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

9th Quarterly Research Performance Progress Report  
Reporting Period: October 1, 2023 to December 31, 2023  
Project Performance Period: 10/01/2021 – 12/31/2024

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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 the 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 workshops and assemble REE research-related articles for an REE-centered issue of *Lite Geology*. 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 provides a listing of the revised project milestones, along with anticipated delivery dates (SOPO). Please note that we have additional funded contracts with the U.S. Geological Survey (USGS) that are examining critical minerals in several areas in New Mexico, including the Zuni Mountains. One of the USGS contacts is examining the critical minerals in mine wastes. We are using the same sampling and characterization procedures in both the USGS and DOE projects.

TABLE 1. Revised List of Milestones (SOPO) (**bold=completed**) Prefixed with E=added in the extension to the project. Deliverables are posted on project web page at <https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html>

Task/ Subtask	Milestone Title	Planned Completion	Verification method	Status
	Quarterly reports	Quarterly	1 <sup>st</sup> Quarter: October, November, December; Deadline report is due <u>January 30<sup>th</sup></u> 2 <sup>nd</sup> Quarter: January, February, March; Deadline report is due <u>April 30<sup>th</sup></u> 3 <sup>rd</sup> Quarter: April, May, June; Deadline report is due <u>July 30<sup>th</sup></u> 4 <sup>th</sup> Quarter: July, August, September; Deadline report is due <u>October 30<sup>th</sup></u>	<b>1-9<sup>th</sup> quarters completed</b> see <a href="https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html">https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html</a>
	Year 1 interim report	Year 1	Submitted	<b>Completed</b> <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/ProjectSummary1_23_v1.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/ProjectSummary1_23_v1.pdf</a>
	Year 2 interim report	Year 2	Submitted	<b>Completed</b> <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/ProjectSummaryYr2_10_23_v1.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/ProjectSummaryYr2_10_23_v1.pdf</a>
	Year 3 interim report	Year 3, 9/31/24	Due September 2024	<b>Ongoing</b>
	Biweekly meetings with research group	biweekly	Informal notes of meetings sent to the group and DOE project manager at end of meeting	<b>Ongoing</b>
	Meetings with DOE manager	12/7/22, 4/11/23, 7/11/23, 9/12, 12/12, 1/10/24	Attend, monthly	<b>Presentation given</b>
	Attend DOE National project meetings	10/24-27/2022, 6/27-28/2023	Attended	Plan to attend in April 2023

1.0	<b>A: Project Kick-off meeting</b>	10/15/21	Attend, report	<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> )
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.	<b>Completed 1/5/21</b>
2.1	B: Identification of Sampling Sites	Quarterly	Reports every quarter (quarterly reports), environmental questionnaire completed	<b>Ongoing</b> , planned in 2 phases Phase 1 ( <a href="https://geoinfo.nmt.edu/staff/mclemore/SampleLocations1_23.xlsx">https://geoinfo.nmt.edu/staff/mclemore/SampleLocations1_23.xlsx</a> ), environmental questionnaire completed and revision submitted
2.2	C: Collection and Review of Existing Data	2 <sup>nd</sup> quarter	Map, description	<b>Report completed</b> <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/legacycychemistryrpt23.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/legacycychemistryrpt23.pdf</a> , ongoing activity, <b>REE in produced waters</b> <a href="https://geoinfo.nmt.edu/staff/mclemore/ree_produced_waters_for_GIS.xlsx">https://geoinfo.nmt.edu/staff/mclemore/ree_produced_waters_for_GIS.xlsx</a> and <b>USGS coal chemistry</b> <a href="https://geoinfo.nmt.edu/staff/mclemore/REEcoal.mpk">https://geoinfo.nmt.edu/staff/mclemore/REEcoal.mpk</a> are on the project web site; summary of data and preliminary interpretations <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreGSA22Wed10-12-22.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreGSA22Wed10-12-22.pdf</a>
2.3	<b>D: 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 available and being updated.
2.4	E: Collect Samples	Quarterly	Report, database	Started sampling in April 2022 (see Table 1), permit to collect on Navajo Tribal Lands issued April 2023 and

				ended June 30, 2023, see <a href="https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem1223.xlsx">https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem1223.xlsx</a> for list of samples for which chemistry have been completed
2.5	F: Characterization	Quarterly	Progress report quarterly, database	<b>Ongoing</b> once samples are collected, <b>samples submitted to laboratories for chemical analyses, chemical analyses received</b> Chemical analyses at <a href="https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem_003.xlsx">https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem_003.xlsx</a> , preliminary report by Sandia <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/Coal9Petrography.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/Coal9Petrography.pdf</a>
2.6	G: Application of Machine Learning techniques for Basin-wide Assessment	12/31/2022	Progress report quarterly, database, 1 <sup>st</sup> summary report completed	<b>Completed</b> , Submitted 8/9/2023, update report due March 2023
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	<b>Ongoing</b> , chemical analyses at <a href="https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem_000.xlsx">https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem_000.xlsx</a>
4.0	I: Results of Basinal Infrastructure, Industries and Business Assessment	03/31/2023	Progress report quarterly, database, publications	Future activity; 4.3 <b>Life cycle analysis completed (see below)</b> , Extraction techniques report completed <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/January2023ExtractionTechnique.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/January2023ExtractionTechnique.pdf</a>
E1.0	Project management plan for extension	12/31/2024	To be included as an appendix to the Final Scientific/ Technical Report	<b>Ongoing, submitted with extension</b>
E1.1	Summary of Environmental	9/30/2024 interim report, final	To be included as an appendix to the Final Scientific/Technical Report	<b>Ongoing, attending DOE working group meetings</b>

	Justice Considerations	report 12/31/2024		
E1.2	Summary of Economic Revitalization and Job Creation Outcomes	9/30/2024 interim report, final report 12/31/2024	To be included as an appendix to the Final Scientific/ Technical Report	<b>Ongoing, attending DOE working group meetings</b>
E1.3	Environmental, Safety, and Health Analysis	Completed, revised as needed	To be included as an appendix to the Final Scientific/ Technical Report, also see SOPs (Appendix 1)	<b>Ongoing, attending DOE working group meetings, HASP completed and revised as needed</b> <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_11.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_11.pdf</a>
E2	Overall CORE-CM Resource Sampling Plan providing sampling locations, sampling methods for each location, and site-specific access agreements	9/30/2024 interim report, final report 12/31/2024	Due at the end of the Period of Performance.	<b>Ongoing,</b> <a href="https://geoinfo.nmt.edu/staff/mclemore/SampleLocations1_23.xlsx">https://geoinfo.nmt.edu/staff/mclemore/SampleLocations1_23.xlsx</a> , environmental questionnaire completed and revision submitted, see Appendix 1 for permit to sample on Navajo Tribal Lands; site agreements not needed on Federal or state lands
E2	Initial Basinal Resource Assessment	9/30/2024 interim report, final report 12/31/2024	Due at the end of the Period of Performance.	<b>Ongoing</b>
E2	Characterization and Data Acquisition Plan	9/30/2024 interim report, final report 12/31/2024	Due at the end of the Period of Performance.	<b>Ongoing, attending DOE working group meetings</b>
E3	Initial Waste Stream Reuse Plan	9/30/2024 interim report, final report 12/31/2024	Due at the end of the Period of Performance.	<b>Ongoing</b>

E4	Results of the Basinal Strategies for Infrastructure, Industries and Business Assessment	9/30/2024 interim report, final report 12/31/2024	Due at the end of the Period of Performance.	<b>Ongoing, attending DOE working group meetings</b>
E5	Initial Technology Assessment and Field Development Plan	9/30/2024 interim report, final report 12/31/2024	Due at the end of the Period of Performance.	<b>Ongoing</b>
E6	Initial Technology Innovation Center Plan	9/30/2024 interim report, final report 12/31/2024	Due at the end of the Period of Performance.	<b>Ongoing</b>
E7	Initial Stakeholder Outreach and Education Plan	9/30/2024 interim report, final report 12/31/2024	Due at the end of the Period of Performance.	<b>Ongoing, see</b> <a href="https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html">https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html</a>
E1	Phase 1 Interim Report	9/30/2023, <b>9/30/2024</b>	Due to NETL Project Manager 12 months <b>and 24 months</b> after award. At 12 months, this will include an outline of deliverable reports and preliminary findings to date. <b>At 24 months this will include a summary of findings over the prior 12 months.</b>	<b>Completed (9/30/2023)</b> <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/PHASE1INTERIMREPORTDE-FE0032052SEPTEMBER302022CONFIDENTIAL.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/PHASE1INTERIMREPORTDE-FE0032052SEPTEMBER302022CONFIDENTIAL.pdf</a> <b>Summary report completed</b> <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/DOE_Summary3_23.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/DOE_Summary3_23.pdf</a> this report
E2	Energy Data Exchange (EDX) FOA-2364 REE Researcher Database Template (per Appendix G of FOA 2364) <b>(includes</b>	10/3/2023, 9/30/2024 interim report, final report 12/31/2024	<b>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</b>	<b>Chemistry spreadsheet submitted</b> <a href="https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem10_3_23.xlsx">https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem10_3_23.xlsx</a>



	<b>resource assessment, i.e. endowment)</b>		<p>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.*</p> <p>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.</p>	
E2	Inputs for NETL REE-SED Sample Data Needs (per Appendices H and I of FOA	9/30/2024 interim report, final report 12/31/2024	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	<b>Ongoing</b>

	2364)		EDX Database, for use in NETL RIC's Geologic Models. See Note below.*	
E2	Resource Samples for Mineral Characterization and Analysis	12/31/2024	<p>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.</p>	<b>Ongoing, samples have been archived and stored in storage facility</b>

Accomplishments during 9<sup>th</sup> quarter

**Task 1.0 Project Management and Planning**

Project management activities during this quarter included the implementation of procedures including regular management and biweekly working group meetings with our partners. The team also meets with the New Mexico Bureau of Geology and Mineral Resources (NMBGMR)

Economic Group group to develop the project database and review progress of student work. Meetings with the DOE coordinator/manager have been held to update the DOE about project development.

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

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

#### ***Subtask 2.1 Identification of Sampling Sites (COMPLETED)***

1. Sample sites include the coal fields and mines (including abandoned mines, AML) in the San Juan and Raton basins, shown in Figure 1. Potential sample sites are listed at [https://geoinfo.nmt.edu/staff/mclemore/SampleLocations1\\_23.xlsx](https://geoinfo.nmt.edu/staff/mclemore/SampleLocations1_23.xlsx).
2. Received permit from Navajo Tribe to sample on Tribal lands April-July 2023; sampling began in April and was completed in June 2023.

#### ***Subtask 2.2 Collection and Review of Existing Data (COMPLETED)***

Legacy chemistry data have been collected. See preliminary results in Geological Society of America presentations by McLemore (<https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreGSA22Wed10-12-22.pdf> , <https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreGSA23.pdf> ) , DOE workshop presentation (<https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreDOE22Tues10-25-22.pdf> ), group presentation on geochemistry (11/15.22), and report (<https://geoinfo.nmt.edu/staff/mclemore/documents/legacychemistryrpt23.pdf> ).

#### ***Subtask 2.3 Develop a Sampling Plan (COMPLETED)***

The field sampling plan is completed and revised as needed ([https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan\\_v5.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v5.pdf) ). Figure 1 shows the coal fields and mines in the area. Table 2 is a list of the coal fields.

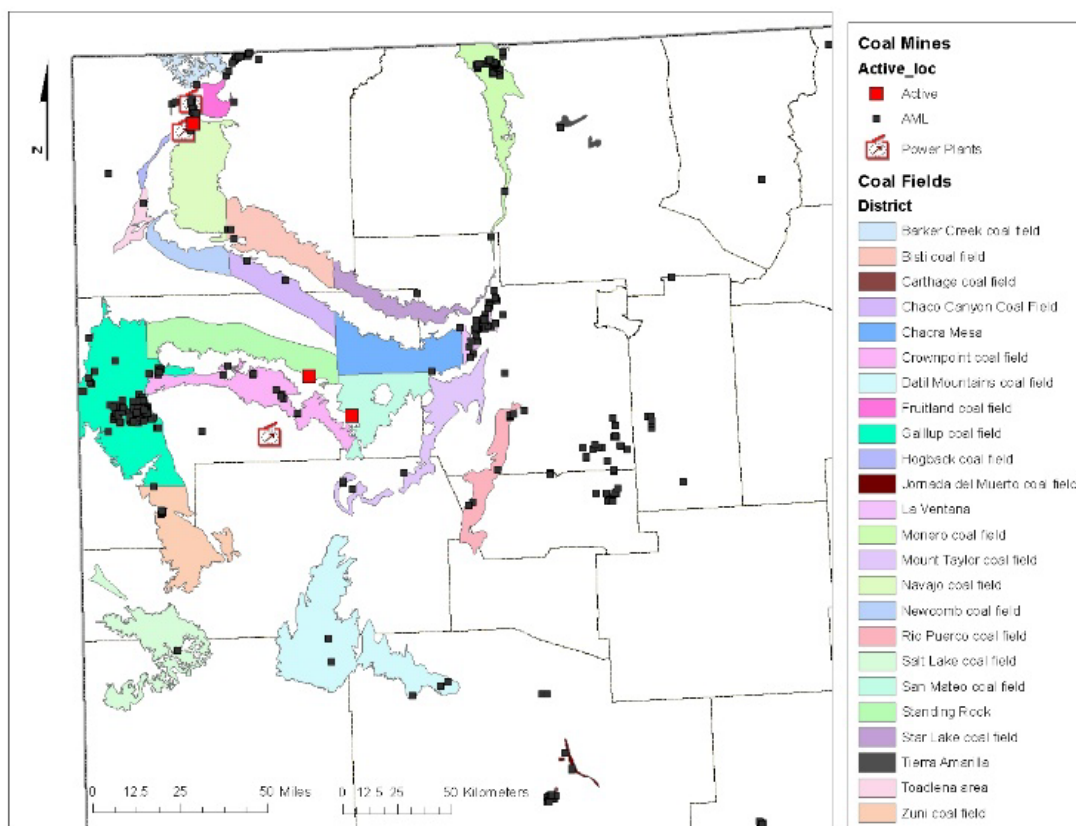


FIGURE 1. Location map of coal fields in the San Juan basin, New Mexico (modified from Hoffman, 2017). Active coal mines are surface operations. Lee Ranch mine suspended operations in 2016, but plans to reopen. Coal fields are summarized in Table 2. Only the Four Corners power plant remains open. There are two power plants in Arizona (St. Johns, Springerville) that receive coal from the El Segundo mine in New Mexico.

TABLE 2. Samples from coal fields in the San Juan and Raton basins. Coal fields and reserves are delineated by Hoffman (1996, 2017). District name (coal field) 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 coal analyses at this time.

District (coal field)	Year of Discovery	Year of Initial Production	Year of Last Production	Estimated Cumulative Production	Formation	Number of samples analyzed total	Number of coal (including humate) analyzed	Number of samples analyzed from legacy data	Number of samples to be analyzed	Drill core available
Barker Creek	1882		1905		Menefee	9	6			no
Bisti	1961	1980	1988	40,075,148	Fruitland	53	16			yes
Carthage	1856	1861	1963		Crevasse Canyon, Tres Hermanos	2	2			no
<b>Chaco Canyon</b>	1905	1905			Menefee	1	1			no
Chacra Mesa	1922		1945		Menefee	29	13			yes

Crownpoint	1905	1914	1951	20,758	Crevasse Canyon	12	8		1	no
Dakota	na	na	na	na	Dakota	4	4			
<b>Datil</b>	1913	1917	1940	66,980	Crevasse Canyon, Tres Hermanos	1	1			yes
Fruitland	1889	1889	2001	3,137,957,050	Fruitland	5	4	62		no
Gallup	1881	1882	2001	121,522,629,885	Crevasse Canyon	48	27		2	yes
<b>Hogback</b>	1907	1907	1971	301,237	Menefee					no
Jornada del Muerto	1910		1927		Crevasse Canyon	6	3			yes
La Ventana	1884	1904	1983		Menefee	4	4			no
Monero	1882	1882	1970	5,277,552	Menefee	13	11	6		yes
Mount Taylor	1936	1952	1953	69,948	Crevasse Canyon	7	5			no
Navajo	1933	1963	9999	4,714,689,147	Fruitland	20	11			yes
<b>Newcomb</b>	1955				Menefee	3				no
Raton	1820	1898	2002	954,470,032	Vermejo, Raton	29	12	30	1	yes
<b>Rio Puerco</b>	1901	1937	1944	139,555	Crevasse Canyon			47		no
Salt Lake	1980	1987	1987	100,000	Moreno Hill	2	1	13		yes
San Mateo	1905	1983	2001	1,678,742,326	Menefee	9	5	169		yes
Standing Rock	1934	1952	1958		Menefee	8	4			yes
Star Lake	1907				Fruitland	45	30			yes
<b>Tierra Amarilla</b>	1935	1955	1955		Menefee					no
Toadlena	1950				Menefee	15	6			no
Zuni	1908	1908	1926	16,010	Crevasse Canyon, Tres Hermanos	1	1	3		no
coal ash						4		2	1	
beach placer sandstone						113				
sedimentary copper						32		2		
uranium sandstone								23	1	
Other samples						23				
total samples						498	175	357	6	

### *Health and safety plan (COMPLETED)*

HASP is completed and revised as needed

([https://geoinfo.nmt.edu/staff/mclemore/documents/HASP\\_10.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_10.pdf)). NMT requires all projects to have a **Safe and Inclusive Working Environment Plan for Off-Campus or Off-Site Research**, which has been added to the HASP.

### *Subtask 2.4 Collect Samples*

Sampling at the beginning of the project was delayed due to poor weather, vacation schedules, closures of Federal land because of fire danger, and students not available because of school schedules. We started sampling in April 2022.

We have logged 3162 ft of core (33 holes). We have collected 498 samples (Table 2; [https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem12\\_23.xlsx](https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem12_23.xlsx)).

Additional samples are being collected.

Photographs of drill core are at <https://photoarchive.nmt.edu/> (you need to search by coal and sample).

### Subtask 2.5 Sample Characterization

Chemical analysis was delayed at the beginning of the project due to obtaining quotes and proper paperwork required by NM Tech (completed August 2022).

Samples have been analyzed for major and trace elements (see Attachment 3, [https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem12\\_23.xlsx](https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem12_23.xlsx)).

Sandia is working on characterization (will submit in the future).

Los Alamos is now also working on sample characterization (results pending Q2).

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

Los Alamos is working on machine learning analyses (the first summary report has been submitted). Los Alamos is planning model rerun with updates to sample analysis database during Q2. Data curation has begun.

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

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

These samples are included in Task 2, but will be discussed in a separate chapter of the final report.

Two separate projects are using bench-scale leaching techniques to 1) extract aluminum from coal and related strata, including clays and 2) conduct leaching studies of humate. These are student projects and separate reports will be released; the results will be summarized in the final technical report.

### *Subtask 3.2 Coal Ash*

We have collected 8 coal ash samples from Generating Plants. These samples are included in Task 2, but will be discussed in a separate chapter of the final report.

### *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* (UPDATED AND COMPLETED, see 7<sup>th</sup> quarterly report).

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

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

Sandia NL has tested 8 samples, including coal and clinkers, using 0.5M citric acid leaching at 70C. The total rare earth recovery ranges from 5% (coal #26) to 62% (coal #2).

### *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**

Memo written describing meetings with parties to establish COE.

## **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

([https://nmt.edu/advancement/goldpan\\_archives/2022\\_Summer\\_GoldPan\\_Digital2.pdf](https://nmt.edu/advancement/goldpan_archives/2022_Summer_GoldPan_Digital2.pdf))

Another short summary of the project written for Lite Geology

([https://geoinfo.nmt.edu/publications/periodicals/litegeology/51/Ig\\_v51.pdf](https://geoinfo.nmt.edu/publications/periodicals/litegeology/51/Ig_v51.pdf))

The NMBGMR Rockin' Around New Mexico was in Socorro, NM July 5-8, 2023

Other outreach activities see <https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html>

Outline of outreach report completed and draft sent to the CORE-CM group for comments.

### **Subtask 7.2 Lessons Learned and Narratives Constructed**

There is no update on this subtask.

### **Subtask 7.3 Publications and presentations**

See Section 2 below

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

- Sonoash has worked on relationships, mainly with John Elling's Santa Fe lab, and related projects, as well as with partnerships with a large (\$100m/y) Farmington-area industrial company.
- Sonoash also was accepted into the initial DOE/MESC cohort of 14 US companies, receiving \$2m in technical assistance through DOE, working with independent engineering firms to work initial cost estimate (Class IV) for San Juan County.
- Sonoash remain pushing for the ETAC grant we were told we won for the project in the Summer.

## **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>)

#### *3<sup>rd</sup> quarter*

Rockin' Around New Mexico 2022 Critical Minerals presentation

<https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreRockinCM22.pdf>

Rockin' Around New Mexico 2022 Critical Minerals activities

<https://geoinfo.nmt.edu/staff/mclemore/documents/Rockin22.pdf>

#### *4th quarter*

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>

#### *5th quarter*

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

<https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreDOE22Tues10-25-22.pdf>

#### *6th quarter*

Badonie, M., Newcomer, J., Shaver, S., and McLemore, V.T., 2023, REE in coal and associated strata in the San Juan and Raton Basins, New Mexico: Minexchange, 2023 SME Annual Conference Technical Program, preprint 23-055, 5 p., <https://geoinfo.nmt.edu/staff/mclemore/documents/23-055.pdf>

McLemore, V.T., 2023, Critical minerals in New Mexico, (abstr.), New Mexico Geological Society, Spring meeting, <https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2892>

Shaver, D.R., McLemore, V.T., and Owen, E., 2023, Alteration and geochemistry of clinkers in the San Juan Basin, New Mexico (abstr.): New Mexico Geological Society, Spring meeting, <https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2933>

Leo-Russell, M.R. and McLemore, V.T., 2023, A review of lithium as a critical industrial material and engagement prospects in New Mexico (abstr.), New Mexico Geological Society, Spring meeting, <https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2926>

Lempke, J., Frey, B., Goehring, B., and McLemore, V.T., 2023, Rare earth elements in humates mined in the San Juan Basin (abstr.): New Mexico Geological Society, Spring meeting, abstract <https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2954>  
presentation [https://nmgs.nmt.edu/meeting/presentations/2023/2926/NMGS-Presentation-Lithium\\_LeoRussell-McLemore\\_1.pdf](https://nmgs.nmt.edu/meeting/presentations/2023/2926/NMGS-Presentation-Lithium_LeoRussell-McLemore_1.pdf)

Badonie, M.N. and McLemore, V.T., 2023, Rare earth elements and critical minerals in coal and related strata in the San Juan Basin in northern New Mexico (abstr.): New Mexico Geological Society, Spring meeting,

<https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2939>



Lempke, J., Frey, B., Goehring, B., and McLemore, V.T., 2023, Rare earth elements in humates mined in the San Juan Basin (abstr.): New Mexico Geological Society, Spring meeting, <https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2954>

McLemore, V.T. and Gysi, A., 2023, Critical minerals in New Mexico: Earth Matters, winter 2023, [https://geoinfo.nmt.edu/publications/periodicals/earthmatters/23/n1/em\\_v23\\_n1.pdf](https://geoinfo.nmt.edu/publications/periodicals/earthmatters/23/n1/em_v23_n1.pdf)

#### *7<sup>th</sup> quarter*

Owen, E.J. and McLemore, V.T., 2023, Distribution of REE in selected deposits in New Mexico: Forum on the Geology of Industrial Minerals, presentation, <https://geoinfo.nmt.edu/staff/mclemore/documents/ejo.FGIM23AustinDistributionofREEinselectedNMdeposits0.1.pdf>

McLemore, V.T., 2023, Industrial minerals in the San Juan Basin, New Mexico: Forum on the Geology of Industrial Minerals, presentation, [https://geoinfo.nmt.edu/staff/mclemore/documents/fgim23-ppt\\_sm.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/fgim23-ppt_sm.pdf)

Shaver, D., 2023, Coal mining history of New Mexico (abstr.): Mine History Association annual meeting, Socorro, NM, June 2023, <https://geoinfo.nmt.edu/staff/mclemore/documents/CoalMiningHistoryNewMexico.pdf>

McLemore, V.T., 2023, Rare Earth Elements and Critical Minerals in Late Cretaceous Coal and Related Strata in the San Juan and Raton Basins, New Mexico: Lite Geology, v. 51, [https://geoinfo.nmt.edu/publications/periodicals/litegeology/51/lg\\_v51.pdf](https://geoinfo.nmt.edu/publications/periodicals/litegeology/51/lg_v51.pdf)

Matt Powell, Guangping Xu, Mark J Rigali, Virginia McLemore, Shuya We<sup>2</sup> and Robert Happney, 2023, Microwave Digestion for Rare Earth Elements (REE) Quantification in Coal and Coal Ash (abstr.): Goldschmidt2023 conference, July, 2023

#### *8<sup>th</sup> quarter*

McLemore, Virginia, Owen, Evan, Badonie, Megan, Shaver, Devlon, and Newcomer, Jakob, 2024, Rare Earth Elements (REE) And Other Critical Minerals In Late Cretaceous Coal And Related Strata In The San Juan Basin, New Mexico: Preliminary Observations (abstr.): Geological Society of America, Annual Meeting, <https://gsa.confex.com/gsa/2023AM/top/papers/index.cgi?username=392235&password=680673&personid=227838>  
<https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreGSA23.pdf>

Shaver, D. and McLemore, V., 2024, Alteration and Geochemistry of Clinkers in the San Juan Basin, New Mexico (abstr.): SME Annual Conference, abstract accepted

McLemore, V.T. and Owen, E., 2024, Geochemistry of Critical Minerals in Mine Wastes in New Mexico (abstr.): SME Annual Conference, abstract and preprint accepted

McLemore, V.T., Owen, E., Badonie, M., Shaver, D., and Newcomer, J., 2024, 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 (abstr.): SME Annual Conference, abstract and preprint accepted

Owen, E.J and McLemore, V.T., 2023, Mineralogy and geochemistry of heavy mineral beach-placer sandstones in New Mexico(abstr.): SME Annual Conference, abstract and preprint accepted

*9<sup>th</sup> quarter*

McLemore, V.T., 2023, Update on critical minerals research in New Mexico 2023: presentation given at American Exploration and Mining Association annual conference, Reno, Nv, Dec, 2023,  
[https://geoinfo.nmt.edu/staff/mclemore/documents/aema\\_mclemore\\_23.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/aema_mclemore_23.pdf)

### **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**

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

- Sampling plan
- 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<sup>rd</sup> quarter*

- Revised sampling plan  
([https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan\\_v5.pdf](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](https://geoinfo.nmt.edu/staff/mclemore/ree_produced_waters_for_GIS.xlsx)) and USGS coal chemistry (<https://geoinfo.nmt.edu/staff/mclemore/REEcoal.mpk>)
- McLemore attended Mining and Metallurgical Society of America AML summit in Phoenix April 6-7, 2022
- Rockin' Around New Mexico was held in Farmington July 5-8, 2022

*6<sup>th</sup> quarter*

- Participated on the DOE working subgroups (Characterization, Infrastructure, Social Justice)
- Submitted request for extension until Dec. 2024
- Submitted request, budget, and work plan for \$500,000 extension ending Dec 2024

*7<sup>th</sup> quarter*

- Attended DOE 2023 Carbon ore, rare earth, and critical minerals (CORE-CM) initiative workshop #2, June 2023
- Mining in New Mexico with emphasis on Critical Minerals, Leadership Academy, May 2023, <https://geoinfo.nmt.edu/staff/mclemore/documents/LeadershipMining2023.pdf>

- GSA Earth Scope—had two interns from 2-yr colleges for the summer (one will present on coal mine wastes)
- Rockin’ Around New Mexico was held in Socorro July 5-8, 2023
- Abstracts being written for presentation at Geological Society of America (Oct, 2023) and Society of Mining, Metallurgy, and Exploration (Feb, 2024) annual meetings

#### 8<sup>th</sup> quarter

- 1 graduate thesis being written (Megan Badonie)
- Outline of final report completed and sent to team for review

#### 9<sup>th</sup> quarter

- Presented a general presentation on “Update on Critical Minerals Research in New Mexico 2023” at the American Exploration and Mining Association annual meeting in December.

### **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.

### **Preliminary conclusions**

- The New Mexico coal, humate, and clinker deposits are relatively moderate to 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<sub>2</sub>O<sub>3</sub> (as much as 40%) and Sr (as much as 3740 ppm), both critical minerals.
- Whole-rock and trace element geochemical data of beach placer sandstone deposits show expectedly high values of critical minerals such as TiO<sub>2</sub> (29.4%), total REE + Y (1.4%), Zr (>1%), and Hf (0.16%).
- 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.
- Common minerals hosting the critical minerals in these rocks from the San Juan and Raton Basins include clay minerals, zircon, and rutile/anatase.
- Potential geologic sources of REE and other critical minerals in New Mexico coal, humate, and clinker deposits include Proterozoic granitic and metamorphic rocks (such as those found in the Zuni and Nacimiento Mountains), the Jurassic-Cretaceous arc volcanism and magmatism forming the Mogollon Highlands to the south and west, and recycling of older sediments, although hydrothermal or weathering fluids could concentrate some of the critical minerals.
- More chemical and mineralogical analyses are required to fully understand the distribution and origin of REE and critical minerals in these deposits.
- As the demand for some of these elements increases because of increased need and short supplies, the dollar value per ton of ore rises, 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.

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

#### **A. Individuals involved in project** (strikeout=no longer on 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-Russell 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.~~

Mr. Evan Owen is Economic Geologist at NMBGMR- 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.

Dr. Mark J Rigali

***San Juan College***

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

Summer Begay

Craig J. Williams

***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~~

Dr. Brent Goehring

***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

Bruce Sifton

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

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

Craig Williams and Summer Begay are now representing San Juan College.

Evan Owen at NMBGMR was added to the project to assist with Tasks.

Only NMT, Sandia and Los Alamos National Laboratories are funded for the 6 month extension.

**4. SPECIAL REPORTING REQUIREMENTS: Mandatory**

No update

**5. BUDGETARY INFORMATION: MANDATORY**

See separate report

**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	Health and safety plan for field and laboratory work
FSP	Field Sampling Plan	Field sampling plan

Number	Name	Description
GMP	Geologic mapping plan	Geologic mapping plan
SOP 1	Data management	entering, reporting, verification, and validation of data to the database
SOP 2	Sample management	procedures of handling samples from field to laboratory to archive
SOP 3	Surveying (GPS)	field procedures using GPS and other surveying methods
SOP 4	Photography	procedures taking photographs in the field and laboratory
SOP 5	Sampling outcrops, rock piles, and drill core	field procedures for taking surface solid samples
SOP 6	Drill logging and sampling of subsurface	field procedures for drilling, logging, and sampling of subsurface samples (solids)
SOP 7	Sample equipment Decontamination	field procedures for decontamination of sampling equipment
SOP 8	Sample preparation	laboratory procedures for sample preparation (solids)
SOP 11	Paste pH and paste conductivity	laboratory procedures for paste pH and paste conductivity
SOP 12	Field measurements of water	field procedures for measuring water flow, pH, conductivity, alkalinity, temperature when collecting water samples
SOP 14	Field filtration of water samples	procedures for filtering water samples in the field
SOP 15	Surface water and seep sampling	field procedures for collecting samples of surface and seep water samples
SOP 22	Analytical data validation	procedures for data validation
SOP 24	Petrographic analysis	laboratory procedures for describing petrographic samples
SOP 26	Electron microprobe analyses	laboratory procedures use for analyses using the electron microprobe
SOP 27	X-ray diffraction (XRD) analyses	laboratory procedures for mineralogical analyses by x-ray diffraction (XRD)
SOP 28	X-ray fluorescence (XRF) analyses	laboratory procedures for chemical analyses by x-ray fluorescence (XRF)
SOP 30	ICP-OES analyses	laboratory procedures for chemical analyses using ICP-OES
SOP 31	ICP-MS analyses	laboratory procedures for chemical analyses using ICP-MS
SOP 33	Particle size analysis	laboratory procedures for determining particle size analyses
SOP 36	Sample preservation, storage, custody, shipping	procedures for sample preservation, storage, and shipment
SOP 44	Argon/argon geochronology	laboratory procedures for argon/argon dating
SOP 62	Acid-base accounting (ABA)	Procedures for acid base accounting in laboratory

Number	Name	Description
SOP 67	Solid sample collection and compound analysis	procedures for solid sample collection and compound analysis
SOP 68	Water analyses	water analyses in lab
SOP 69	Other chemical analyses on solids	other chemical analyses on solids (ammonia, nitrate, fluorine, etc)
SOP 75	Specific gravity	procedures for determining specific gravity
SOP 91	Color	procedures for obtaining the color of a soil sample
SOP 100	ABA	Procedure for analyzing acid generation potential and neutralizing potential
SOP 101	Water Sampling and Field Measurements	
SOP 102	Microbe sampling	
SOP 103	Use of Masonry Wet Saw	
SOP 104	Use of MK Diamond MK-101 Wet Tile Saw	
SOP 105	Collection of solid samples for waste rock characterization - sampling	Collection of waste rock materials (dumps, soils, tailings, slags)
SOP 106	Shipping and submitting samples for analyses	Procedures for shipping and submitting samples for analyses
SOP107	Collection of stream sediment samples Sampling, storage, and shipping	Procedures for shipping and submitting stream sediment samples for analyses
SOP108	Archiving	Procedures for archiving samples
SOP109	Use of Porter Cable Wet Tile Saw	Use of Porter Cable Wet Tile Saw