

An Overview of Critical Mineral Research in New Mexico

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New Mexico Bureau of Geology and Mineral Resources

A non-regulatory governmental agency (the state's geological survey) that conducts scientific investigations leading to responsible economic development of the state's mineral, water, and energy resources. We are a research division of New Mexico Tech

Founded in 1927 through state legislation.

Currently **66 full and part time staff** with a range of expertise. We have a number of active emeritus staff and mentor and employ a total of around 40 graduate and undergraduate students.



Critical Minerals

- In May 18, 2018 U.S. Department of Interior published a list of 35 critical minerals, based on USGS PP 1802
- **New Mexico has many of these critical minerals**
 - Potash is currently being produced in Carlsbad
 - Porphyry copper deposits in Grant County contain rhenium, indium, and germanium
 - Uranium deposits in the Grants district
 - Exploration for other critical minerals include REE, tellurium, lithium, beryllium, cobalt
 - Other critical minerals were once produced from New Mexico (tin, vanadium, manganese, fluorspar, barite, graphite, REE, tellurium, beryllium)

Critical Minerals in New Mexico

- Element currently producing in NM
- Element once produced from NM
- Element found in NM
- Element not found in NM

Legend:

- Element once produced from NM (Blue)
- Element found in NM (Green)
- Element not found in NM (Yellow)

Additional labels:

- C=graphite
- F=fluorite
- Ba=barite

The periodic table shows the following color-coding for elements:

- Blue (Produced from NM):** Li, Be, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Kr, Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe, Cs, Ba, La, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn, Fr, Ra, Ac, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr.
- Green (Found in NM):** Mg, Sc, Ti, Ca, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe, Cs, Ba, La, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn, Fr, Ra, Ac, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr.
- Yellow (Not found in NM):** K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Kr, Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe, Cs, Ba, La, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn, Fr, Ra, Ac, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr.

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.

History

- A U.S. Bureau of Mines office was housed at New Mexico Tech until the 1950s. The USBM records were the start of the Bureau of Geology's mining archives, which are part of our Geological Information Center.
- Many of our early publications, as well as many recent ones, focus on resources that are now considered to be critical minerals.
- Metallurgical studies carried out on barite, fluorite and potash
- Involvement in National Uranium Resource Evaluation (NURE) in the 1970s
- Ongoing work on helium (Broadhead, 2005)
- Ongoing work (initiated in the 1980s) on REE mineralization of Cambrian-Ordovician and Tertiary alkaline and carbonatitic magmatism in New Mexico

NEW MEXICO SCHOOL OF MINES

STATE BUREAU OF MINES AND MINERAL RESOURCES

E. H. WELLS, PRESIDENT AND DIRECTOR

BULLETIN NO. 4

Fluorspar In New Mexico

BY

WILLIAM DRUMM JOHNSTON, JR.



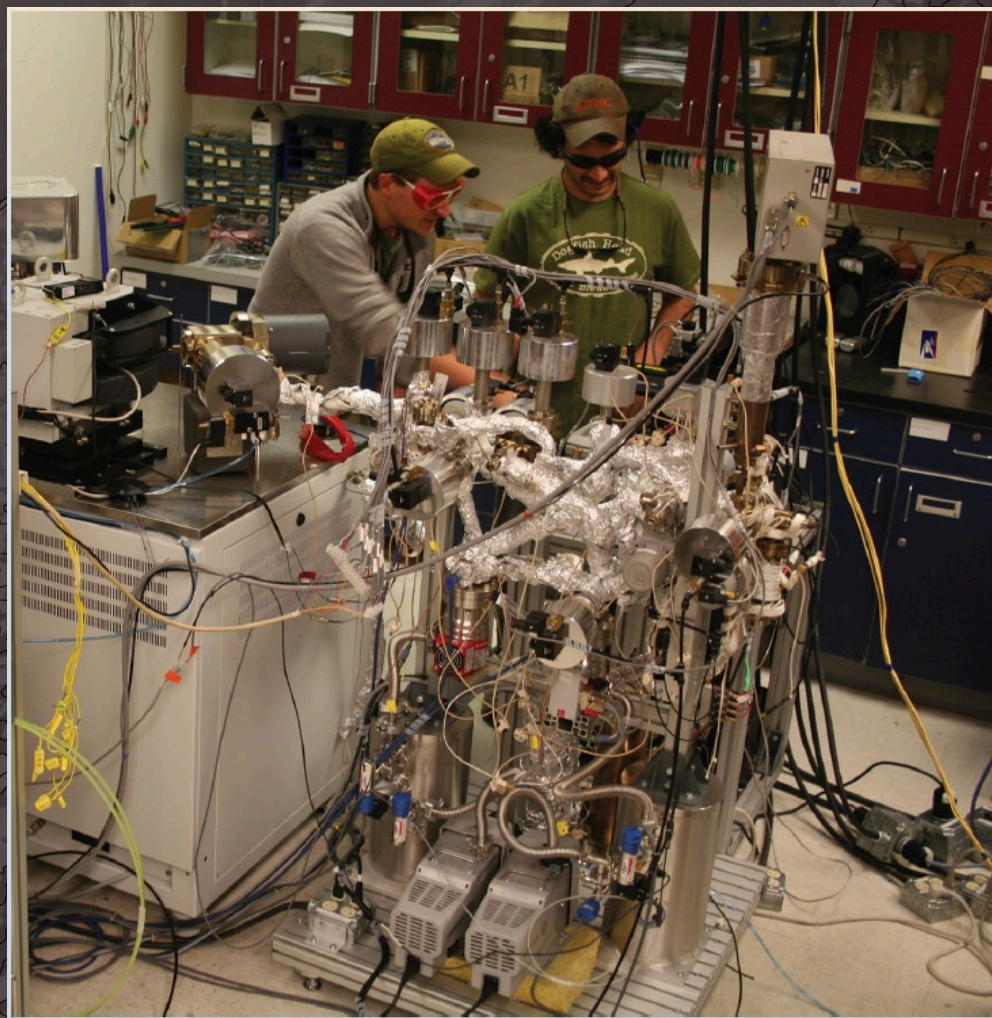
SOCORRO, N. M.

1928

The Bureau's Laboratories

The New Mexico Bureau of Geology and Mineral Resources houses a range of state-of-the-art laboratory facilities that have played important roles in supporting critical mineral research in New Mexico

New Mexico Geochronology Research Laboratory (Ar/Ar)



Microbeam/X-Ray

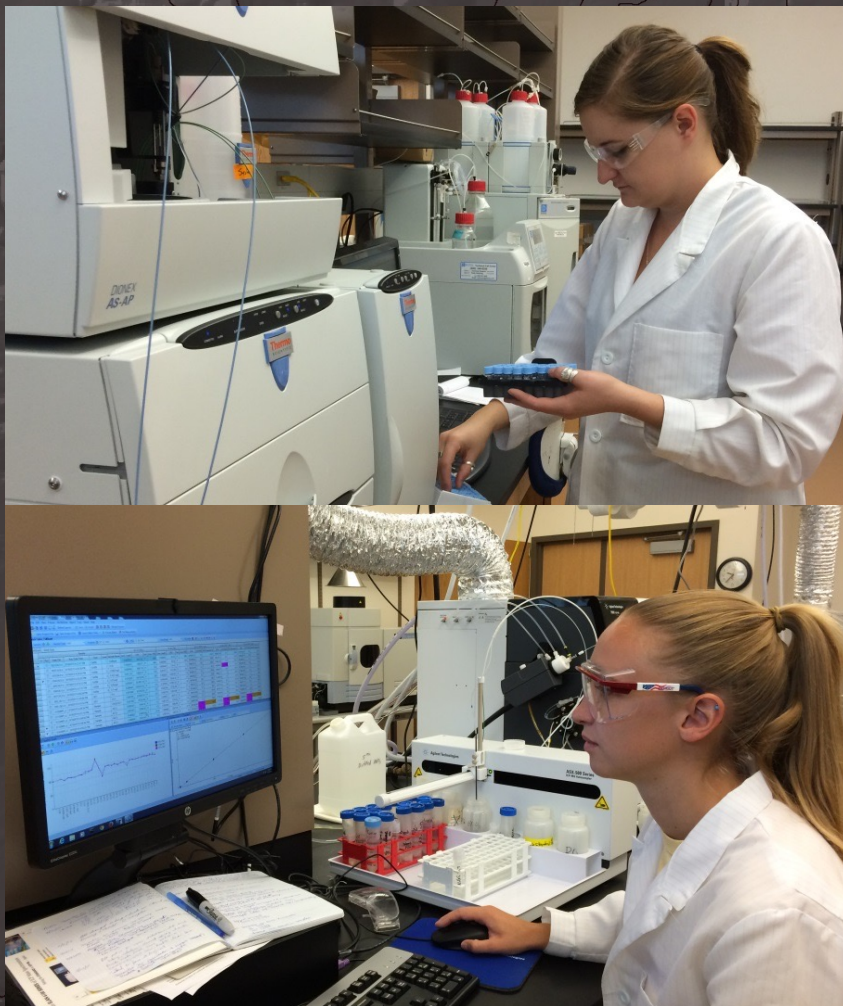
Electron microprobe

Scanning electron
microscopy

X-ray Diffraction (XRD)



Water-focused equipment

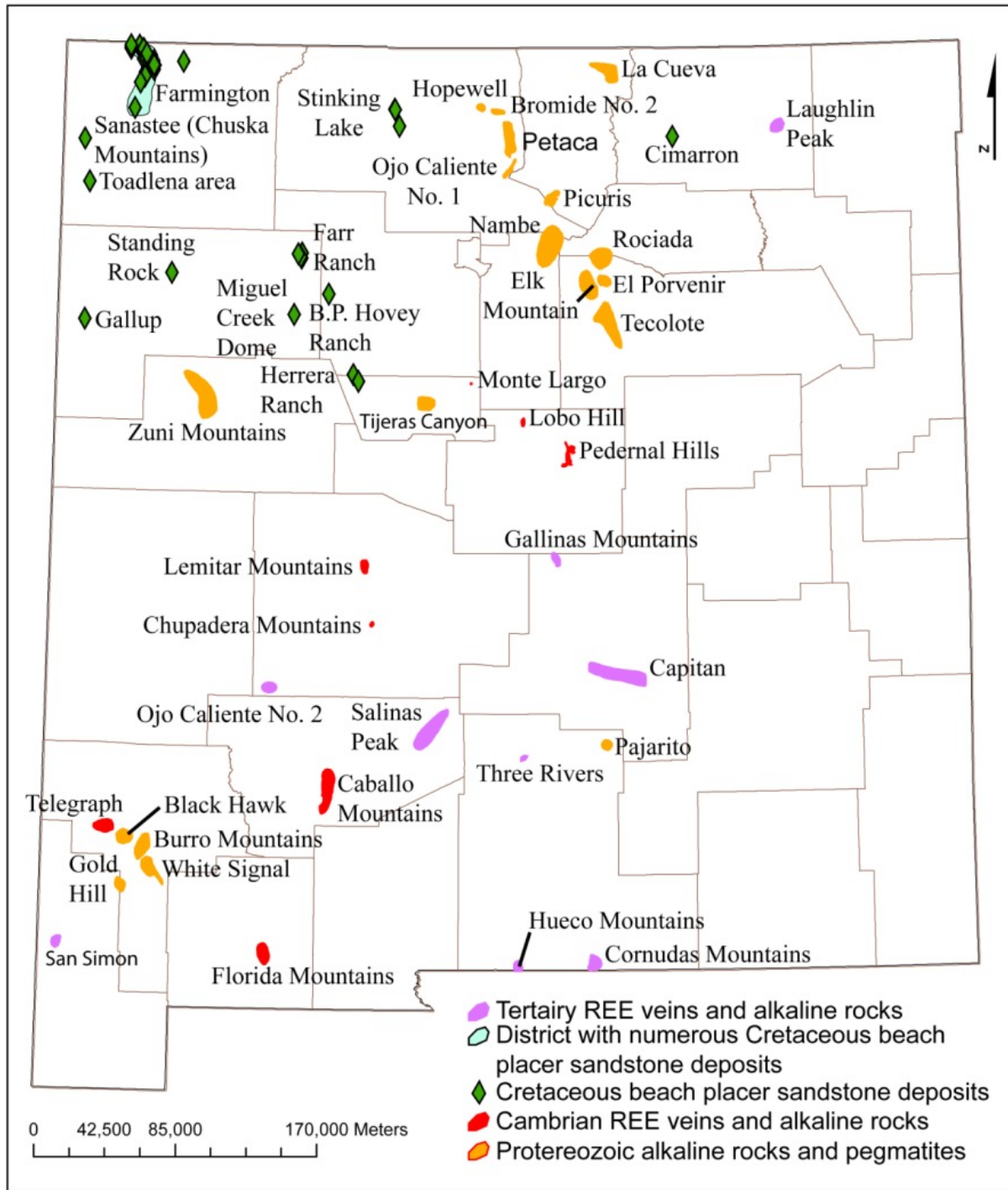


Analytical Chemistry Laboratory

- ICP-MS
- ICP-OES
- Flow injection analyzer
- Flame atomic absorption spectrophotometer
- Ion chromatograph with conductivity detector, UV/Vis detector, and electrochemical detector
- Cold vapor mercury analyzer, direct reading emission spectroscope, fluorometers, and UV/Vis spectrophotometers

The background of the slide is a dark gray topographic map showing contour lines and a river. A solid teal vertical bar is positioned on the far left side of the image.

And, more..... (stay tuned)



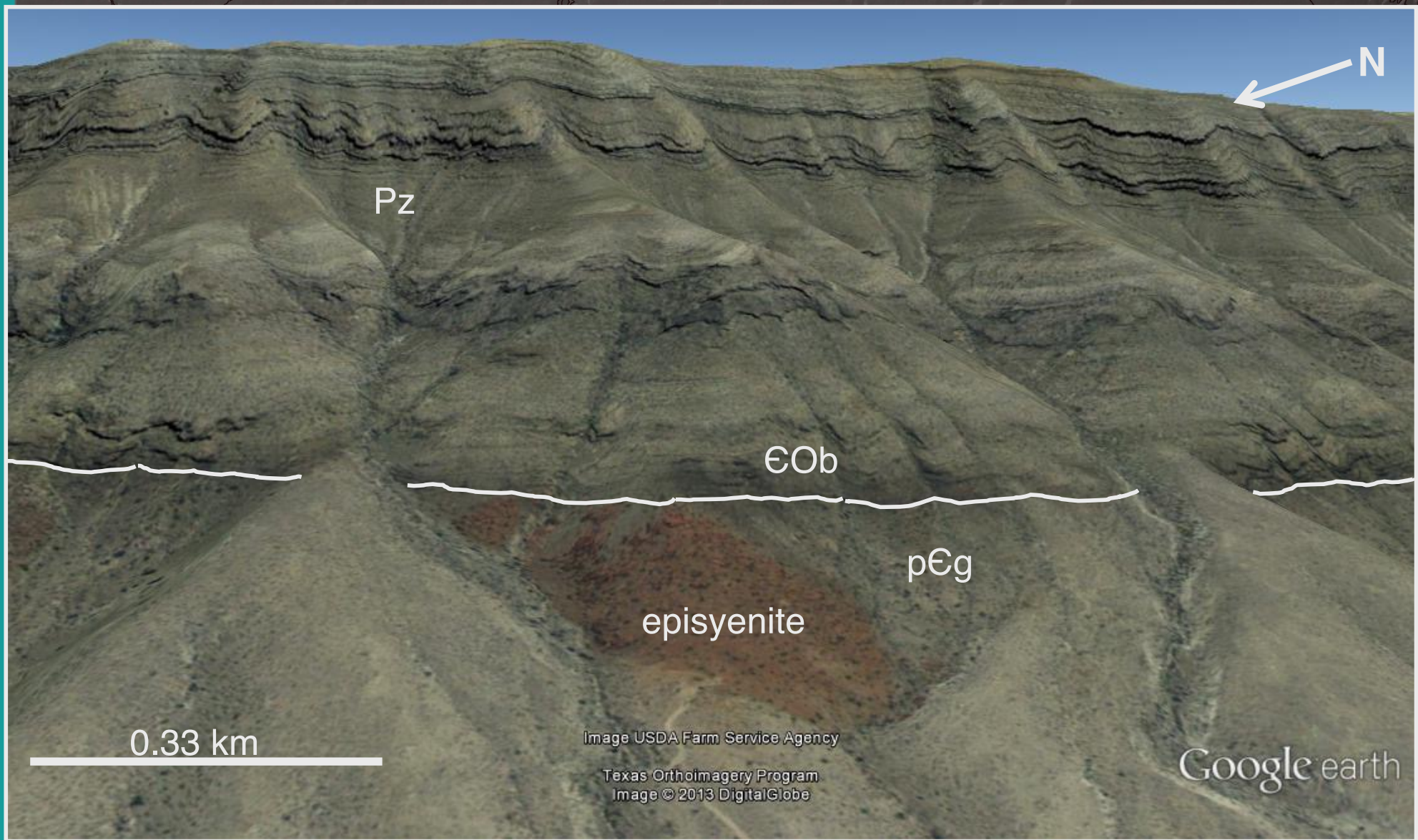
Occurrences of Rare Earth Elements (REE) in New Mexico

Co-funded by NMBGMR and
USGS Minerals
Program (Meinert)

Annelise Riggins
Nelía Dunbar,
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Matthew Heizler,
William McIntosh
Kwame Frempong

Origin of the Caballo and Burro Mountains REE-bearing Episyenites

Photo by N. Dunbar



Caballo Mountains, South of Palomas Gap



K-feldspar rich, quartz poor (Bulk rock 15 wt.% K_2O)
Anomalous concentrations of U, Th and REE

Igneous or metasomatic? Evidence from field



Unaltered
Jack Creek
Rapakivi
Granite,
Burro Mtns

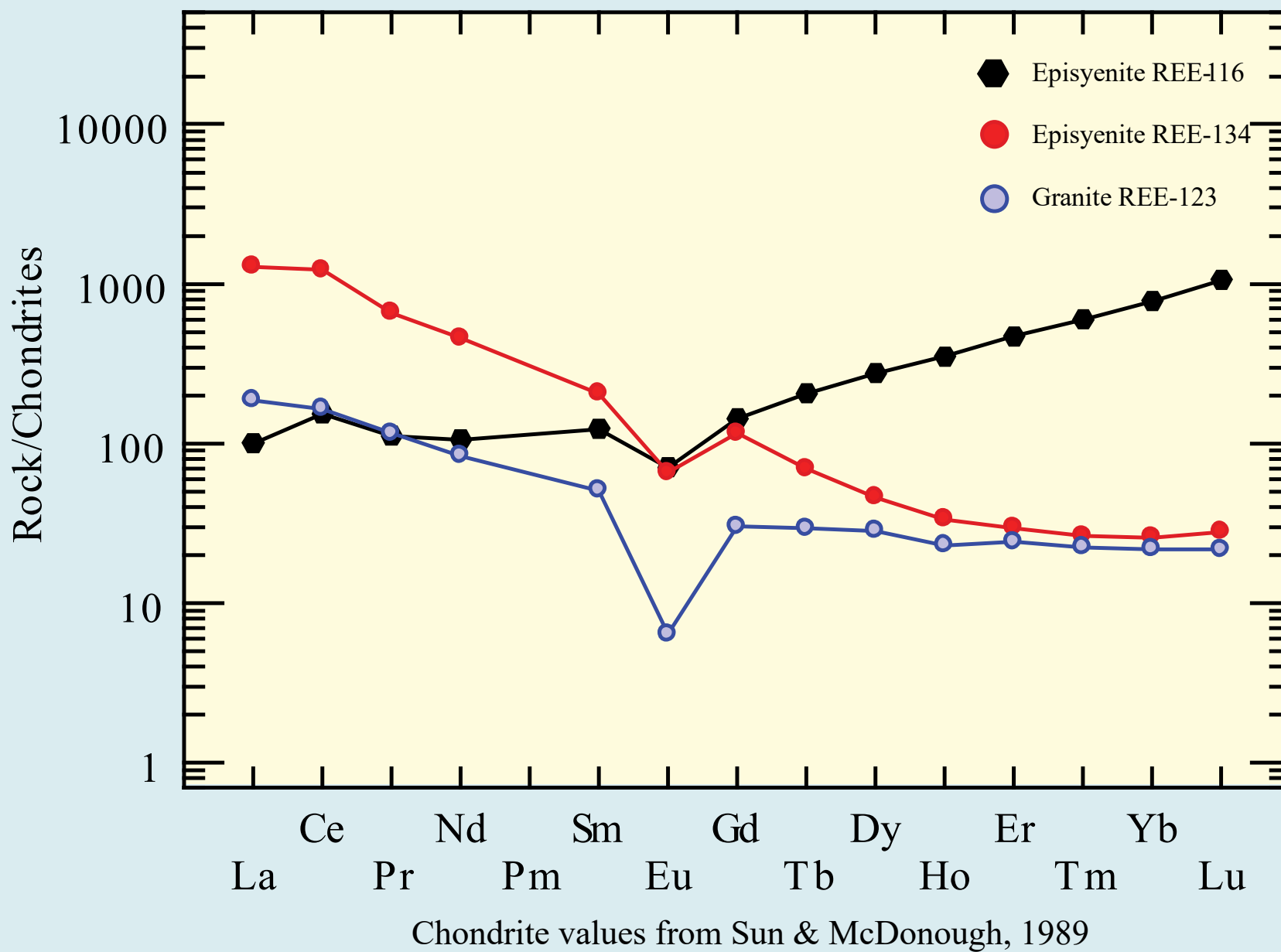


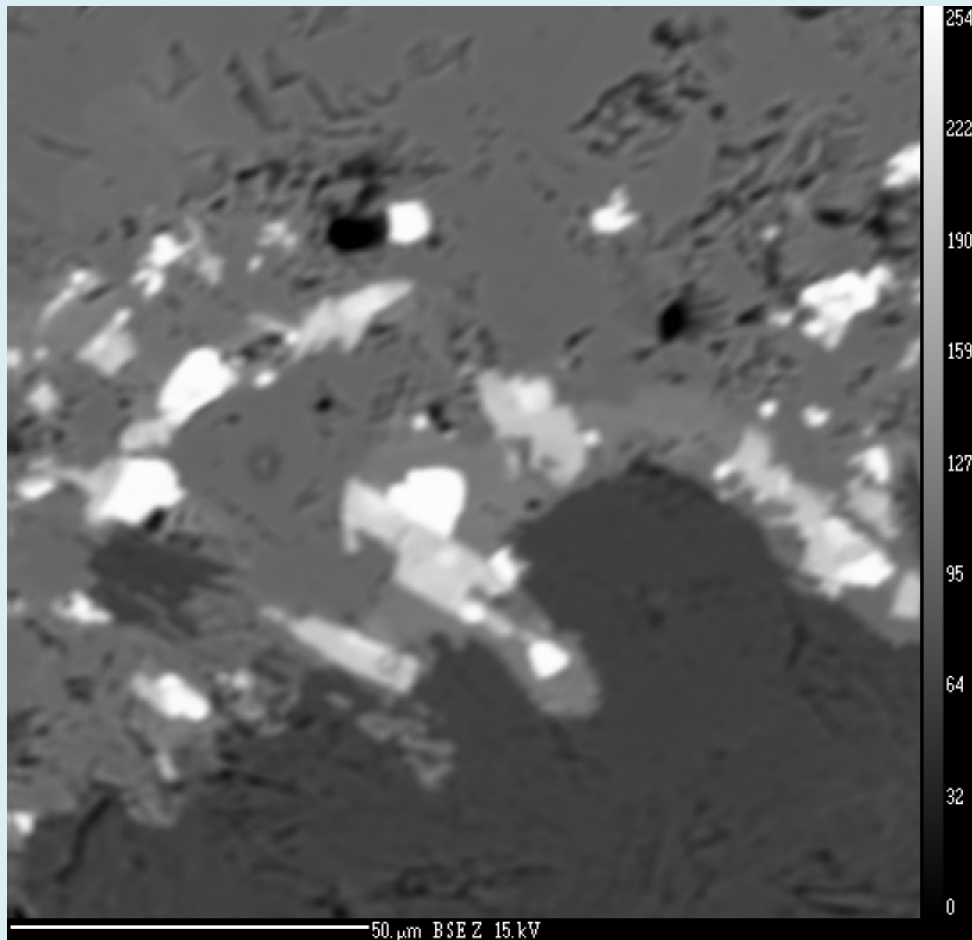
Contact between granitic gneiss and
episyenite in Caballo Mtns



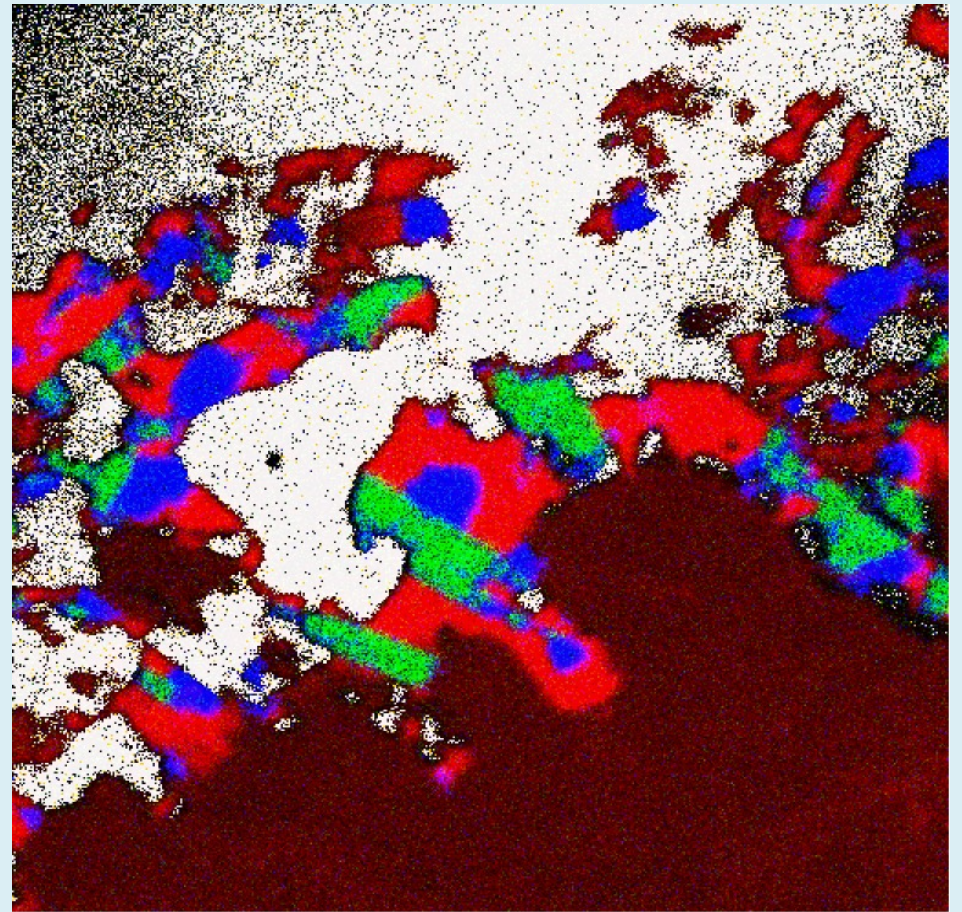
Altered Jack Creek

Chemistry

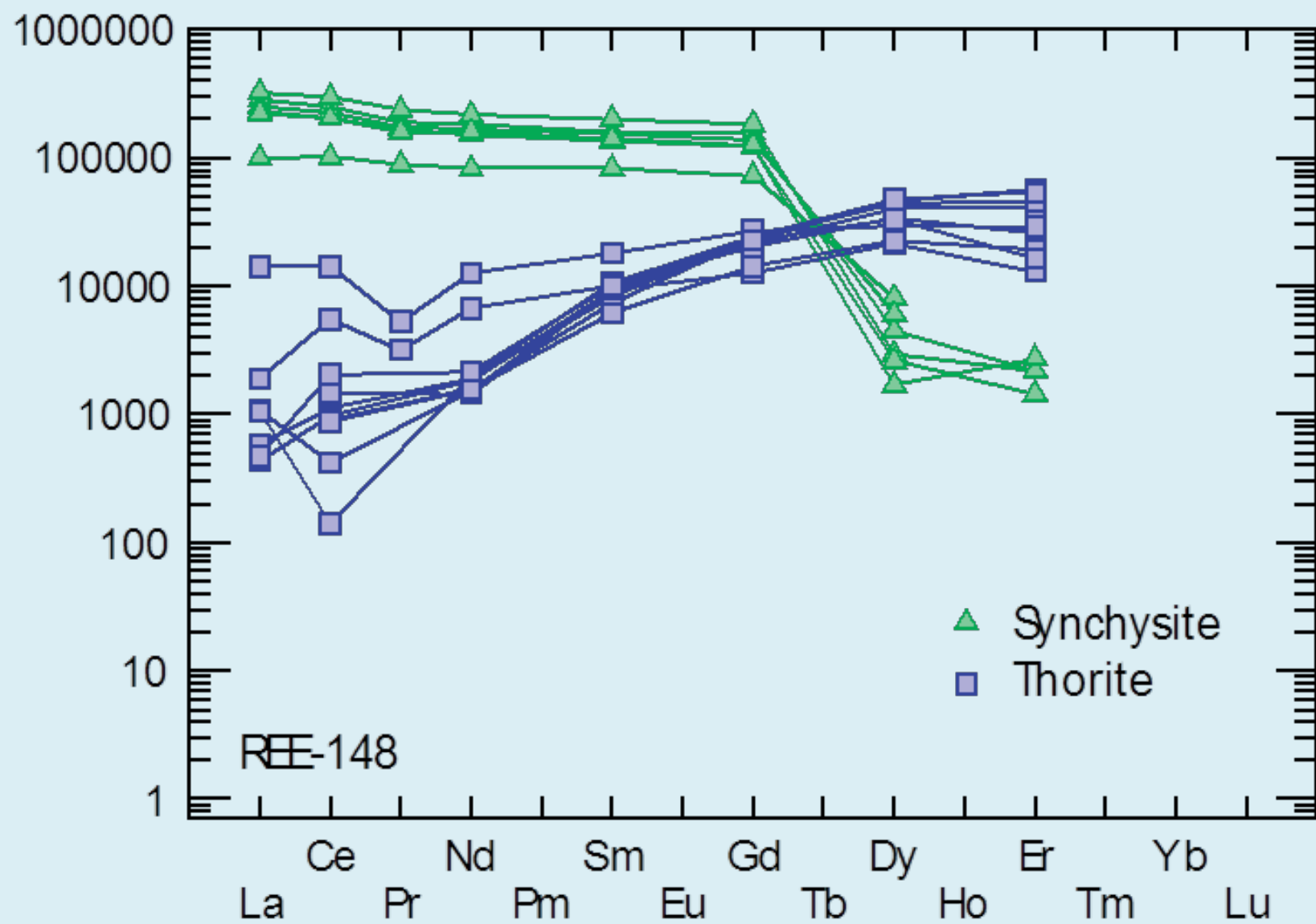




Synchysite
 $\text{Ca}(\text{LREE})(\text{CO}_3)_2\text{F}$

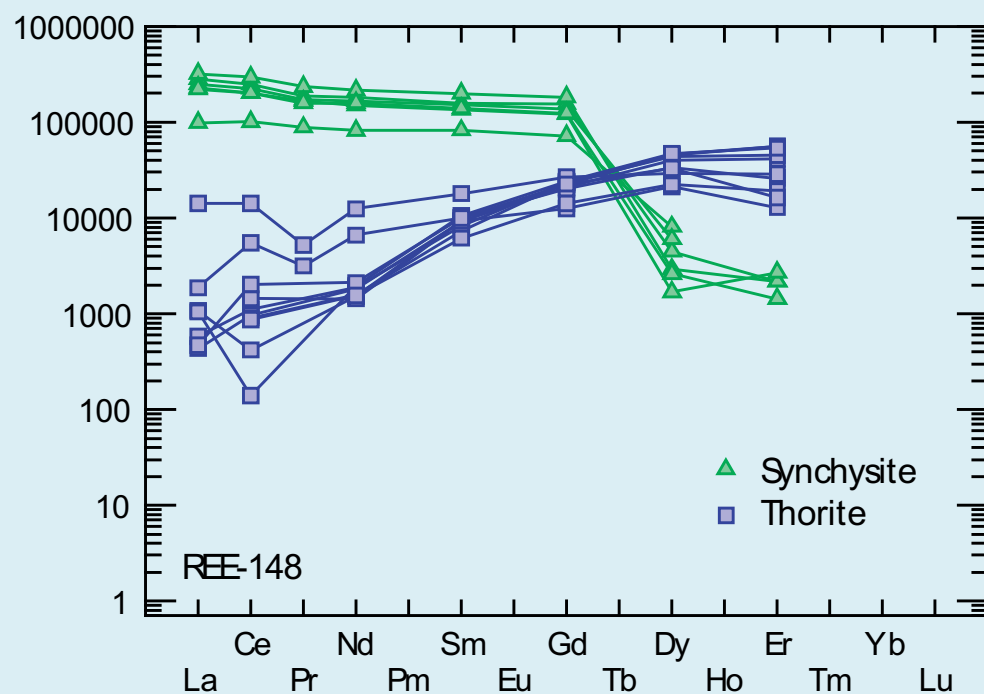


Thorite
 $(\text{Th}, \text{U})\text{SiO}_4$

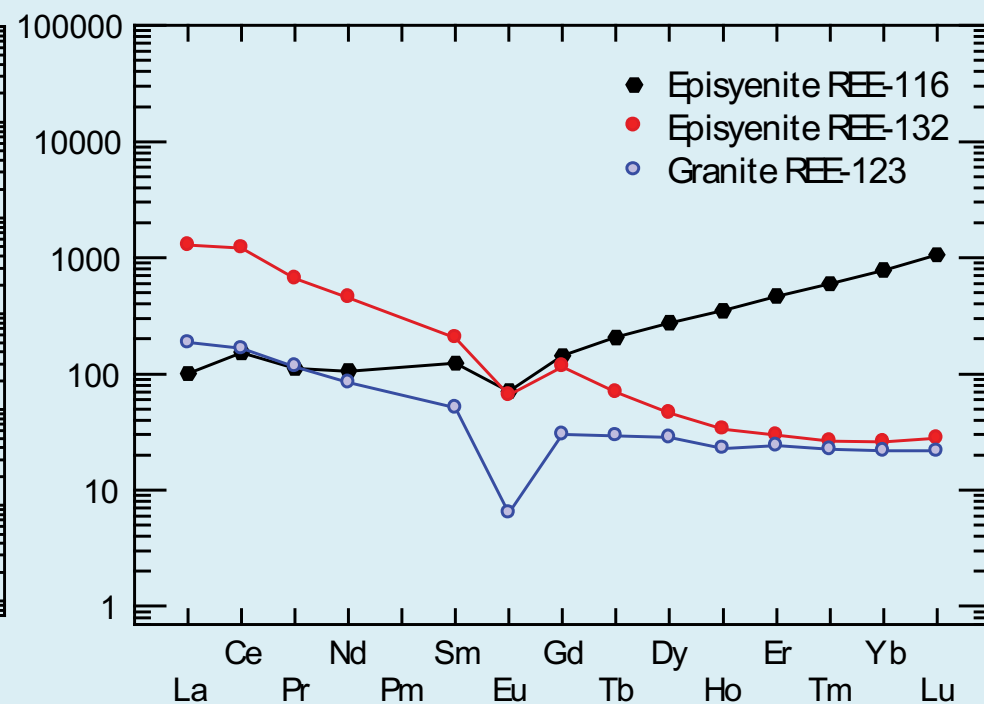


Chondrite values from Sun and McDonough, 1989

Mineral Compositions



Whole-rock Compositions



Chondrite values from Sun and McDonough, 1989

Conclusions

- Episyenites metasomatic in origin
- Mineralogy suggests alteration by one type of fluid
- Fluid may be related to unexposed E-O alkaline/carbonatite intrusions

USGS Earth MRI Project

Mapping REE in Gallinas Mountains, Lincoln County, NM

Drs. Virginia McLemore, Shari Kelley, Matt Zimmerer, Alex Gysi
and many students

$^{40}\text{Ar}/^{39}\text{Ar}$ Geochronology Results

- Early magmatic activity (38.5-29.3 Ma)
- Alkaline intrusive flare-up (28.8-28.0 Ma)
- Alteration and younger intrusions (25.8-24.4 Ma)



Yellow bastnäsite
[(Ce,Lu)(CO₃)F] in
purple fluorite breccia
from the Red Cloud
mine (length is ~8 mm).
Bastnaesite is the most
common REE mineral
mined in the world
today.



Five types of mineral deposits (* production)

- *Hydrothermal breccia and fissure veins (red)
- F replacements/disseminations
- Intrusive breccia pipes (maroon)
- *Fe skarn-contact replacement deposits
- Carbonate breccias

Major faults are not mineralized with the exception of the Pride and Buckhorn faults

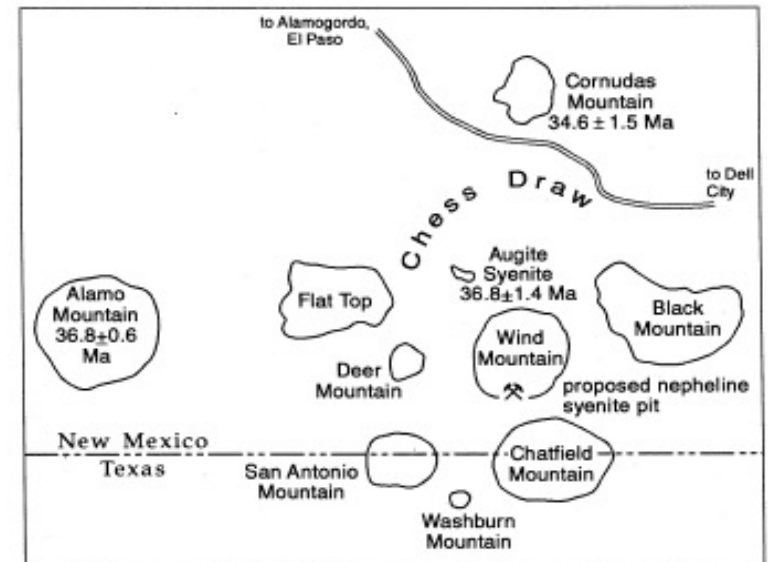
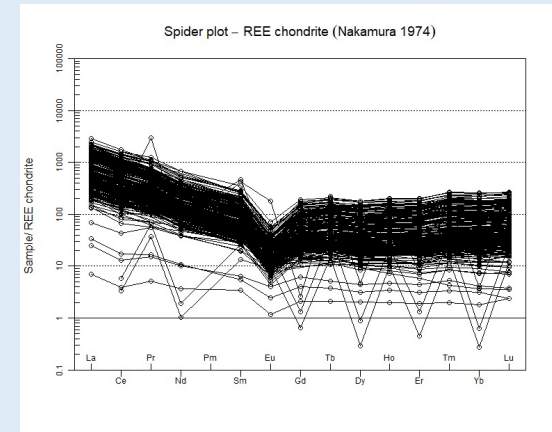


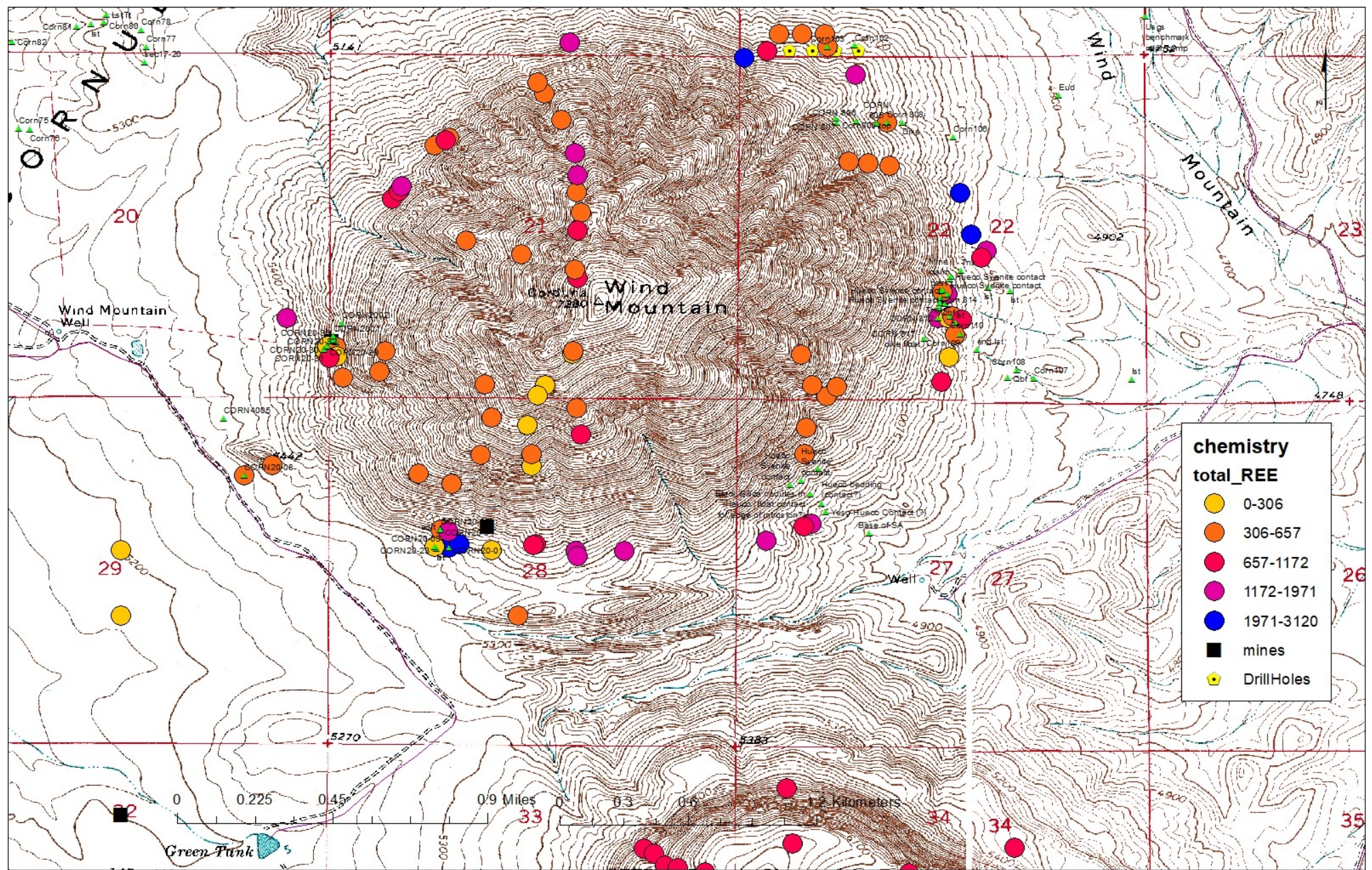
USGS Earth MRI Project

Mapping REE in Cornudas Mountains, Otero County, NM

Drs. Virginia McLemore, Nels Iverson, Snir Attia, and students

- Differential cooling of the magma resulted in the textural variations at Wind Mountain
- Chemical analyses—3790 ppm total REE, 2332 ppm Nb, 92 ppm Be, and 3137 ppm F
- Eudialyte is primary REE mineral
- 36.32 ± 0.15 Ma
- Additional mineralogy, mapping, and dating underway

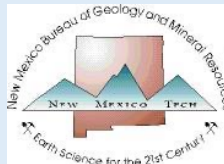
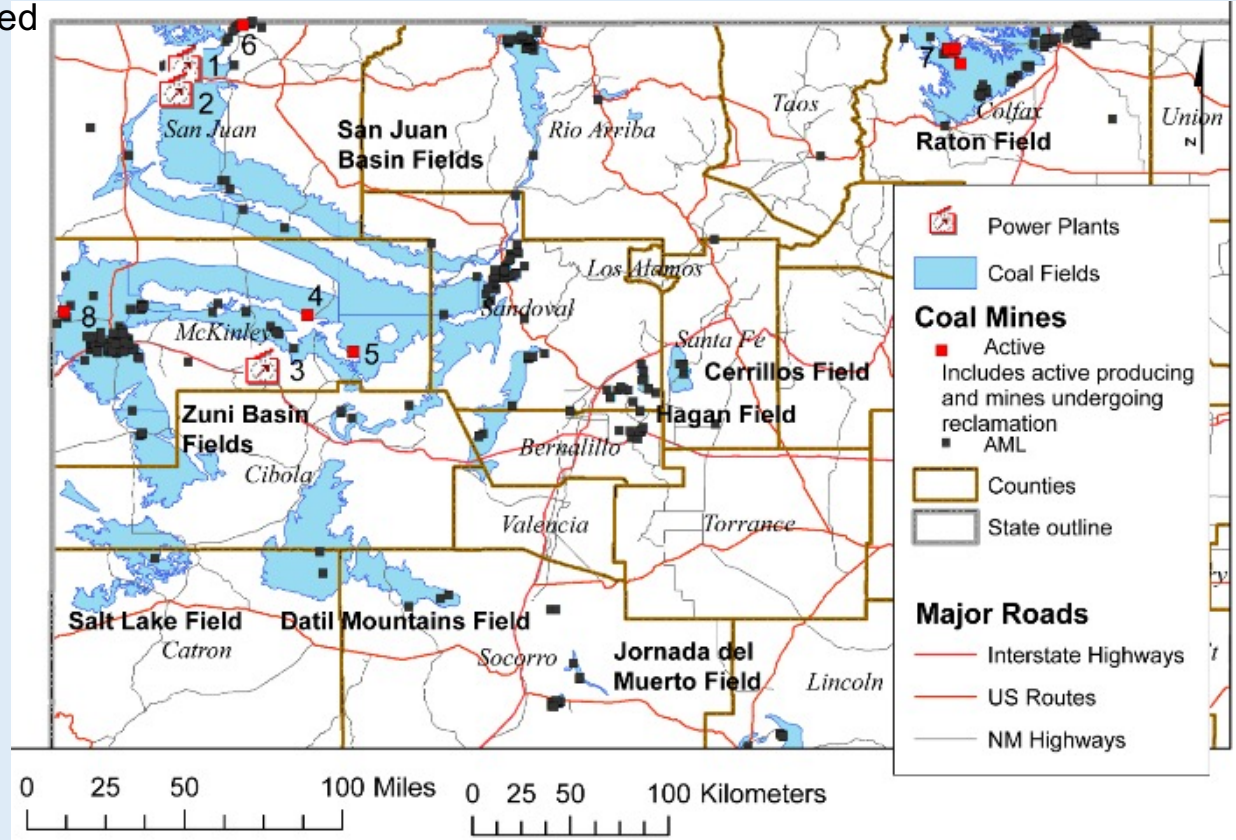




DOE CORE-CM project—San Juan River-Raton Basin, New Mexico DOE contract (Oct 2021-Sept 2023)

Drs. Virginia McLemore, Nels Iverson and many others

- CORE-CM=Carbon Ore, Rare Earth and Critical Minerals
- Identify and quantify the distribution of REE and CM in coal beds and related stratigraphic units in the San Juan and Raton basins
- Identify, sample, and characterize coal waste stream products
- Sandia: Microscale characterization techniques to identify where REEs and critical metals are hosted
- LANL: Field-portable, in situ LIBS/RAMAN analysis

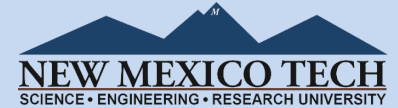


Ore Deposits and Critical Minerals research group



Alexander Gysi (alexander.gysi@nmt.edu)

Bureau of Geology & Mineral Resources
Department of Earth & Environmental Science



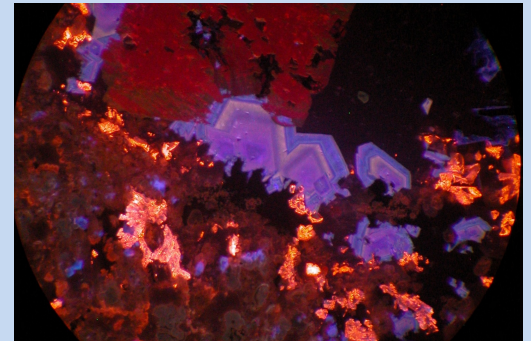
- **Research**

- **Ore deposits and critical minerals experimental laboratory**
- Development of the **MINES thermodynamic database**
- **Field observations in critical mineral deposits**

- **Funding of ~ \$3M from DOE and NSF-EAR/-CAREER**

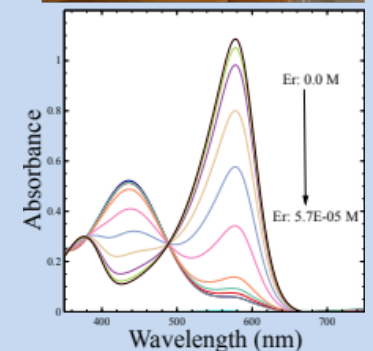
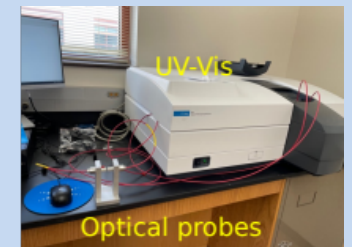
- **Team:** 3 PhD and 2 MS students, 1 undergraduate students and 2 Postdoctoral Fellows

- New **U.S. geoscience critical minerals experimental – thermodynamic research hub** NMT-LANL-IUB plus search for 3 new PhD and 3 Postdocs!



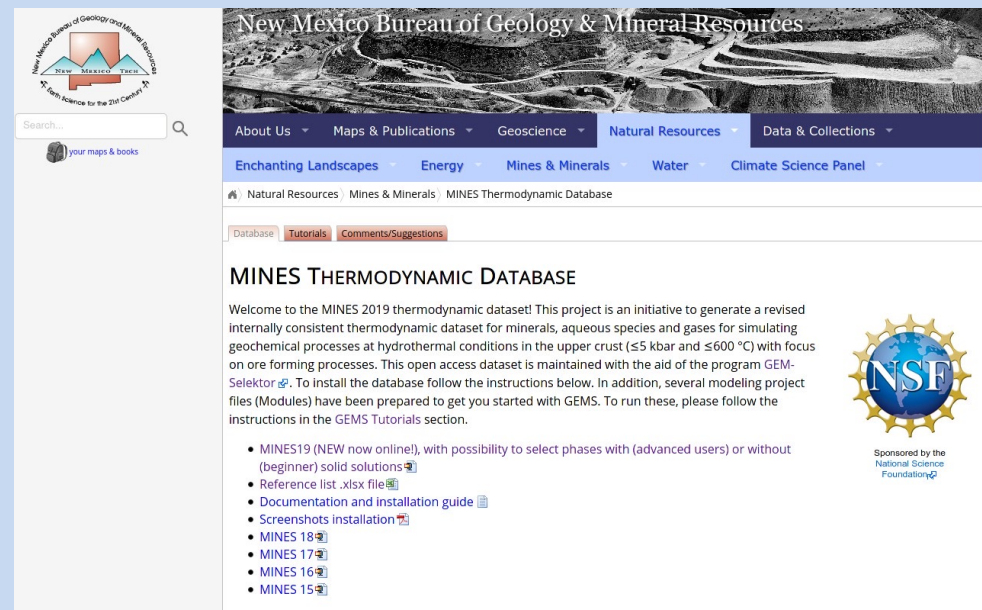
Ore Deposits and Critical Minerals experimental lab

- **Hydrothermal fluid-mineral experiments**
 - Synthesis/dissolution of REE minerals (xenotime, monazite)
 - REE incorporation into calcite, fluorite, apatite
- **Thermodynamic properties of critical minerals and their solid solutions**
 - Hydrothermal solution calorimetry (enthalpy of mixing), heat capacity measurements, and mineral stability
- **UV-vis spectrophotometry**
 - High temperature complexation of aqueous REE species
 - Flow-through experiments
- **NEW Raman laser – hydrothermal diamond anvil cell facility – NSF MRI/DOE research hub**



MINES thermodynamic database

- **Project goal:**
 - Simulate **fluid-rock interaction** and evaluate mineralization/alteration in a variety of **mineral deposits**
- **Features:**
 - Free and open access thermodynamic database
 - **Rock-forming minerals**, aqueous species, and gases
 - Focus on critical elements, **comprehensive database on REE**
 - Includes **base and precious metals**
- **Workshops:**
 - Annually either online or conferences
 - Gitbook tutorial
<https://apgyi.github.io/gems-mines-tutorial/>



<https://geoinfo.nmt.edu/mines-tdb>

Conclusions

- The New Mexico Bureau of Geology and Mineral Resources has a long research history in the field critical minerals
- Our laboratories are essential components to critical mineral research in our state. Opportunities for laboratory support for other state surveys
- We have a number of ongoing research projects in the broad field of critical minerals, with strong field and laboratory components. We plan to continue and grow this research area
- We are actively training the next generation of critical mineral scientists, ranging from undergraduate students to post-doctoral research associates.