RARE EARTH ELEMENTS (REE) AND OTHER CRITICAL MINERALS IN LATE CRETACEOUS COAL AND RELATED STRATA IN THE SAN JUAN AND RATON BASINS, NEW MEXICO: PRELIMINARY OBSERVATIONS (YEAR 2)

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- Students and staff at NM Tech
- Partners at Los Alamos and Sandia National Lab, Sonoash

Purpose—how much critical minerals, including REE, are found in:

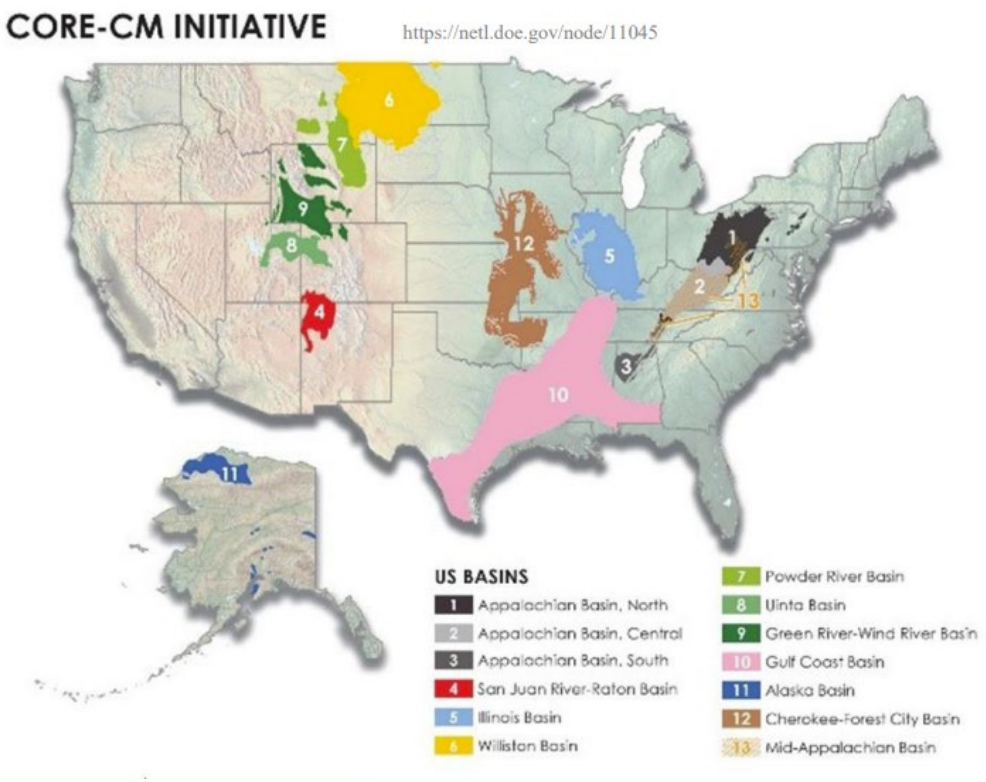
- Late Cretaceous heavy-mineral beach placer sandstone deposits in San Juan Basin
- Late Cretaceous coal deposits
- Late Cretaceous humate deposits
- Late Cretaceous clinker deposits

Future Work

- How do these deposits relate to one another
- Source of REE and other critical minerals

CORE-CM project—Rare Earth Elements and Critical Minerals in the San Juan and Raton Basins, northern New Mexico (DOE project)

- CORE-CM=Carbon Ore, Rare Earth and Critical Minerals
- Identify and quantify the distribution of REE and CM in coal beds and **related stratigraphic units** in the San Juan and Raton basins
- Identify, sample, and characterize coal waste stream products



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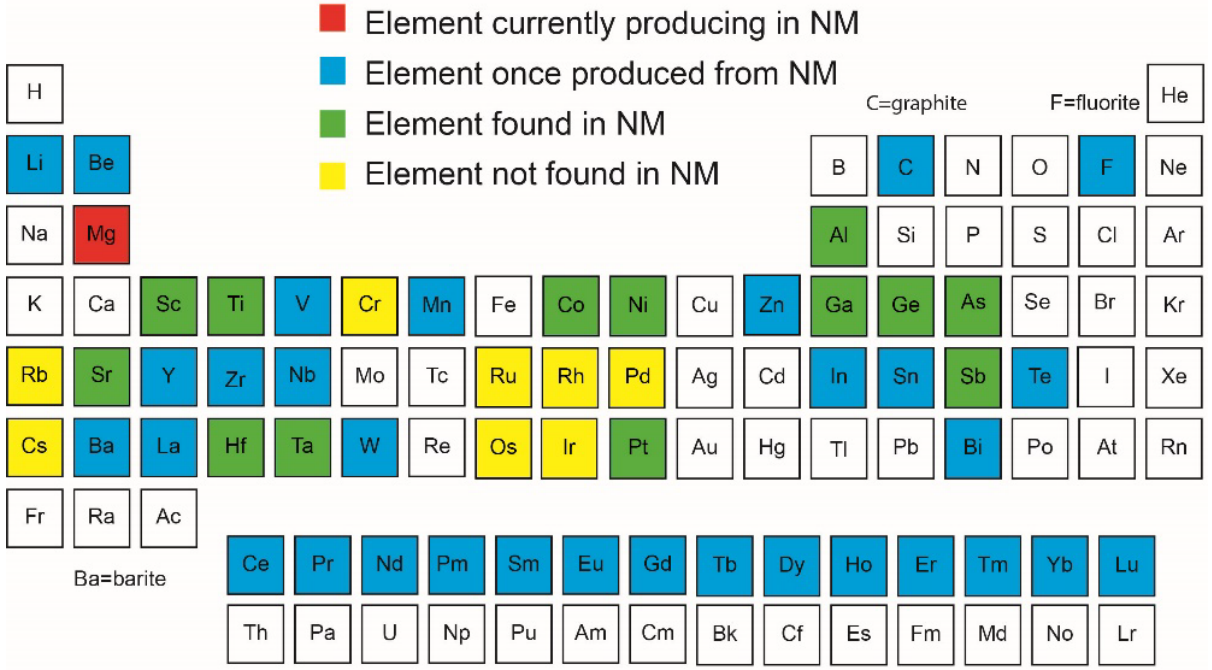
SonoAsh

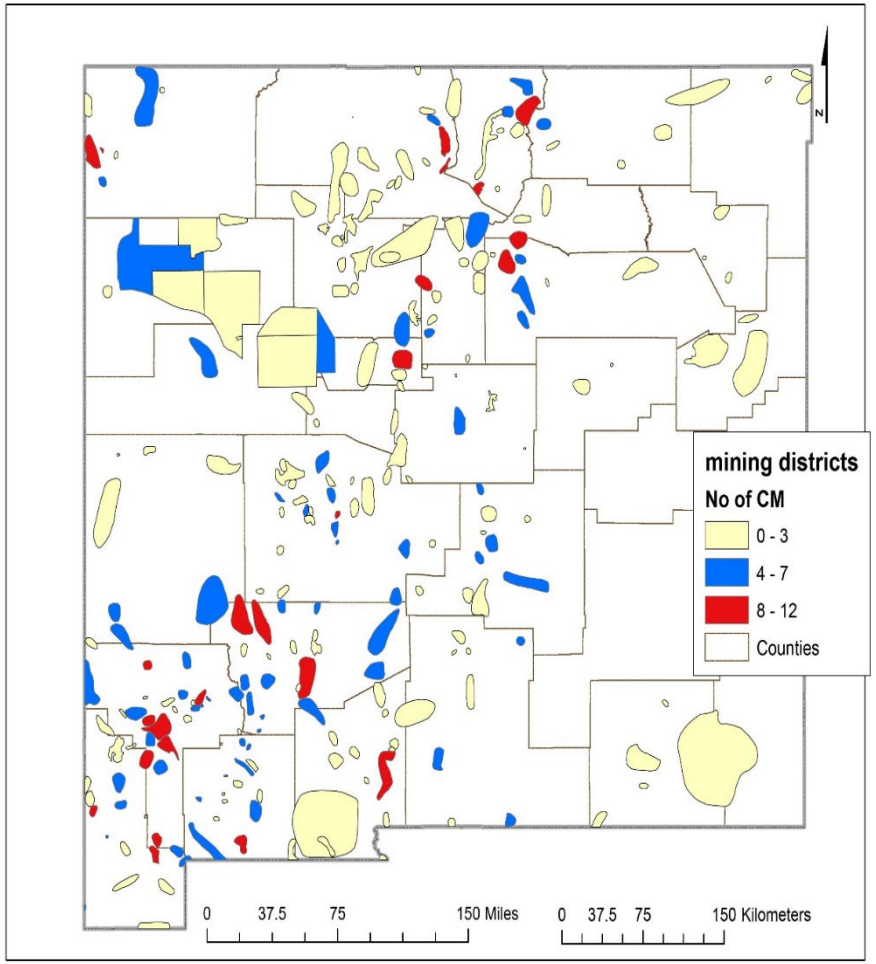
In the United States, a critical mineral is a nonfuel mineral commodity that is essential to the economic and national security of the United States, and is from a supply chain that is vulnerable to global and national disruption.

Critical Minerals in New Mexico



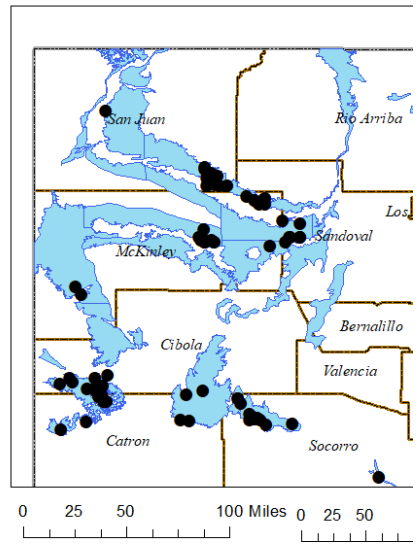
Note that any element or commodity can be considered critical in the future depending upon use and availability. Coal contains several of these critical elements.

U, Re, He, and K (potash) were removed from the critical minerals list in 2022 and Zn and Ni were added.



Geological Background – San Juan Basin

- An asymmetrical structural depression forming southeast margin of the Colorado Plateau
- Upper Cretaceous–Early Tertiary age
- 26,000 + square miles
- San Juan Basin has 3 major coal-bearing units
  - Crevasse Canyon
  - Menefee
  - Fruitland Formations
- ~ 24 coal fields
- Stratigraphy of the San Juan basin dips inward from the highlands towards the center of the basin, creating a “trough-like” feature



Stratigraphic section of the San Juan basin, Northern New Mexico (Hoffman, 2017)

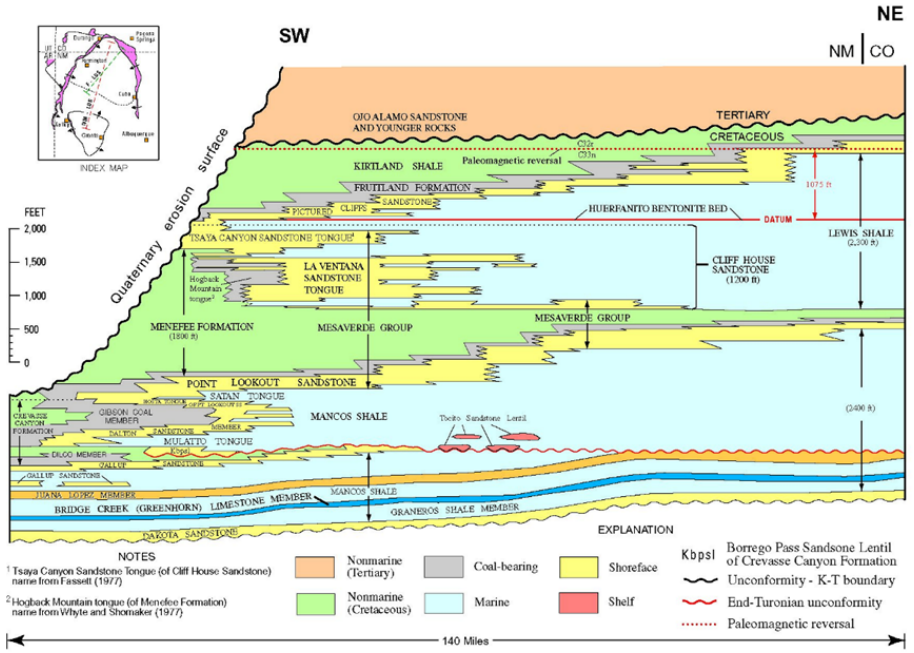
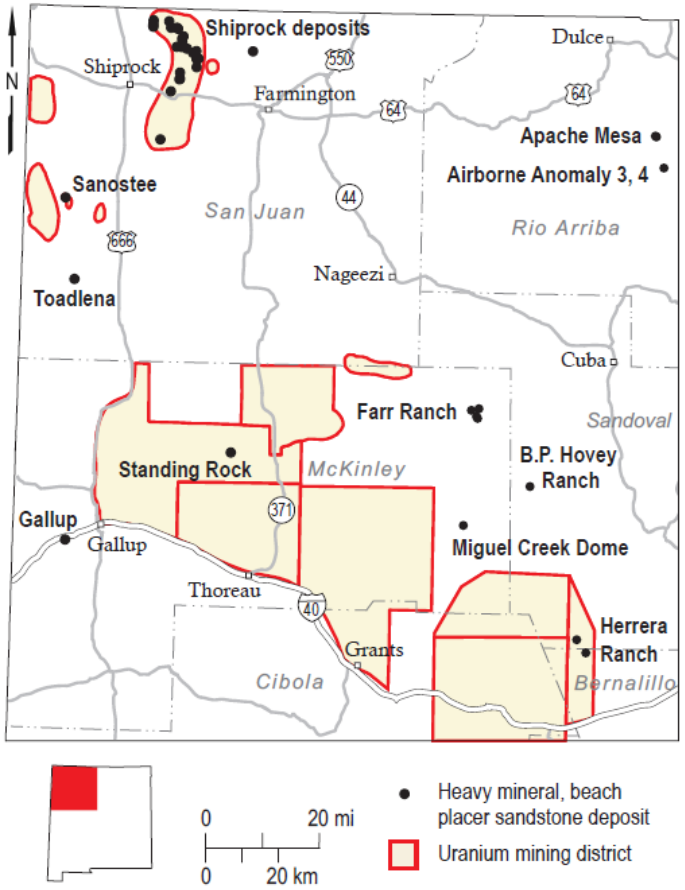
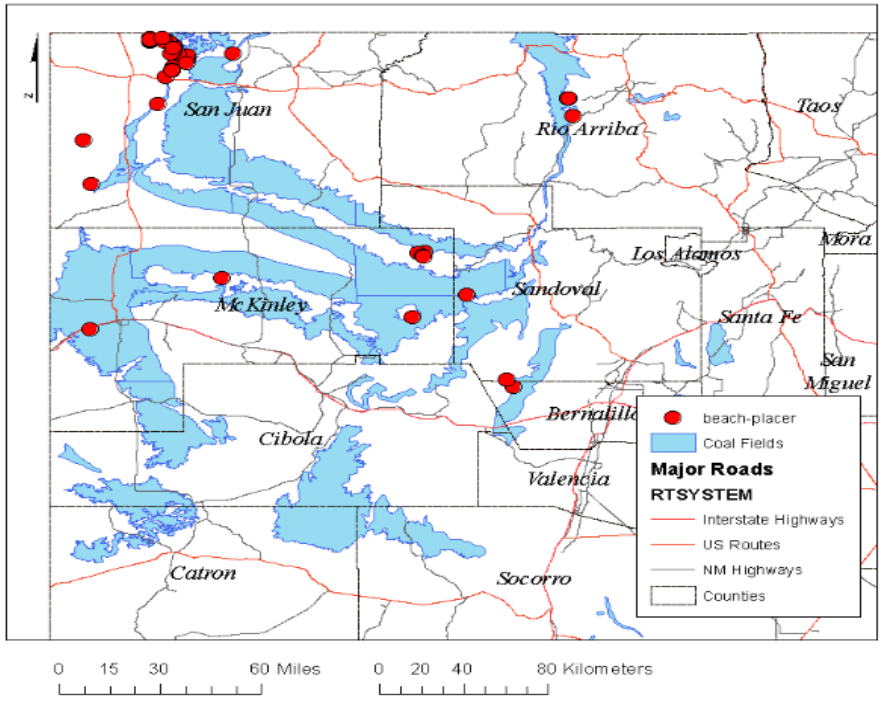


Figure 4. Stratigraphic section showing Upper Cretaceous rocks in the San Juan Basin, New Mexico and Colorado. Tocito Sandstone Lentil and coal-bearing zones are shown diagrammatically. Stratigraphy of rock units from the Point Lookout Sandstone upward is modified from Fassett (1977), stratigraphy for lower part of section is modified from Nummedal and Molenaar (1995). F - LOS on index map is Fassett (1977) line of cross section; NM - LOS is Nummedal and Molenaar (1995) line of cross section. Position of paleomagnetic reversal from chron C33n to C32r is from Fassett and Steiner (1997). Vertical exaggeration x 55.

Beach-placer sandstone deposits

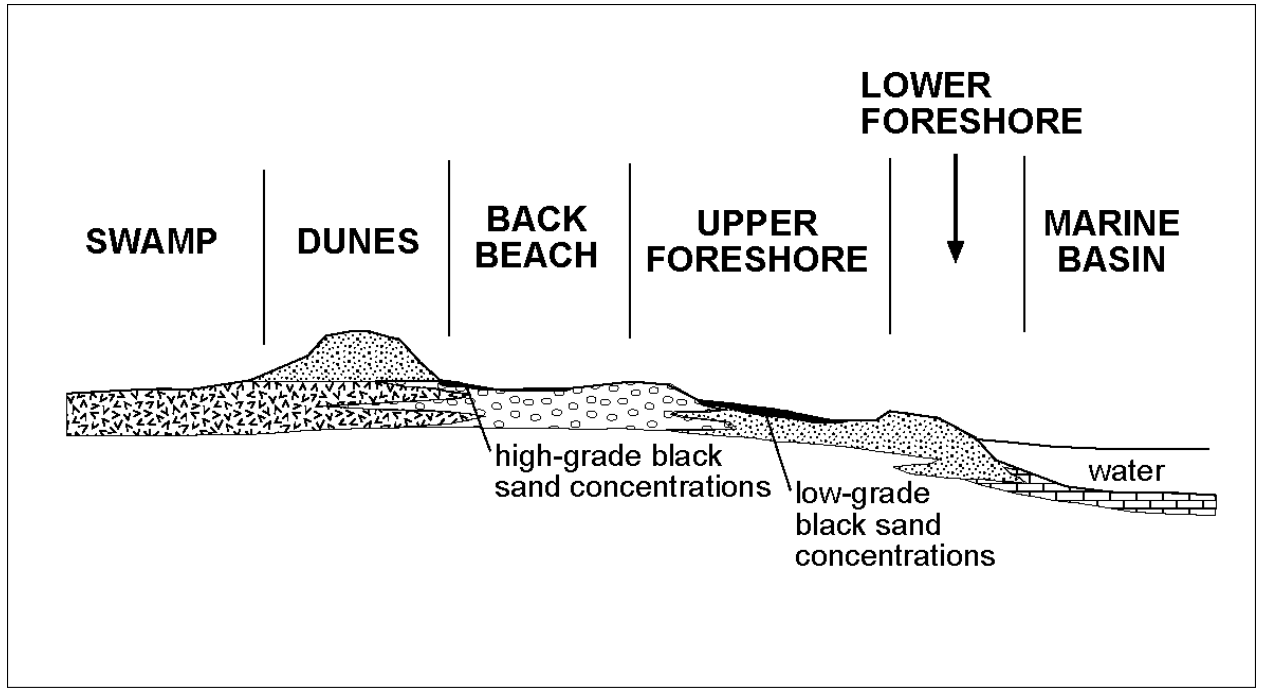
- Beach-placer sandstone deposits in the San Juan Basin are restricted to Late Cretaceous rocks and contain high REE
  - NM REE database
- Gallup, Dalton, Point Lookout, and Pictured Cliffs Sandstones
- Are in the vicinity of coal deposits
- Small-intermediate tonnage

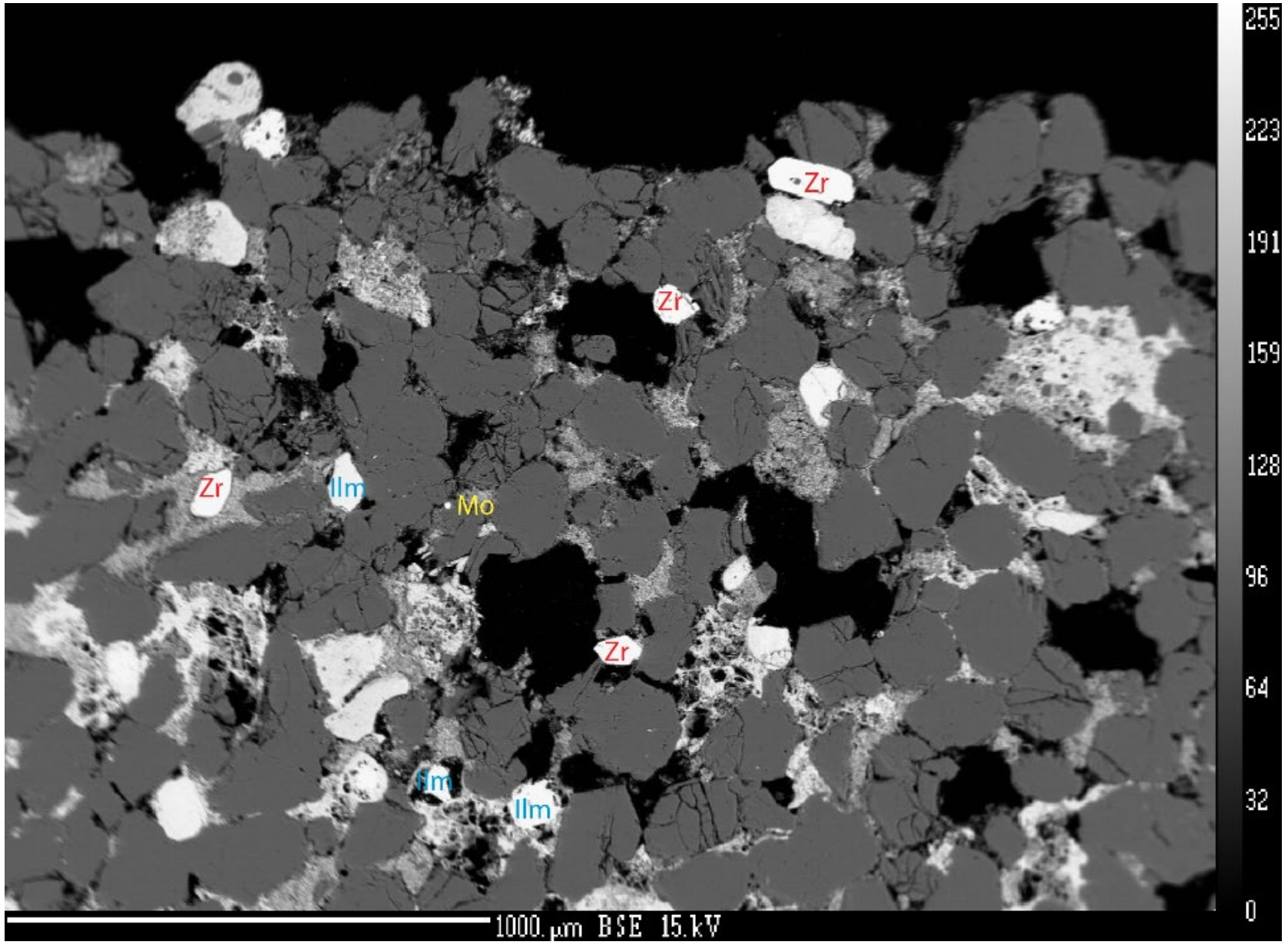




Beach-placer sandstone deposits

Beach-placer sandstone deposits are accumulations of heavy, resistant minerals (i.e. high specific gravity) that form on upper regions of beaches or in long-shore bars in a marginal-marine environment.





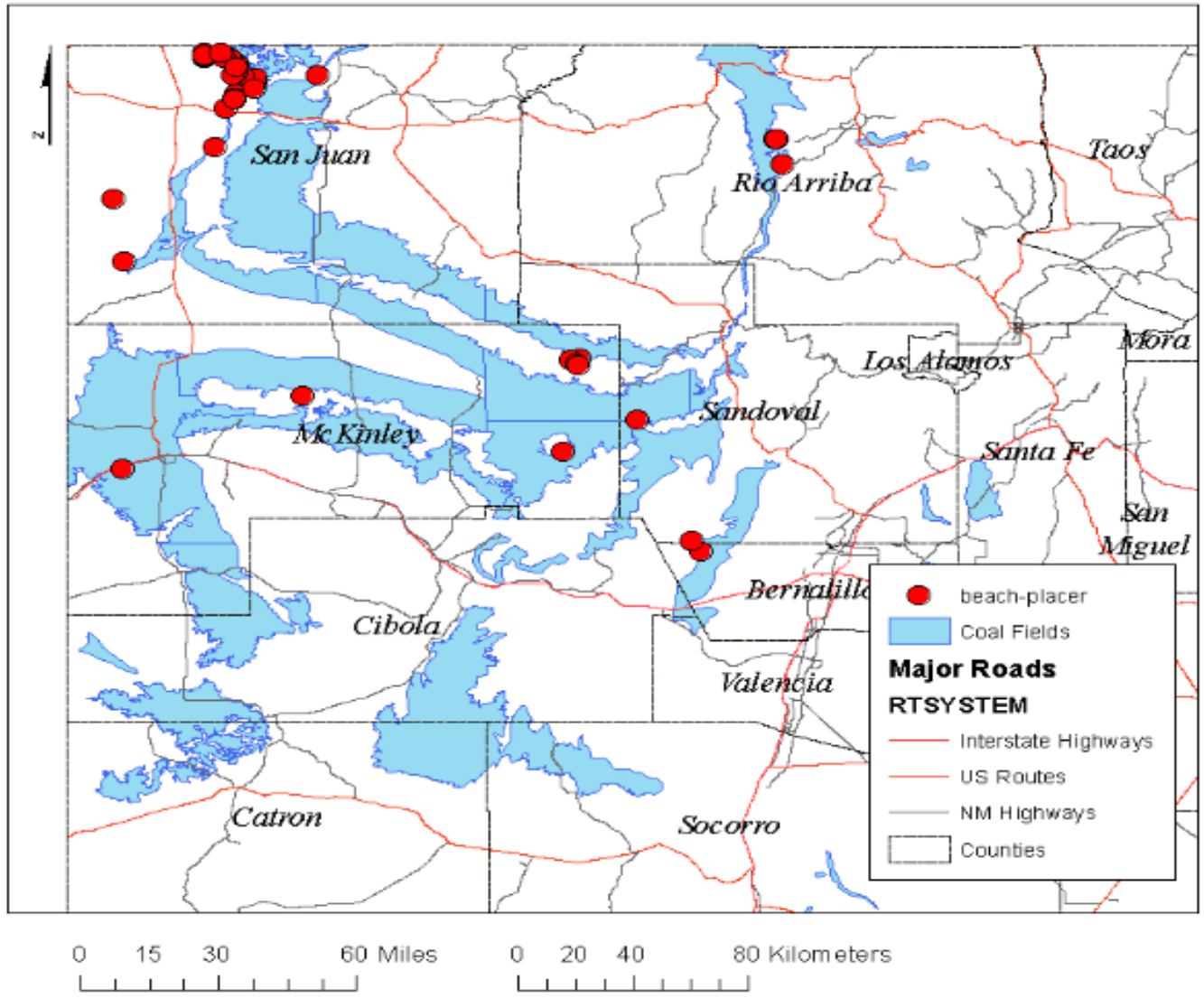
Electron microprobe photo in sample SAN 6 (Sanostee). Zircon grains are labeled in red, ilmenite in blue, and monazite in yellow. Mottled, lighter colored cement is iron oxide (hematite). Dark grey grains are mainly quartz. Black areas are pore spaces.

Coal in New Mexico

- Fuels electrical generating plants (1 in NM and fuels Arizona plants)
- 2 surface mines in San Juan Basin
  - El Segundo
  - Lee Ranch (soon to reopen)
  - Navajo
- Resources at Raton, Sierra Blanca fields
- 12th coal in production in U.S. in 2020
  - 10,249,000 short tons
  - Production decreasing because of mine closure
- 15th in estimated recoverable coal reserves in U.S.
  - 65 million short tons of recoverable reserves at mines
  - 6,719 million short tons estimated recoverable reserves

New Mexico Coal Fields

- The coal/shale deposits are in the San Juan Basin
- Are restricted to Late Cretaceous rocks belonging to the Gallup, Dalton, Point Lookout, and Pictured Cliffs Sandstones



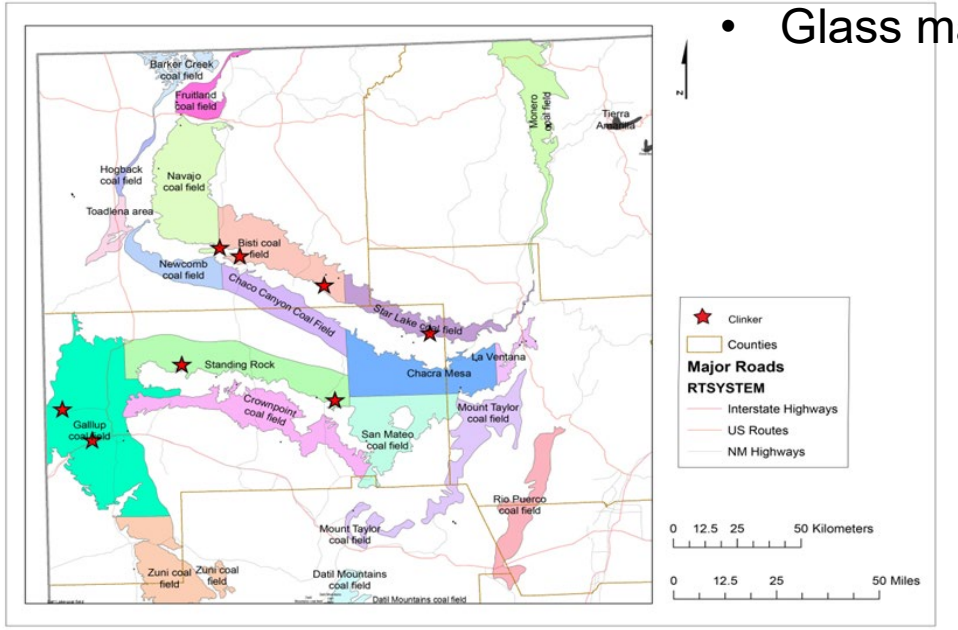
Humates

- Weathered coal and organic material
- Leonardite, weathered lignite
- Transitions to coal at depth
- Humic acids
- Coal burns, high quality humate dissolves in water
- Mining began in New Mexico in 1980s
- Used as a soil conditioner, medicinal uses, dispersant and viscosity control in oil-well drilling muds, stabilizer for ion-exchange resins in water treatment, source of water-soluble brown stain for wood finishing
- Possibly REE from water soluble products

Clinker

- Clinkers (red) are sedimentary rocks pyrometamorphosed by fire
- Coal seam fires can start from multiple causes at the surface
  - Wildfires
  - Lightning strikes
  - Spontaneous combustion by the oxidation of pyrite
- Coal seam fires can spread extensively underground
- Temperatures can reach 1000°F, baking surrounding rocks
- Clinkers can be indicators of coal resources that aren't exposed
  - Resistant to erosion

- Aggregate for roads
- Decorative stone
- Naturally burned coal
- Metal working
- Glass manufacture



Preliminary Mineralogy (XRD, probe, thin section analysis)

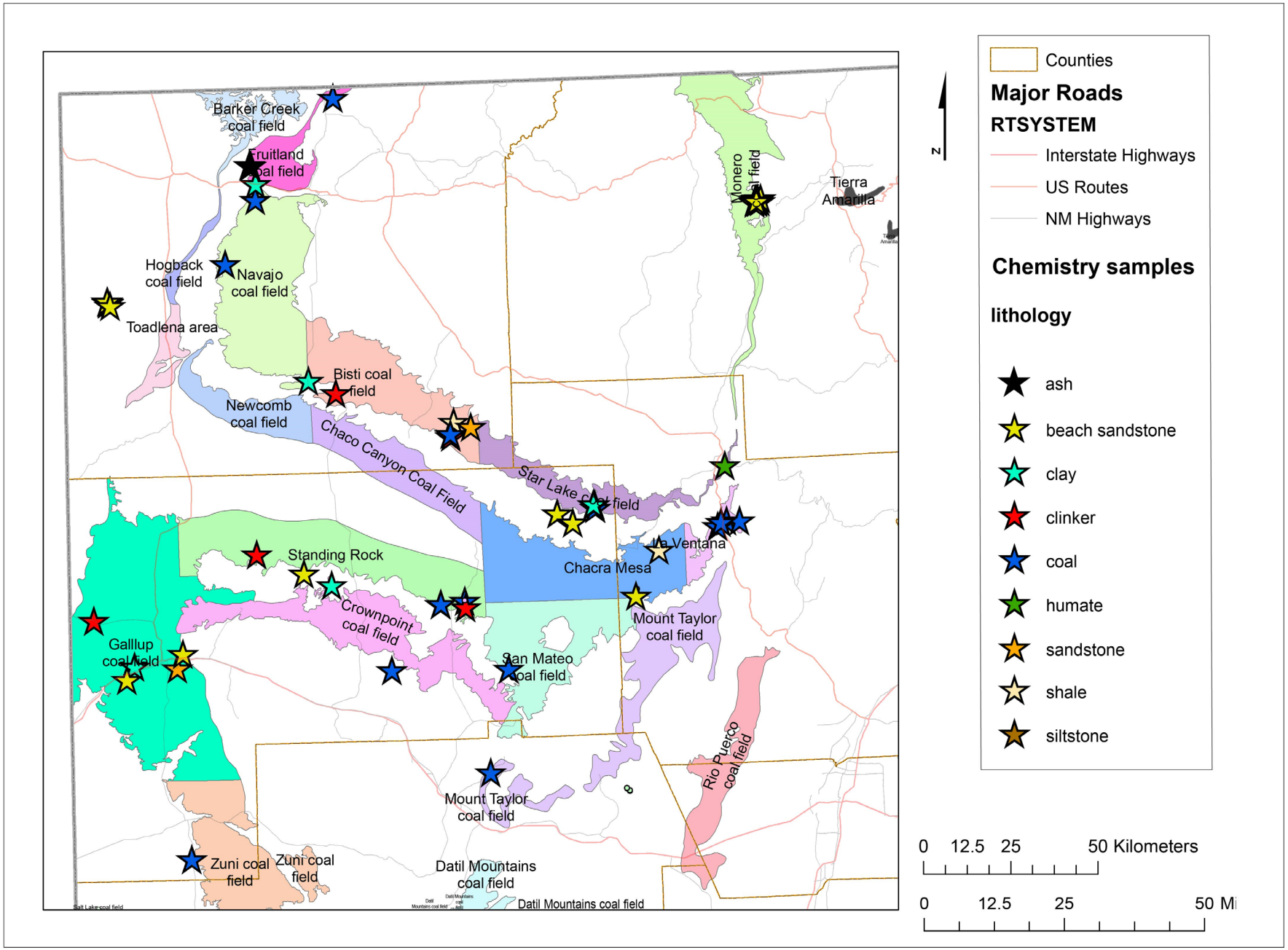
- Quartz
- Clay minerals
- Zircon
- Ilmenite
- Rutile/anatase
- Hematite
- Monazite
- Xenotime

Geochemistry

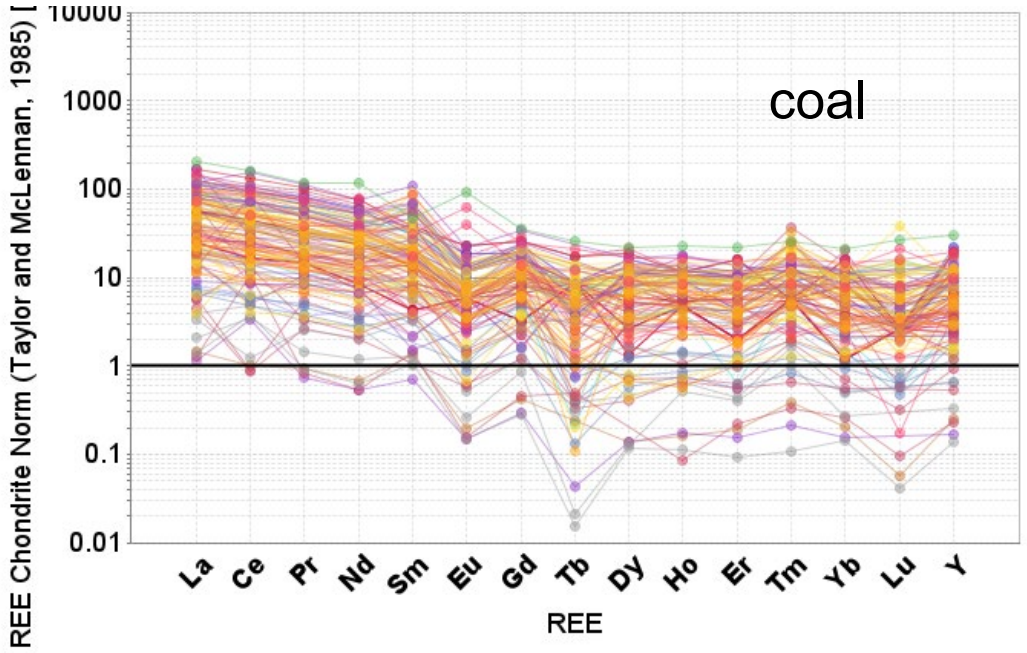
- Geochemical data of the beach-placer sandstone deposits are from a compilation by McLemore et al. (2016) that includes samples collected by McLemore and analyzed in 2010, 2015-2017 and by Zech et al. (1994) (REE by ICP-MS)
- Coal samples are difficult to analyze
  - Preferred ASTM sample preparation methods ash the coal samples
  - SGS and University of Kentucky
- Legacy geochemical data of the coal deposits are from Baker, 1989; Araya, 1993; Affolter, 2019 [USGS coal quality database]) and new unpublished data collected for the DOE project
  - USGS coal quality data has many issues with the analyses; most REE analyzed by ICP-MS
  - Baker (1989) and Araya (1993) are thesis data analyzed at NM Tech; REE by neutron activation
  - New unpublished data has provided a more consistent data set analyzed by ASTM standards

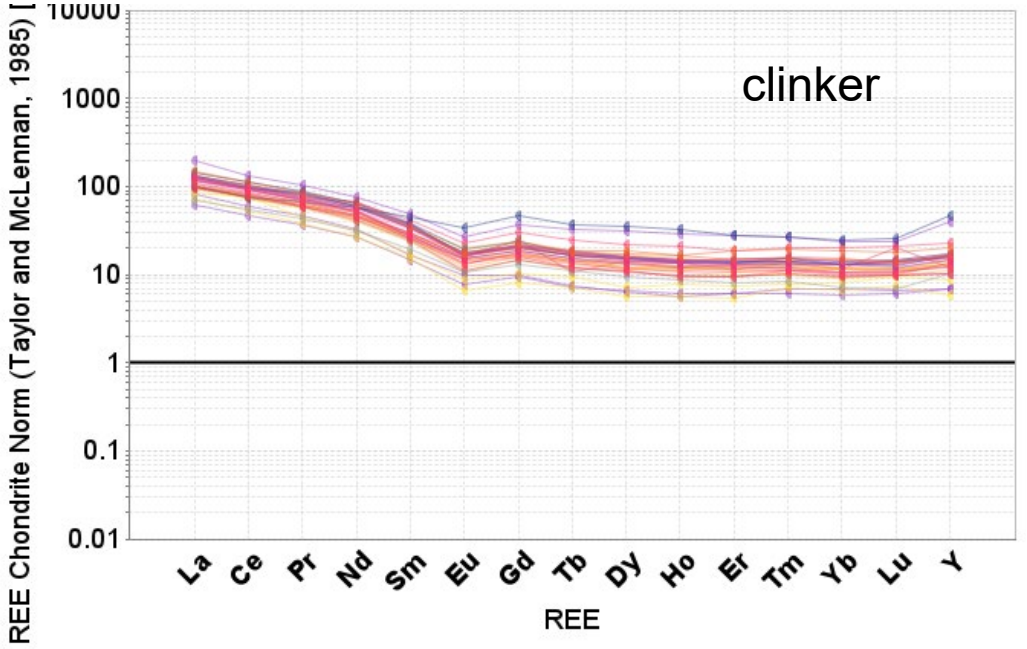
Chemistry Samples from 22 fields (total 26)

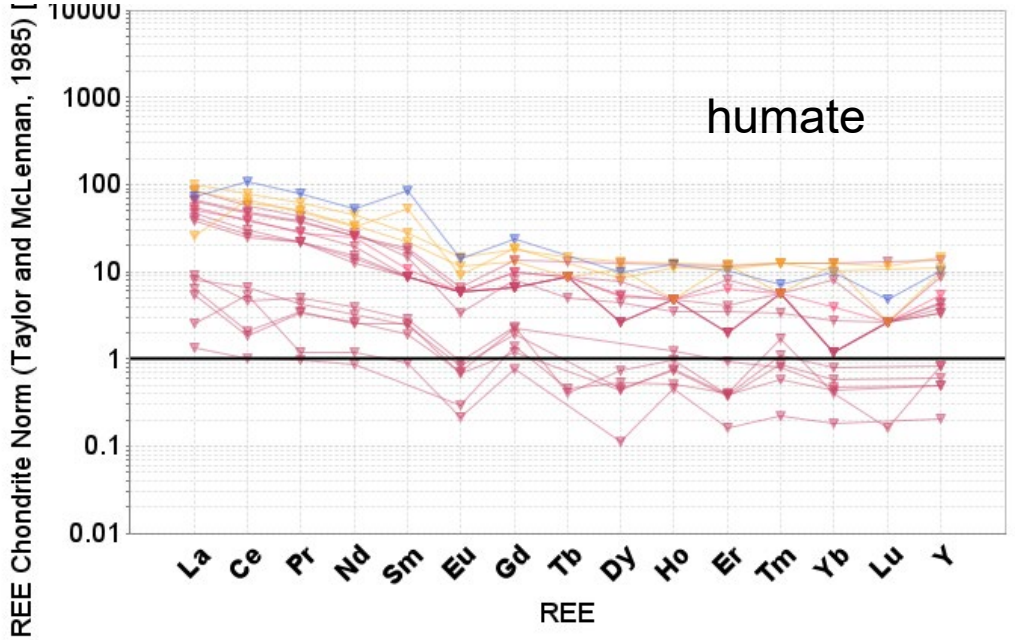
- 148 coal, 5 ash, 18 humate, 34 clinker samples
- 119 igneous rocks, shale, sandstone, clay, other
- 93 beach placer

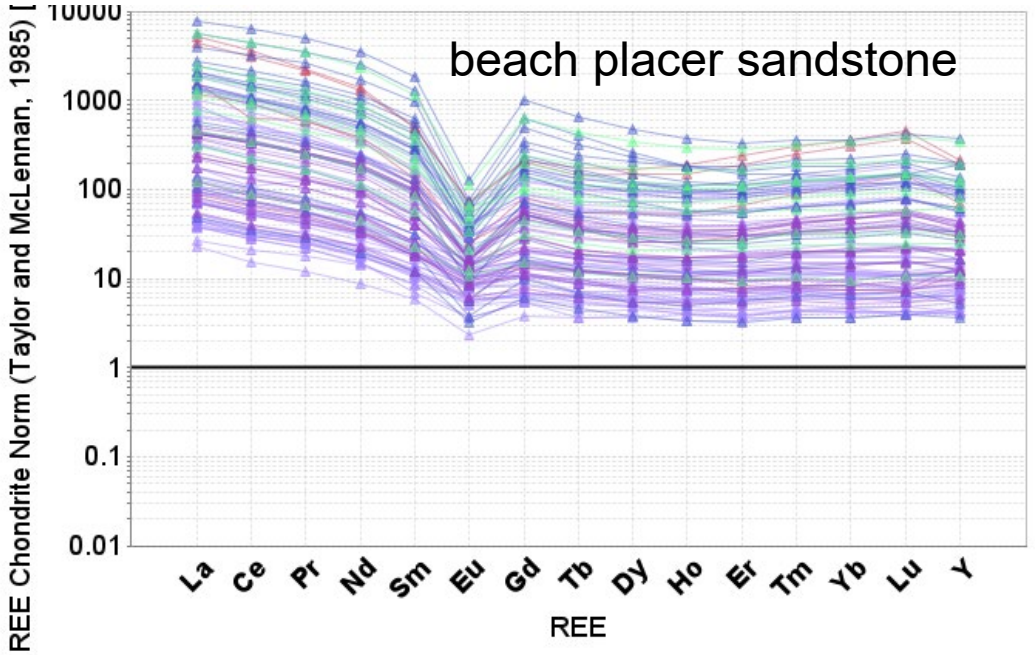


REE chondrite-normalized REE of samples by coal fields in the San Juan Basin

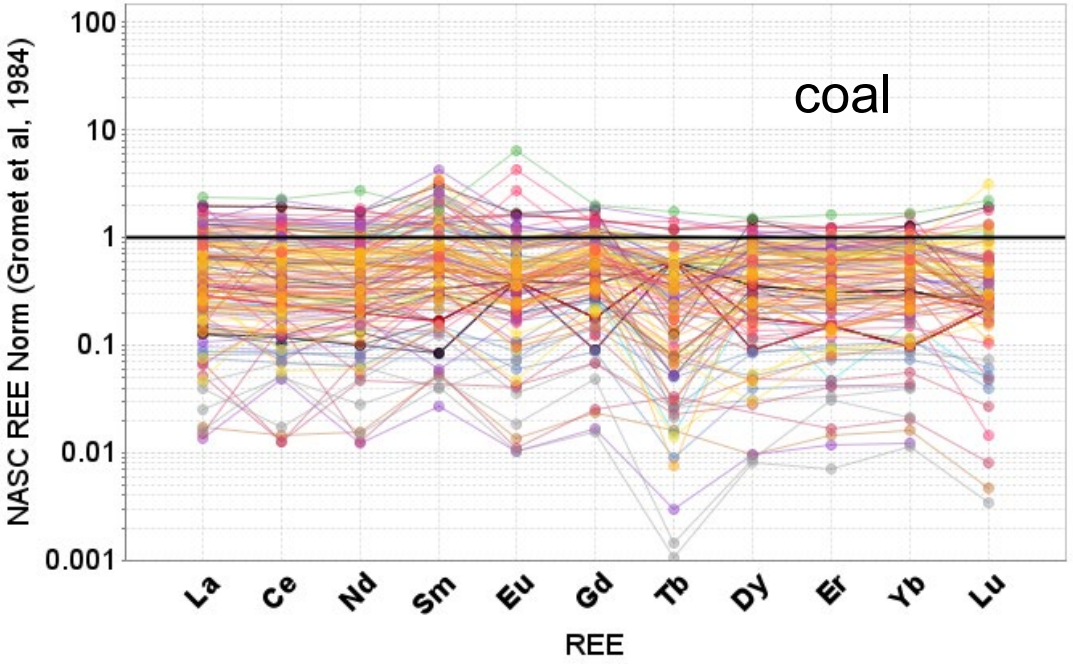


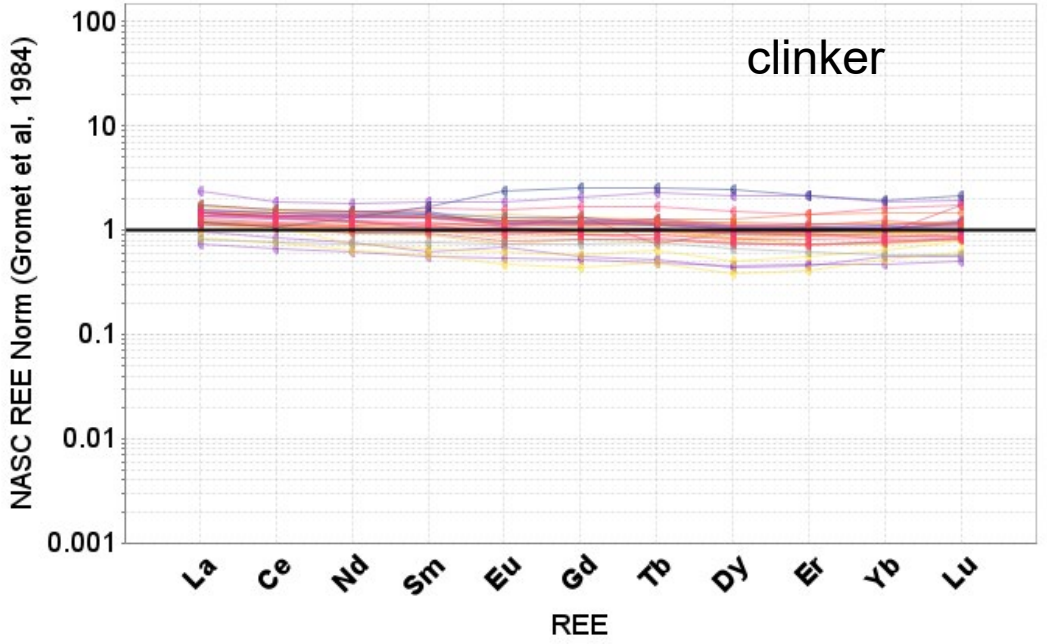


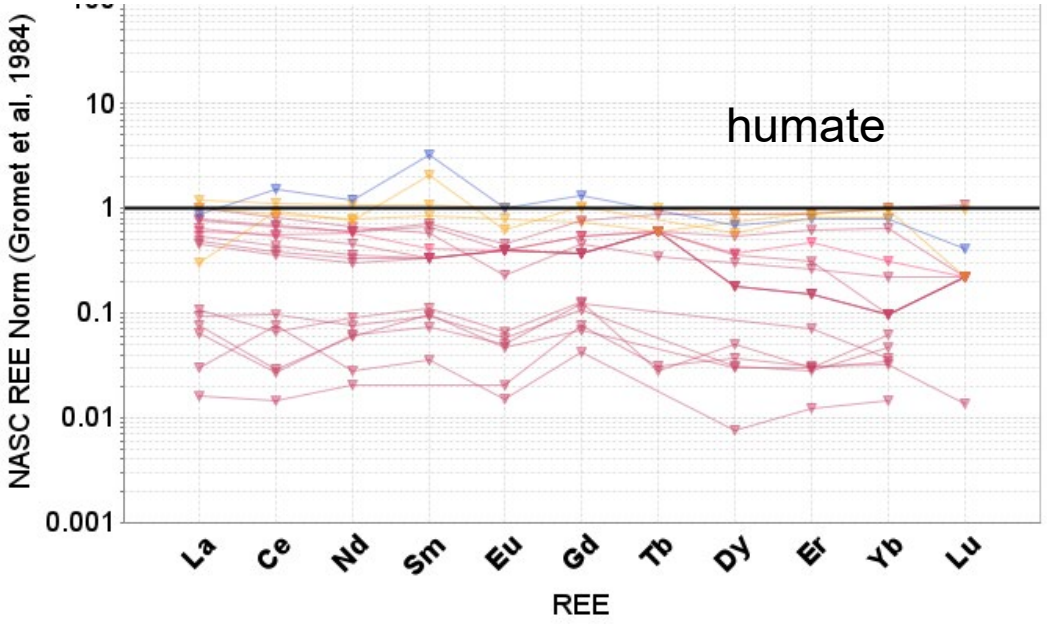


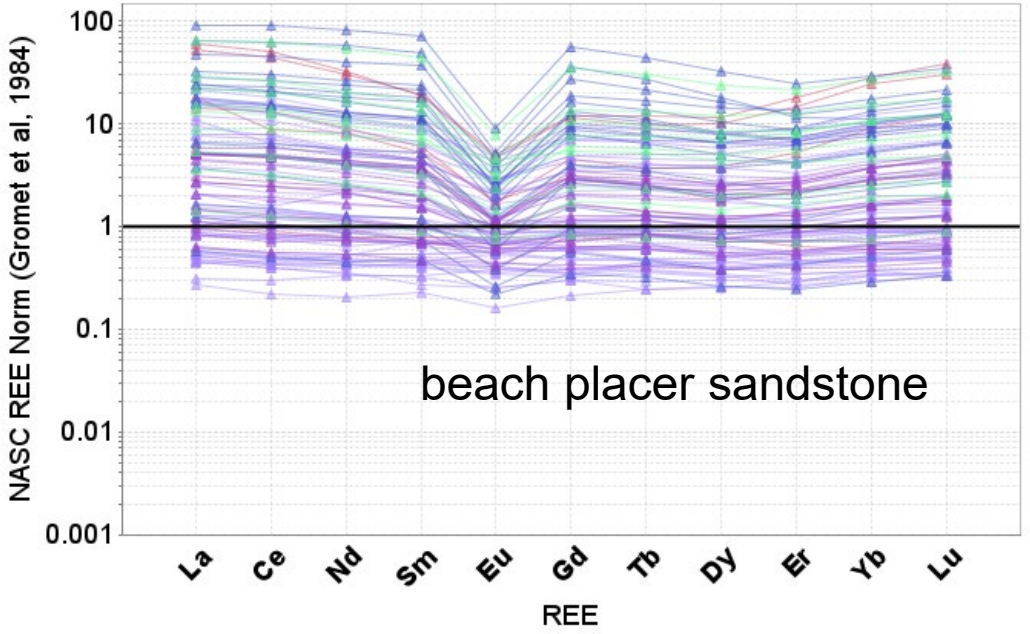


REE NASC-normalized REE of samples by coal fields in the San Juan Basin

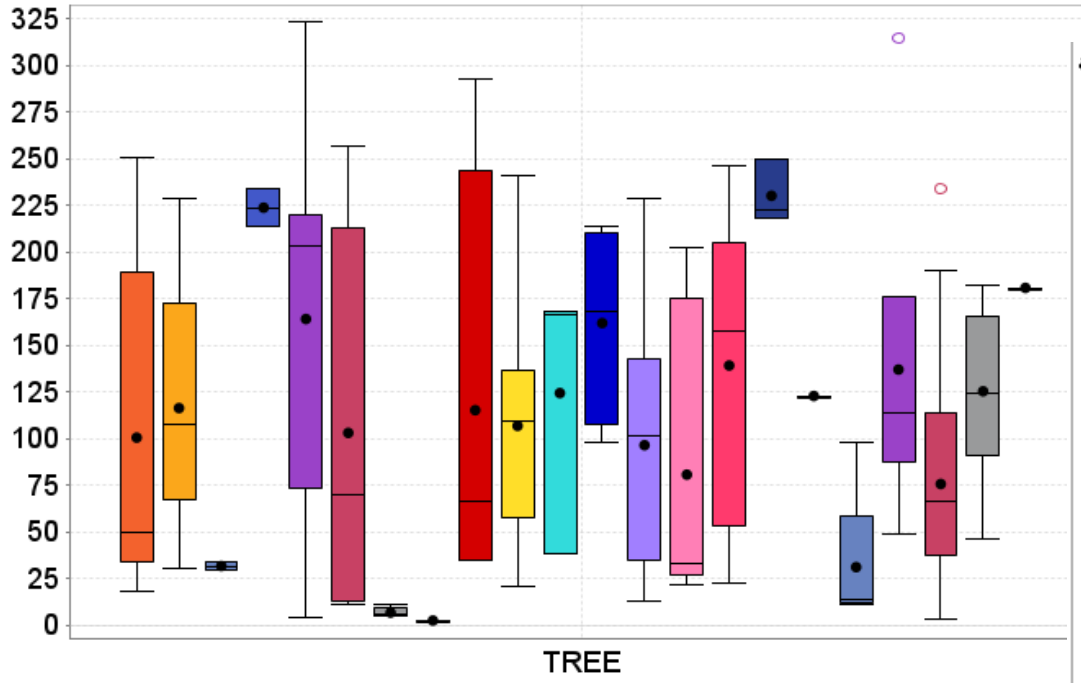


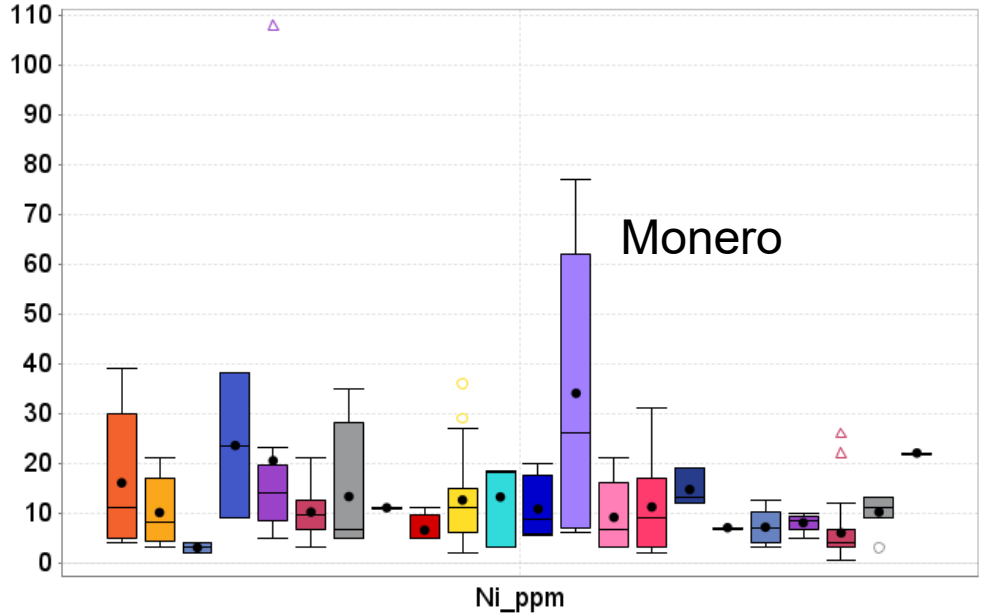


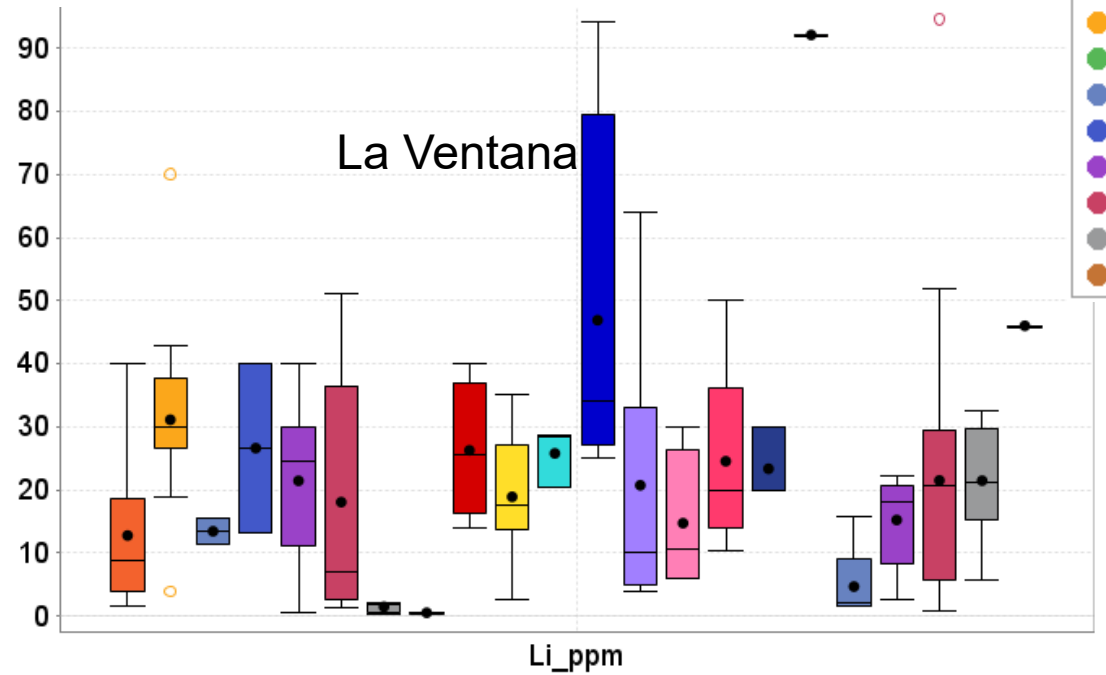


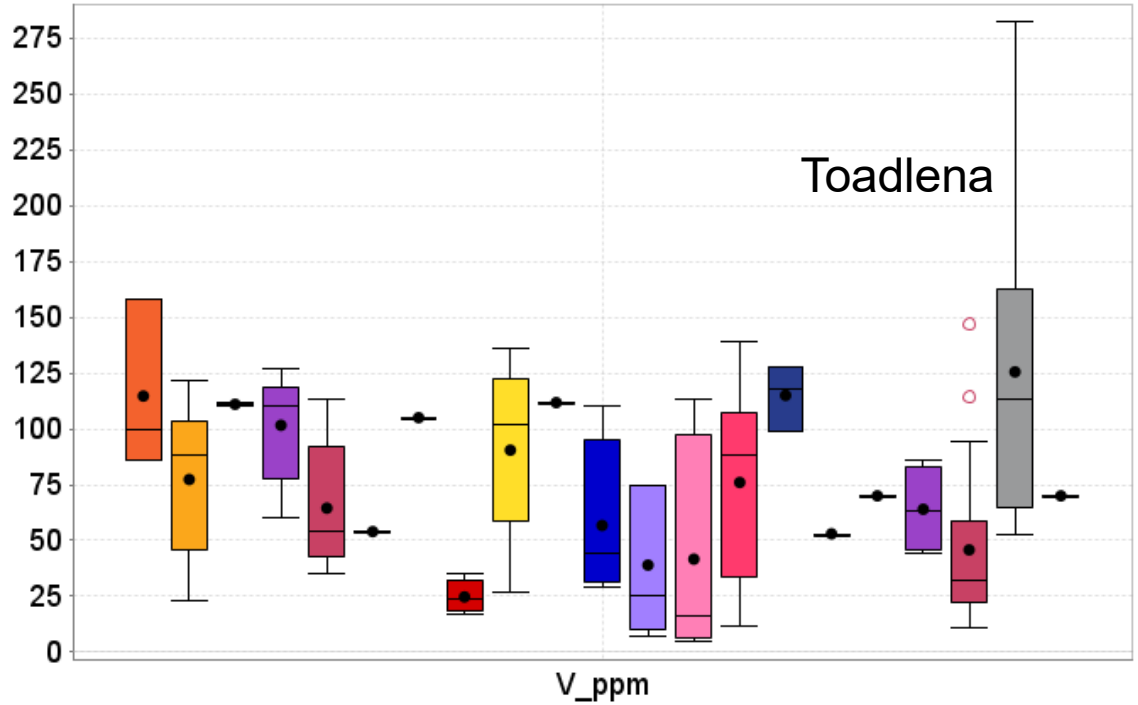


Critical minerals in coal, clinker, humate









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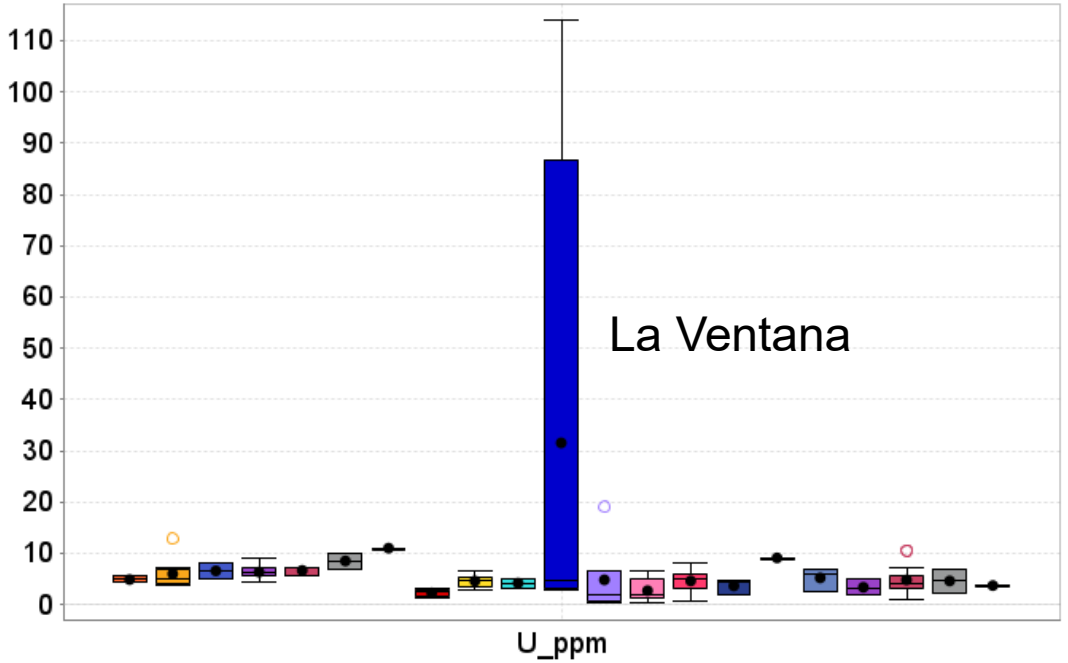
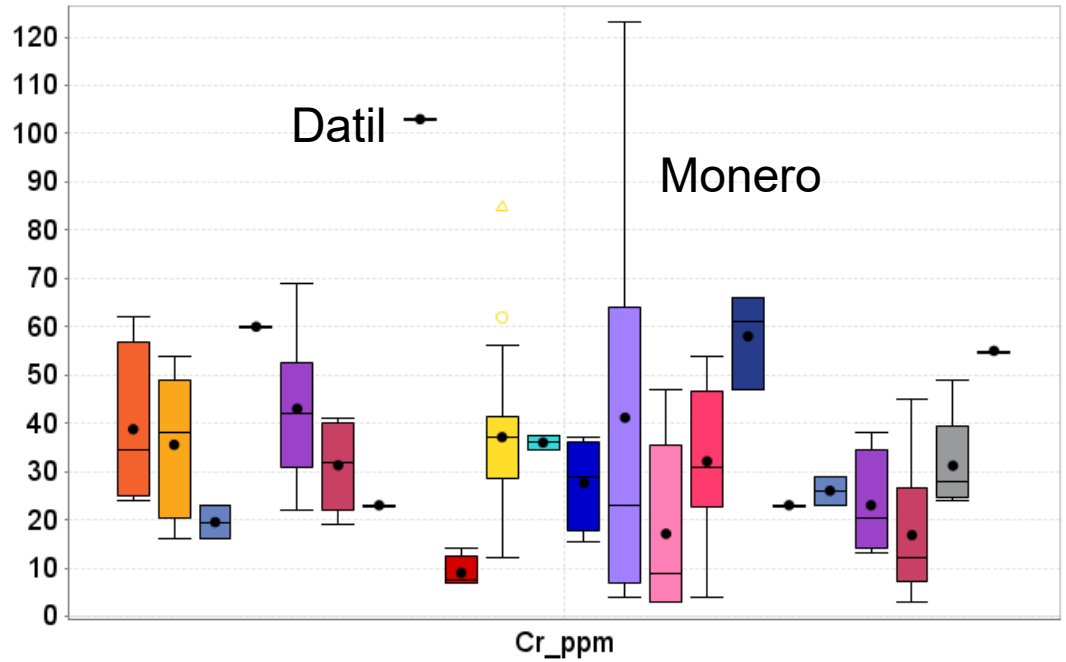
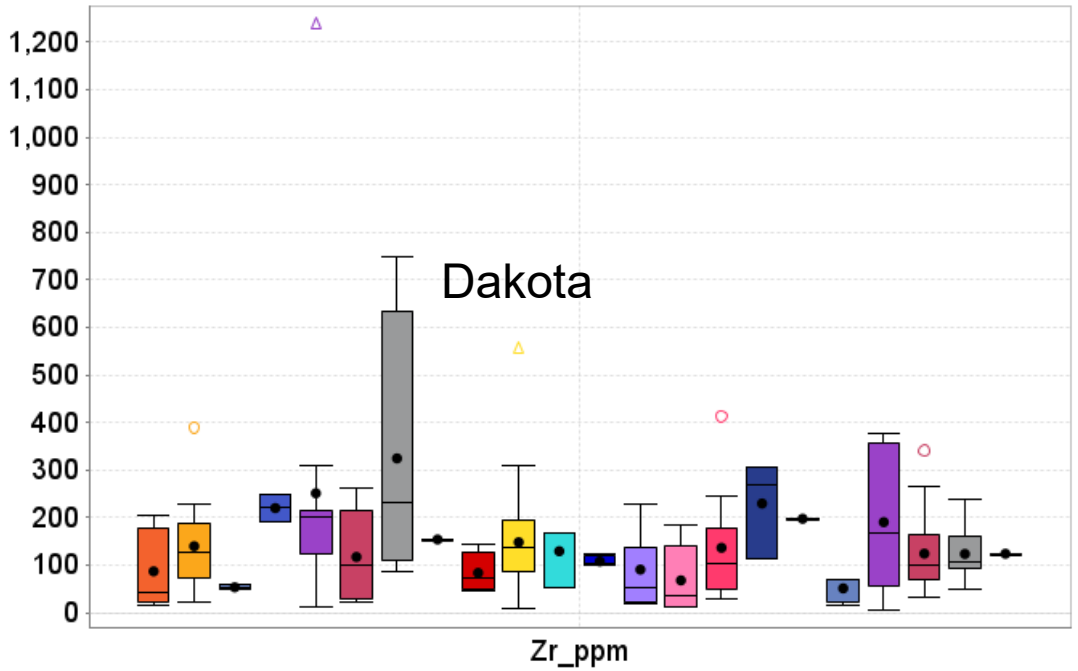
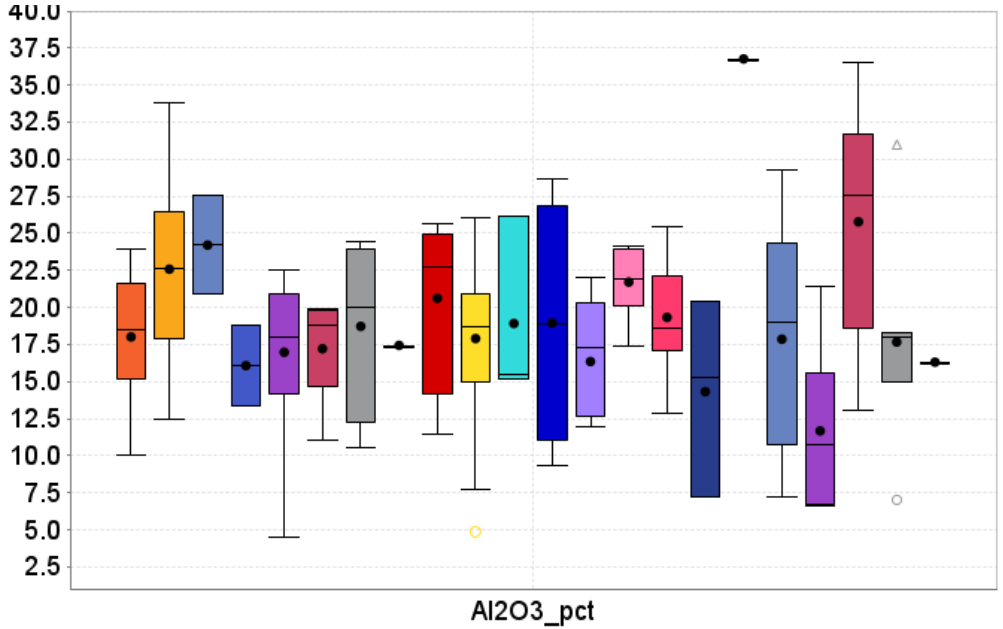
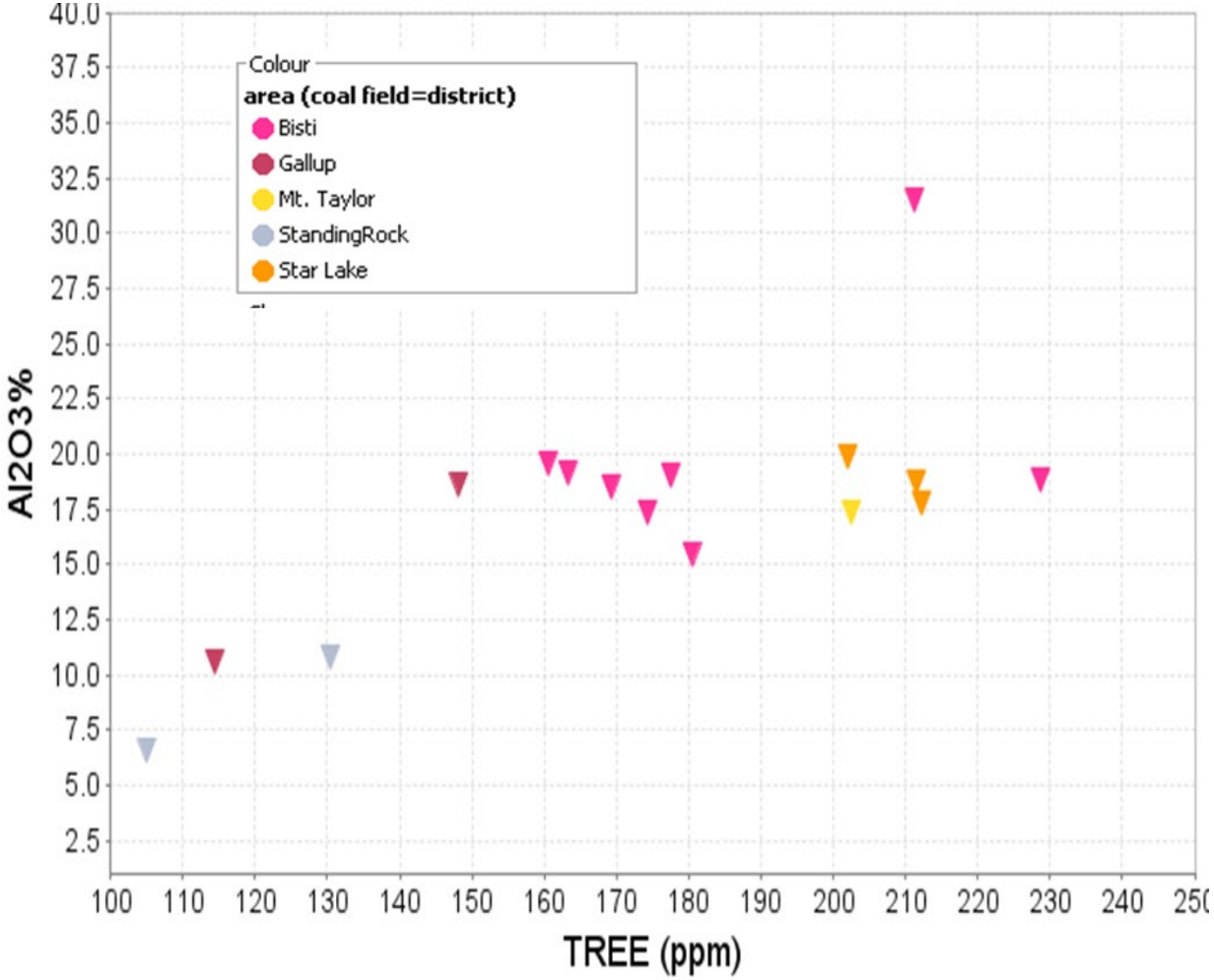








Clinkers



Up to 32% Al_2O_3

Preliminary Conclusions

- Mineralogy of the deposit is consistent with the chemical analysis and similar in coal, clinker, humate, and beach placer sandstone deposits
- The New Mexico coal, humate, and clinker deposits are relatively low-intermediate in REE (<325 ppm TREE), Li (<90 ppm), V (<168 ppm), Co (<51 ppm), Ni (<108 ppm), Zr (<557 ppm), Hf (<14 ppm), and many other critical minerals compared to normal economic deposits. However, some of these rocks are enriched in Al_2O_3 (as much as 32%) and Sr (as much as 3740 ppm), both critical minerals
- Common minerals hosting the critical minerals in these rocks include clay minerals, zircon, ilmenite, rutile/anatase, monazite

Preliminary Conclusions—continued

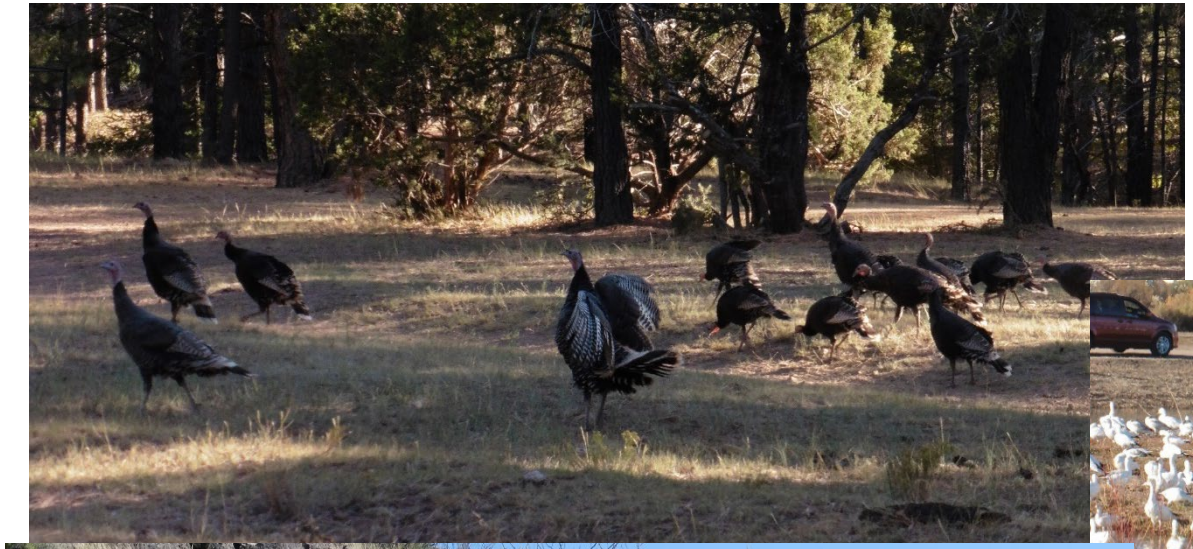
- Although, local high concentrations of Ti, Zr, U, Th, and REE are found in some heavy mineral, beach-placer sandstone deposits in the San Juan Basin, it is unlikely that any of these deposits in the San Juan Basin will be mined in the near future because of small tonnage, high degree of cementation through lithification, high iron content, and distance to processing plants and markets.
- However, as the demand for some of these elements increases because of increased demand and short supplies, the dollar value per ton of ore may rise, enhancing deposit economics.
- Ultimately, economic potential will most likely depend upon production of more than one commodity, maybe even from different deposit types (coal, humate, clinker, and beach placer sandstone deposits).

Future work

- Continue to sample known beach-placer sandstone, sandstone hosted copper deposits, and coal/humate deposits
- Compile geochemical and mineralogical analyses
- Identify possible sources
- Evaluate the mineral-resource potential and estimate the potential endowment of REE and critical minerals

QUESTIONS?

See project web page at
https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html



Economics of modern mineral sands

- Economic deposits are 10 million tons of >2% heavy minerals

- Zirconium as zircon (1-50%)
  - Ceramic tiles, bricks used to line steel making furnaces, mold and chill sands, alloying agent in steel, laboratory crucibles
- Titanium as ilmenite (10-60%), rutile, leucoxene (titanium, 5-25%)
  - white pigment found in toothpaste, paint, paper, glazes, and some plastics, heat exchangers in desalination plants, alloys in aircraft, welding rods
- REE as monazite $(Ce,La,Y,Th)PO_4$) (<15%)
  - Catalyst, glass, polishing, re-chargeable batteries, magnets, lasers, glass, TV color phosphors
- Other minerals
  - Garnet, starolite, kyanite trace-50%