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

2nd 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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April, 2022
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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**

<table>
<thead>
<tr>
<th>Task</th>
<th>Subtask</th>
<th>Description</th>
</tr>
</thead>
</table>
| 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 |
| | Task 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. Revised List of Milestones (bold=completed)**

<table>
<thead>
<tr>
<th>Task/ Subtask</th>
<th>Milestone Title</th>
<th>Planned Completion</th>
<th>Verification method</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Quarterly reports</td>
<td>Quarterly reports</td>
<td>Quarterly</td>
<td>Report every quarter</td>
<td>2/6/2022 completed</td>
</tr>
<tr>
<td>2.0 A: Project Kick-off meeting</td>
<td>10/15/21</td>
<td>Attend, report</td>
<td>Completed (see <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMfinal.pdf">link</a>)</td>
<td></td>
</tr>
<tr>
<td>2.1 B: Identification of Sampling Sites</td>
<td>Quarterly</td>
<td>Reports every quarter</td>
<td>Ongoing, planned in 2 phases</td>
<td></td>
</tr>
<tr>
<td>2.2 C: Collection and Review of Existing Data</td>
<td>2nd quarter</td>
<td>Map, description</td>
<td>Report in progress, ongoing activity</td>
<td></td>
</tr>
</tbody>
</table>
### B. Accomplishments during 2nd 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.

---

<table>
<thead>
<tr>
<th>Activity</th>
<th>Frequency</th>
<th>Task Description</th>
<th>Initial Date</th>
<th>Progress Date</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>D: Sampling Plan</td>
<td>Quarterly</td>
<td>Database</td>
<td>10/31/2021, progress report 2nd quarter.</td>
<td>3/31/2022</td>
<td>Sampling plan is completed (<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.</td>
</tr>
<tr>
<td>E: Collect Samples</td>
<td>Quarterly</td>
<td>Report, database</td>
<td></td>
<td>Start sampling in May 2022 (weather and COVID permitting)</td>
<td></td>
</tr>
<tr>
<td>F: Characterization</td>
<td>Quarterly</td>
<td>Progress report quarterly, database</td>
<td></td>
<td>Ongoing once samples are collected</td>
<td></td>
</tr>
<tr>
<td>H: Sampling and Characterization of Waste Streams</td>
<td>Quarterly</td>
<td>Progress report quarterly, database</td>
<td></td>
<td>Ongoing, future activity</td>
<td></td>
</tr>
<tr>
<td>I: Results of Basinal Infrastructure, Industries and Business Assessment</td>
<td>Quarterly</td>
<td>Progress report quarterly, database, publications</td>
<td>03/31/2023</td>
<td>Future activity</td>
<td></td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>District id</th>
<th>District</th>
<th>Year of Discovery</th>
<th>Year of Initial Production</th>
<th>Year of Last Production</th>
<th>Estimated Cumulative Production</th>
<th>Formation</th>
<th>Prefix used for sample id</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIS257</td>
<td>Barker Creek coal field</td>
<td>1882</td>
<td>1905</td>
<td></td>
<td></td>
<td>Menefee</td>
<td>BAR</td>
</tr>
<tr>
<td>DIS150</td>
<td>Bisti coal field</td>
<td>1961</td>
<td>1980</td>
<td>1988</td>
<td>$40,075,148.00</td>
<td>Fruitland</td>
<td>BIS</td>
</tr>
<tr>
<td>DIS259</td>
<td>Chaco Canyon Coal Field</td>
<td>1905</td>
<td>1905</td>
<td></td>
<td></td>
<td>Menefee</td>
<td>CHACO</td>
</tr>
<tr>
<td>District id</td>
<td>District</td>
<td>Year of Discovery</td>
<td>Year of Initial Production</td>
<td>Year of Last Production</td>
<td>Estimated Cumulative Production</td>
<td>Formation</td>
<td>Prefix used for sample id</td>
</tr>
<tr>
<td>------------</td>
<td>----------------------</td>
<td>-------------------</td>
<td>----------------------------</td>
<td>-------------------------</td>
<td>-------------------------------</td>
<td>--------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>DIS260</td>
<td>Chacra Mesa coal field</td>
<td>1922</td>
<td>1945</td>
<td></td>
<td></td>
<td>Menefee</td>
<td>CHACA</td>
</tr>
<tr>
<td>DIS174</td>
<td>La Ventana</td>
<td>1884</td>
<td>1904</td>
<td>1983</td>
<td></td>
<td>Menefee</td>
<td>LAV</td>
</tr>
<tr>
<td>DIS118</td>
<td>Crownpoint coal field</td>
<td>1905</td>
<td>1914</td>
<td>1951</td>
<td>$20,758.00</td>
<td>Crevasse Canyon</td>
<td>CRWN</td>
</tr>
<tr>
<td>DIS155</td>
<td>Fruitland coal field</td>
<td>1889</td>
<td>1889</td>
<td>2001</td>
<td>$3,137,957,050</td>
<td>Fruitland</td>
<td>FRUIT</td>
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<tr>
<td>DIS119</td>
<td>Gallup coal field</td>
<td>1881</td>
<td>1882</td>
<td>2001</td>
<td>$121,522,629.85</td>
<td>Crevasse Canyon</td>
<td>GALL</td>
</tr>
<tr>
<td>DIS156</td>
<td>Hogback coal field</td>
<td>1907</td>
<td>1907</td>
<td>1971</td>
<td>$301,237.00</td>
<td>Menefee</td>
<td>HOG</td>
</tr>
<tr>
<td>DIS146</td>
<td>Monero coal field</td>
<td>1882</td>
<td>1882</td>
<td>1970</td>
<td>$5,277,552.00</td>
<td>Menefee</td>
<td>MON</td>
</tr>
<tr>
<td>DIS016</td>
<td>Mount Taylor coal field</td>
<td>1936</td>
<td>1952</td>
<td>1953</td>
<td>$69,948.00</td>
<td>Crevasse Canyon</td>
<td>TAY</td>
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<tr>
<td>DIS157</td>
<td>Navajo coal field</td>
<td>1933</td>
<td>1963</td>
<td>9999</td>
<td>$4,714,689,147</td>
<td>Fruitland</td>
<td>NAV</td>
</tr>
<tr>
<td>DIS258</td>
<td>Newcomb coal field</td>
<td>1955</td>
<td></td>
<td></td>
<td></td>
<td>Menefee</td>
<td>NEW</td>
</tr>
<tr>
<td>DIS021</td>
<td>Raton coal field</td>
<td>1820</td>
<td>1898</td>
<td>2002</td>
<td>$954,470,032.00</td>
<td>Vermejo, Raton</td>
<td>RAT</td>
</tr>
<tr>
<td>DIS003</td>
<td>Rio Puerco coal field</td>
<td>1901</td>
<td>1937</td>
<td>1944</td>
<td>$139,555.00</td>
<td>Crevasse Canyon</td>
<td>RIO</td>
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<tr>
<td>DIS009</td>
<td>Salt Lake coal field</td>
<td>1980</td>
<td>1987</td>
<td>1987</td>
<td>$100,000.00</td>
<td>Moreno Hill</td>
<td>SALT</td>
</tr>
<tr>
<td>DIS121</td>
<td>San Mateo coal field</td>
<td>1905</td>
<td>1983</td>
<td>2001</td>
<td>$1,678,742,326</td>
<td>Menefee</td>
<td>MAT</td>
</tr>
<tr>
<td>DIS261</td>
<td>Standing Rock coal field</td>
<td>1934</td>
<td>1952</td>
<td>1958</td>
<td></td>
<td>Menefee</td>
<td>STND</td>
</tr>
<tr>
<td>DIS158</td>
<td>Star Lake coal field</td>
<td>1907</td>
<td></td>
<td></td>
<td>$0.00</td>
<td>Fruitland</td>
<td>STAR</td>
</tr>
<tr>
<td>DIS263</td>
<td>Tierra Amarilla coal field</td>
<td>1935</td>
<td>1955</td>
<td>1955</td>
<td></td>
<td>Menefee</td>
<td>AMAR</td>
</tr>
<tr>
<td>DIS159</td>
<td>Toadlena</td>
<td>1950</td>
<td></td>
<td></td>
<td>$0.00</td>
<td>Menefee</td>
<td>TOAD</td>
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<tr>
<td>DIS124</td>
<td>Zuni coal field</td>
<td>1916</td>
<td>1908</td>
<td>1926</td>
<td>$16,010.00</td>
<td>Crevasse Canyon</td>
<td>ZUNI</td>
</tr>
</tbody>
</table>

**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  

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  
1st 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  
2nd quarter  

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  
1st quarter  
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)
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. Guangpring 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 st 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

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<th>FY 2022</th>
<th>FY 2023</th>
<th>Total</th>
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<td>DOE funds</td>
<td>Cost Share</td>
<td>DOE funds</td>
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<td>NMIMT</td>
<td>564,432</td>
<td>101,114</td>
<td>544,856</td>
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<td>Los Alamos National Laboratory</td>
<td>93,750</td>
<td>-</td>
<td>93,750</td>
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<td>Sandia National Laboratories</td>
<td>99,946</td>
<td>-</td>
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<td>SonoAsh LLC</td>
<td>-</td>
<td>115,000</td>
<td>-</td>
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<td>Total ($)</td>
<td>758,128</td>
<td>216,114</td>
<td>725,660</td>
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<tr>
<td>Total Cost Share</td>
<td>22.2%</td>
<td>23.2%</td>
<td>22.7%</td>
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7. **APPENDICES**

**APPENDIX 1. List of SOPs and plans**  
(see [https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html](https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html) for copies as they are completed)

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Description</th>
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<td>HASP</td>
<td>Health and Safety Plan (HASP)</td>
<td>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>)</td>
</tr>
<tr>
<td>SOP 1</td>
<td>Data management</td>
<td>entering, reporting, verification, and validation of data to the database</td>
</tr>
<tr>
<td>SOP 2</td>
<td>Photography</td>
<td>procedures taking photographs in the field and laboratory</td>
</tr>
<tr>
<td>SOP 3</td>
<td>GPS surveying</td>
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