U.S. Department of Energy
Office of Fossil Energy and Carbon Management
DE-FE0032051

Carbon Ore, Rare Earth, and Critical Minerals (CORE-CM) Assessment of San Juan River-Raton Coal Basin

PROJECT SUMMARY
YEAR 2 REPORT
Submitted October 9, 2023
Project Performance Period: 10/1/2022-9/30/24

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GOAL

The objective of this project is to determine the rare earth elements (REE) and other critical minerals (CM) resource potential in coal and related stratigraphic units in the San Juan and Raton basins, New Mexico. Tasks summarized in Table 1 were identified in the original 2-yr project. Tasks identified in Table 2 are identified in the new 6-month extension. This project will delineate favorable geologic terranes and priority areas containing potential REE and CM deposits for the DOE mandate, which is also a priority of the New Mexico Bureau of Geology and Mineral Resources (NMBGMR, the state geological survey) and state of New Mexico.

TABLE 1. List of tasks and subtasks for Phase 1. See below for status of deliverables.

Task 1.0 Project Management and Planning
Task 2.0 Basinal Assessment of CM and REE in the San Juan and Raton Basins Subtask 2.1 Identification of Sampling Sites Subtask 2.2 Collection and Review of Existing Data Subtask 2.3 Develop a Sampling Plan Subtask 2.4 Collect Samples Subtask 2.5 Sample Characterization Subtask 2.5.1 Bulk Rock Characterization Subtask 2.5.2 Micro-scale Characterization Subtask 2.5.3 3D Multiscale Petrography Subtask 2.5.4 In situ LIBS/RAMAN Analyses Subtask 2.6 Application of Machine Learning techniques for basin-wide resource assessment
Task 3.0 Basinal Strategies for Reuse of Waste Streams Subtask 3.1 Waste Streams Sampling and Characterization Subtask 3.2 Coal Ash Subtask 3.3 Technology Development of Basinal Reuse Strategy
Task 4.0 Basinal Strategies for Infrastructure, Industries and Businesses Subtask 4.1 Infrastructure Investigation Subtask 4.2 Competitiveness and Challenge Subtask 4.3 Life-Cycle Analysis
Task 5.0 Technology Assessment, Development and Field Testing Subtask 5.1 Identify and Assess, Existing and Novel Technologies Specific to the Resource Subtask 5.2 Develop Plan for Field Testing
Task 6.0 Technology Innovation Centers Subtask 6.1 SonoAsh Center of Excellence
Task 7.0 Stakeholder Outreach and Education Subtask 7.1 New Mexico State and Regional Education Subtask 7.2 Lessons Learned and Narratives Constructed Subtask 7.3 Publications Subtask 7.4 Training and Conferencing with SJC and Sonoash COE

TABLE 2. List of tasks and subtasks for the extension. See below for status of deliverables.

Task	Deliverable	Due Date
1.0	Project Management Plan	Update due 30 days after award. Revisions to the PMP shall be submitted as requested by the NETL Project Manager.
1.1	Summary of Environmental Justice Considerations	To be included as an appendix to the Final Scientific/ Technical Report
1.2	Summary of Economic Revitalization and Job Creation Outcomes	To be included as an appendix to the Final Scientific/ Technical Report
1.3	Environmental, Safety, and Health Analysis	To be included as an appendix to the Final Scientific/ Technical Report
2	Overall CORE-CM Resource Sampling Plan providing sampling locations, sampling methods for each location, and site-specific access agreements	Due to NETL Project Manager before accessing the site.
2	Initial Basinal Resource Assessment	Due at the end of the Period of Performance.
2	Characterization and Data Acquisition Plan	Due at the end of the Period of Performance.
3	Initial Waste Stream Reuse Plan	Due at the end of the Period of Performance.
4	Results of the Basinal Strategies for Infrastructure, Industries and Business Assessment	Due at the end of the Period of Performance.
5	Initial Technology Assessment and Field Development Plan	Due at the end of the Period of Performance.
6	Initial Technology Innovation Center Plan	Due at the end of the Period of Performance.
7	Initial Stakeholder Outreach and Education Plan	Due at the end of the Period of Performance.
1	Phase 1 Interim Report	Due to NETL Project Manager 12 months and 24 months after award. At 12 months, this will include an outline of deliverable reports and preliminary findings to date. At 24 months this will include a summary of findings over the prior 12 months.

2	Energy Data Exchange (EDX) FOA-2364 REE Researcher Database Template (per Appendix G of FOA 2364)	All available collected data shall be submitted by 9/30/23 to the NETL Project Manager. A revised template including all data collected during project performance will be due at the end of the Period of Performance to the NETL Project Manager. Due 60 days after data is produced and a (final) update is due with Phase 2 down-select application. State-specific, county-specific, and site-specific resource characterization and geographic location data (i.e., elemental concentrations; proximate/ultimate analyses; ash content; phase identification/concentrations; morphology information; etc.), and characterization information will be supplied to NETL and made publicly available through inclusion on NETL's EDX database platform. See Note below.* Note: Resource assessment may include data retrieved from literature review or obtained from unpublished sample repositories/historical samples, etc. Every effort should be made to provide the DOE this data, from where the data was obtained (i.e., tables/citations in final report), and any other pertinent info such as testing and characterization method. DOE asks the awardee to complete the REE Researcher Database Template as best as they can for this data.
2	Inputs for NETL REE-SED Sample Data Needs (per Appendices H and I of FOA 2364)	Due at the end of the period of performance. This information will be supplied in the format specified in Appendix H for uploading into NETL's Geospatial EDX Database, for use in NETL RIC's Geologic Models. See Note below.*
2	Resource Samples for Mineral Characterization and Analysis	Due to NETL Technology Manager at the end of the Period of Performance, in coordination with assigned NETL Project Manager. Recipients will provide NETL with a single split REE and CM sample for each type of material or core sample assessed in Phase 1 (and if appropriate in continuing phases) that reflects the highest achieved REE or CM concentration identified during conduct of the project effort, and which reflects materials used by the award recipient for their economic assessment. The quantity of sample material should be adequate for laboratory analysis of the sample. Material Safety Data Sheets (MSDS) are required to accompany material supplied to NETL. See Note below.* Recipients will provide NETL, when possible, splits/slabs of any core obtained during the conduct of the project effort. NETL will retain possession any submitted material. Safety Data Sheets (SDS) are required to accompany material supplied to NETL.

*Note: Geospatial Data Products should be compliant with requirements of the Federal Geospatial Data Act of 2018 and DOE's Geospatial Data Strategy https://www.energy.gov/cio/downloads/doe-geospatial-data-management-strategy-2021-2025

PERFORMERS INVOLVED IN THE DOE CORE-CM PROJECT

New Mexico Tech

Dr. Navid Mojtabai (PI) is a professor and department chair in the Mineral Engineering Department at New Mexico Tech - Tasks 1, 3, 5, and 7, and 6 month extension.

Dr. Virginia McLemore (Co-PI) is the Principal Senior Economic Geologist for the NMBGMR - Tasks 1, 2, 3, 5 and 7 and 6 month extension.

~~Dr. Robert Balch (PM) is the Project manager for this project and is the Director of the PRRC – Task 1, 2, 4 and 7. Not involved in 6 month extension.~~

~~Dr. William Ampomah (Co-PI) is a Research Engineer and Section Head at PRRC – Task 1, 4, 5 and 7. Not involved in 6 month extension.~~

Dr. Sai Wang is a Research Associate at PRRC - Tasks 4.

Dr. William Chavez is a professor in the Mineral Engineering department at New Mexico Tech – Task 2 and 3.

Mr. Mark Leo is the NMBGMR database specialist - Task 2 and 3, and 6 month extension

~~Mr. Mark Mansell: is the NMBGMR GIS specialist – Task 2. NO LONGER ON PROJECT~~

Ms. Cynthia Connolly is the Education Outreach Manager at the NMBGMR – Task 7.

Dr. Shari Kelley is a senior field geologist and geophysicist at the NMBGMR – Task 2 and 7.

Mr. Christopher Armijo is the NMBGMR computer specialist - Task 1, 2, and 6 month extension.

Mr. Brian Wheeler is the NMBGMR fleet manager - Tasks 2, 3, and 6 month extension.

~~Ms. Gretchen Hoffman is the NMBGMR emeritus coal geologist – Task 2 and 3. NO LONGER ON PROJECT~~

Mr. Evan Owen is the Economic Geologist at NMBGMR- Task 2, 3, and 6 month extension.

Sandia National Laboratories(SANL)

Dr. Jason Heath is a hydrogeologist at SANL. –Task 2, 5, and 6 month extension.

Dr. Guangpring Xu is an experimental geochemist at SANL - Tasks 2, 3, 5, and 6 month extension.

San Juan College

~~Dr. John Burris is a Professor of Geology and Department Chair at San Juan College – Tasks 7. NO LONGER ON PROJECT~~

Craig Williams San Juan College - Tasks 7. Will continue working during the 6 month extension, using remaining funds.

Los Alamos National Laboratory (LANL)

Dr. Hakim Boukhalfa is a Senior Scientist at LANL – Task 5 and 6

Dr. Brent Goehring and 6 month extension

SonoAsh

Mr. Claudio Arato is the CTO of SonoAsh company - Task 3, 4, 5, 6 and 7. Will continue working to develop phase 2 activities.

Mr. Brad MacKenzie is the VP of SonoAsh company – Task 4 and 6

Change in support levels of key persons
Only NMT, Sandia and Los Alamos National Laboratories are funded for the 6 month extension.

BACKGROUND

The San Juan and Raton basins are predominant Laramide structural basins in northern New Mexico and southern Colorado. They host important energy and mineral resources that have produced significant amounts of coal, uranium, petroleum, and gas (Fig. 1). Cretaceous coal units in the San Juan and Raton basins are listed in Table 3. These coal and associated stratigraphic units have the potential for many critical minerals (CM), especially REE (Finkelman et al., 2018). Coal deposits throughout the world are known to contain high concentrations of CM and REE (Dai and Finkelman, 2018). A basin-wide geochemical, mineralogical, and geochemical characterization study of New Mexico coals is needed to determine the potential for CM and REE in coals in the San Juan and Raton basins.

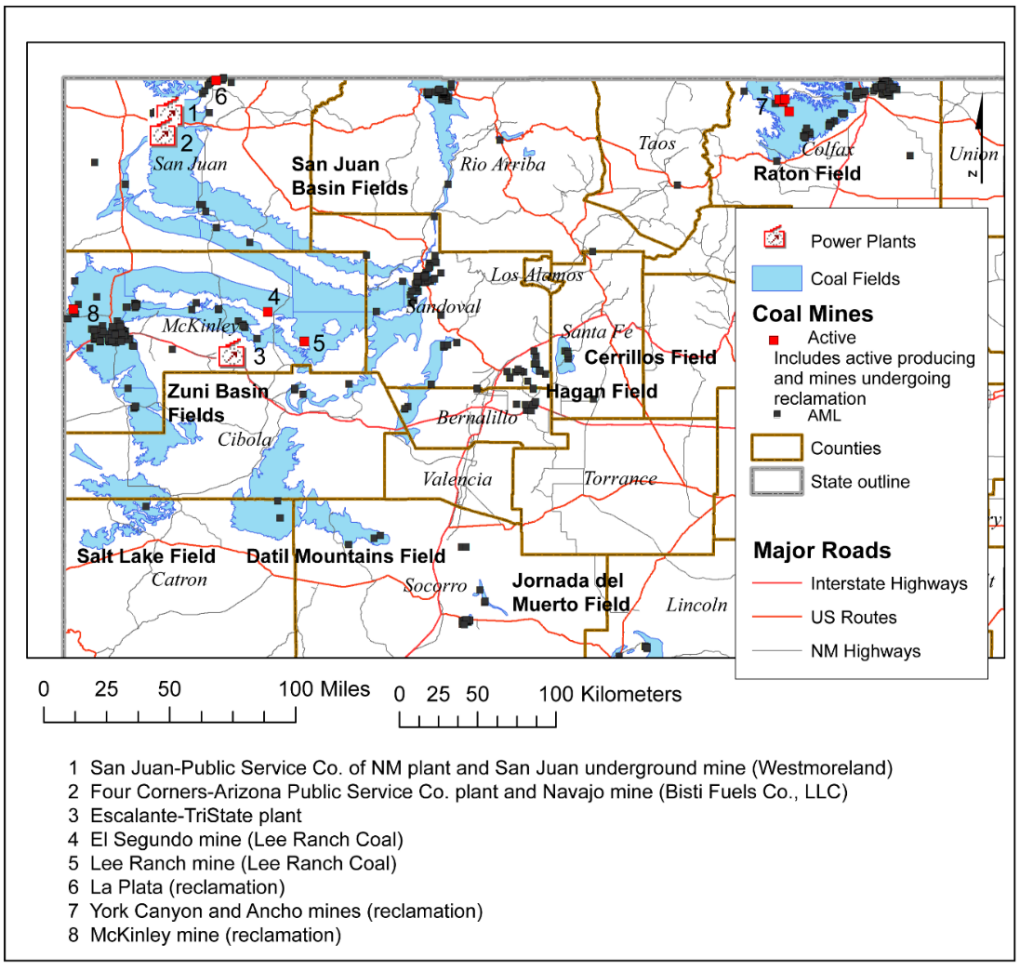

FIGURE 1. Location map of coal fields, active mines, AML (abandoned mine lands) sites, and power plants in the San Juan and Raton basins, New Mexico (from Hoffman, 2017). Coal mines are surface operations except for the underground mine at the San Juan mine. Lee Ranch mine suspended operations in 2016. Coal fields are listed in Table 2. Note that the San Juan mine and generating plant closed in September 2022.

TABLE 3. Samples from coal fields in the San Juan and Raton basins. Coal fields and reserves are delineated by Hoffman (1996, 2017). District Id is from the New Mexico Mines Database (McLemore, 2010a, 2017). Representative samples have been and will be collected from each coal field. At least 3 samples will be collected from each coal field. Red=no analyses at this time

District id	District (coal field)	Year of Initial Production	Year of Last Production	Estimated Cumulative Production	Formation	Number of samples analyzed	Number of coal analyzed	Number of samples analyzed from legacy data	Number of samples to be analyzed	Demonstrated resources, million tons (Hoffman, 2017)
DIS257	Barker Creek		1905		Menefee	9	6			183
DIS150	Bisti	1980	1988	40,075,148	Fruitland	50	16		1	872
DIS208	Carthage	1861	1963		Crevasse Canyon, Tres Hermanos	2	2			30
DIS259	Chaco Canyon	1905			Menefee	2	1			46
DIS260	Chacra Mesa		1945		Menefee	25	8		7	140
DIS118	Crownpoint	1914	1951	20,758	Crevasse Canyon	12	8			663
na	Dakota	na	na	na	na	4	4			
DIS262	Datil	1917	1940	66,980	Dakota	1	1			47
DIS155	Fruitland	1889	2001	3,137,957,050	Crevasse Canyon, Tres Hermanos	5	4	63		550
DIS119	Gallup	1882	2001	121,522,629,885	Fruitland	48	26		12	610
DIS156	**Hogback**	1907	1971	301,237	Crevasse Canyon				7	66
DIS264	Jornada del Muerto		1927		Menefee	6	3			0
DIS174	La Ventana	1904	1983		Crevasse Canyon	4	4			263
DIS146	Monero	1882	1970	5,277,552	Menefee	9	7			40
DIS016	Mount Taylor	1952	1953	69,948	Menefee	7	5		4	19
DIS157	Navajo	1963	9999	4,714,689,147	Crevasse Canyon	19	9		4	1340
DIS258	Newcomb				Fruitland		3			126
DIS021	Raton	1898	2002	954,470,032	Menefee	27	12	30	2	
DIS003	**Rio Puerco**	1937	1944	139,555	Vermejo, Raton					25
DIS009	Salt Lake	1987	1987	100,000	Crevasse Canyon	2	1	13		323
DIS121	San Mateo	1983	2001	954,470,032	Moreno Hill	9	5	170		385
DIS261	Standing Rock	1952	1958		Menefee	11	4			392
DIS158	Star Lake				Menefee	47	30		2	946
DIS263	**Tierra Amarilla**	1955	1955		Fruitland					4.5
DIS159	Toadlena				Menefee	16	6		1	0
DIS124	**Zuni**	1908	1926	16,010	Menefee	1	1	3		83
	coal ash					5		2	1	

District id	District (coal field)	Year of Initial Production	Year of Last Production	Estimated Cumulative Production	Formation	Number of samples analyzed	Number of coal analyzed	Number of samples analyzed from legacy data	Number of samples to be analyzed	Demonstrated resources, million tons (Hoffman, 2017)
	beach placer sandstone					40		103	22	
	uranium sandstone							23		
	Other samples					18				
	total samples					379	166	407	63	7153.5

Research Activities

A revised list and status of milestones is in Table 4.

TABLE 4. Revised List of Milestones for both Phase 1 and extension (E) **(bold=completed)**

Task/ Subtask	Milestone/ Deliverable Title	Planned Completion	Verification method	Status
	Quarterly reports	Quarterly	Report every quarter	**1-7th quarters completed** (see https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html)
	Year I interim report	Year 1	Submitted	**Completed** https://geoinfo.nmt.edu/staff/mclemore/documents/PHASE1INTERIMREPORTDE-FE0032052SEPTEMBER302022CONFIDENTIAL.pdf **Summary report completed** https://geoinfo.nmt.edu/staff/mclemore/documents/DOE_Summary3_23.pdf
	Year 2 progress report (this report)	Year 2	Submitted this report	**Completed**
	Meetings with DOE manager	12/7/22, 4/10/23, 7/11/23, 9/12/23	Attended	**Presentations given**
	Attend DOE project meetings	10/24-27/2022, 6/27-28/2023	Attended	Plan to attend in April 2023
1.0	Project Management Plan		Update due 30 days after award. Revisions to the PMP shall be submitted as requested by the NETL Project Manager.	**Completed 1/5/21**

1.0	A: Project Kick-off meeting	10/15/21	Attended, report	**Completed** (see https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMfinal.pdf)
2.1	B: Identification of Sampling Sites	Quarterly	Reports every quarter (quarterly reports), environmental questionnaire, no permit required for Federal Land, permit for Navajo Tribal Lands Appendix 1	**Ongoing** (https://geoinfo.nmt.edu/staff/mclemore/SampleLocations1_23.xlsx), environmental questionnaire completed and revision submitted, see Appendix 1 for permit to sample on Navajo Tribal Lands
2.2	C: Collection and Review of Existing Data	2nd quarter	Map, description	**Report completed** (https://geoinfo.nmt.edu/staff/mclemore/documents/legacychemistryrpt23.pdf), ongoing activity, **REE in produced waters** (https://geoinfo.nmt.edu/staff/mclemore/ree_produced_waters_for_GIS.xlsx) and **USGS coal chemistry** (https://geoinfo.nmt.edu/staff/mclemore/REEcoal.mpk) are on the project web site; summary of data and preliminary interpretations https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreGSA22Wed10-12-22.pdf
2.3	D: **Sampling Plan** Database	10/31/2021, progress report 2nd quarter. 3/31/2022	**Sampling plan** Database, web forms, reports.	**Completed** (https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf). Database and data entry web pages are available and being updated.
2.4	E: Collect Samples	Quarterly	Report, database	**Ongoing**
2.5	F: Characterization	Quarterly	Progress report, quarterly reports, database	**Ongoing** once samples are collected, **samples submitted to laboratories for chemical analyses,** chemical analyses at https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem_000.xlsx XRD completed on some samples

2.6	G: Application of Machine Learning techniques for Basin-wide Assessment	12/31/2022	Report completed	**Completed** https://geoinfo.nmt.edu/staff/mclemore/documents/MLGeomodelingSummary.pdf
3.0	H: Sampling and Characterization of Waste Streams	Quarterly	Progress report quarterly, database, part of 2.5, no permit required for Federal Land, permit for Navajo Tribal Lands Appendix 1	**Ongoing,** chemical analyses at https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem_000.xlsx
4.0	I: Results of Basinal Infrastructure, Industries and Business Assessment	03/31/2023	Progress report quarterly, database, publications	Future activity; 4.3 **Life cycle analysis completed (see below)**
E1.0	Project management plan for extension	9/30/2024	To be included as an appendix to the Final Scientific/ Technical Report	**Ongoing, due Oct. 30, 2023**
E1.1	Summary of Environmental Justice Considerations	9/30/2024	To be included as an appendix to the Final Scientific/Technical Report	**Ongoing, attending DOE working group meetings**
E1.2	Summary of Economic Revitalization and Job Creation Outcomes	9/30/2024	To be included as an appendix to the Final Scientific/ Technical Report	**Ongoing, attending DOE working group meetings**
E1.3	Environmental, Safety, and Health Analysis	completed	Due to NETL Project Manager before accessing the site.	**Ongoing, attending DOE working group meetings**
E2	Overall CORE-CM Resource Sampling Plan providing sampling locations, sampling methods for each location, and site-specific access agreements	9/30/2024	Due at the end of the Period of Performance.	**Ongoing**, (https://geoinfo.nmt.edu/staff/mclemore/SampleLocations1_23.xlsx), environmental questionnaire completed and revision submitted, see Appendix 1 for permit to sample on Navajo Tribal Lands; site agreements not needed on Federal lands
E2	Initial Basinal Resource Assessment	9/30/2024	Due at the end of the Period of Performance.	**Ongoing**
E2	Characterization and Data Acquisition Plan	9/30/2024	Due at the end of the Period of Performance.	**Ongoing, attending DOE working group meetings**
E3	Initial Waste Stream Reuse Plan	9/30/2024	Due at the end of the Period of Performance.	**Ongoing**

E4	Results of the Basinal Strategies for Infrastructure, Industries and Business Assessment	9/30/2024	Due at the end of the Period of Performance.	**Ongoing, attending DOE working group meetings**
E5	Initial Technology Assessment and Field Development Plan	9/30/2024	Due at the end of the Period of Performance.	**Ongoing**
E6	Initial Technology Innovation Center Plan	9/30/2024	Due at the end of the Period of Performance.	**Ongoing**
E7	Initial Stakeholder Outreach and Education Plan	9/30/2024	Due at the end of the Period of Performance.	**Ongoing, see** REE in Coal (nmt.edu)
E1	Phase 1 Interim Report	9/30/2023, 9/30/2024	Due to NETL Project Manager 12 months and 24 months after award. At 12 months, this will include an outline of deliverable reports and preliminary findings to date. At 24 months this will include a summary of findings over the prior 12 months.	**Completed** https://geoinfo.nmt.edu/staff/mclemore/documents/PHASE1INTERIMREPORTDE-FE0032052SEPTEMBER302022CONFIDENTIAL.pdf **Summary report completed** https://geoinfo.nmt.edu/staff/mclemore/documents/DOE_Summary3_23.pdf this report
E2	Energy Data Exchange (EDX) FOA-2364 REE Researcher Database Template (per Appendix G of FOA 2364)	10/3/2023, 9/30/2024	All available collected data shall be submitted by 9/30/23 to the NETL Project Manager. A revised template including all data collected during project performance will be due at the end of the Period of Performance to the NETL Project Manager. Due 60 days after data is produced and a (final) update is due with Phase 2 down-select application. State-specific, county-specific, and site-specific resource characterization and geographic location data (i.e., elemental concentrations; proximate/ultimate analyses; ash content; phase identification/concentrations; morphology information; etc.), and characterization information will be supplied to NETL and made publicly available through inclusion on NETL's EDX database platform. See Note below.*	**Chemistry spreadsheet submitted** https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem10_3_23.xlsx

			Note: Resource assessment may include data retrieved from literature review or obtained from unpublished sample repositories/historical samples, etc. Every effort should be made to provide the DOE this data, from where the data was obtained (i.e., tables/citations in final report), and any other pertinent info such as testing and characterization method. DOE asks the awardee to complete the REE Researcher Database Template as best as they can for this data.	
E2	Inputs for NETL REE-SED Sample Data Needs (per Appendices H and I of FOA 2364)	9/30/2024	Due at the end of the period of performance. This information will be supplied in the format specified in Appendix H for uploading into NETL's Geospatial EDX Database, for use in NETL RIC's Geologic Models. See Note below.*	**Ongoing**
E2	Resource Samples for Mineral Characterization and Analysis	9/30/2024	Due to NETL Technology Manager at the end of the Period of Performance, in coordination with assigned NETL Project Manager. Recipients will provide NETL with a single split REE and CM sample for each type of material or core sample assessed in Phase 1 (and if appropriate in continuing phases) that reflects the highest achieved REE or CM concentration identified during conduct of the project effort, and which reflects materials used by the award recipient for their economic assessment. The quantity of sample material should be adequate for laboratory analysis of the sample. Material Safety Data Sheets (MSDS) are required to accompany material supplied to NETL. See Note below.* Recipients will provide NETL, when possible, splits/slabs of any core obtained during the conduct of the project effort. NETL will retain possession any submitted material. Safety Data Sheets (SDS) are required to accompany material supplied to NETL.	**Ongoing, samples have been archived and stored in storage facility**

*Note: Geospatial Data Products should be compliant with requirements of the Federal

Geospatial Data Act of 2018 and DOE's Geospatial Data Strategy
https://www.energy.gov/cio/downloads/doe-geospatial-data-management-strategy-2021-2025

Impact

Not only are proposed data collection required in order to delineate favorable geologic terranes and priority areas containing potential CM and REE deposits for the DOE and USGS mandates, but identification and examination of CM and REE is a high priority of the NMBGMR. This project is important to the state of New Mexico because CM and REE resources must be identified before land exchanges, withdrawals, or other land-use decisions are made by government officials. Potential cleanup of hazardous contaminated AML sites could be funded by the production of CM and REE from coal and other mine wastes, including AML sites. Future mining of potential economic CM and REE deposits will directly benefit the economy of New Mexico. Furthermore, it is crucial to re-establish a domestic CM and REE production industry in the U.S. to help secure the nation's clean energy future, reduce the vulnerability of the U.S. to material shortages related to national defense, and to maintain our global technical and economic competitiveness. Potential CM and REE deposits in New Mexico, especially coal, could contribute to the resource base in the U.S. Most CM and REE are imported into the U.S. and have specific, critical uses in our economy. Disruptions of imports may occur because of natural disasters, labor strife, trade disputes, resource nationalism, armed conflict, and so on, which requires knowledge of CM and REE deposits in the U.S. that could provide the required raw materials. Another aspect of this project is the training of the future workforce because students at the New Mexico Institute of Mining and Technology and San Juan College are hired to work on this project. Many of the PIs (McLemore, Mojtabai, Kelley, Chavez) have a strong history of mentoring minority (BIPOC) students, thereby contributing to diversity in the geoscience workforce. We are and will present information at meetings, project workshops, journal papers, and final project reports (will be a NMBGMR open file report and available to the public). A Center of Excellence is being established in the Farmington area to assist with education and stakeholder activities.

Current Status

Current status is in Table 4.

Summary of results to date

- Chemical analyses of coal deposits from the literature (including the USGS coal quality database) are not always accurate and must be used with caution.
- However, chemical analyses from the literature do provide guides for interpretations.
- Chemical analyses can be used to approximate the mineralogy of the deposit.
    - Coal samples are difficult to analyze for chemical composition.
- The TREE and other critical minerals in San Juan Basin coal deposits are low, but since ash is produce from burning coal, REE and perhaps some critical minerals could be recovered from the ash, especially if there are industrial uses for the ash (additional study underway).
- Humates (weathered coal) are produced from coal and humate mines and humate production will continue even though coal mines are closing.
- Clinkers (burned coal deposits) are used in road construction and decorative stone.
- Clinker and humate samples are similar in REE and other CM concentrations to coal samples.

- The New Mexico coal, humate, and clinker deposits are relatively low 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 40%) and Sr (as much as 3740 ppm), both critical minerals.
- Common minerals hosting the critical minerals in these rocks include clay minerals, zircon, and rutile/anatase.
- 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 coal, humate, and clinker deposits.

A. Publications, conference papers, and presentations

Badonie, M.N. and McLemore, V.T., 2022, REE in coalbeds in the San Juan-Raton coal basins (abstr.): New Mexico Geological Society, Spring Meeting, https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2838. Poster at https://geoinfo.nmt.edu/staff/mclemore/documents/NMSG.Poster2022COPY2.pdf.

Rockin' 22 Critical Minerals presentation (https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreRockinCM22.pdf)

Rockin' 22 Critical Minerals activities (https://geoinfo.nmt.edu/staff/mclemore/documents/Rockin22.pdf)

New Mexico Mining Association abstract and presentation: REE in the coal and associated strata in the San Juan and Raton Basins, New Mexico, 2022, Megan Badonie, Jakob Newcomer, Devlon Shaver Advised by: Dr. Virginia T. McLemore, https://geoinfo.nmt.edu/staff/mclemore/documents/NMAAPresentationNMMAFINAL2022.pdf

McLemore, V.T., 2022, Rare Earth Elements (REE) in Late Cretaceous coal and beach-placer sandstone deposits in the San Juan Basin, New Mexico: Preliminary Observations (abstr.): Geological Society of America, Annual Conference, October, https://gsa.confex.com/gsa/2022AM/meetingapp.cgi/Paper/378264, presentation https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreGSA22Wed10-12-22.pdf

McLemore, V.T., 2022, Rare earth elements (REE) in Late Cretaceous coal and beach-placer sandstone deposits in the San Juan Basin, New Mexico: Preliminary results: presentation at the DOE National Energy Technology Laboratory Resource Sustainability Project Review Meeting, Oct. 25-27, 2022

McLemore, V.T., 2022, Identifying critical mineral resources in New Mexico: Arizona Mineralogical Society, monthly meeting, March 17, https://geoinfo.nmt.edu/staff/mclemore/projects/mining/REE/documents/CM_MSAZMcLemore22.pdf

McLemore, V.T, 2022, New Mexico AML Project: Inventory and characterization of inactive/abandoned mine features: MMSA 4th Abandoned Mine Land Summit, April 6, https://geoinfo.nmt.edu/staff/mclemore/projects/mining/REE/documents/McLemorePhoenixAML22.pdf

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https://gsa.confex.com/gsa/2023AM/top/papers/index.cgi?username=392235&password=680673&personid=227838

B. Website(s) or other Internet site(s)

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

C. Technologies or techniques

No update

D. Inventions, patent applications, and/or licenses

No update

E. Other products

Sampling plan (https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf)

Health and safety plan (https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf)

SOP17 Drillhole logging (https://geoinfo.nmt.edu/staff/mclemore/documents/SOP17DrillholeLoggingupdated.pdf)

Revised sampling plan (https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v5.pdf)

REE in produced waters (https://geoinfo.nmt.edu/staff/mclemore/ree_produced_waters_for_GIS.xlsx) and USGS coal chemistry (https://geoinfo.nmt.edu/staff/mclemore/REEcoal.mpk)

Kickoff presentation October 15, 2021 (https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMfinal.pdf)

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Papers and posters planned for GSA annual conference in October 2023 and SME annual conference in February 2024.

Project Start October 2021

Project New End September 30, 2024

Contact Information

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New Mexico Bureau of Geology and Mineral Resources
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APPENDIX 1. Navajo tribal permit

THE NAVAJO NATION

Dr. Buu Nygren, President | Richelle Montoya, Vice President | Yideeskąądi Nitsáhákees

March 23, 2023

Dr. Virginia T. McLemore, PhD
New Mexico Institute of Mining and Technology
New Mexico Bureau of Geology and Mineral Resources
801 Leroy Place
Socorro NM 87801-4796

Dear Dr. McLemore:

The Minerals Department has reviewed your request for a permit to conduct geological reconnaissance on the Navajo Nation. Receipt of the $25.00 permit application fee is acknowledged and a Geological Reconnaissance Permit is hereby granted to you, Shari Kelley, Evan Owen (NMBGMR staff) and Megan Badonie, Zohreh Kazemi Motlagh, Jakopb Newcomer and Devlon Shaver (NMT students) for geologic investigations on the Navajo Nation.

Specifically, this permit is valid for observation and sampling San Juan River-Raton Coal Basin, New Mexico, as shown on the enclosed map.

This Permit is also subject to the following conditions:

1. The rights of local Navajo people will be respected and protected.
2. The applicable laws of the Navajo Nation will be obeyed.
3. Personnel of the Minerals Department retain the right to accompany and monitor the field work. Please contact the Minerals Department at (928) 871-7949 at least three (3) working days prior to the field work.
4. The field work will be conducted at your own risk and the Navajo Nation will not be held liable for any personal injury or property damage that might occur during the course of the field work.
5. Vehicle access to all field localities will be restricted to existing roads and trails.
6. Sampling will be limited to 120 5-gallon samples of rock that will not result in any significant surface disturbance. All samples collected remain the property of the Navajo Nation and shall be returned to the Nation upon request. The disturbance, collection, or quarrying of paleontological or archaeological remains is not permitted.
7. The disturbance, collection, or quarrying of paleontological or archaeological remains is not permitted.

MINERALS DEPARTMENT
POST OFFICE BOX 1910 – WINDOW ROCK, AZ 86515 – PHONE: (928) 871-6588 – FAX: (928) 871-7095

8. All data obtained from geological observations on Navajo land will be provided to the Minerals Department. A detailed report of the activities and results of the investigations are to be provided to the Minerals Department upon completion of the field work.

9. All reports resulting from the field work on Navajo Land shall be submitted to the Minerals Department. A complete copy of any thesis, manuscript, report, abstract, etc., resulting from the field work must be submitted to the Mineral Department, P.O. Box 1910, Window Rock, Arizona 86515, upon completion. In the acknowledgement section, this statement must appear:

"Field work on the Navajo Nation was conducted under a permit from the Minerals Department. Any persons wishing to conduct geologic investigations on the Navajo Nation must first apply for and receive a permit from the Minerals Department, P.O. Box 1910, Window Rock, Arizona 86515 and Telephone No. (928) 871-6588."

10. The permittee(s) will be liable for any damages to the Navajo Nation, its residents, or property resulting from the negligence of the permittee(s).

11. This Permit is valid from April 1, 2023 through July 1, 2023.

Please signify your acknowledgement and agreement to comply with the terms and conditions of this Permit by signing below and returning one signed original copy of this Permit to the Minerals Department. This Permit will not be considered valid until the signed original copy is received by the Minerals Department. By signing this Permit, it is understood that all other individuals covered under this Permit will be made aware of the permit conditions, and are bound to comply with the permit terms and conditions individually and collectively.

If you have any questions or comments, please do not hesitate to contact me or Mr. Richard Carlton, Senior Geologist at (928) 871-7949.

Sincerely,

Rowena Cheromiah

Rowena Cheromiah
Minerals & Royalty Mgmt. Director

ACKNOWLEDGEMENT

Dr. Virginia T. McLemore PhD

3/23/23
Date

RC/RC:adr
xc: Hope Wilson, Department Manager III, Resource Enforcement/DNR