Rare Earth Elements and Critical Minerals in the San Juan and Raton Coal Basins, Northern New Mexico

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Presentation Outline

- Introduction
- Purpose of Study
- Coal in New Mexico
- Method of Study
  - Sampling Work
  - Drill core Logging
  - Compiling Existing/Historical Data
- Preliminary Results
- Economic Resouce Calculation/Coal Boundaries
- Future Work
- Preliminary Conclusions
- Acknowledgements
- Q/A

Introduction

CORE - CM Project.

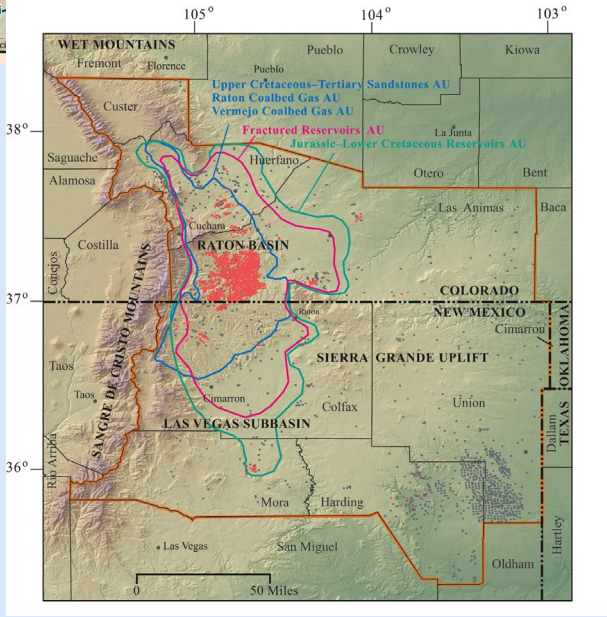
- Carbon Ore, Rare Earth Elements (REE), and Critical Minerals (CM)
  - DOE awarded New Mexico Tech contract
    - Examine REE and CM in the San Juan and Raton coal basins
  - Structural coal basins contain elevated concentrations of REE and CM

Main Objective

- Basinal assessment of CORE-CM resources in the San Juan and Ration coal basins
  - Identify/quantify distribution of REE and CM
    - Coal beds
    - Related statgraphic units
  - Identify/quantify sources of REE and CM

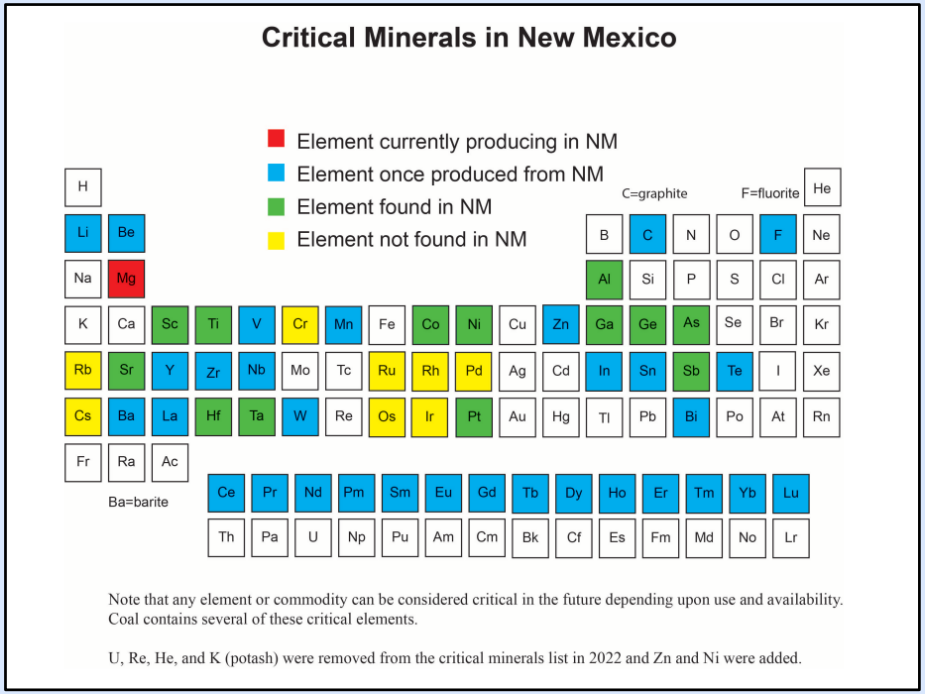
Upper Left: San Juan Basin (USGS)

Lower Right: Raton Basin (USGS)



Purpose of Study

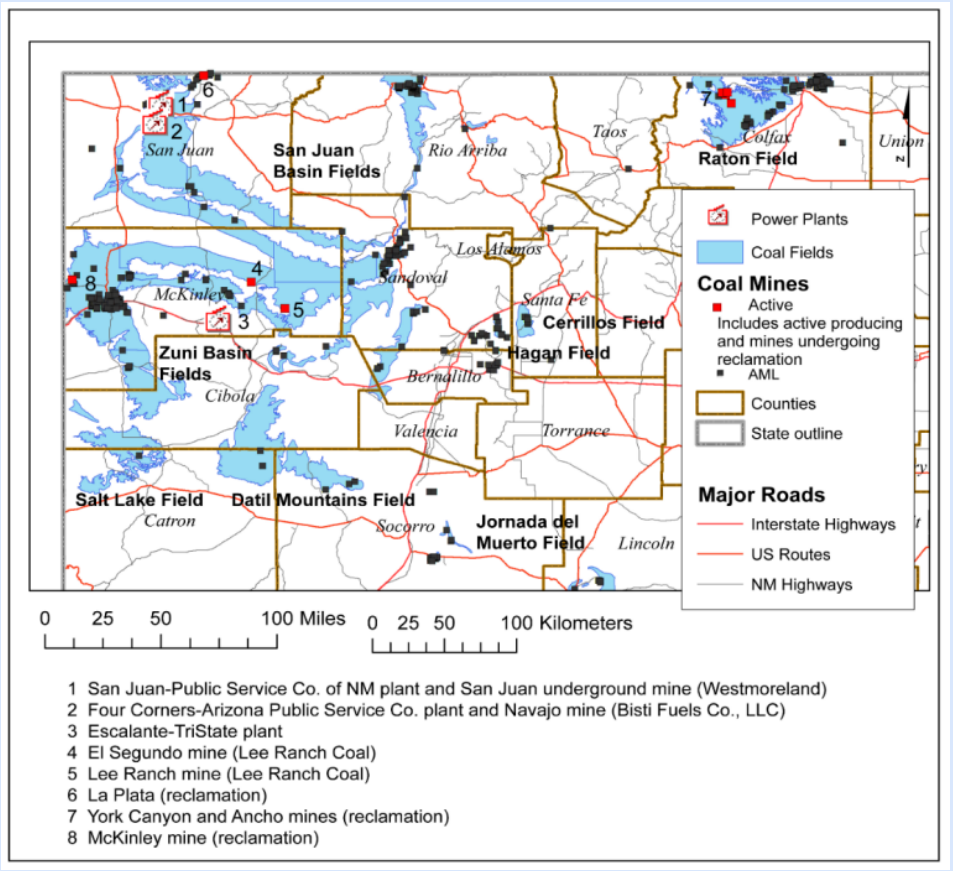
- REE and CM are non-renewable resources
  - Essential to US economic and national security
- Supply potentially susceptible to disruption
  - War, Famine, Importation
- Highly Important to U.S. green/clean energy development
  - Continued advancement of technology
  - Used in batteries, solar panels, and wind turbines
- Identifying and producing REE and CM in New Mexico may directly benefit the economy



Elemental Table of Critical Minerals significant to New Mexico
(https://geoinfo.nmt.edu/resources/minerals/critical/home.html)

Coal in New Mexico

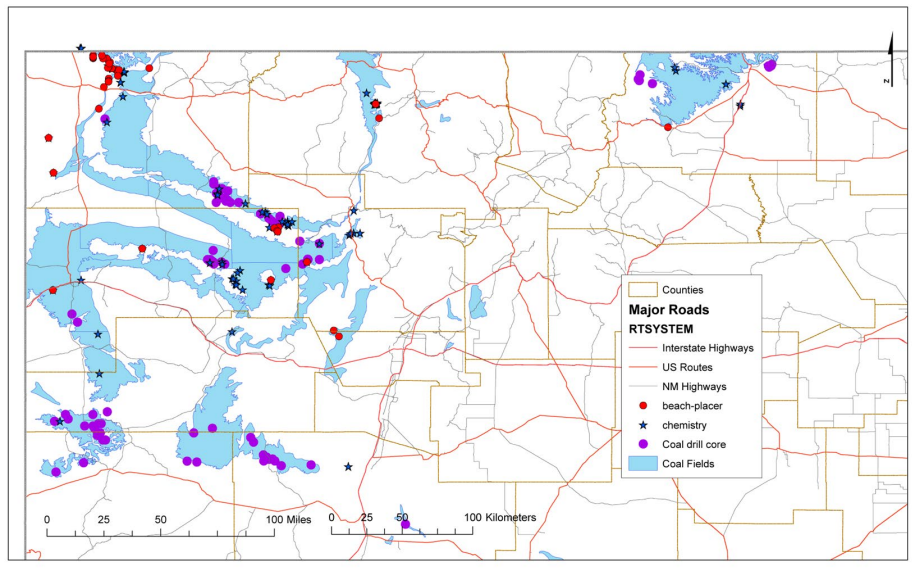
- Coals in the San Juan and Raton basin are Late Cretaceous in age
  - Hosts important energy and mineral resources
- San Juan Basin has 3 coal bearing sequences
  - Crevasse Canyon, Menefee, Fruitland Formations
  - ~ 20 coal fields
- Raton Basin has 2 major coal being sequences
  - Vermejo and Raton Formations
- As of October 2022, NM has two operating surface coal mines
  - El Segundo Mine, in Grants, NM
  - Navajo Mine, in Fruitland, NM



CORE-CM Project Area, San Juan and Raton coal fields (Hoffman, 2017)

Method of Study - Sampling Work

- Samples collected from 8 sources
  1. Coal seams, stratigraphic units above/below coal seams of existing drillcore
  2. Field exposures of coal, shale, volcanic ash beds, and humate deposits
  3. Coal ash
  4. Coal refuse and waste piles
  5. Acid mine drainage from active & AML
  6. Coal and other ore tailings
  7. Boiler slag
  8. Other related strata
     - Beach-placer sandstones, clays, clinkers, etc
- Current Samples collected
  - ~24 coal fields between San Juan and Raton Basins
    - 17 coal fields have been sampled
  - Sampled using Sampling SOP of NMBGMR



Map of coal fields and drill-core locations in northern, New Mexico (McLemore, 2017)

Method of Study- Drill Core Logging

- > 3162 feet logged, 33 holes
  - Logged/Photographed
- Logging geological information
  - Lithology
    - Sandstone, Siltstone, mudstone, coal, and shale
  - Color
  - Grain size and shape
  - Textures
    - Bedding, foliation, stratification
  - Mineral Composition
  - Weathering/alteration
  - Hardness/fractures
  - Other relevant notes
    - Odors, contamination, fossils, mineralizations

Torreon Wash, Sandoval County, NM - Boxes C5 and C6. Well ID - 6393 and 6376. Both collected from Menefee Formation (Photos by M.Badonie)

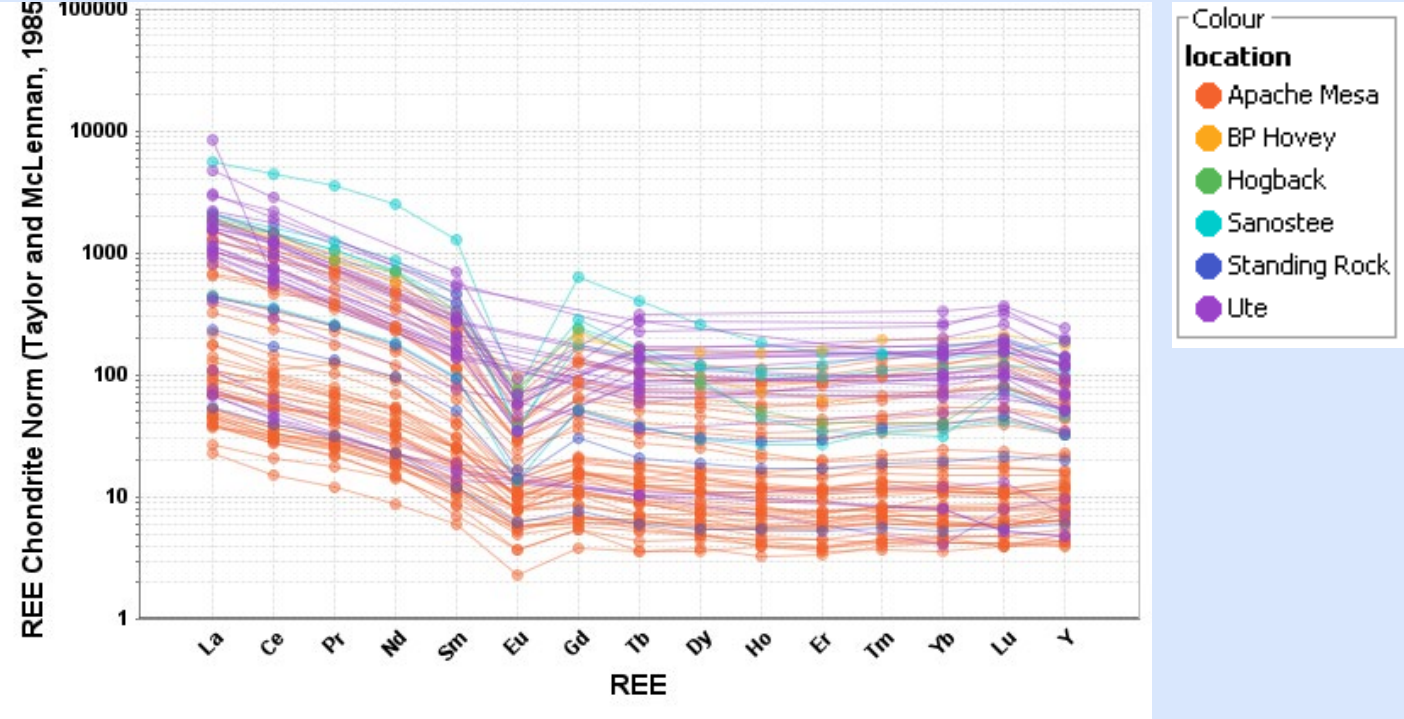
Method of Study - Compiling Historical & Existing Data

- Existing and Historical Data
  - Drill core, geologic maps, hand samples, and past reports
  - 247 Legacy samples
  - 131 new samples
    - 106 from the San Juan Basin
    - 25 from the Raton Basin
- A database is being created
    - Historical and incoming data
    - Public access
- Interpretation of legacy geochemistry
    - Used with caution due to accuracy
    - Still used as a guide for interpretation

District ID	District (Coal Field)	Formation	Basin	Year of Discovery	Year of Initial Production	Year of Last Production	Estimated Cumulative Production	Number of Samples Collected
DIS257	**Barker Creek**	Menefee	San Juan	1882		1905		
DIS150	Bisti	Fruitland	San Juan	1961	1980	1988	$40,075,148	13
DIS259	**Chaco Canyon**	Menefee	San Juan	1905	1905			
DIS260	Chacra Mesa	Menefee	San Juan	1922		1945		3
DIS174	La Ventana	Menefee	San Juan	1884	1904	1983		4
DIS118	Crownpoint	Crevasse Canyon	San Juan	1905	1914	1951	$20,758	4
DIS155	Fruitland	Fruitland	San Juan	1889	1889	2001	$3,137,957,050	6
DIS119	Gallup	Crevasse Canyon	San Juan	1881	1882	2001	$121,522,629,885	13
DIS156	**Hogback**	Menefee	San Juan	1907	1907	1971	$301,237	
DIS146	Monero	Menefee	San Juan	1882	1882	1970	$5,277,552	7
DIS016	Mount Taylor	Crevasse Canyon	San Juan	1936	1952	9999	$69,948	8
DIS157	Navajo	Fruitland	San Juan	1933	1963	9999	$4,714,689,147	2
DIS258	**Newcomb**	Menefee	San Juan	1955				
DIS021	Raton	Raton	Raton	1820	1898	2002	$954,470,032	25
DIS003	**Rio Puerco**	Crevasse Canyon	San Juan	1901	1937	1944	$139,555	
DIS009	Salt Lake	Moreno Hill		1980	1987	1987	$100,000	2
DIS121	San Mateo	Menefee	San Juan	1905	1983	2001	$1,678,742,326	1
DIS261	Standing Rock	Menefee	San Juan	1934	1952	1958		3
DIS158	Star Lake	Fruitland	San Juan	1907			N/A	30
DIS263	**Tierra Amarilla**	Menefee	San Juan	1935	1955	1955		
DIS159	**Toadlena**	Menefee	San Juan	1950			N/A	
DIS124	Zuni	Crevasse Canyon	San Juan	1916	1908	1926	$16,010	1
DIS208	Carthage	Crevasse Canyon	San Juan	1862	1862	1981	N/A	3
DIS264	Jornada del Muerto	Crevasse Canyon	San Juan	1910	1910	1927	N/A	6
							Total Samples	131

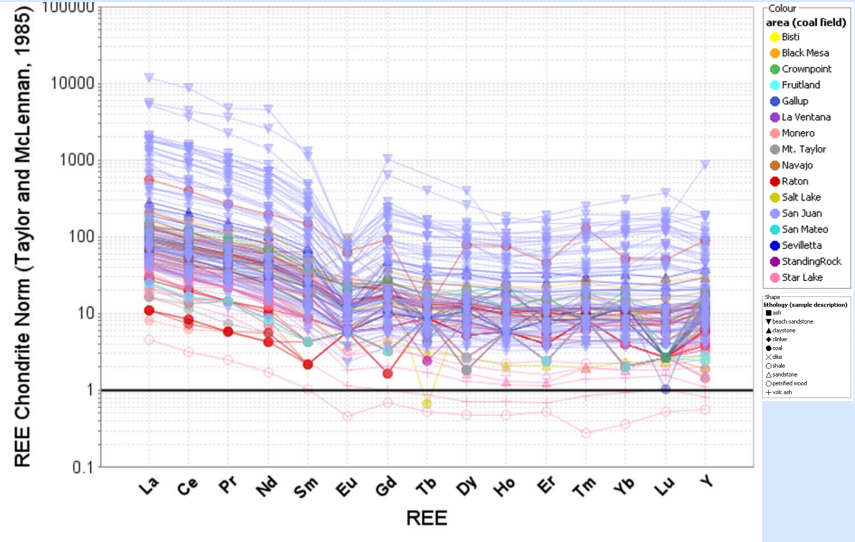
TABLE 1. Coal fields in New Mexico that have been sampled, does not include legacy data. Red bolded words are coal fields that don't have any chemical analyses

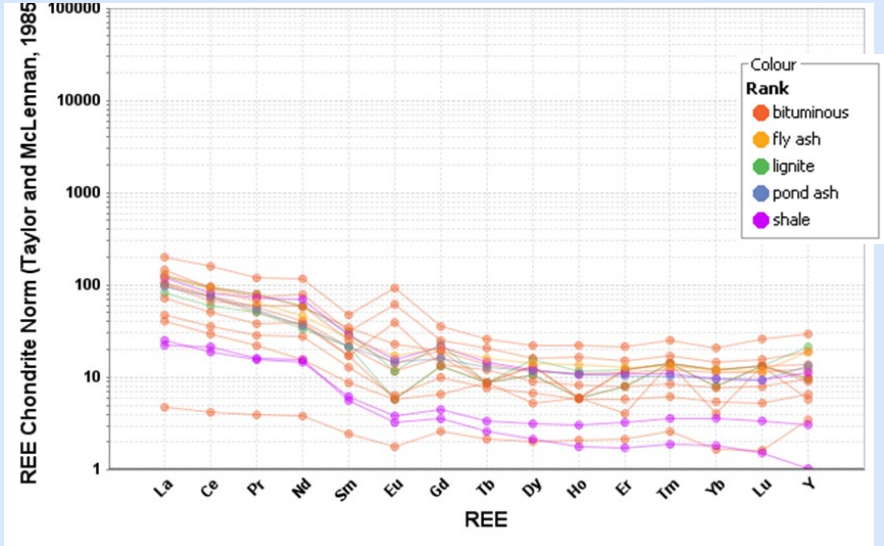
Preliminary Results - Legacy Data - Beach Placer Sandstone Deposits



Chondrite-normalized plot of REE content in beach-placer sandstone deposits.
They have high concentrations of TREE, Zr, Ti, Nb.
(Data from McLemore et al., 2016)

Preliminary Results – REE Chondrite Normalized Graphs

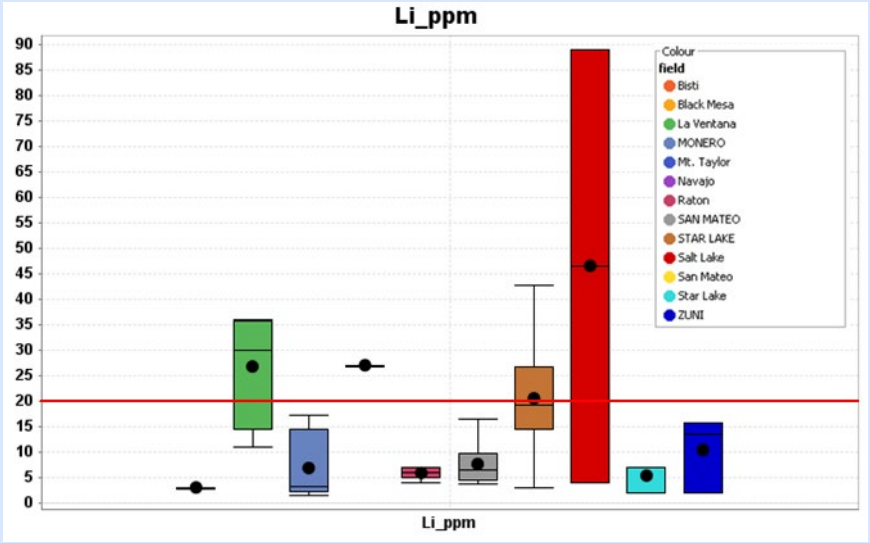


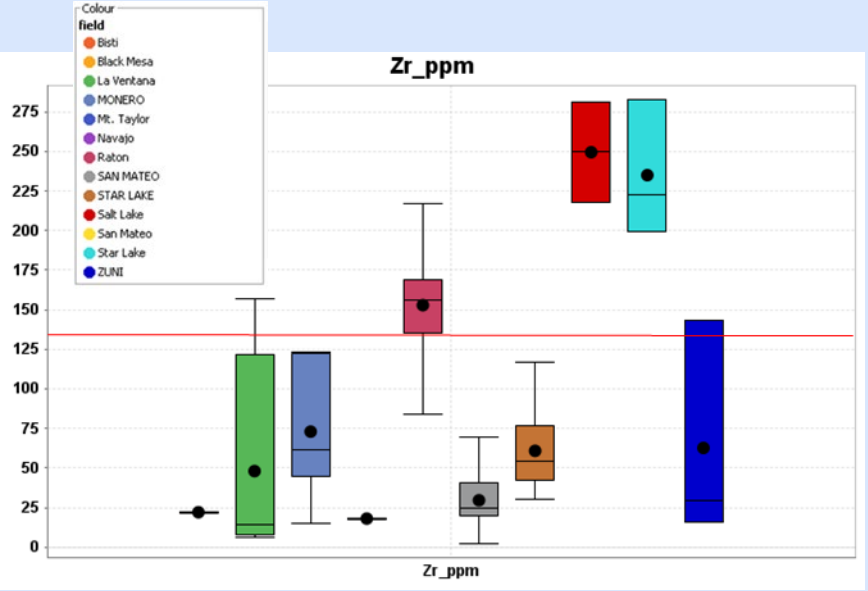


LEFT: Chondrite normalized REE plot of new sample data from San Juan and Raton basins. Includes coal and non-coal samples. Note that Beach-placer sandstone deposits have greater than 1000 ppm total REE.

RIGHT: Chondrite normalized REE plot of new samples from the San Juan basin, including coal, shale, and ash deposits. Note that coal ash samples have greater than 200 ppm total REE.

Preliminary Results - Chemical plots of CM of samples from the San Juan Basin



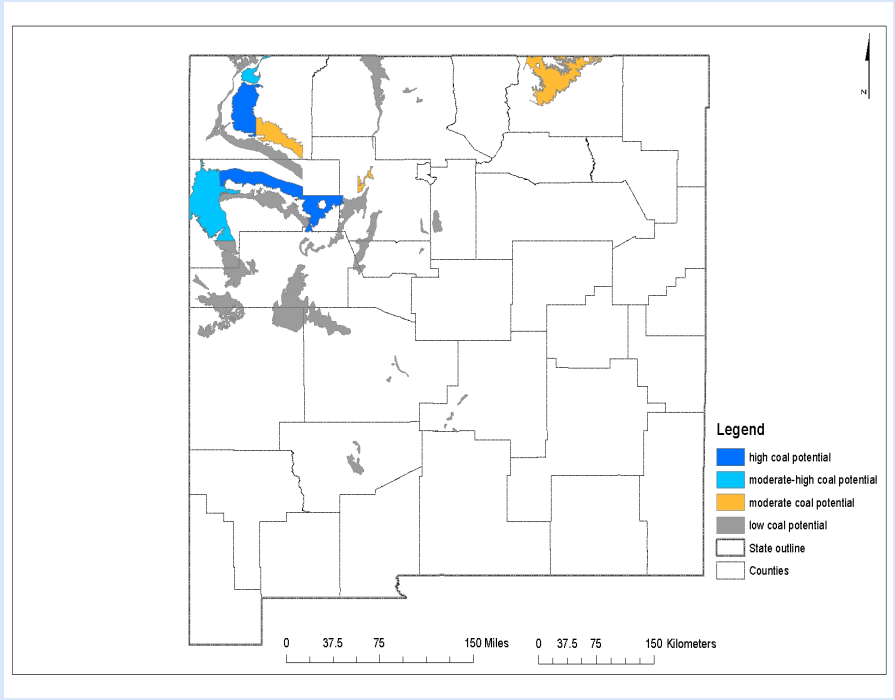


LEFT. Box plot of Li concentrations in the San Juan Basin, classified by coal fields. Slight Li elevated concentration at 89 ppm. Red line is average crustal abundance (Aral, H., & Vecchio-Sadus, A., 2011).

RIGHT. Box Plot of Zr Concentrations in the San Juan Basin, classified by coal fields. Slight Zr elevated concentration at 283 ppm. Red line is average crustal abundance (Münker, C. (2016).

Economic Resource Calculations/ Coal Boundaries

- **Resources Potential**
  - Calculate coal volume mineral resouce potential
    - Apply REE and CM chemistry
    - Resource estimate in the San Juan and Raton Basins
  - Establishing procedure using ArcGIS
- **Coal Boundaries**
  - Drill Core coordinates show core collected outside of coal field boundary
  - Based on coal thickness in seams



Coal potential map of New Mexico coal fields (Hoffman, 2018)

Future Work

- Collect more samples of coal, humates, clinkers, beach placer sandstones, etc
  - 7 remaining coal fields within the San Juan and Raton Basins
  - Premit for additonal sampling on tribal lands in April
- Continue characterization analyses
  - Coal is difficult to chemically analyze by traditional methods
    - There are some discrepancies being worked out
  - Geochemistry
  - Mineralogy
  - Thin sections
- Geochemical interpretation upon receiving chemistry data
  - Send samples to Sandia and Los Alamos for characterization
- Use the information to survey and map
  - Identify possible sources for REE and CM
  - Evaluate the mineral resource potential

Preliminary Conclusions

- REE in the San Juan and Raton basins coal deposits are relatively low in concentration.
- Other critical minerals, such as Li and Zr, are slightly elevated and could have future potential in the San Juan basin.
- Ash is a product of burning coal, and REE and perhaps some critical minerals can be recovered from the ash, especially if there are additional industrial uses for the ash (additional study underway).
- Beach-placer sandstone deposits are found in coal fields throughout New Mexico. These beach-placer sandstones exhibit LREE enrichment in chondrite normalized REE patterns, and are more enriched in total REE than the coal deposits.
- The economic potential of REE and critical minerals in coal deposits in New Mexico will depend upon the production of more than one commodity from more than one type of deposit.
- REE and CM are low compared to economic deposits, but maybe significant in terms of coal volume and production.
- CM has variable concentrations between coal districts and seams, and there needs to be thorough sampling.

Acknowledgments

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Questions? Comments?

Thank you!

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