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

1st Quarterly Research Performance Progress Report
Reporting Period: October 1, 2021- December 31, 2021
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1. ACCOMPLISHMENTS

The objective of this project is to determine the REE and CM resource potential in coal and related stratigraphic units in the San Juan and Raton basins, NM. 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 project deliverables, along with anticipated delivery dates.

TABLE 1. List of tasks and subtasks

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 Milestones

Task/ Subtask	Milestone Title	Planned Completion	Status
1.0	A: Project Kick-off meeting	10/15/21	Completed (see https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMfinal.pdf)
2.1	B: Identification of Sampling Sites	10/31/2021	Ongoing, planned in 2 phases
2.2	C: Collection and Review of Existing Data	10/31/2021	Report in progress, ongoing activity
2.3	D: Sampling Plan, Database	10/31/2021	Sampling plan is completed (https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf), database is being developed

2.4	E: Collect Samples	Quarterly	Start sampling in April 2022 (weather and COVID permitting)
2.5	F: Characterization	Quarterly	Ongoing once samples are collected
2.6	G: Application of Machine Learning techniques for Basin-wide Assessment	12/31/2022	Future activity
3.0	H: Sampling and Characterization of Waste Streams	Quarterly	Ongoing, future activity
4.0	I: Results of Basinal Infrastructure, Industries and Business Assessment	03/31/2023	Future activity
5.0	J: Initial Technology Assessment and Field Test Development Plan	03/31/2023	Future activity
6.0	K: Initial Technology Innovation Center Plan	09/30/2022	Future activity
7.0	L: Workshop Report, Publications, Web Pages	Quarterly	Presentations, summary article to Gold Pan (NMT alumni newsletter), future activity, web page in progress, ongoing (see https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html)

B. Accomplishments during quarter

Task 1.0 Project Management and Planning

Project management activities during this quarter included the implementation of regular procedures including regular management and working group meetings. Project-wide group meetings were held on October 15th and November 30th, 2021. 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. Dr. McLemore attended the Oklahoma Geological Survey Critical Minerals Workshop from October 8 to October 10, 2021. McLemore presented a summary of the project at DOE Division of Critical Minerals Program Plan Rollout on December 8, 2021, and also attended and gave an oral presentation at the American Exploration and Mining Association annual meeting in Reno, Dec. 5-9, 2021.

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

Status: The team completed the safety plan, the health and safety plan (https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf) and the sampling plan (https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf). Currently the team is developing the database. The team has completed the drilling log SOP (Standard Operating Procedure)   (see https://geoinfo.nmt.edu/staff/mclemore/documents/SOP17DrillholeLoggingupdated.pdf)   and working on other relevant SOPs.

Subtask 2.1 Identification of Sampling Sites

We will have 2 phases of sampling. The actions on the first sampling phase include:
-   Begin identifying sample sites, gather information on potential sites (working on)
-   Sites identified on Federal Land and waiting for better weather to start sampling
-   Contacted State Land Office for permission to sample on state lands. Will need to submit a permit.
-   Contacted Navajo mine for permission to sample.

In the second sampling phase, sample sites will be selected using machine learning techniques (LANL) to select sites to "fill in the gaps" for a complete basin assessment.

Subtask 2.2 Collection and Review of Existing Data

NMBGMR is collecting existing data. A report on existing data is in progress.

NMBGMR has drill core of coal deposits from 146 locations scattered throughout San Juan and Raton Basins (Fig. 1). Holes are selected on the basis of coal field, completeness of the core, core description, radioactivity (measure of elevated REE), and use of LANL LIBS/RAMAN instrument. We will sample the coal seams and layers above and below the coal seams. We have logged and photographed more than 850 ft of drill core.
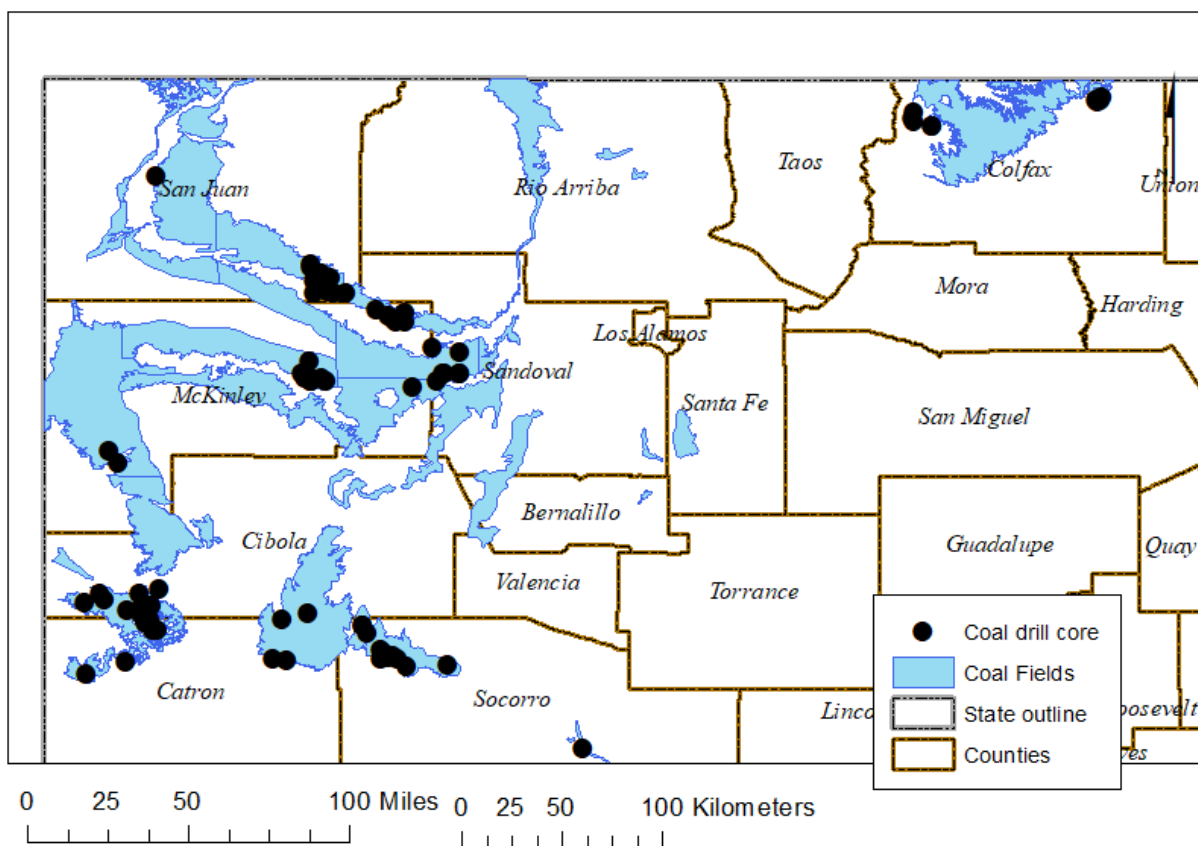

FIGURE 1. Location of drill holes at NMBGMR core facility.

Chemical analyses of Cretaceous beach-placer sandstone deposits in the San Juan Basin (Fig. 2) have been collected and entered into spreadsheets. Cretaceous beach-placer sandstone deposits are found in the vicinity of coal deposits and are restricted to Late Cretaceous rocks and contain high REE (Fig. 3).
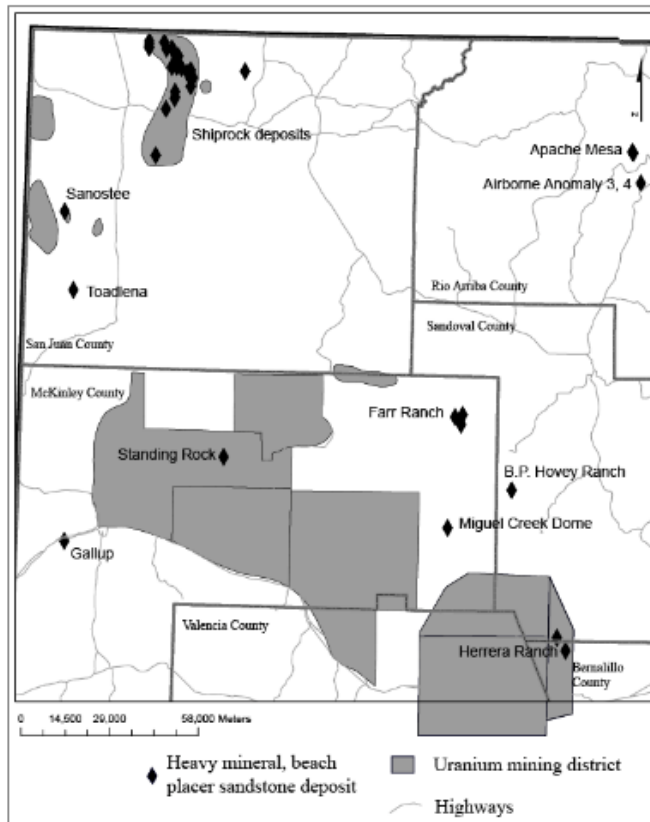

FIGURE 2. Location of Cretaceous beach-placer sandstone deposits in the San Juan Basin.
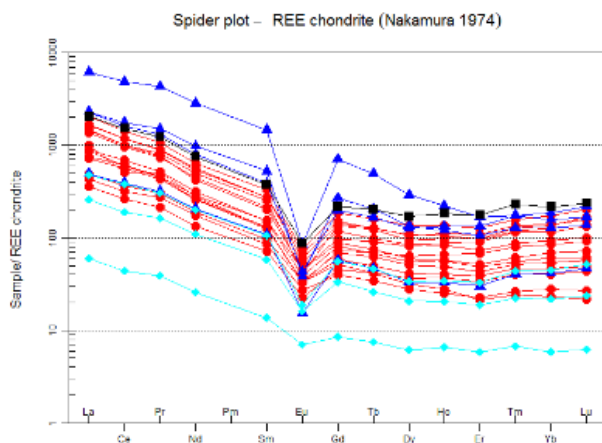

FIGURE 3. Chondrite-normalized REE plot of selected beach-placer deposits, Apache Mesa (red), Standing Rock (light blue), Sanostee (dark blue), and B.P. Hovey (black) in the San Juan Basin, New Mexico. Chondrite values are from Nakamura (1974).

Subtask 2.3 Develop a Sampling Plan

The field sampling plan is completed and summarized below (https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf).

REE sampling program methodology

Representative samples will be collected from each coal field. Clay, black shales, and other stratigraphic units above and below coal seams will be sampled as appropriate. Samples on Federal land do not require any permission for access and will be given higher priority for sampling. Coal waste and by-products will be sampled from active and inactive coal mines. The New Mexico State Land Office has granted permission to sample on state land and a permit is pending. Permission before sampling on private (including active coal mines and power plants) or Tribal lands will be obtained before sampling.

Five types of samples will be collected:
1) Drill core of coal deposits
2) Stratigraphic profile of outcrops with coal seams
3) Samples of waste products from operating active mines, preparation plants, power plants and disposal sites (active and inactive)
4) Samples from Abandoned Mine Lands (AML) sites
5) Samples of water draining from mines and waste storage sites (including process waters), where available (Separate SOP will be written to collect water samples)

To meet the SOPOs listed in section A (Major goals and objectives), the Characterization Team will implement this field sampling program. This sampling plan provides the detail sampling procedures to accomplish the work plan.

Study area

The study area includes the San Juan and Raton Basins in San Juan, Rio Arriba, Sandoval, McKinley, Cibola, Catron, Socorro, and Colfax Counties (Fig. 1, 4, Table 1). Field samples and drill core will be collected (Fig. 1, 4).
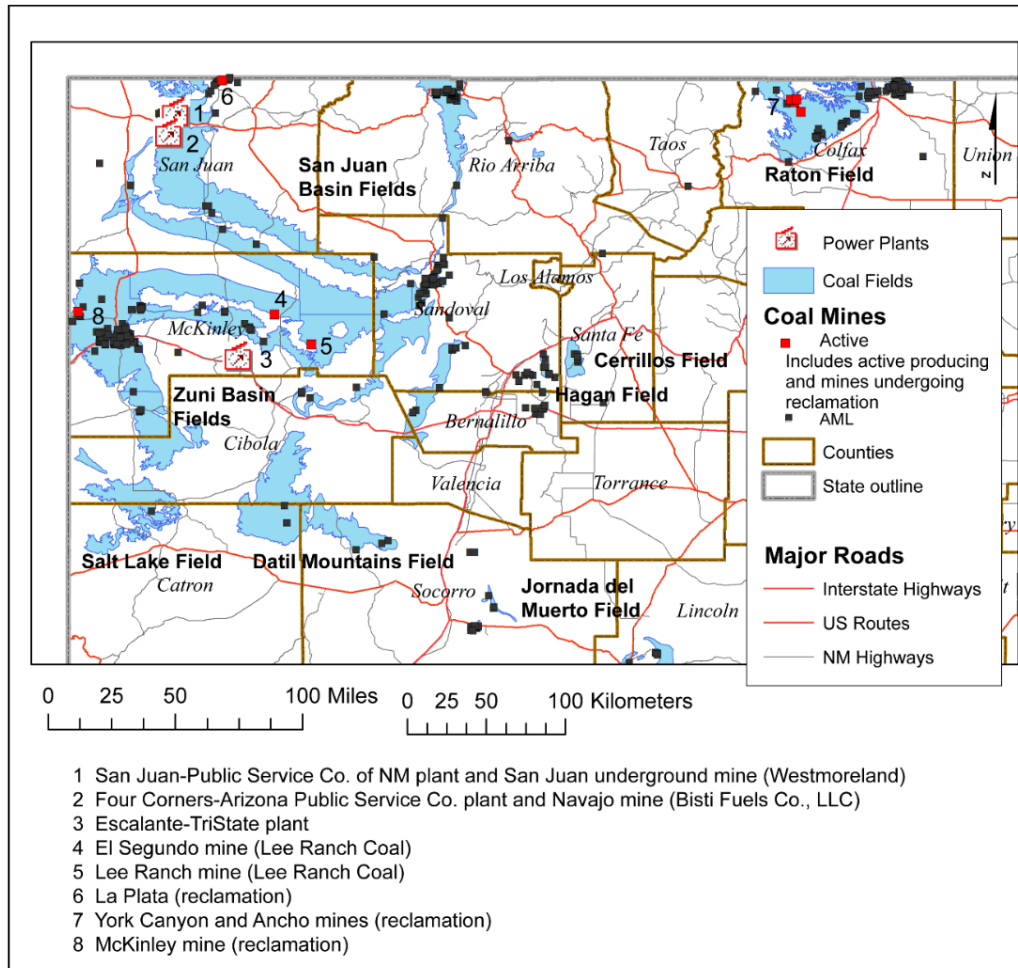
FIGURE 4. Coal fields, active mines, AML (abandoned mine lands) sites, and power plants in the San Juan and Raton Basins.

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
DIS260	Chacra Mesa coal field	1922		1945		Menefee	CHACA

District id	District	Year of Discovery	Year of Initial Production	Year of Last Production	Estimated Cumulative Production	Formation	Prefix used for sample id
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

Investigation approach

The field characterization investigation has been designed to collect data to:

 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.

To accomplish these objectives requires a Basinal Resource assessment of the San Juan and Raton basins as described below. The following tasks will be performed:

1)   Identify the stratigraphic units and coal mine waste products 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. that contain potential economic concentrations of CM and REE (Fig. 1, 2),

2)   Their location within the San Juan and Raton basins (Fig. 1)

3)   Estimate the quantity of each material contained within the San Juan and Raton basins. maps with locations of mines and exploration sites, mine features, waste and rock piles and areas of disturbance (using existing coal resource estimates as determined by the NMBGMR and USGS)

These tasks and supporting activities are described in this field sampling plan (FSP, https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf) and supporting SOPs.

Responsibilities and qualifications

The Senior Characterization Team members will supervise the sampling activities.

The Team Leader and Characterization Team will have the overall responsibility for implementing this sampling field plan (https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf). They will be responsible for assigning appropriate staff to implement this sampling field plan and for ensuring that the procedures are followed.

All personnel performing these procedures are required to have the appropriate health and safety training (see https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf). In addition, all personnel are required to have a complete understanding of the procedures described within this sampling field plan, and receive specific training regarding these procedures, if necessary.

All staff and assay laboratory staff are responsible for reporting deviations from this sampling field plan to the Team Leader.

Permit requirements and notification

State Land Office permit is pending.

List of equipment

The only equipment for the project is the container building for samples, which has been delivered. We will start building shelves as soon as materials are purchased and the weather becomes suitable for construction.

Related standard operating procedures

The procedures set forth in this plan are intended for use with the SOPs listed in Appendix 1.

Field activities

This section describes field activities that will be performed for the project and consist of the following activities:

1) Premobilization and site reconnaissance
2) Drill core
3) Sample site selection
4) Surveying
5) Sampling
6) Water sampling and determination of hydrologic conditions
7) Quality control and quality assurance procedures

Instructions for implementing these tasks are given in the sampling plan (https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf) and standard operating procedures (SOPs). Any identified deviations from this SP or SOPs will be documented and the Team Leader and Principle Investigators will be informed.

Premobilization and site reconnaissance
One or more reconnaissance trips may be needed to identify sampling sites and address any potential safety issues. All trips must be scheduled with Virginia McLemore.

Drill core
Drill core stored at the NMBGMR is being logged and photographed. NMBGMR has drill core of coal deposits from 146 locations scattered throughout San Juan and Raton basins (Fig. 1). Holes are selected on the basis of coal field, completeness of the core, core description, radioactivity (measure of elevated REE), and use of LANL LIBS/RAMAN instrument. Personnel from LANL will use the LIBS/RAMAN instrument to determine mineralogical and chemical analyses of the core. Samples will be selected for laboratory analyses to compare to the instrument analyses. We will sample the coal seams and layers above and below the coal seams. SOP is in Appendix 4.

Sample site selection
Topographic and geologic maps will be imported into ArcGis along with land ownership databases. Sample sites will be selected using ArcGis and these maps on the basis of:

1) Safe access and sampling (no landslides or other disturbed slopes)
2) Active mines and power plants (Fig. 4)
3) AML sites (Fig. 4)
4) Outcropping coal seams with exposed units above and below the coal seam
5) Near known coal mines (coals are likely to be thick enough to mine)

      6)   On Federal or State land
      7)   Coals known to have uranium concentrations (McLemore, 1983)
      8)   Accessible (roads nearby)
      9)   Other criteria (such as near faults where fluids flow to potentially enrich coals with REE, near dikes or other intrusions where REE could be sourced, near known clay beds)
      10)   Coal wastes from active, reclamation, and AML sites
            a) Fly ash, bottom ash
            b) Waste rock piles (dumps)
            c) AMD (acid mine drainage)
            d) Processing waters

Selected sample locations will be marked with aluminum tags. Photographs will be taken (SOP 4).

We will have two phases of sampling. Representative samples will be collected from the coal fields. LANL will then select phase 2 sample sites using machine learning techniques (LANL) to select sites to "fill in the gaps" for a complete basin assessment.

Surveying
Conventional use of handheld GPS survey techniques will be used to locate samples; elevations will be taken from topographic maps. SOP 3 describes the procedures for GPS surveying.
Sampling
Different sampling strategies will be employed based upon the purpose of each sampling task. Field geologists with experience in the regional stratigraphy and in the recognition of altered and weathered rocks perform the sampling. The types of samples to be collected include:
      1)   Drill core of coal deposits (Fig. 1)
      2)   Stratigraphic profile of outcrops with coal seams
      3)   Samples of waste products from operating active mines, preparation plants, power plants or owning the disposal sites (active and inactive) (Fig. 4)
      4)   Samples from Abandoned Mine Lands (AML) sites (Fig. 4)
      5)   Samples of water draining from mines and waste storage sites, where available (SOP 7)

All of the coal fields and major lithologic units using outcrop localities (overburden, waste rock piles, underlying rocks, and other country rocks), drill core, and waste rock piles, will be sampled as appropriate. SOP 5 describes the procedures for sampling outcrops, rock piles, and drill core (solid samples).

A standardized protocol will be followed after each sample is taken (SOP 2). At each site, a select, grab, or bulk sample of rock or other material is collected for petrographic study and geochemical analyses that is representative of the DQO being addressed. Radioactive readings will be taken using a scintollometer (REE locally are found in areas of higher radioactivity). A hand specimen also is collected for thin section and archived. Each sample is collected in a separate bag or bucket, assigned a unique number (field id), and logged on a field description form (https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf). Selected sample sites are marked in the field and a digital photograph (SOP 3) is taken at all localities. Photographs provide visual record of the sample site; the photograph form identifies site specifics, provides basic

location and other data about the photograph (SOP 3). Location information by GPS, type of sample, and field and laboratory petrographic descriptions will be collected. Each sample will be clearly identified. Geologic observations are recorded on the field description form and each site is located on a map. A global positioning system (GPS) reading is recorded as well (SOP 3). Hand specimen description provides a record of what was collected, aids in petrographic description, and provides information on sample for the labs (high S may be treated differently than low S). The hand specimen description is the preliminary data required to determine what samples need specific detailed analyses to meet the DQOs. NMBGMR will archive all samples for potential future studies.

The samples are transported from the field to NMBGMR, where each sample is prepared for analyses. Samples will be cut and chips will be sent for preparation of polished thin sections. The prepared samples are then sent to a laboratory for chemical analyses. NMBGMR standards are submitted blind to the commercial laboratory with each sample batch to assure analytical quality.

Petrographic analysis and mineral identification are important in differentiating various rock units, determining rank and intensity of alteration, determining chemistry of alternating fluids, describing cementation, and determination of paragenesis of mineralization, alteration, and cementation. Alteration rank is based upon the mineral assemblages, which infers temperature, pressure, and permeability conditions at the time of formation. Petrography will be performed using standard petrographic and reflected ore microscopy techniques. Mineral concentrations will be estimated using standard charts and data. Estimates of both primary and alteration minerals will be determined, cementation described, and the alteration intensity will be determined from the concentration of alteration minerals. Forms are in the database. Digital photographs will be taken (SOP 3).

Sampling Procedure:
1) Collect samples of all of the major lithologic units using outcrop localities (ArcGis and geologic maps), drill core (Fig. 2), and AML waste rock piles (Fig. 1). The numbering system we will use will be a letter abbreviation that represent the coal field (Table 1) followed by sequential numbers. For example, STAR1 is the sample #1 collected from the Star Lake coal field. Samples of clay, shale, weathering profiles should be collected wherever possible and given unique sample numbers. Location data is entered into **waypoint form** (Appendix 2).
2) Record geologic observations on the **sample description form** (Appendix 2).
3) Record site description on the **sample description form** (Appendix 2).
4) Locate each site on a topographic map and take a GPS reading (NAD 27, UTM) and enter on the **waypoint form (SOP 3)** (Appendix 2)**.**
5) Photograph sample site (information recorded on **photograph form,** SOP 4, (Appendix 2). The numbering system for the photograph will be the field identification number, followed by P1 sequentially, Ros1-P1. Photographs will be taken at highest resolution as jpeg or tif. files and stored in separate folders corresponding to their image type.
6) Archive hand sample prior to sample preparation.
7) All data are entered into the project database.

Surface water and seep sampling
Should any surface water or seeps be encountered in or near the rock piles, sampling could occur according to SOP 7.

Analytical activities

This section describes analytical activities that will be performed for the Project and consist of the following activities:
1) Sample preparation
2) Geochemical and statistical analyses
3) Quality control and quality assurance procedures

Sample preparation and analysis (solid)
1) Hand samples will be sawed in half, photographed and archived.
2) Solid samples cut for thin sections (information recorded on sample preparation form, Appendix 2, SOP 8).
3) Polished thin sections of selected samples will be prepared by a commercial laboratory.
4) Polished probe sections of selected samples for microprobe analysis will be prepared by NMIMT lab and examined for mineralogy (petrographic description form, SOP 24, Appendix 2,).
5) Photograph taken of thin sections (information recorded on photograph form, SOP 4, Appendix 2,).
6) Selected thin sections and other samples for electron microprobe study (SOP 26).
7) Samples analyzed for bulk mineralogy using XRD and recorded in **mineralogy table** (SOP 27).

Geochemical and statistical analyses
Bulk mineral identification can be used to identify minerals present in quantities greater than approximately 3%. Altered, unaltered, and mineralized samples, including select samples of cement, will be powdered and analyzed by X-ray diffraction (XRD).

Chemical analyses of solids (ICP, XRF, other, SOP 30, 31, 28) provide detailed concentrations of abundance of specific elements that directly relate to mineralogy and water quality. Chemical analyses of water samples provide information on pore water chemistry and relates to the sequence of alteration SOP 30, 31).
1. Solid samples analyzed for major and trace elements using XRF, ICP, and other methods
2. Water samples analyzed for major and trace elements using ICP and other methods

Paste pH and paste conductivity (SOP 11) are used to evaluate the geochemical behavior of mine rock materials subject to weathering under field conditions and to estimate the pH and conductivity of the pore water resulting from dissolution of secondary mineral phases on the surfaces of oxidized rock particles.

Electron microprobe analyses (SOP 26) provide mineral identification, specific mineral chemistry, relationships between the minerals, provide information on how minerals are altering, and what

new minerals forming at a microscopic level. Probe analysis can identify rims around sulfide minerals that could inhibit alteration of the mineral.

Quality control and quality assurance procedures

A standardized protocol will be followed after each sample is taken and chain of custody and request for analyses will be completed. Location data by GPS, type of sample, and field and laboratory petrographic descriptions will be collected. Each sample will be clearly identified. The samples will be transported from the field to NMBMMR. The samples will be sent to a laboratory for analyses.

For each batch of 25 samples, 1 set of duplicate samples with different sample_id numbers will be run. NMBGMR internal standards will be submitted blind to the laboratory with each sample batch of 25 samples to assure analytical quality. NMBGMR will archive a split of all samples for future studies.

The accuracy of the data is how close the measured value is to the true value. Analyzing certified standards as unknown samples and comparing with known certified values monitors accuracy. The precision of an analysis is the repeatability of a measurement. Precision is monitored by multiple analyses of many sample duplicates and internal standards. Estimates of accuracy and precision will be determined. Errors due to accuracy will be determined by multiple analyses of commercial standards for which accepted values are known. Errors due to precision will be determined by multiple analyses of selected sample splits, as well as multiple analyses of standard samples. There are numerous reasons why duplicate samples and/standards do not always agree. Some samples, such as rhyolite and andesite, grind into powder more easily than other samples, such as stream-sediment and rock pile samples. Fusion techniques required for XRF analyses vary from lab to lab and may also differ between different personnel that could result in variations between sample pairs. Analytical error is higher for analyses with concentrations close to the detection limit. In addition, mine samples and alluvium, such as the Capulin standard (CAP-MLJ-0001), are very heterogeneous and difficult to completely homogenize.

Another problem encountered with mine samples, is the variability of sample collection. Only trained geologists will collect the AML samples using the exact procedures to avoid variations between sample collectors. In addition, three samples will be collected at two separate sites by one sampler to estimate sample heterogeneity and assigned different field_id numbers.

Data for the Project will be obtained from a combination of sources, including field and laboratory measurements. The process of collecting and managing data is a coordinated effort (described in SOP 1) and will be conducted by project staff and laboratories working closely together. Laboratory data will be provided, when appropriate, in electronic form, in addition to the required hard-copy analytical data package. Data quality will be examined (SOP 1) before results are presented or used in subsequent activities. The laboratory will confirm sample receipt, sample condition, and required analyses. All pertinent information about each sample will be recorded.

Sampling schedule

Preliminary field reconnaissance April 2022.

Analyses schedule

As samples are collected, sample preparation and analyses will occur.

Field documentation

Forms will be used to record field and laboratory data (Appendix 3). These forms include:
1) Sample description form
2) Photograph form
3) Drill log

All forms that are completed by hand and all field forms will be archived in a binder in Socorro for future reference. Data will be immediately entered into the database. Copies of the database forms after completion also will be stored in binders.

Geologic observations and site description are recorded on the **sample description form**. Each site is located on a topographic map and a GPS reading taken (NAD 27, UTM) (SOP 3) and entered on the **sample description form.** Forms are in Appendix 3.

Photographs are taken of sample site (SOP 4; information recorded on **photograph form**). Photographs will be taken at the highest resolution as jpeg or tif and stored in separate folders corresponding to their image type.

Sample Archival and Disposal

All solid samples will be collected and archived at NMBGMR for potential future evaluation. Groundwater, surface water, and microbe sample aliquots will not be archived as a part of the study for future analysis or consideration. Any water sample volume not consumed during sample analysis will be disposed of by the laboratories as described in the laboratory QAM, and in accordance with all applicable rules and regulations.

Health and safety

The site health and safety plan (HASP) will be followed by all contractors and subcontractors working on the sites (https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf). It is the policy of New Mexico Tech to provide a safe and healthful work place for all employees, subcontractors, and clients in compliance with MSHA requirements.

Safety shall take precedence over expediency or short cuts. It is a condition of employment that all employees and subcontractors work safely and follow established safety rules and procedures. All injuries, vehicle accidents, and incidents with potential for injury or loss will be investigated. Appropriate corrective measures will be taken to prevent recurrence, and to continually improve the safety of the work place. Molycorp has a mandatory drug testing program that all personnel working on the property must follow.

Subtask 2.4 Collect Samples

The sample collection will be performed in April 2022 (delayed due to weather). The performance may be affected by the weather condition and the COVID permitting.

Subtask 2.5 Sample Characterization

Sample core for mineralogical and chemical characterization as soon as LANL has their paperwork completed and ready.
The characterization of the samples includes:
- Field characterization (location, lithology, description of units, radioactivity, thickness)
- Paste pH, S, C, acid base accounting of mine wastes (ARD diagram)
- Mineralogy (petrography, XRD)
- Whole-rock chemical analyses (ALS)
- Electron microscopy (mineral chemistry, texture, identification and location of REE and other CM)
  - Particle size analyses of mine wastes
  - Field-portable, in situ LIBS/RAMAN analysis
  - Micro X-ray CT (μ-XRCT)
  - Focused ion beam–scanning electron microscopy (FIB-SEM)

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

There is no update on this session.

Subtask 3.2 Coal Ash

There is no update on this session.

Subtask 3.3 Technology Development of Basinal Reuse Strategy

There is no update on this session.

Task 4.0 Basinal Strategies for Infrastructure, Industries and Businesses
Subtask 4.1 Infrastructure Investigation

There is no update on this session.

Subtask 4.2 Competitiveness and Challenge

There is no update on this session.

Subtask 4.3 Life-Cycle Analysis

There is no update on this session.

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 session.

Subtask 5.2 Develop Plan for Field Testing

There is no update on this session.

Task 6.0 Technology Innovation Centers
Subtask 6.1 SonoAsh Center of Excellence

There is no update on this session.

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.

Subtask 7.2 Lessons Learned and Narratives Constructed
There is no update on this session.

Subtask 7.3 Publications and presentations

Subtask 7.4 Training and Conferencing with SJC and Sonoash COE
There is no update on this session.

2. PRODUCTS
A. Publications, conference papers, and presentations
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)

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
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

Spend Plan by Fiscal Year Format						
	FY 2022		FY 2023		Total	
	DOE funds	Cost Share	DOE funds	Cost Share	DOE	Cost Share
NMIMT	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
Total ($)	758,128	216,114	725,660	219,147	1,483,787	435,261
Total Cost Share %		22.2%		23.2%		22.7%

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 (https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf)
FSP	Field Sampling Plan (FSP)	Field sampling plan (https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf)
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) (https://geoinfo.nmt.edu/staff/mclemore/documents/SOP17DrillholeLoggingupdated.pdf)
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)

APPENDIX 2. Data entry forms
(note these are not the final data entry forms, additional data will be added when the database is completely designed). All field specified in DOE DE-FOA-0002364 REE Researcher Database Template and NETL REE-SED Sample Data Needs 2020-07-17, i.e. DOE attachments 2 and 3 will be incorporated into the project database and these forms).

Waypoint form (sample location information)

Waypoint Entry

| Waypoint id | | County | | State | | District id | |

| Mine id | | Date inspected | | | Geologist | |

LOCATION

| Latitude | | Longitude | | Coor system | |

| UTM easting | | UTM northing | | UTM zone | |

| Township | | Range | | Section | | Elevation | |

Location assurrance [ ]   USGS quadrangle [ ]

Method of obtaining elevation [ ]   ☑ Were field photos taken

Weather conditions [ ]

SAMPLE PREP

☑ Was_sample_collected   ☑ Thin_section   ☑ Handsample   ☑ Scanned

☑ Slabbed   ☑ Chemistry_available   ☑ Reflective_light

DESCRIPTIVE INFORMATION

Sample location [ ]

Reason for sampling [ ]   ☑ Is_this_legacy_data

☑ Is_brecciation_present   ☑ Is_mineralization_present   ☑ Travertine_spring

☑ Is_fluorite_present   ☑ Is_alteration_present   ☑ Is_hemitization_present

Radiometric reading [ ]   Stratigraphy [ ]   Map Unit [ ]

Visible_minerals [ ]

Sample form (information on sample collected)

Sample Entry

Sample id [   ]   **Waypoint id** [   ]   Collected by [▽]

Media [▽]   Type of sample [▽]   Depth start [   ]

Method of sample collection [▽]   Depth end [   ]

Sample Source [▽]   ☑ Is this legacy data   ☑ Is alteration present

Reason for sampling [   ]   ☑ Is fluorite present

☑ Is brecciation present   ☑ Is mineralization present   ☑ Is hemitization present

DESCRIPTION

Rock Type [▽]   Rock Name [▽]

Geologic Age [▽]   Rock Mineralization [▽]

Rock Alteration [▽]   Structure Sample (igneous rock) [▽]

Deposit Environment [▽]   Source Rock (metamorphic) [▽]

Metamorphism [▽]   Facies Grade [▽]   Quantity [   ]

Sample Comments [   ]

Entered by [▽]   **Date of entry** [   ]   Modified by [▽]

Date of last modification [   ]   Modification [   ]

Mineralogy Deposit Type [▽]

Petrographic form (information on petrographic description)

Petrographic Form

Sample id [ ]   Petrographer [▾]   Date examined [ ]

INFORMATION FROM SAMPLE AND WAYPOINT FORMS (correct if needed)

Waypoint id [ ]   Type of sample [▾]   Rock Type [▾]

Rock Name [▾]   Stratigraphy [▾]   ☑ Is_brecciation_present

☑ Is_mineralization_present   ☑ Is_alteration_present   ☑ Is_hemitization_present

☑ Is_fluorite_present   Visible_minerals [ ]

Rock Mineralization [▾]   Rock Alteration [▾]

Sample Comments [ ]   Reason for sampling [ ]

Changes_in_fiel [ ]

Date of last modification [ ]   Modified_by [▾]

Modification [ ]   Mineralogy_Deposit_Typ [▾]

☑ **Thin_section**   ☑ **Handsample**   ☑ **Scanned**   ☑ **Slabbed**   ☑ **Chemistry_available**

☑ **Reflective_light**

GENERAL DESCRIPTION

Grain size [▾]   Alteration [ ]

Rock_fragments [ ]   Alteration Rank [▾]

Texture [ ]   Alteration Intensity [ ]   ☑ Are_organics_present

Hand description [ ]   Structure Description [▾]

Photographs

Fieldphotos		— ☐ ✕
Photo_number:		**Photographer:** ⌄
Image_type: Field ⌄	**Date:**	**Feature_id:**
Location:	**Direction:**	
Keywords:		
Caption:		
Comments:		
Link:	**Digital** ⊠ **Slide** ⊠ **Photograph** ⊠	
Camera Type:	**Pixels** 0	

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