

# RARE EARTH ELEMENTS IN COAL, RATON BASIN, NM

Jakob Newcomer<sup>1</sup>



<sup>1</sup>New Mexico Institute of Mining and Technology

# INTRODUCTION TO RARE EARTH ELEMENTS

- Group of 17 elements; Includes the Lanthanides, Yttrium, and Scandium
- Diverse modern applications for green energy and electronics e.g. alloys, lasers, phosphors, magnets, and other compounds with unique physical and magnetic properties
- Not rare, but enriched deposits are uncommon and difficult to mine economically

Rare Earth Elements

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo
		*	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
		**	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

 Light Rare Earth Element       Heavy Rare Earth Element

# REE DEPOSIT TYPES

- Igneous

- Carbonatites LREE
- Alkaline intrusive LREE
- Pegmatites LREE

- Sedimentary

- Ion adsorption clays HREE
- Beach placer sandstones LREE, HFSE
- Phosphorites HREE
- Black Shales LREE



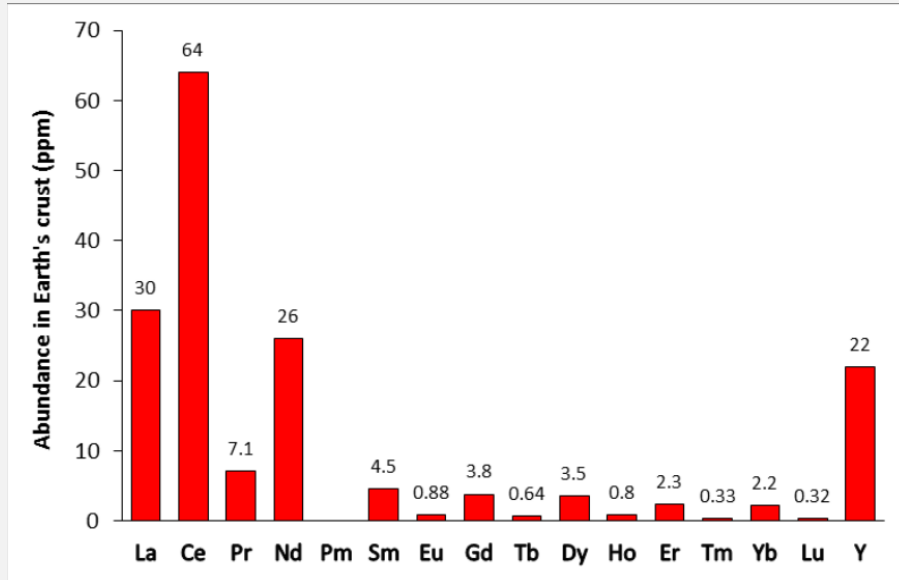
Bayan Obo, Inner Mongolia, China  
<https://www.mindat.org/gallery.php?pco=2&doc=720>



Mountain Pass Mine, California  
<https://www.mindat.org/gallery.php?pco=2&doc=11616>

# RARE EARTHS IN COAL

- Preliminary Data from literature and samples, from V. T. McLemore



[https://www.researchgate.net/figure/The-abundance-of-rare-earth-elements-in-the-crust-in-ppm-Reproduced-from-Wall-2014\\_fig1\\_329735877](https://www.researchgate.net/figure/The-abundance-of-rare-earth-elements-in-the-crust-in-ppm-Reproduced-from-Wall-2014_fig1_329735877)

Sample Id	TREE ppm	Rank
Coal1	158	bituminous
Coal3	171	bituminous
Coal5	214	lignite
Coal6	136	lignite
Coal7	65	bituminous
Coal8	219	bituminous
sample A	246.3	bituminous
sample B	128.5	bituminous
Sample E	379.2	bituminous
1coal	18.128151	bituminous
2shale	43.630952	shale
3coal	84.683773	bituminous
4shale	40.687769	shale
5coal	165.18552	bituminous
6shale	189.58268	shale
93922	203.13315	fly ash
93923	162.80516	pond ash

# ASH REPOSITORIES

- Coal ash (fly ash, bottom ash, boiler slag) becomes enriched in REE's and other critical minerals during the burning process

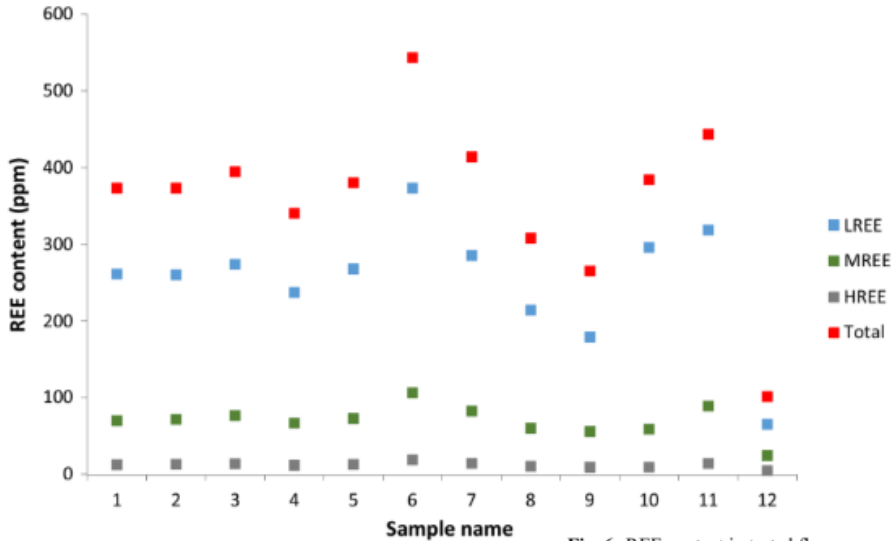


Fig. 6 REE content in tested fly ashes

From Franus et al, 2014

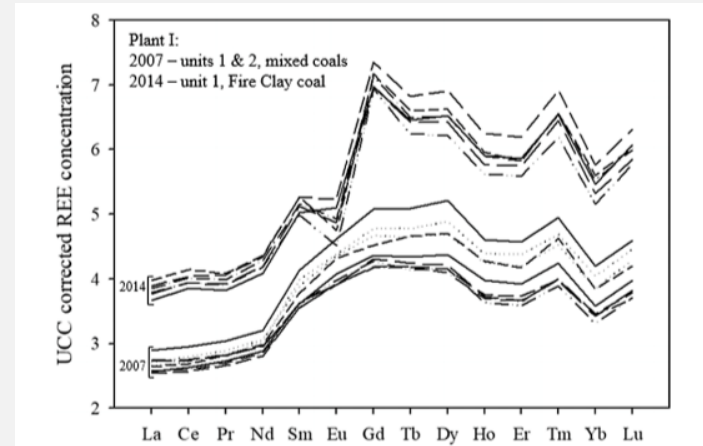


Fig. 1. Upper continental crust-corrected rare earth concentrations (after McLennan and Taylor<sup>38</sup>) for the fly ashes from the combustion of an Eastern Kentucky coal blend collected in 2007 and the Fire Clay coal collected in 2014. The collections were from units 1 and 2 (2007) and unit 1 (2014) of Kentucky Plant I.

From Hower et al, 2021

# ASH REPOSITORIES

- Processes are being developed to extract REE's, as well as V, U, and Mo, from coal waste
- Different deposits have varying trace element signatures and compositions, possibly requiring different ideal methods of extraction

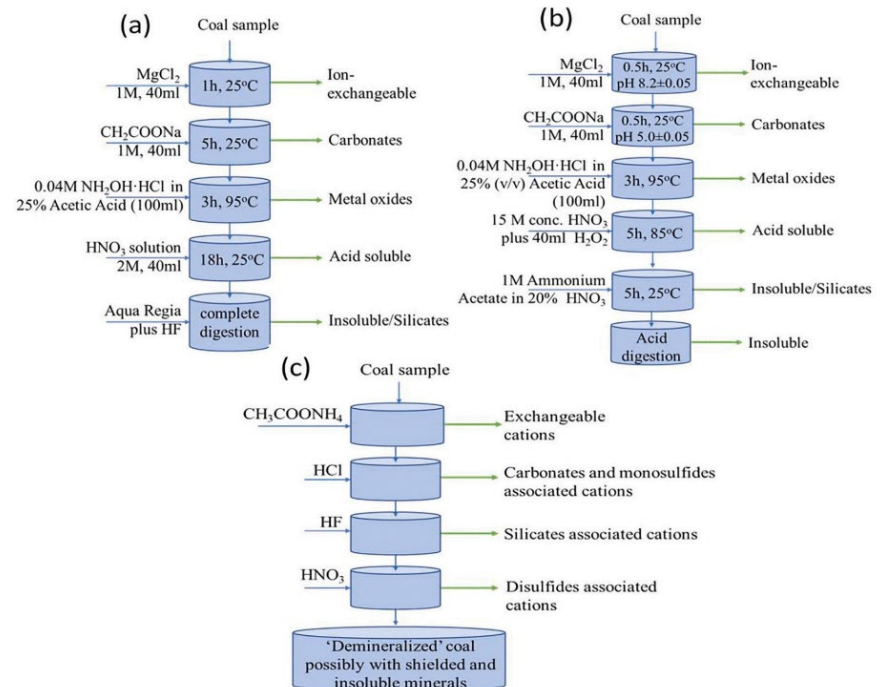


Fig. 5. Sequential extraction schemes showing targeted phase (a) Zhang and Honaker (2019a), (b) Zhang and Honaker (2020) (c) Finkelman et al. (2018).

# REE AND OTHER CRITICAL MINERALS

- Many trace elements are enriched in coal and adjacent sediments, including REE's, and can be used as environmental proxies
- Concentration and trends in trace metals e.g. V, Ni, Co, Cr, U; are dependent on deposit, deposit type, and environmental conditions

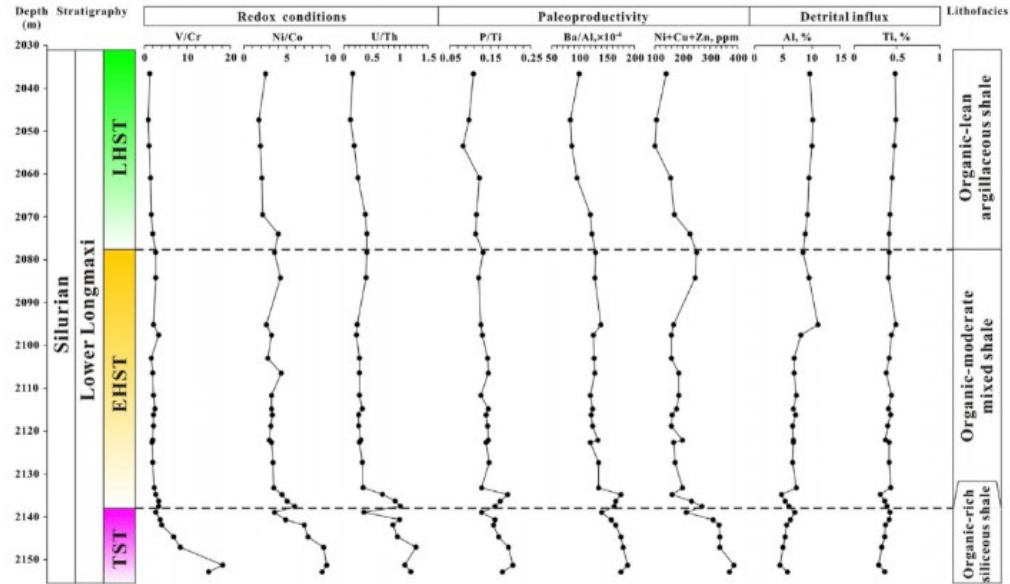
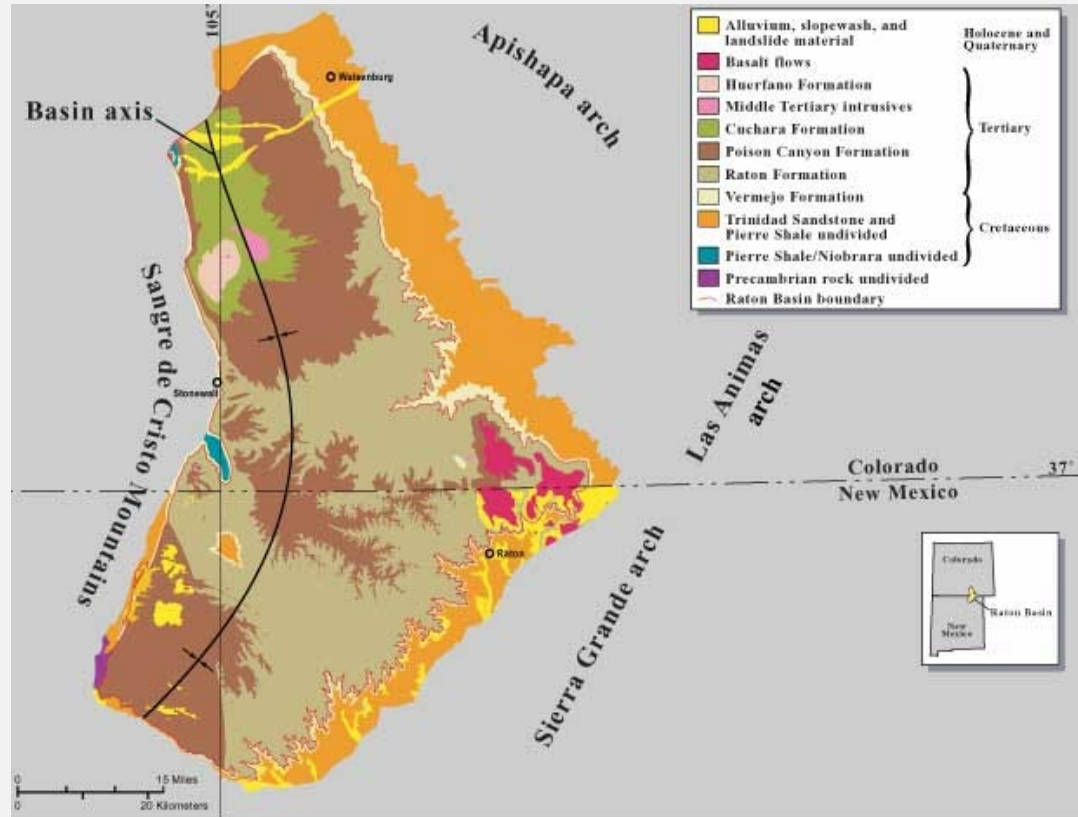


Fig. 2. Stratigraphic distributions of redox (V/Cr, Ni/Co and U/Th), paleoproductivity (P/Ti, Ba/Al, and Ni + Cu + Zn) and detrital influx (Al and Ti) proxies in well PY1.

# RATON BASIN GENERAL GEOLOGY

- The Raton basin consists dominantly of a thick Upper Cretaceous and Tertiary sedimentary sequence
- These include: Pierre Shale, Trinidad Sandstone, and Vermejo formation, the latter of which hosts most of the local coal
- The area shows Laramide age angular unconformities and lithologic changes
- Many Eocene age sills, dikes, plugs, and laccoliths have intruded into the sediments





# FIELD OBSERVATIONS



# METHODS

- Sample Collection
- Thin sections
- Whole rock chemistry
- Ash chemistry
- Microprobe
- Raman Spectroscopy
- $^{40}\text{Ar}/^{39}\text{Ar}$  Geochronology





# QUESTIONS?

## References:

Johnson et al, 1966, *NMGSA Fall Field Conference Guidebooks* New Mexico Bureau of Geology, pp.-98  
<https://geoinfo.nmt.edu/publications/nmgs/guidebooks/home.cfm>

Zhang, L., et al., 2019, *Effect of sedimentary environment on the formation of organic-rich marine shale: Insights from major trace elements and shale composition*, *International Journal of Coal Geology*, <https://www.sciencedirect.com/science/article/abs/pii/S0166516218308061?via%3Dihub>

Eterigholkelegbe, O., et al., 2021, *Rare earth elements from coal and coal discard: A review*, *Minerals Engineering*,  
<https://www.sciencedirect.com/science/article/abs/pii/S0892687521004167?via%3Dihub>

Hower, J. C., et al., *Signatures of rare earth element distributions in fly ash derived from the combustion of Central Appalachian, and Powder River basin coals*, *Fuel*, <https://www.sciencedirect.com/science/article/abs/pii/S0016236121009273?via%3Dihub>

Franus, W., et al., 2014, *Coal fly ash as a resource for rare earth elements*, *Environmental Science and Pollution Research*,  
<https://link.springer.com/article/10.1007/s11356-014-1111-9>