

U.S. Department of Energy  
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**Carbon Ore, Rare Earth, and Critical Minerals (CORE-CM) Assessment of San Juan  
River-Raton Coal Basin**

2<sup>nd</sup> Quarterly Research Performance Progress Report  
Reporting Period: December 31, 2021-March 31, 2022  
Project Performance Period: 10/01/2021 – 09/30/2023

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## 1. ACCOMPLISHMENTS

The objective of this project is to determine the rare earth elements (REE) and critical minerals (CM) resource potential in coal and related stratigraphic units in the San Juan and Raton basins, New Mexico. We will conduct the following tasks: (1) a basinal assessment for CM and REE potential, using state-of-the-art technologies to estimate basin-wide CM and REE resources in coal and related stratigraphic units; (2) identify, sample, and characterize coal waste stream products; (3) conduct bench tests to develop a basinal reuse of waste strategy; (4) illustrate the current status of the feedstock supply of REE and CM to understand the basinal REE industry's capital expenditures and obstacles to expanding REE-related business development; (5) develop a life-cycle analysis to establish pathways, process engineering, and design requirements to upgrade REE processing industry, (6) evaluate technology gaps, (7) establish a Center of Excellence and Training Center (COE) for coal ash beneficiation at San Juan County; and (8) create REE research-based activities that can be shared during the NMBGMR summer geology teacher workshop and assemble REE research-related articles for an REE-centered issue of *Lite*. 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 NMBGMR and state of NM.

### **A. Major goals and objectives**

The following are the major goals of this project as described in the approved Statement of Project Objectives (SOPO):

1. Identify and quantify the distribution of critical minerals (CM), including rare earth elements (REE), in coal beds and related stratigraphic units in the San Juan and Raton basins in New Mexico (including coal, coal refuse, ash, coal seam, interstitial clays/shales, volcanic ash beds, acid mine drainage, associated sludge samples, mine dumps, other nonfuel carbon-based products, process waters, etc.).
2. Identify possible sources of CM and REE in the basins.
3. Identify the coal mine and nonfuel carbon-based waste products that could contain CM and REE.
4. Characterize the CM and REE in these materials.
5. Determine the economic viability of extracting CM and REE from these materials
6. Test and develop new technologies in identifying and quantifying CM and REE in high-fidelity geologic models.

Table 1 describes the tasks and subtasks that will be undertaken to accomplish these goals and Table 2 provides a listing of the revised project milestones, along with anticipated delivery dates.

TABLE 1. List of tasks and subtasks

<b>Task 1.0 Project Management and Planning</b>
<b>Task 2.0 Basinal Assessment of CM and REE in the San Juan and Raton Basins</b> 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
<b>Task 3.0 Basinal Strategies for Reuse of Waste Streams</b> Subtask 3.1 Waste Streams Sampling and Characterization Subtask 3.2 Coal Ash Subtask 3.3 Technology Development of Basinal Reuse Strategy
<b>Task 4.0 Basinal Strategies for Infrastructure, Industries and Businesses</b> Subtask 4.1 Infrastructure Investigation Subtask 4.2 Competitiveness and Challenge Subtask 4.3 Life-Cycle Analysis
<b>Task 5.0 Technology Assessment, Development and Field Testing</b> Subtask 5.1 Identify and Assess Existing and Novel Technologies Specific to the Resource Subtask 5.2 Develop Plan for Field Testing
<b>Task 6.0 Technology Innovation Centers</b> Subtask 6.1 SonoAsh Center of Excellence
<b>Task 7.0 Stakeholder Outreach and Education</b> 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. Revised List of Milestones (**bold=completed**)

Task/ Subtask	Milestone Title	Planned Completion	Verification method	Status
	Quarterly reports	Quarterly	Report every quarter	<b>2/6/2022 completed</b>
<b>1.0</b>	<b>A: Project Kick-off meeting</b>	<b>10/15/21</b>	<b>Attend, report</b>	<b>Completed</b> (see <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMfinal.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMfinal.pdf</a> )
2.1	B: Identification of Sampling Sites	Quarterly	Reports every quarter	Ongoing, planned in 2 phases
2.2	C: Collection and Review of Existing Data	2 <sup>nd</sup> quarter	Map, description	Report in progress, ongoing activity

2.3	D: <b>Sampling Plan</b>  Database	10/31/2021, progress report 2 <sup>nd</sup> quarter.  3/31/2022	<b>Sampling plan</b>  Database, web forms, reports.	<b>Sampling plan is completed</b> ( <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf</a> ).  Database and data entry web pages are being developed; initial availability expected 3/31/2022.
2.4	E: Collect Samples	Quarterly	Report, database	Start sampling in May 2022 (weather and COVID permitting)
2.5	F: Characterization	Quarterly	Progress report quarterly, database	Ongoing once samples are collected
2.6	G: Application of Machine Learning techniques for Basin-wide Assessment	12/31/2022	Progress report quarterly, database	Future activity
3.0	H: Sampling and Characterization of Waste Streams	Quarterly	Progress report quarterly, database	Ongoing, future activity
4.0	I: Results of Basinal Infrastructure, Industries and Business Assessment	03/31/2023	Progress report quarterly, database, publications	Future activity

## **B. Accomplishments during 2<sup>nd</sup> quarter**

### ***Task 1.0 Project Management and Planning***

Project management activities during this quarter included the implementation of regular procedures including regular management and biweekly working group meetings. The team also has regular weekly meetings of the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) database group to develop the project database. McLemore and other team members attended DOE CORE-CM Workshop March 22, 2022.

### ***Task 2.0 Basinal Assessment of CM and REE in the San Juan and Raton Basins***

#### ***Status:***

#### ***Subtask 2.1 Identification of Sampling Sites***

Sample sites include the coal fields and mines in the San Juan and Raton basins, shown in Figure 4. Samples from each coal field (Table 1) will be collected. Sampling will begin in May 2022.

#### ***Subtask 2.2 Collection and Review of Existing Data***

Legacy chemistry data have been collected and a report evaluating that data is in progress.

#### ***Subtask 2.3 Develop a Sampling Plan***

The field sampling plan is completed

([https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan\\_v3.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf)). Figure 4 shows the coal fields and mines in the area. Table 1 is a list of the coal fields.

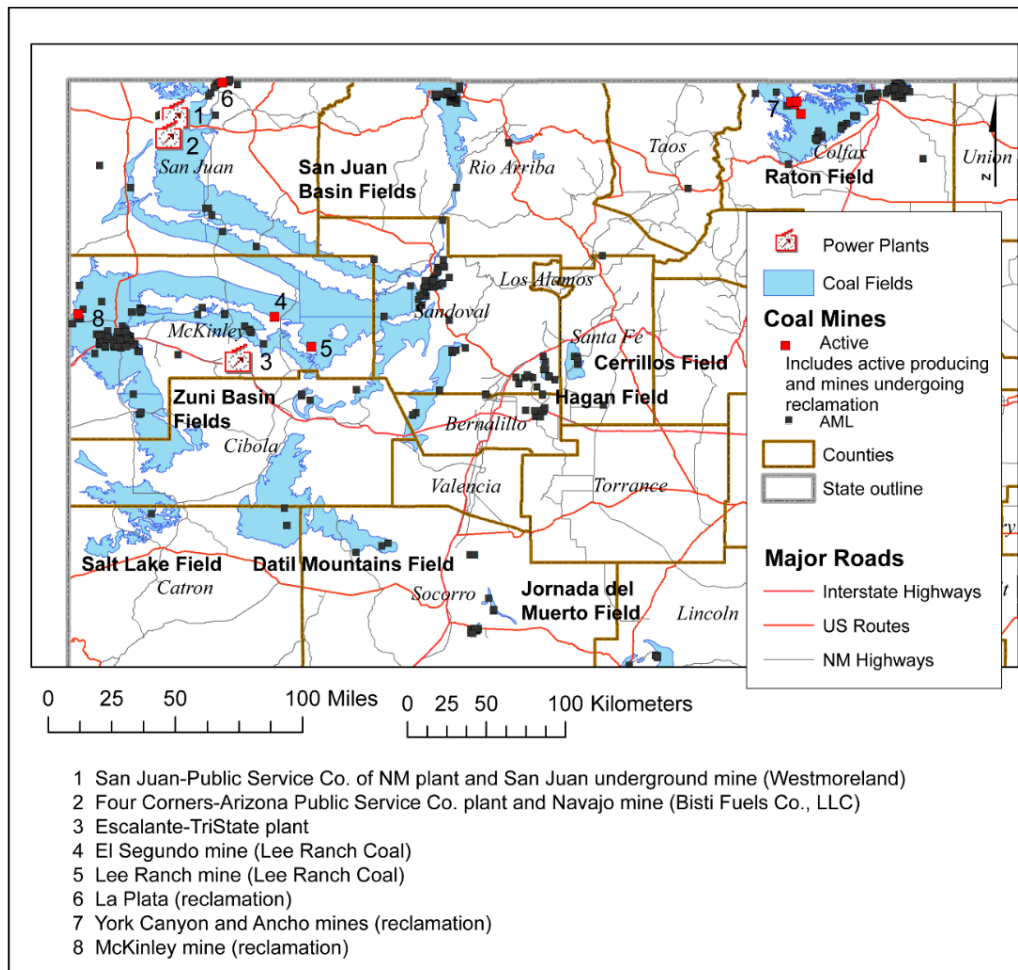


FIGURE 4. Coal fields, active mines, AML (abandoned mine lands) sites, and power plants in the San Juan and Raton Basins.

TABLE 1. Coal fields in the San Juan and Raton basins, studied in this project, delineated by Hoffman (1996, 2017). District Id is from the New Mexico Mines Database (McLemore, 2010a, 2017). Representative samples will be collected from each coal field. Each field sample will be prefixed with an abbreviation representing each coal district. Each drill core sample will be identified by the hole number and depth. At least 3 samples will be collected from each coal field. Approximately 130 samples will be collected each year.

District id	District	Year of Discovery	Year of Initial Production	Year of Last Production	Estimated Cumulative Production	Formation	Prefix used for sample id
DIS257	Barker Creek coal field	1882		1905		Menefee	BAR
DIS150	Bisti coal field	1961	1980	1988	\$40,075,148.00	Fruitland	BIS
DIS259	Chaco Canyon Coal Field	1905	1905			Menefee	CHACO

District id	District	Year of Discovery	Year of Initial Production	Year of Last Production	Estimated Cumulative Production	Formation	Prefix used for sample id
DIS260	Chacra Mesa coal field	1922		1945		Menefee	CHACA
DIS174	La Ventana	1884	1904	1983		Menefee	LAV
DIS118	Crownpoint coal field	1905	1914	1951	\$20,758.00	Crevasse Canyon	CRWN
DIS155	Fruitland coal field	1889	1889	2001	\$3,137,957,050	Fruitland	FRUIT
DIS119	Gallup coal field	1881	1882	2001	\$121,522,629,885	Crevasse Canyon	GALL
DIS156	Hogback coal field	1907	1907	1971	\$301,237.00	Menefee	HOG
DIS146	Monero coal field	1882	1882	1970	\$5,277,552.00	Menefee	MON
DIS016	Mount Taylor coal field	1936	1952	1953	\$69,948.00	Crevasse Canyon	TAY
DIS157	Navajo coal field	1933	1963	9999	\$4,714,689,147	Fruitland	NAV
DIS258	Newcomb coal field	1955				Menefee	NEW
DIS021	Raton coal field	1820	1898	2002	\$954,470,032.00	Vermejo, Raton	RAT
DIS003	Rio Puerco coal field	1901	1937	1944	\$139,555.00	Crevasse Canyon	RIO
DIS009	Salt Lake coal field	1980	1987	1987	\$100,000.00	Moreno Hill	SALT
DIS121	San Mateo coal field	1905	1983	2001	\$1,678,742,326	Menefee	MAT
DIS261	Standing Rock coal field	1934	1952	1958		Menefee	STND
DIS158	Star Lake coal field	1907			\$0.00	Fruitland	STAR
DIS263	Tierra Amarilla coal field	1935	1955	1955		Menefee	AMAR
DIS159	Toadlena	1950			\$0.00	Menefee	TOAD
DIS124	Zuni coal field	1916	1908	1926	\$16,010.00	Crevasse Canyon	ZUNI

### *Health and safety plan*

HASP is complete ([https://geoinfo.nmt.edu/staff/mclemore/documents/HASP\\_v2.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf)).

### *Subtask 2.4 Collect Samples*

Sampling has been delayed due to poor weather, vacation schedules, and students not available because of school schedule. We will start sampling in May.

We have logged 1160 ft of core. Some of the drill holes have had all of the coal removed, whereas other holes contain only cuttings and no core.

*Subtask 2.5 Sample Characterization*

There is no update on this subtask.

*Subtask 2.6 Application of Machine Learning techniques for basin-wide resource assessment*

There is no update on this subtask.

***Task 3.0 Basinal Strategies for Reuse of Waste Streams***

***Subtask 3.1 Waste Streams Sampling and Characterization***

There is no update on this subtask.

***Subtask 3.2 Coal Ash***

There is no update on this subtask.

***Subtask 3.3 Technology Development of Basinal Reuse Strategy***

There is no update on this subtask.

***Task 4.0 Basinal Strategies for Infrastructure, Industries and Businesses***

***Subtask 4.1 Infrastructure Investigation***

There is no update on this subtask.

***Subtask 4.2 Competitiveness and Challenge***

There is no update on this subtask.

***Subtask 4.3 Life-Cycle Analysis***

There is no update on this subtask.

***Task 5.0 Technology Assessment, Development and Field Testing***

***Subtask 5.1 Identify and Assess Existing and Novel Technologies Specific to the Resource***

There is no update on this subtask.

***Subtask 5.2 Develop Plan for Field Testing***

There is no update on this subtask.

***Task 6.0 Technology Innovation Centers***

***Subtask 6.1 SonoAsh Center of Excellence***

There is no update on this subtask.

***Task 7.0 Stakeholder Outreach and Education***

***Subtask 7.1 New Mexico State and Regional Education***

A short summary of the project was written for Gold Pan, NMIMT Alumni Newsletter. Working on a short summary of the project for Lite Geology.

The NMBGMR Rockin' Around New Mexico will be in Farmington, NM July 6-8, 2022. Plans are underway to include lectures on critical minerals and coal.



*Subtask 7.2 Lessons Learned and Narratives Constructed*

There is no update on this subtask.

*Subtask 7.3 Publications and presentations*

New Mexico Geological Society abstract: 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>.

*Subtask 7.4 Training and Conferencing with SJC and Sonoash COE*

There is no update on this subtask.

**2. PRODUCTS****A. Publications, conference papers, and presentations***1<sup>st</sup> quarter*

Kickoff presentation October 15, 2021

(<https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMfinal.pdf>)

DOE Division of Critical Minerals Program Plan Rollout on December 8, 2021

([https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMDOEsummary12\\_21.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMDOEsummary12_21.pdf))

*2<sup>nd</sup> quarter*

New Mexico Geological Society abstract: 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>.

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

See preliminary 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***1<sup>st</sup> quarter*

Sampling plan ([https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan\\_v3.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf))

Health and safety plan ([https://geoinfo.nmt.edu/staff/mclemore/documents/HASP\\_v2.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf))

SOP17 Drillhole logging

(<https://geoinfo.nmt.edu/staff/mclemore/documents/SOP17DrillholeLoggingupdated.pdf>)

### **3. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS**

#### **A. Individuals involved in 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.

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

Dr. Robert Balch (PM) is the Project manager for this project and is the Director of the PRRC – Task 1, 2, 4 and 7.

Dr. William Ampomah (Co-PI) is a Research Engineer and Section Head at PRRC – Task 1, 4, 5 and 7.

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.

Mr. Mark Mansell: is the NMBGMR GIS specialist - Task 2.

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 and 2.

Mr. Brian Wheeler is the NMBGMR fleet manager - Tasks 2 and 3.

Ms. Gretchen Hoffman is the NMBGMR emeritus coal geologist - Task 2 and 3.

##### ***Sandia National Laboratories(SANL)***

Dr. Jason Heath is a hydrogeologist at SANL. –Task 2 and 5.

Dr. Guangping Xu is an experimental geochemist at SANL - Tasks 2, 3 and 5.

##### ***San Juan College***

Dr. John Burris: is a Professor of Geology and Department Chair at San Juan College - Tasks 7.

##### ***Los Alamos National Laboratory (LANL)***

Dr. Kirsten Sauer is a Scientist at LANL - Task 5.

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

Dr. Sam Clegg is Senior Scientist at LANL – Task 2

##### ***SonoAsh***

Mr. Claudio Arato is the CTO of SonoAsh company - Task 3, 4, 5, 6 and 7.

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

#### **B. Change in support levels of key persons**

Dr. Rajesh Pawar had shifted his responsibilities on this project to Dr. Kirsten Sauer.

### **4. SPECIAL REPORTING REQUIREMENTS: Mandatory**

No update

**5. BUDGETARY INFORMATION: MANDATORY**

<b>Spend Plan by Fiscal Year Format</b>						
	<b>FY 2022</b>		<b>FY 2023</b>		<b>Total</b>	
	<b>DOE funds</b>	<b>Cost Share</b>	<b>DOE funds</b>	<b>Cost Share</b>	<b>DOE</b>	<b>Cost Share</b>
<b>NMIMT</b>	564,432	101,114	544,856	104,147	1,109,287	205,261
Los Alamos National Laboratory	93,750	-	93,750	-	187,500	-
Sandia National Laboratories	99,946	-	87,054	-	187,000	-
SonoAsh LLC	-	115,000	-	115,000	-	230,000
<b>Total (\$)</b>	<b>758,128</b>	<b>216,114</b>	<b>725,660</b>	<b>219,147</b>	<b>1,483,787</b>	<b>435,261</b>
<b>Total Cost Share %</b>		<b>22.2%</b>		<b>23.2%</b>		<b>22.7%</b>

Table for Actual Incurred Costs

Table for Remaining Balance

**6. REFERENCES**

## 7. APPENDICES

### APPENDIX 1. List of SOPs and plans

(see <https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html> for copies as they are completed)

Number	Name	Description
HASP	Health and Safety Plan (HASP)	Health and safety plan for field and laboratory work ( <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf</a> )
FSP	Field Sampling Plan (FSP)	Field sampling plan ( <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf</a> )
SOP 1	Data management	entering, reporting, verification, and validation of data to the database
SOP 2	Photography	procedures taking photographs in the field and laboratory
SOP 3	GPS surveying	Procedures for use of handheld GPS surveying
SOP 4	Sampling outcrops, rock piles, and drill core	field procedures for taking surface solid samples
SOP 17	Drillhole logging	procedures for drilling, logging, and sampling of subsurface samples (solids) ( <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/SOP17DrillholeLoggingupdated.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/SOP17DrillholeLoggingupdated.pdf</a> )
SOP 6	Soil paste pH and paste conductivity	laboratory procedures for soil paste pH and paste conductivity
SOP 7	Field measurements of water	field procedures for measuring water flow, pH, conductivity, alkalinity, temperature when collecting water samples
SOP 8	Surface water and seep sampling	field procedures for collecting samples of surface and seep water samples
SOP 9	Petrographic analysis	laboratory procedures for describing petrographic samples
SOP 10	Electron microprobe analyses	laboratory procedures use for analyses using the electron microprobe
SOP 12	X-ray diffraction (XRD) analyses	laboratory procedures for mineralogical analyses by x-ray diffraction (XRD)