GEOC5089 ME5089 Exploration Geochemistry INTRODUCTION

INSTRUCTOR—Dr. Virginia T. McLemore

FALL 2023

Goals in this class

- Fundamentals of geochemical exploration for mineral deposits
- How to plan for field activities
- How to implement a sampling program
- How to work as a team
- Follow sampling plans and SOPs
- QA/QC programs
- Skills used in exploration geochemistry are useful in environmental geochemistry

Class

- The class will meet one day per week for 2-3 hrs—Tuesdays
- Remaining time spent on field trips or extra discussion sessions (other presentations, guest speakers)
  - 1st field trip will be Aug 18-20
  - 2nd field trip will be Aug 25-27 (camp)
  - 3rd field trip will be Aug 30-31 (how many can do)
  - 4th field trip will be Sept 22-24? (camp)
- May require extra time for the project presentations and field trips

- If you are sick—stay home

Class Details

- Exam: Midterm—take home exam that will emphasize short answer and essay questions.
- Term project—you will be assigned an area in the Zuni Mountains and a team. As a team you will design a stream sediment program, implement it, submit samples, and provide interpretation.
- Safety—each class will start with a safety share, prepared by one of you. Powerpoint or short discussion.
- Discussion—Each student will research papers on Exploration Geochemistry and select one to be read prior to class by everyone. You will lead the discussion on the paper. A presentation is required.
- Field trips—we will be sampling both stream sediments and rocks in the Zuni Mountains. Rocks will include both host, unmineralized and mineralized rocks.
- Link to lectures and assignments: https://geoinfo.nmt.edu/staff/mclemore/teaching/Critical.html
- Link to information on Zuni Mountains mining district: https://geoinfo.nmt.edu/staff/mclemore/projects/MiningDistricts.html

Grades

• Midterm	10%
• Safety share	10%
• Paper Presentations	10%
• Lab exercises	20%
• Term project presentation	20%
• Class Participation	30%

Class Participation 30%

- Point system based upon tasks completed by individuals or teams
- Examples
  - Archiving samples—Devlon
  - Writing and editing the SOPs—Ernest
  - Who has GIS skills?
  - Driving
    - Who has the NMT Driving Certificate?
  - Team leaders
    - Jakob, Zohreh, Charlie, Kyle, Mark
  - 1st aid
    - Who has 1st aid certifications?
  - Who has worked for a mining company?
  - Assisting with logistics

Sources of data

- Internet
- http://minerals.usgs.gov/minerals/pubs/commodity/myb/
- http://www.minerals.com/
- USGS and DOE reports
- Societies (SME, others)
- My web site
- Library
- Bureau GIC records
- Other reports not in electronic form

Wikipedia

- Use sparingly
- Some of the information on Wikipedia is incorrect
- Some of your best data and sources of information are in the library and not in electronic form

- Be aware of using copyrighted material—get permission
- Cite references

USGS Earth Mapping Resources Initiative (Earth MRI)

USGS Earth Mapping Resources Initiative (Earth MRI)

USGS's Response to EO 13817 and SO 3359:

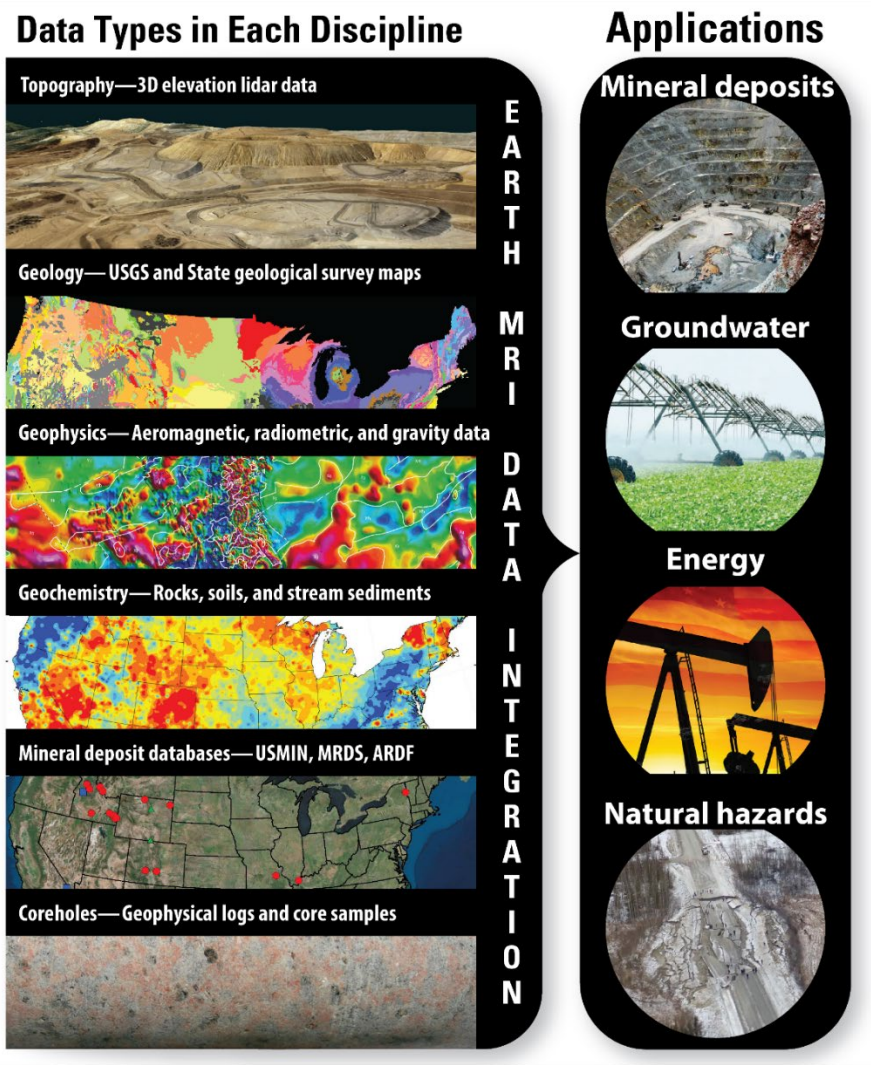
Earth MRI: Partnership between USGS and State Geological Surveys to generate state-of-the-art geologic mapping, geophysical surveys, and lidar data for the Nation in areas with critical mineral potential.

Earth MRI Budget

- **FY 2019**: $9.598M
- **FY 2019 State Matching Funds:** ~$2.9M from 29 States
- **FY 2020:** $10.598M
- **FY 2020 State Matching Funds:** ~$2.2M from 27 States
- Seeking Other Agency Partnerships to leverage funds

Activities

- **FY 2019:** Focused on rare earth elements
- **FY 2020:** Focused on rare earth elements and 10 more commodities: Al, Co, graphite, Li, Nb, PGEs, Ta, Sn, Ti, and W



USGS

Briefing Materials Only

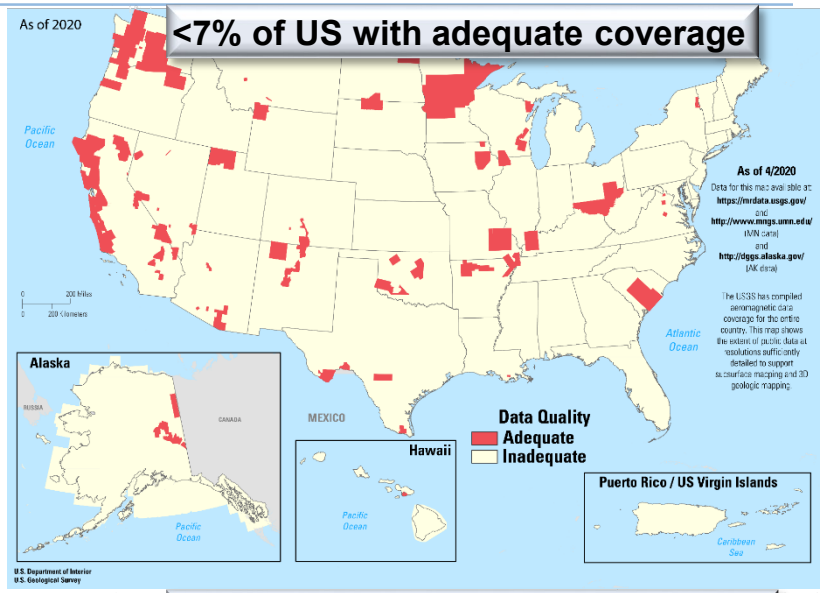
Components of Earth MRI: Geophysics, Geology, Lidar, Data Preservation Coordinated through USGS Mineral Resources Program

75% of Earth MRI Funds for Data Acquisition and Preservation

- **Minerals Resources Program:** Designs and interprets new airborne geophysical surveys in cooperation with State Geological Surveys (~$2.69M in FY20)
- **National Cooperative Geologic Mapping Program:** Funds geologic mapping and geochemistry reconnaissance projects by State Geological Surveys ($2.27M in FY20)
- **National Geospatial Program:** Leverages funds from partners to acquire new lidar data ($1.75M in FY20)
- **National Geologic and Geophysical Data Preservation Program:** Supports State Geological Surveys efforts to preserve and make publicly available critical mineral and borehole data and participate in Earth MRI workshops ($762k in FY20)

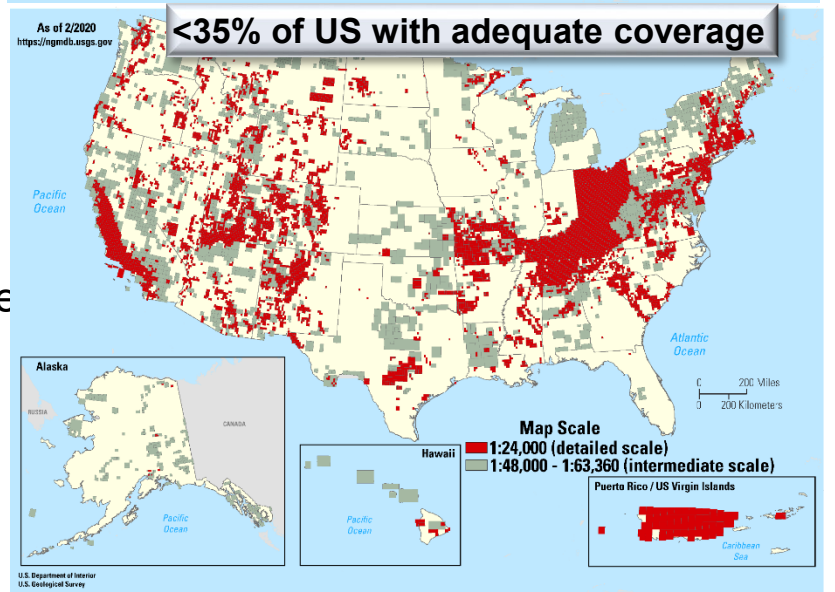
Existing Geophysical Surveys

Usable quality



Existing Geological Mapping

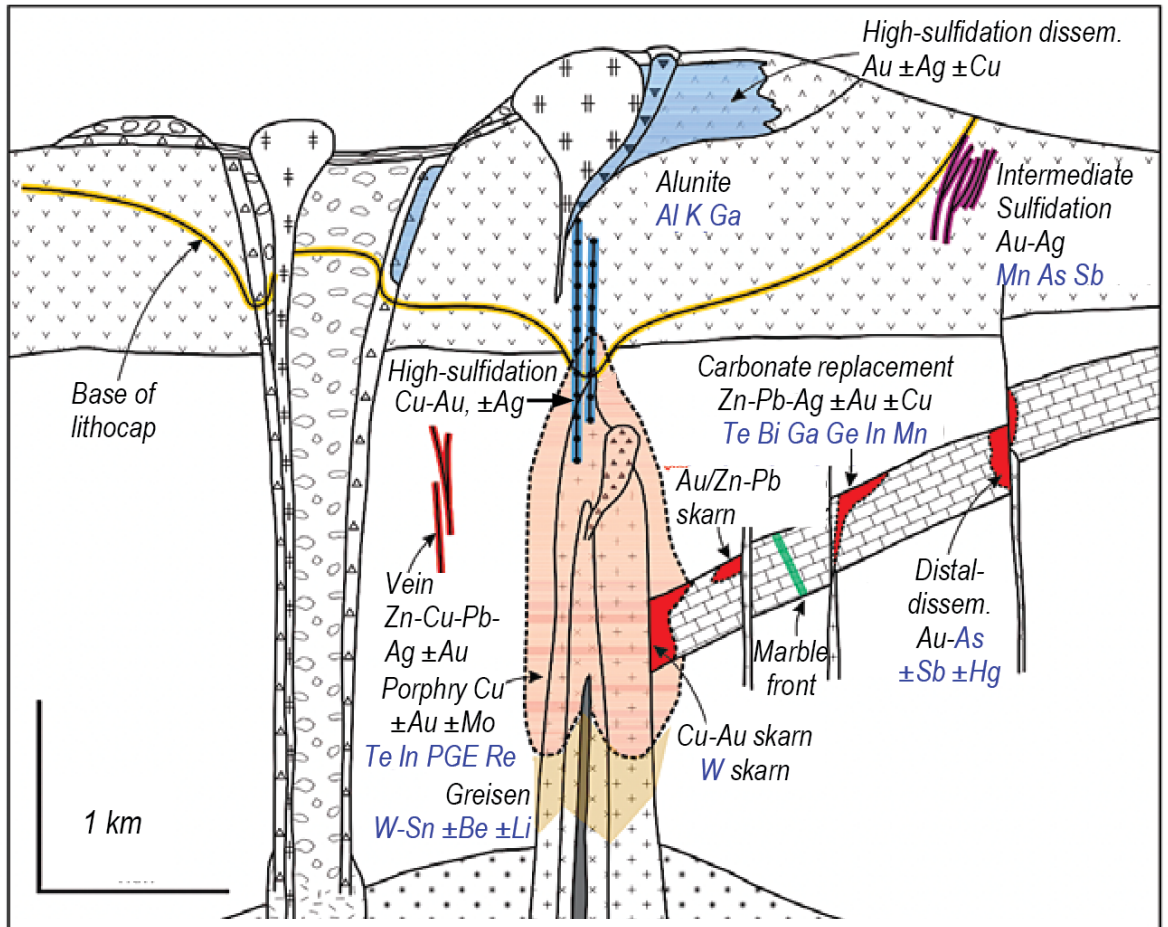
Fine-scale
Moderate



USGS

Mineral Systems Approach

Example: Porphyry Copper-Molybdenum-Gold System

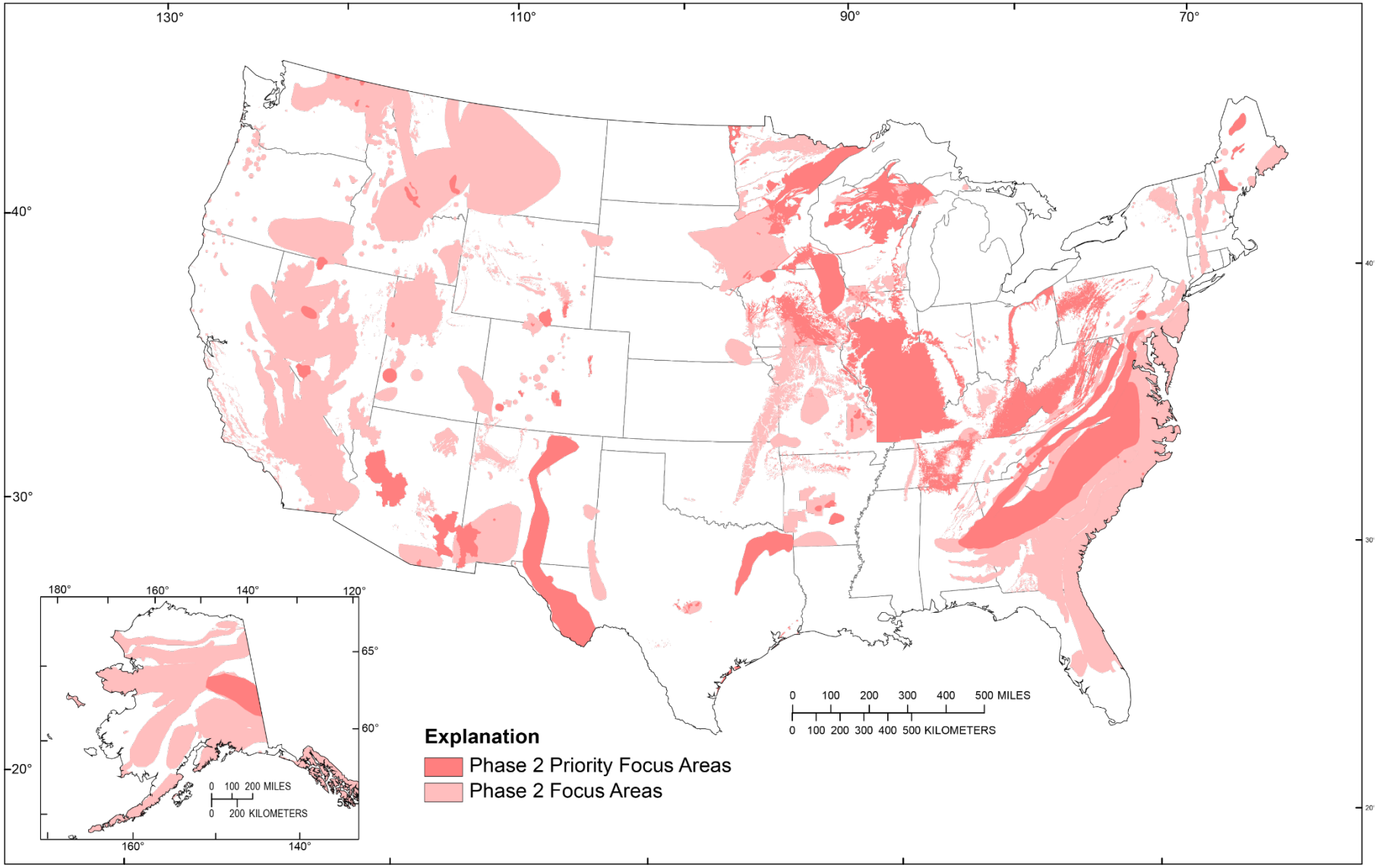


Hofstra and Kreiner (2020), USGS Open-File Report 2020-1042

System Name	Deposit types	Principal Commodities	Critical minerals
Porphyry Cu-Mo-Au	Pegmatite	Li, Cs, Ta	Li, Cs, Ta, Be
	Greisen	Mo, W, Sn	W, Sn
	S-R-V Tungsten	W	W, Bi, Mn
	Porphyry/Skarn Molybdenum	Mo, W, Sn	W, Re, Bi
	Porphyry/Skarn Copper	Cu, Ag, Au, Mo	PGE, Te, Re, Bi, U
	Polymetallic Sulfide S-R-V-IS	Cu, Zn, Pb, Ag, Au	Mn, Ge, Ga, In, Bi, Sb, As, W, Te
	Distal Disseminated Ag-Au	Ag, Au	Sb, As
	High sulfidation Au-Ag	Cu, Ag, Au	As, Sb, Te, Bi, Sn, Ga
	Lithocap Alunite	Al2O3, K2SO4, H2SO4	Al2O3, K2SO4, Ga
	Lithocap Kaolinite	Kaolin	Ga

Abbreviations: **S** skarn, **R** replacement, **V** vein, **IS** intermediate sulfidation.

USGS Earth MRI Focus Areas



USGS and State Survey Process for Identifying and Selecting Focus Area Projects

1) USGS initiates process
- Defines critical minerals to address and prepares draft focus area maps and data

2) Workshops with USGS and States (2019-2022)
- States modify the draft focus area maps
- States prepare 4-page descriptive write-ups of their priority focus areas

3) USGS Mineral Resources Program Scientists
- Evaluates all focus areas based on 4-page descriptive write-ups
- Provides a slate of candidate focus area mapping projects and geophysical surveys

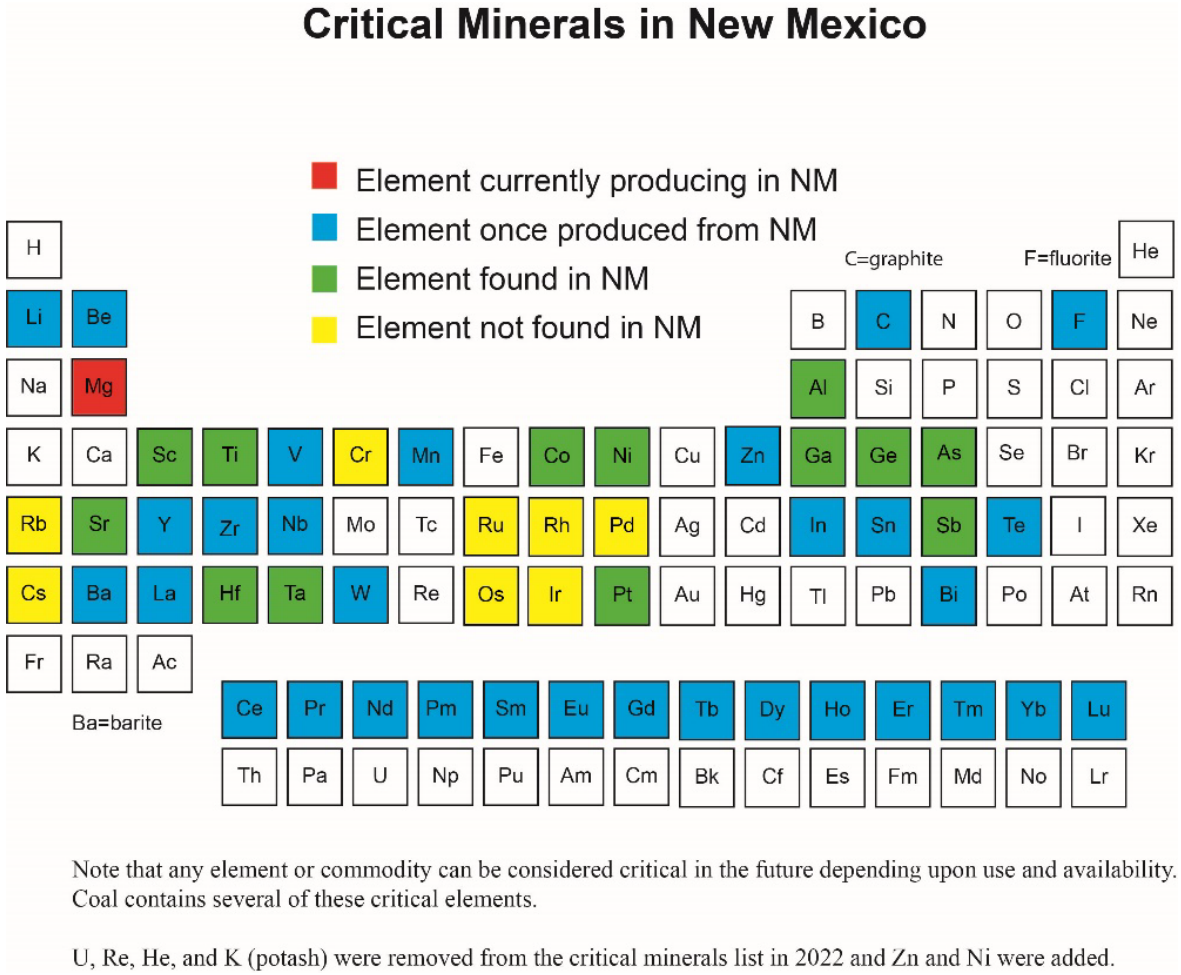
4) USGS works with AASG Earth MRI Committee to select new projects

National Geological and Geophysical Data Preservation Program (NGGDPP)—Critical Minerals in NM

- 5th year we have received funding
- Funds graduate and undergraduate students
  - Published papers on some of this work (with extra funding from other sources)
- Some of our accomplishments
  - State-wide geochemical database of rocks and mineralized deposits containing critical minerals
  - Depth to Precambrian basement
  - Long range plan to evaluate critical minerals in New Mexico
  - Comprehensive database of critical minerals and other minerals deposits (New Mexico Mines Database)
  - Photograph and describe drill core with critical minerals potential
  - Inventory and storage of samples from areas containing critical minerals
  - Identify districts with critical minerals in New Mexico

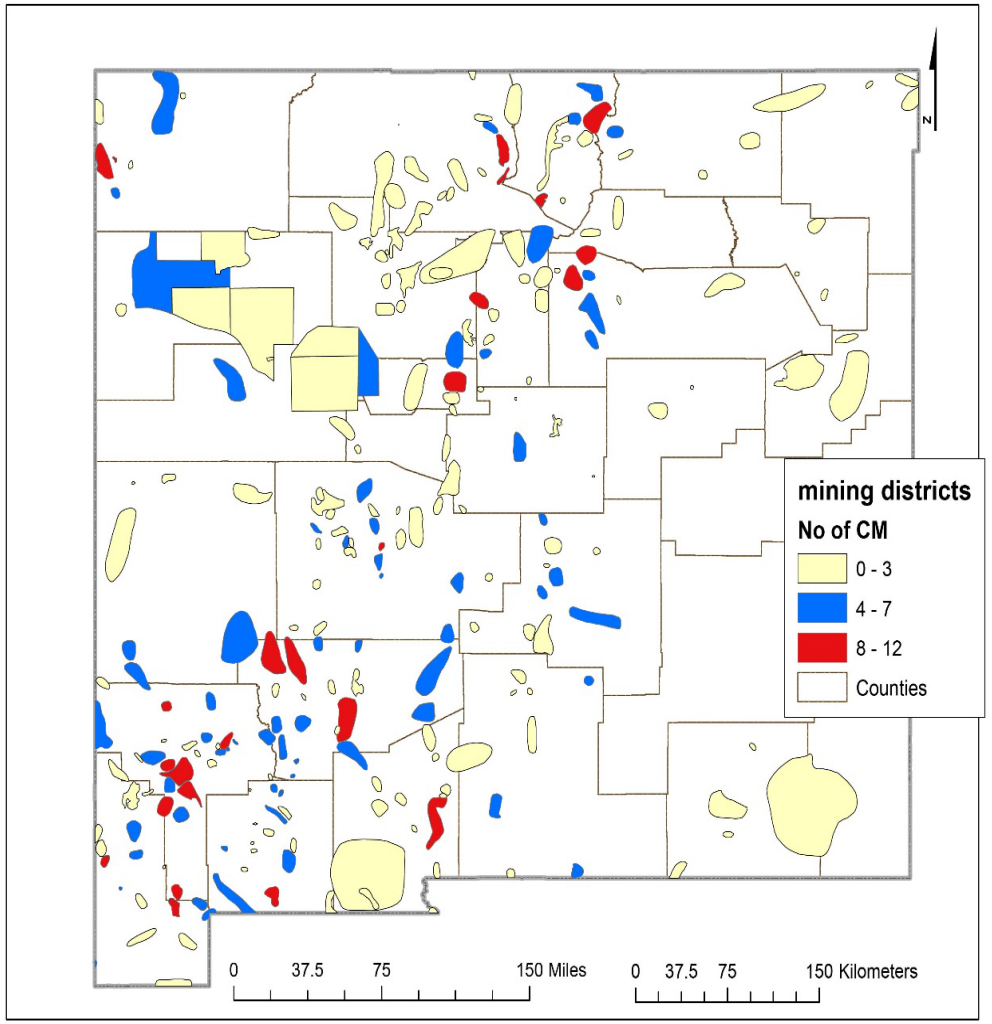
Depth to Precambrian basement

In the United States, a critical mineral is a nonfuel mineral commodity that is essential to the economic and national security of the United States, and is from a supply chain that is vulnerable to global and national disruption.



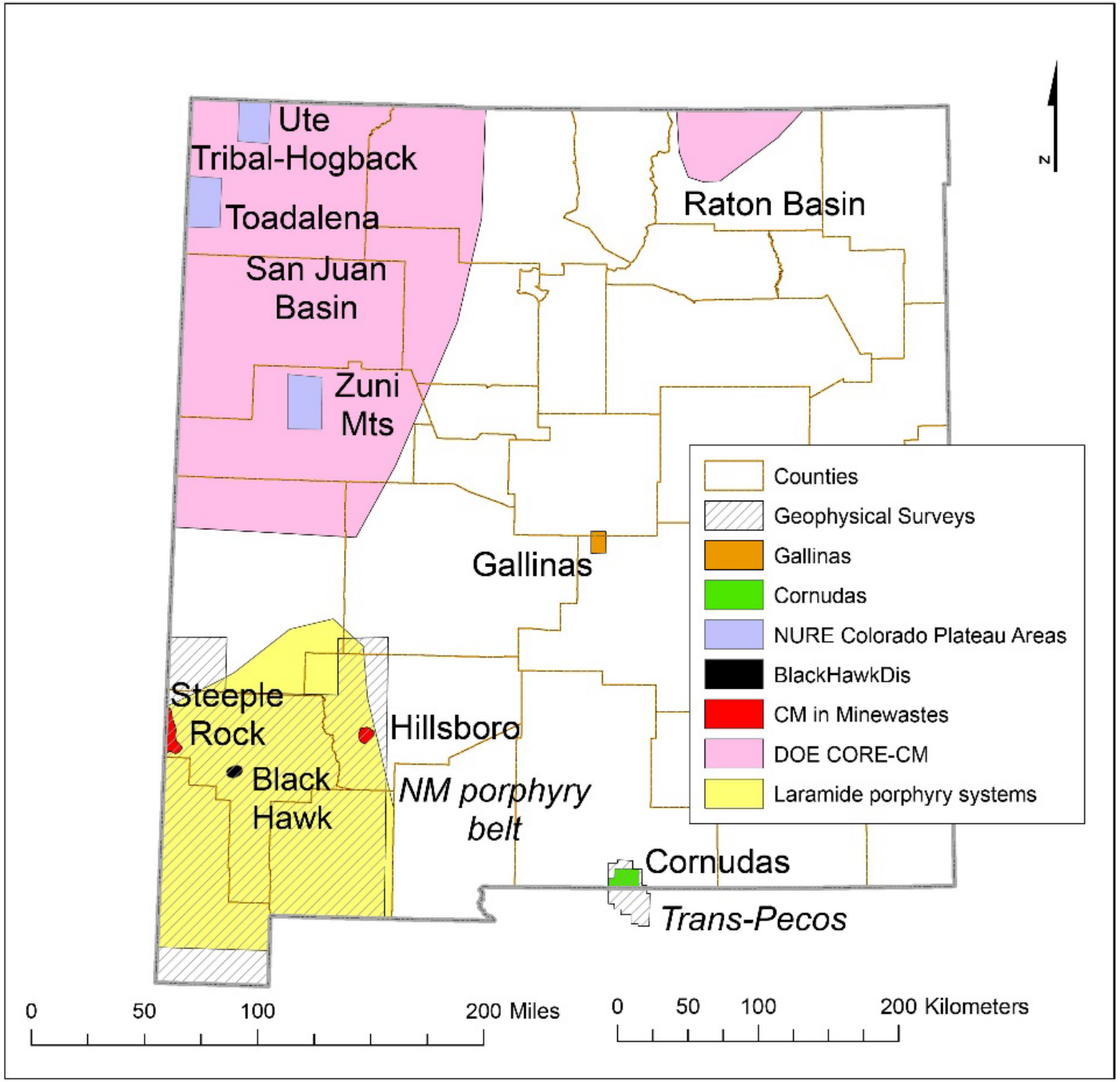
Note that any element or commodity can be considered critical in the future depending upon use and availability. Coal contains several of these critical elements.

U, Re, He, and K (potash) were removed from the critical minerals list in 2022 and Zn and Ni were added.



Copper was just recently added by the DOE

Earth MRI and DOE CORE-CM projects in New Mexico



Summary

- This funding has and will increase our knowledge of where in NM critical minerals are found
  - Land use decisions, including land exchanges
  - Potential for mining=economic benefits to NM
  - Training the work force
  - Outreach components help educate society on the importance of critical minerals
  - Increase our knowledge of geologic processes and models of these deposits=more effective exploration
- Projects are built upon decades of research at NMBGMR and NM Tech
  - Data preservation funding is important to preserve these historic data, records, and drill core
- Cooperation with adjacent states and industry is important
- These projects takes many students and staff, which requires this level of funding
  - Teams are very important, but expensive

GEOCHEMICAL REANALYSIS OF NURE SAMPLES FROM THE COLORADO PLATEAU, NEW MEXICO, UTAH, COLORADO, AND ARIZONA

- Partners include Colorado, Utah, and Arizona
- Geochemistry Reconnaissance
- Evan Owen and Virginia McLemore are PIs
  - Evan will act as the TA for this class
- PROJECT DELIVERABLES
  - Geochemical data (will be published by the USGS separately)
  - Progress reports (yearly)
  - Technical report
  - Results will be presented at conferences in FY24-25 at New Mexico Geological Society spring meetings and annual meetings of the Geological Society of America, Society of Economic Geologists (SEG) and/or Society for Mining, Metallurgy, and Exploration, Inc. (SME)
  - Publication in appropriate journals will follow

SCOPE OF WORK

- Collect approximately 200 stream sediments and rock samples with supporting geologic observations
- Provide these samples to the USGS for analysis by XRF/ICP-MS for the Zuni Mountains area
- Will involve students not paid on the USGS contract, but instead these students will be enrolled in a graduate-level course (Exploration Geochemistry). We have some funding for field expenses Period of performance 8/10/23 thru 8/9/26
- Annual progress reports (8/10/24)
- Final technical report due 120 days after 8/9/26

TASKS

- Define the sampling methods
- Coordinate and monitor all project sample collection
- Conduct In state sample collection and description, and evaluations
- Consolidate the samples acquired by all participating States
- Contribute that composited sample collection to the USGS for analysis
- Construct a well-documented geochemical database, following USGS provision of geochemical data based on analyses of the submitted samples
- Writing a published comprehensive summary report that has undergone appropriate peer review and the associated geochemical database and geospatial map products that presents a regional assessment based on the results from sampling across all states involved in the project

Why Zuni Mountains?

- Source areas for sedimentary deposits in the San Juan Basin (U, V, coal, beach placer sandstones)
- USGS focus areas
  - Zuni Mountains PGE (SW_New_NM_074a)
  - Zuni Mountains fluorspar (SW_New_NM_074b)
  - New Mexico Cambrian alkaline rocks and REE veins (SW013)
  - New Mexico-Texas-Colorado sediment-hosted Cu (SW_P4016)
- Deposit types
  - Potential PGE
  - Potential pegmatites
  - Fluorspar veins
  - REE-bearing episyenites
  - Sandstone-hosted copper deposits that could contain a variety of critical minerals, including REE, Nb, PGE, F, Ba, Ga, U, Co, and others
  - One of the few areas in NM with ultramafic rocks

Details of term project

- Divide into 5 teams with a team leader
- Collect stream sediments ASAP
- Begin to write the technical report
- Everyone in the class will be an author of the final NM technical report (probably in alphabetical order) and will be acknowledged in presentations
  - Line item on your resume
- This will be a guide for other states to follow if they decide
- One MS student will continue with the project
- If there are opportunities for anyone to present a portion of this project lets do it

Details for 1st field trip

- We will stay in hotels this time, future trips camp out
- Drivers need to fill out travel forms
  - Must have a NM Tech certificate
- Use Bureau vehicles
- Everyone is responsible for their lunch in the field, bring it
- Breakfast at the hotel
- Dinner paid by per diem of those who filled out travel
- Read HASP, SOPs
- Leave Friday afternoon, we will have briefing in Grants when everyone arrives
- Evan and I will be waiting at Grants, Mark is the point of contact in Socorro

FIELD NOTES

- The project is no good if the sample is not representative for the purpose of the project.

- And the field notes must be accurate, complete, and provide all of the data on the sample required for the project.

What are field notes?

What are field notes?

- **Done in the field not at camp or office after field work**
- Jottings, scratch notes—minimal notes to get you thru, triggers to remind you
- Diary—personal notes, not for public consumption
- Log—running account of how you spend your time, what you did, how much you spent
- Field notes
  - Methodical
  - Descriptive
  - Analytical

Descriptive (facts, observations) and reflective (thoughts)

Field notes

- In field books or field forms or ipad/smart phone or apps
- Pen or pencil or apps?
- Who needs access to field notes?
- Scan field notes or enter into a database
- Bound books vs loose papers vs numbered pages
- Are they required for legal or contract purposes?

Remember—it costs time and money to perform field investigations and it is important to make the best use of that activity

Field Notes

- Not writing down your observations could result in missed data being recorded and lead to inaccurate conclusions about the rocks being studied.
- Field notes allow you to write down descriptions of fossils, minerals, or rocks while they are being collected. This saves time.
- Sketches are also helpful in interpreting geologic events.
- Field notes can be a legal document, and must be saved for future reference.
- Record any deviations from SOPs.

Field Notes

- Record date, time, location, who, where, weather
- Describe locality, directions, map names
- Sketch
- Photographs
  - Location (lat, long, UTM, datum)
  - Directions
  - Description
  - Direction
  - Relationships
- Other notes, comments, future work, questions

Field Notes

- If you are unsure of the name of a rock, fossil, or mineral, make a description of it, assign a field name or wait until a lab determination is made

- Detailed description
  - Thickness of the beds
  - Describe the rocks
  - Record any fossils or minerals
  - Strike and dip, trend
  - Unique features (layered, cross-bedding, ripple marks)
  - Alteration, mineralization

Field Notes

- Collect samples
  - Date
  - Location
  - Photograph
  - Description
  - Lithology
  - Unit if known
  - Purpose of sampling
- Separate observations from interpretations (inferences)
- Add questions
- Why you did something
- Photographs

Field report

- Title
- Introduction (where, what, who, weather)
- Previous work/mining history
- Methods (how)
- Data
- Interpretations
- Conclusions/summary
- References

Develop safety plan, sampling plan, database, and SOPs

- Provide consistent safety protocols and what to do if there is an incident
- Identify areas to be sampled, how sampling is conducted, what data are obtained on collected samples, sample archive for future studies
- Collect, store, and output data for effective interpretation
- Be compatible with NMBGMR databases, USGS and DOE databases, and GIS
- Provide a consistence set of reliable data
- SOP—standard operating procedures (how to perform project activities)

Data collections and databases

- Database of the data (data management)?
- Mines (NM Mines Database)
- Water wells
- Oil/gas wells
- Geothermal
- QA/QC data
- Project specific databases (location, description of samples, petrography)
  - Questa
  - Gallinas
  - REE in Coal
- GIS data (geologic, other)
- Patented mining claims (NM Mines Database and GIS)
  - Unpatented mining claims
- Geophysical data
- Photographs
  - Core/cuttings
  - Field
  - Historic
  - Hand specimens/slabs
  - Thin sections
  - Electron microprobe photos
- Historic Reports
  - NM Mining Archives—Eveleth and McLemore
  - Web pages
  - Company data
- Samples
  - Rock
  - Core/cuttings
  - Soil
  - Mine dumps/tailings
  - Thin sections
  - Electron microprobe
- Production data
- Resource/reserve data
- Project reports
  - Papers
  - Thesis
  - Abstracts
- Project presentations
- Project data
  - Chemistry
    - NURE data
  - Production
  - Drill data (sample logs, drillers logs, geophysical logs)

Purpose of evaluations of mineral-resource potential

- Estimating mineral-resource availability
  - Determine potential for critical minerals
- Delineate areas requiring more geologic investigation
- Required by government officials in order to make decisions regarding use, acquisition, and restriction of public and state lands

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 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

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**

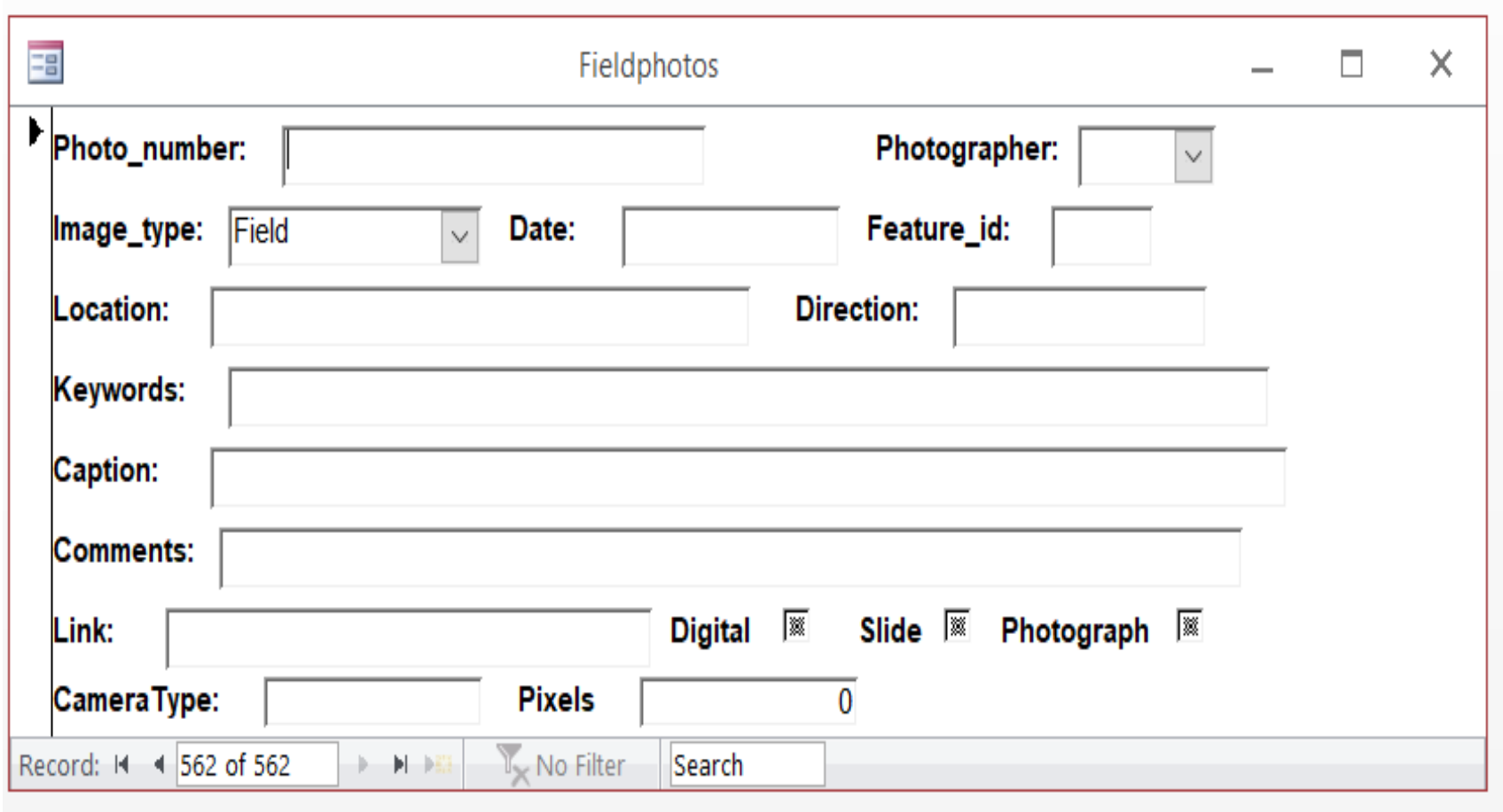
GENERAL DESCRIPTION

Grain size | Alteration

Rock_fragments | Alteration Rank

Texture | Alteration Intensity | ☐ Are_organics_present

Hand description | Structure Description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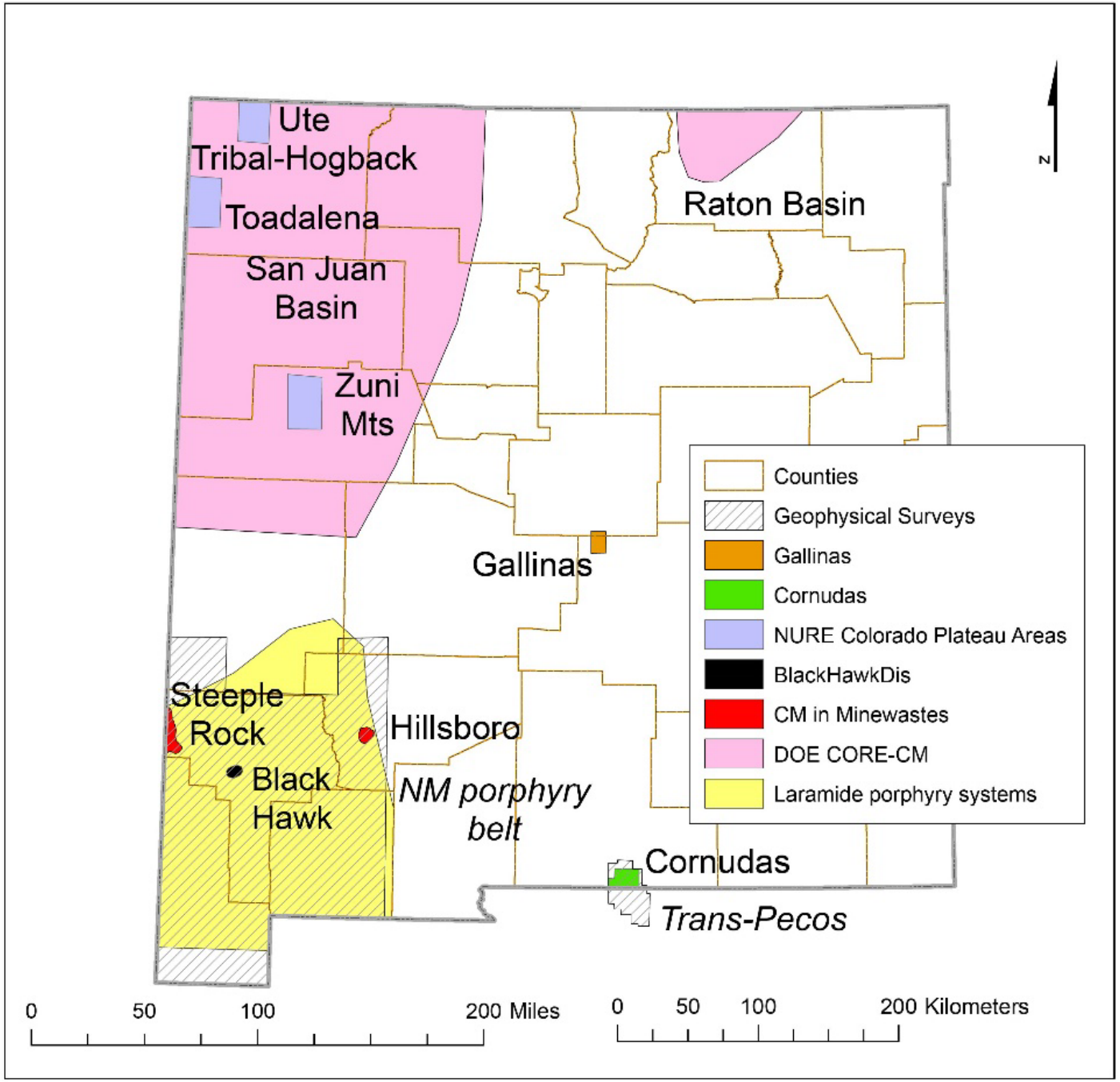
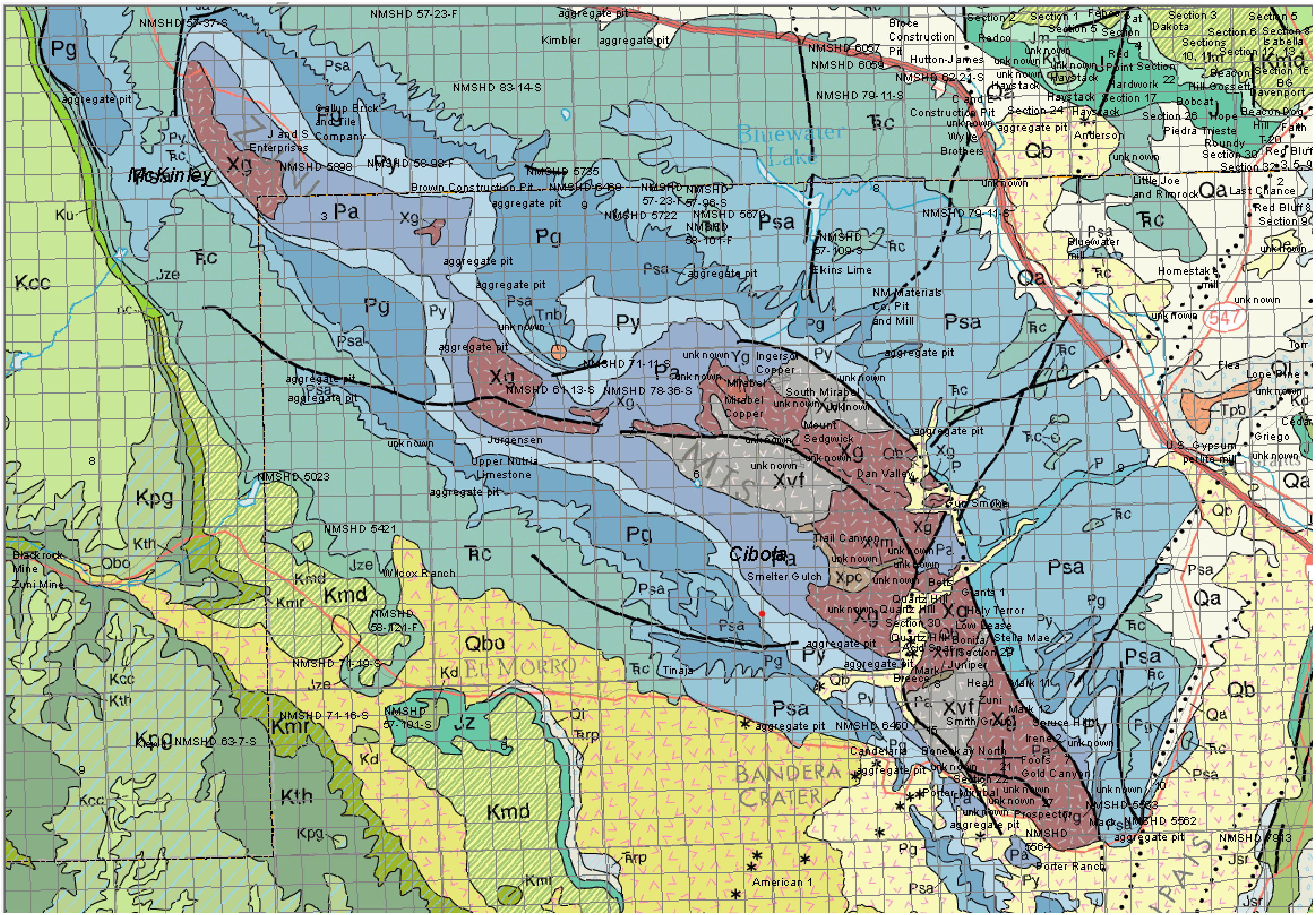
USGS spreadsheet

TABLE 1.7 Goldschmidt's (1888–1947) classification of the elements (Goldschmidt, 1954)

Lithophile	Siderophiles	Chalcophile	Atmophile
Li, Na, K, Rb, Cs	Fe[a], Co[a], Ni[a]	(Cu), Ag[b]	(H), N, (O)
He, Ne, Ar, Kr, Xe	Ru, Rh, Pd, Zn, Cd, Hg[c],	Be, Mg, Ca, Sr, Ba	
B, Al, Sc, Y, REE	Os, Ir, Pt	Ga, In, Tl	
Si, Ti, Zr, Hf, Th	Au, Re[d], Mo[d]	(Ge), (Sn), Pb	
P, V, Nb, Ta	Ge[a], Sn[a], W[e]	(As), (Sb), Bi	
O, Cr, U	C[e], Cu[a], Ga[a]	S, Se, Te	
H, F, Cl, Br, I	Ge[a], As[c], Sb[d]	(Fe), Mo, (Os)	
(Fe), Mn, (Zn), (Ga)		(Ru), (Rh), (Pd)	

Earth MRI and DOE CORE-CM projects in New Mexico





McKinley
Cibola
Bluewater Lake
EL MORRO
BANDERA CRATER
ZUNI MTS
NMSHD 57-23-F
NMSHD 57-37-S
NMSHD 83-14-S
NMSHD 5998
NMSHD 58-98-F
NMSHD 5735
NMSHD 5722
NMSHD 5670
NMSHD 6057
NMSHD 6059
NMSHD 79-11-S
NMSHD 71-11-S
NMSHD 61-13-S
NMSHD 78-36-S
NMSHD 5023
NMSHD 5421
NMSHD 58-121-F
NMSHD 71-19-S
NMSHD 71-16-S
NMSHD 57-101-S
NMSHD 63-7-S
NMSHD 6450
NMSHD 5563
NMSHD 5562
NMSHD 5564
aggregate pit
unknown
Kimbler
Gallup Brick and Tile Company
J and S Enterprises
Brown Construction Pit
Ekins Lime
NM Materials Co. Pit and Mill
Ingersol Copper
South Mirabel
Mirabel Copper
Mount Sedgwick
Dan Valley
Jurgensen
Upper Nutria Limestone
Trail Canyon
Smelter Gulch
Quartz Hill
Holy Terror
Low Lease
Stella Mae
Juniper
Zuni
Candelaria
Porter Ranch
American 1
Tinaja
Wilcox Ranch
Blackrock Mine
Zuni Mine
Bluewater mill
Homestake mill
U.S. Gypsum perlite mill
Hutton-James
Haystack
Anderson
Little Joe and Rimrock
Last Chance
Red Bluff
Lone Pine
Griego
Pg
Py
Psa
Pa
Xg
Xvf
Xpc
Yg
Tnb
Qb
Qa
Qbo
Kcc
Kpg
Kth
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Tpb
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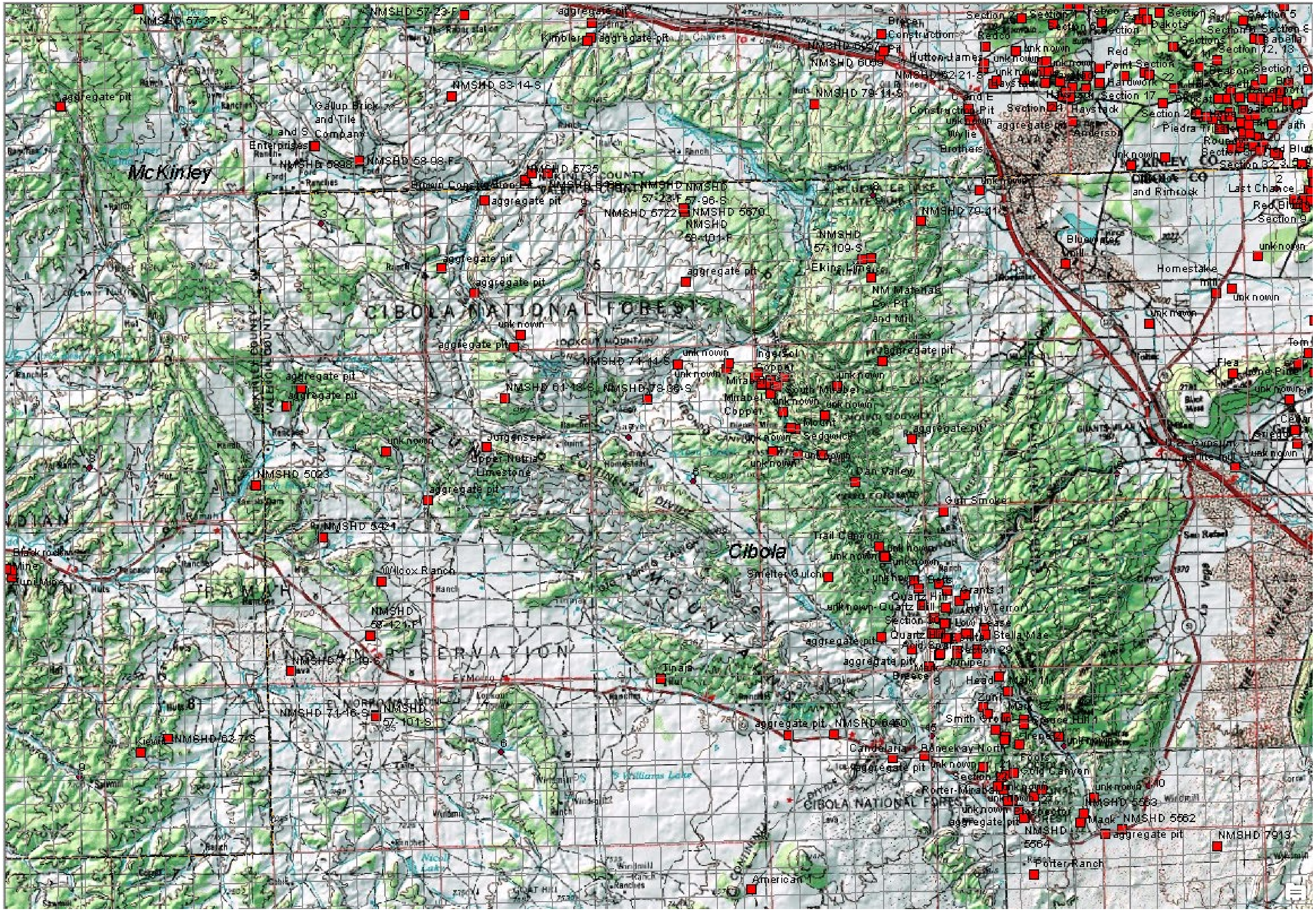
McKinley
Cibola
CIBOLA NATIONAL FOREST
RAMAH
INDIAN RESERVATION
CIBOLA NATIONAL FOREST
aggregate pit
unknown
NMSHD 57-37-S
NMSHD 57-23-F
Kimbler
NMSHD 83-14-S
Gallup Brick and Tile Company
Enterprises
NMSHD 5698
NMSHD 58-98-F
NMSHD 5735
NMSHD 6722
NMSHD 5670
NMSHD 79-11-S
NMSHD 57-109-S
Elkins Lime
NM Materials Co. Pit and Mill
Ingersol Copper
Mirabel
Mirabel Copper
South Mirabel
Mount Sedgwick
NMSHD 71-14-S
NMSHD 61-48-S
NMSHD 78-06-S
Jurgensen
Upper Nutria Limestone
NMSHD 5023
NMSHD 5421
Wilcox Ranch
Blackrock Mine
Zuni Mine
NMSHD 71-19-S
NMSHD 71-16-S
Kleuno
Tinaja
Trail Canyon
Smelter Gulch
Quartz Hill
Gun Smoke
Pan Valley
Bluewater
Homestake
Section 29
Juniper
Stella Mae
Zuni
Smith
Candelaria
Cold Canyon
Porter-Mirabal
NMSHD 5563
NMSHD 5562
NMSHD 5564
NMSHD 7913
Porter Ranch
American 1
Last Chance
Red Bluff
Haystack
Hutton James
Brown Construction
Anderson
Wylie Brothers
Construction Pit
NMSHD 6450
Mack
Flea

Plans for field

- Collect stream sediment samples together
  - Collect a sample by each group in one stream (test sample variability by groups)
  - Collect 5-6 samples to perform chemical analyses on different size fractions
  - Collect 10 samples to perform particle size distributions curves (Abena)
- Examine some of the rock types and mineral deposits found in the Zuni Mountains
- Collect rock samples together
- Collect stream sediment samples in Areas 1-5
- Collect rock samples in Areas 1-5

Team Leaders

- Jakob—Area 2
- Zohreh—Area 4
- Mark—Area 1
- Charlie—Area 3
- Kyle—Area 5

Drivers—need to fill out travel form

- Mark
- Jakob
- Kyle
- Devlon

Assignments

- Safety
- Paper
- Volunteers to edit sampling and shipping SOPs and sampling plan
  - Devlon write an archive of samples SOP
- Literature search on geology of Zuni Mountains
  - Each team submit a list of citations
  - Volunteer to compile a bibliography of citations on geology of Zuni Mountains