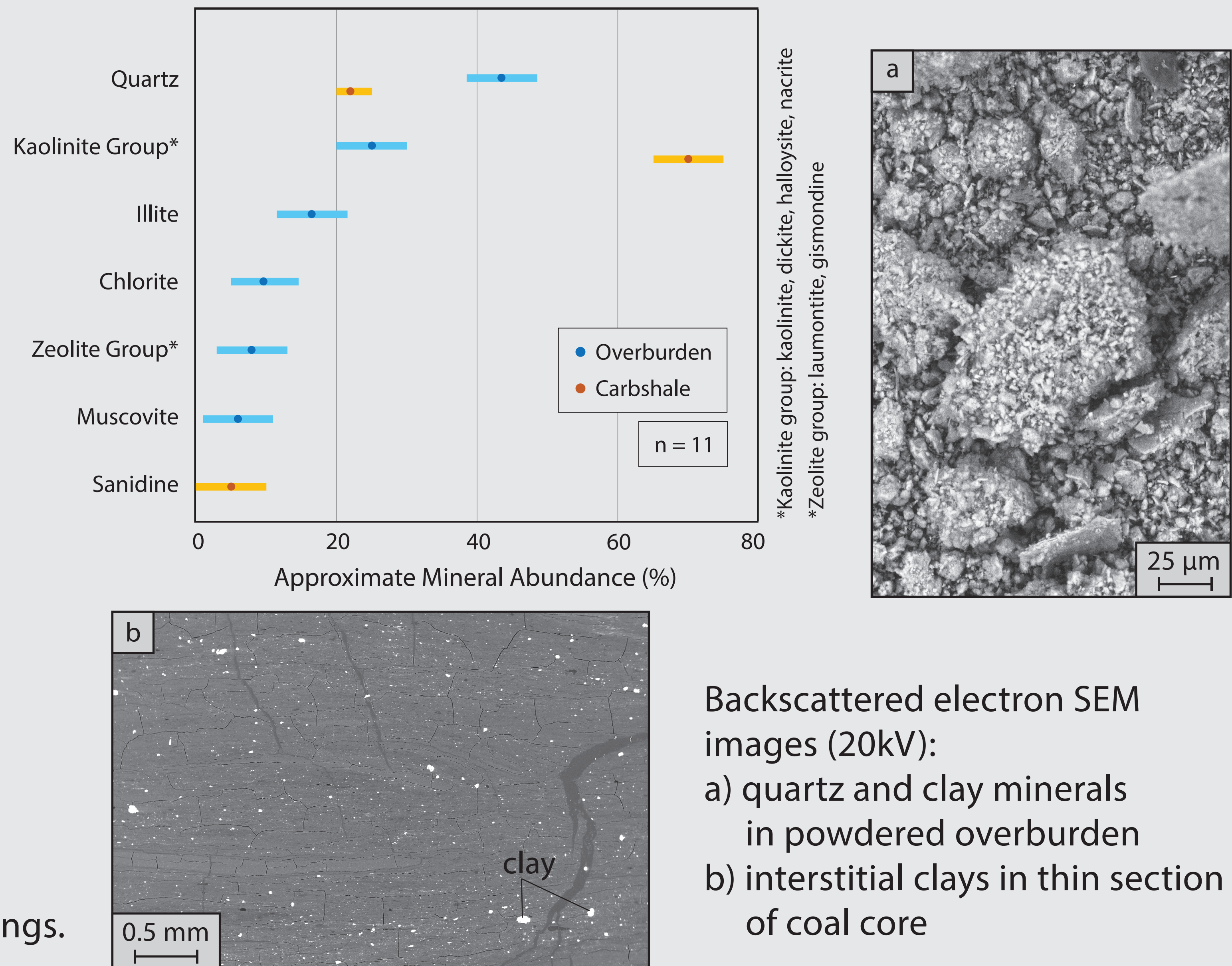
\*Critical element geochemistry of whole rock samples. Size of data points encompasses uncertainty values.

## 4b. Mineralogy and Morphology

Range of mineral abundances in overburden and carbshale parting



Representative x-ray diffractograms showing major phase mineralogy of overburden and carbshale partings.

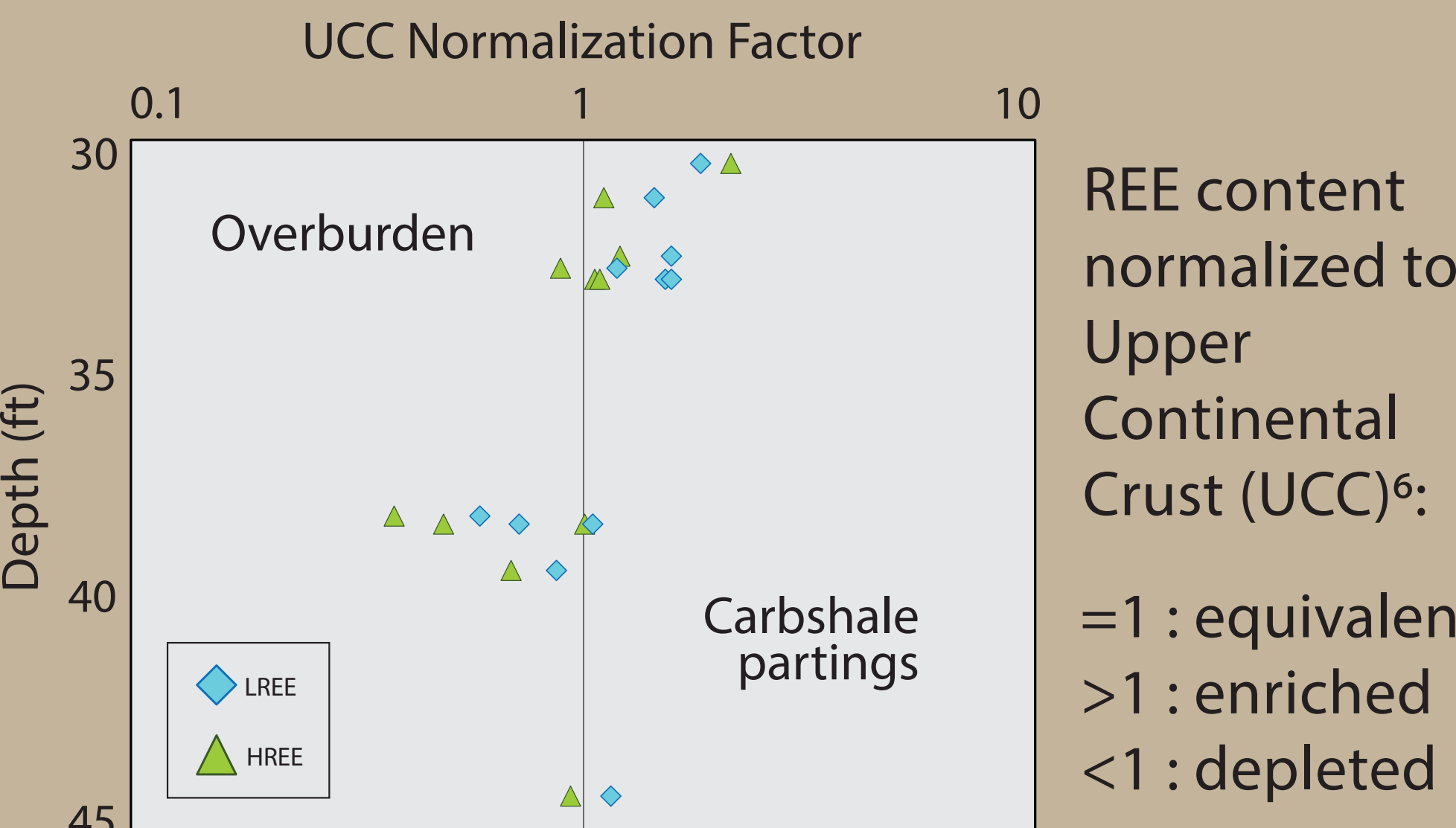


## 5. Discussion

Known correlation between REE and Al content<sup>5</sup>

Similar concentrations of Al in overburden and carbshale parting

- Overburden enriched in LREE and HREE
- REE in carbshale at or below crustal abundance



- Physiosorption may not be primary binding mechanism<sup>5</sup>

## 6. Next Steps

- Isolate clay minerals
  - Perform sequential extractions
  - Quantify supernatant liquids
  - Determine relationship between clays and trace metal occurrence
- Analyze additional clay samples for increased resolution
  - Repeat for coal samples

## 7. References

1. Bagdonas, D.A., Enriquez, A.J., Coddington, K.A., Finnoff, D.C., McLaughlin, J.F., Bazilian, M.D., Phillips, E.H., McLing, T.L. (2022). Rare earth element resource evaluation of coal byproducts: A case study from the Powder River Basin, Wyoming. *Renewable and Sustainable Energy Reviews*, 158 (112148).
2. Berry, R., Morey, M. (2019). Shale gas production in the Powder River Basin: A case study from the Powder River Basin, Wyoming. *U.S. Energy Information Administration*.
3. Van Gosen, B.S., Verplanck, P.L., Embo, P. (2019). Rare earth element mineral deposits in the United States (No. 1454). *U.S. Geological Survey*.
4. Croft, G., Potz, T. (2009). Potential for Coal-to-Liquids Conversion in the U.S. Resource Base. *Nonrenewable Resources*, 18(3), 173-180.
5. Feng, X., Oehl, O., Coudane-Triche, M., Noble, A., Yoon, R., Morris, J.R. (2021). A study of rare earth ion adsorption by the clay minerals kaolinite and illite at basic pH. *Applied Clay Science*, 201 (105920).
6. McLennan, S.M., Nance, W.B., Taylor, S.R. (1980). Rare earth element-thorium correlations in sedimentary rocks, and the composition of the continental crust. *Geochimica et Cosmochimica Acta*, 44(11).

## 8. Acknowledgements

This material is based upon work supported by the Department of Energy under Award Number DE-FE0032048. A special thank you to the UW School of Energy Resources, Kelsey Kehoe (WSGS), Ellen Polites, Isaac Mantelli, Courtney Birdsall, Victoria Konieczka, Emily Clinkscales, and Gracen Wallen for your contributions and support.

*Disclaimer:* This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.