OVERVIEW OF THE MINING INDUSTRY IN NEW MEXICO, WITH EMPHASIS ON CRITICAL MINERALS

Virginia T. McLemore

New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM

ACKNOWLEDGEMENTS

- New Mexico Energy, Minerals and Natural Resource Department
- Company annual reports
- Personal visits to mines
- Historical production statistics from U.S. Bureau of Mines, U.S. Geological Survey, N.M. Energy, Minerals and Natural Resource Department (NM MMD), company annual reports
- Students at NM Tech

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. Active emeritus staff. Mentor and employ around 40 graduate and undergraduate students.

OUTLINE

- What, where, and how much minerals are produced in New Mexico?
  - Where are potential future resources?
- What critical minerals are found in New Mexico?
  - Briefly describe some of the ongoing research
- What are the Mining Issues Facing New Mexico?

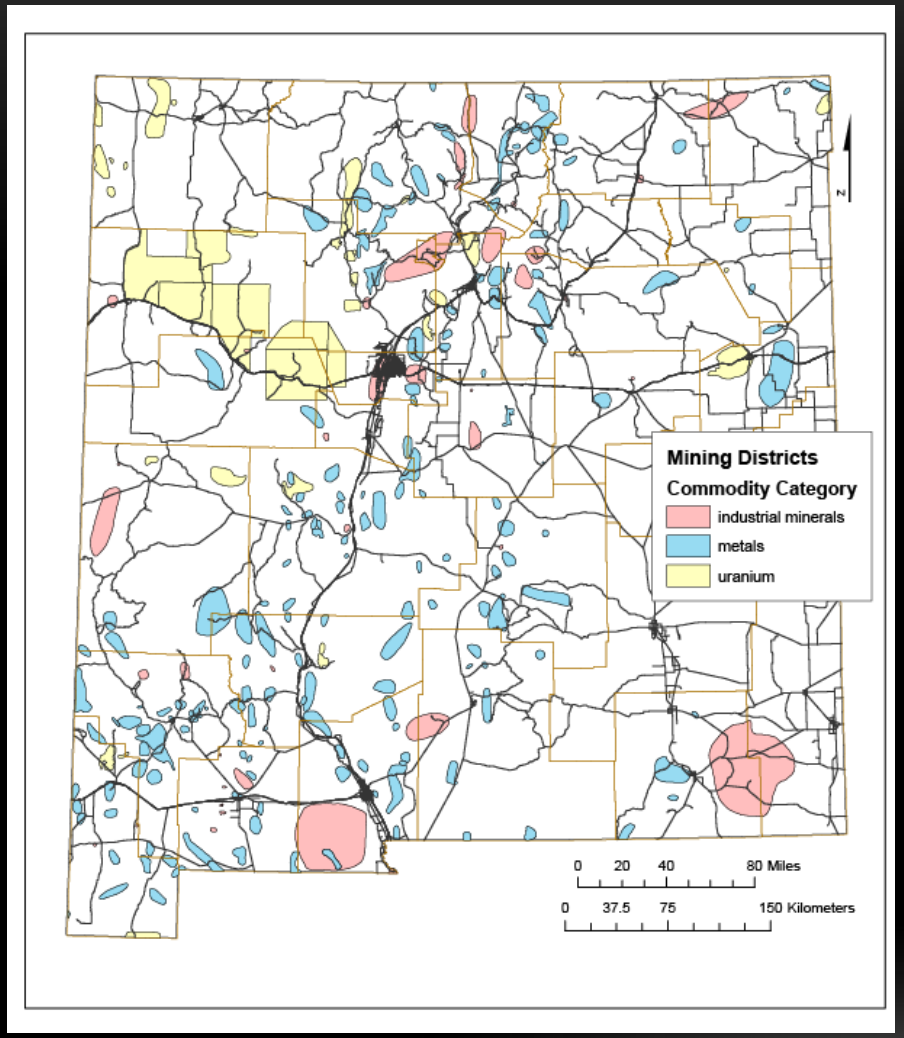
WHAT, WHERE, AND HOW MUCH MINERALS ARE PRODUCED IN NEW MEXICO?

INTRODUCTION

- NM has some of the oldest mining areas in the United States
- Native Americans mined turquoise from Cerrillos Hills district more than 500 yrs before the Spanish settled in the 1600s
- One of the earliest gold rushes in the West was in the Ortiz Mountains (Old Placers district) in 1828, 21 yrs before the California Gold Rush in 1849

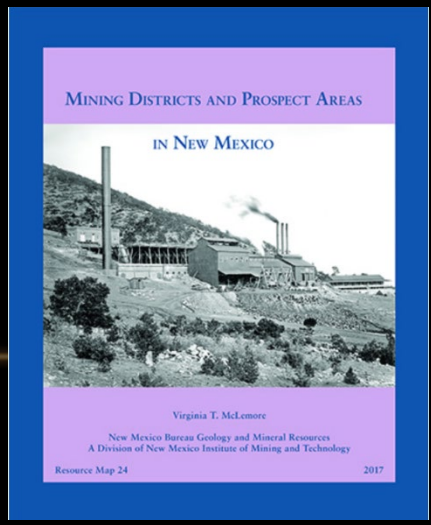
One of the turquoise mines in the Cerrillos Hills district

MINING DISTRICTS IN NEW MEXICO



274 mining districts and prospect areas

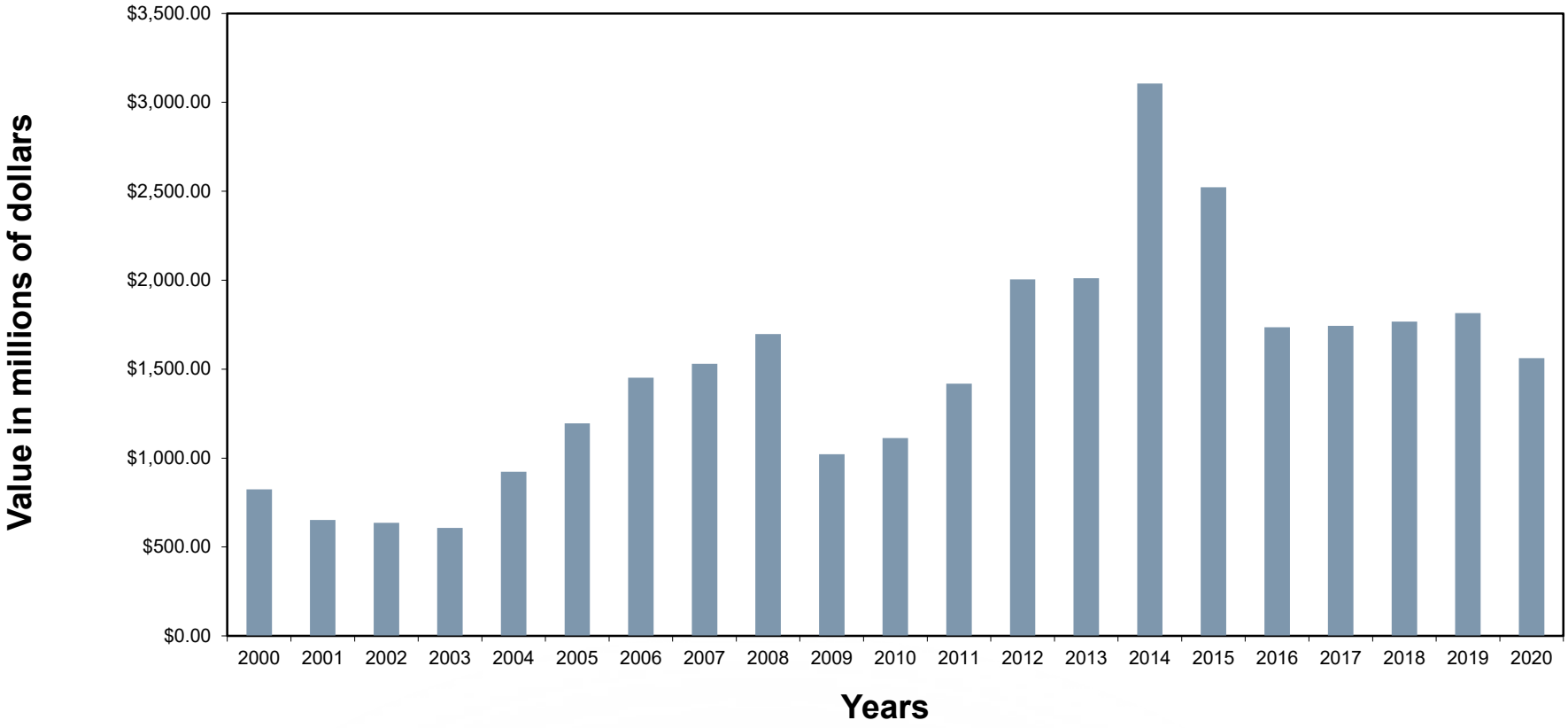
173 metals,
40 industrial minerals
33 uranium districts
28 coal fields



PRODUCTION SUMMARY—2020

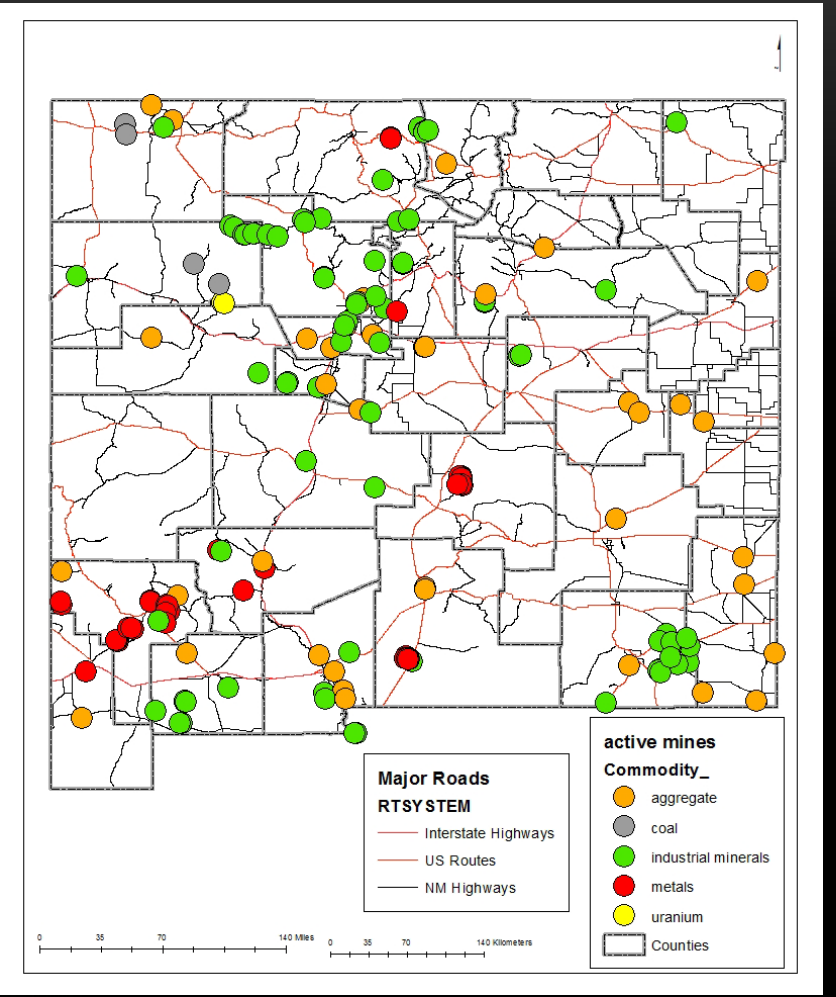
- Value of mineral production in 2020 was $1.56 billion (down from 2019) (does not include oil and gas)—ranked 23rd in the US (18th in 2017)
- Employment in the mining industry is 4,500
- Exploration for garnet, gypsum, limestone, nepheline syenite, agate, specimen fluorite, gold, silver, iron, beryllium, uranium, copper, potash, rare earth elements, humate, clays, lithium
- COVID closed at least one mine, but most of the industrial minerals and aggregate operations increased production
- ***MINERALS PRODUCTION IS DECREASING, ESPECIALLY COAL***

Value of mineral production in New Mexico 2000-2020



ACTIVE MINES 2022

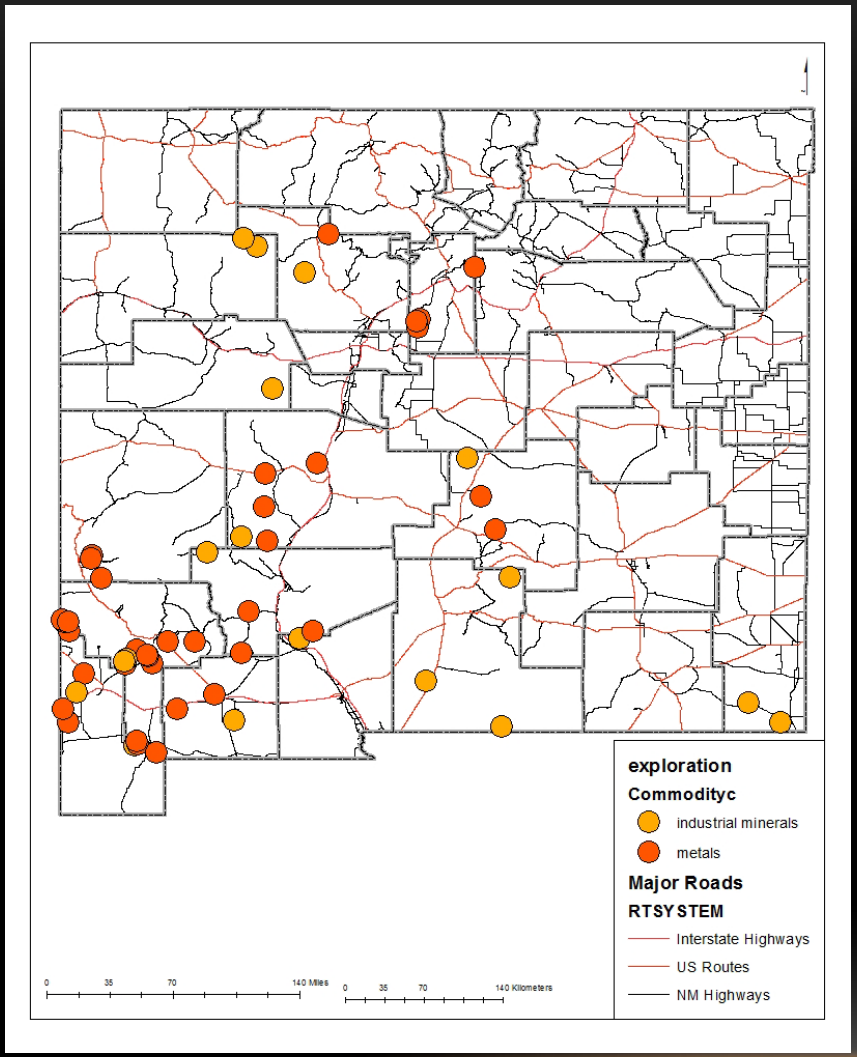
- ~355 active registered mines (NMMMD)
- 4 coal
- 3 potash, 4 potash plants
- 2 copper open pits, 1 concentrator (mill), 2 solvent/electro-winning (SX-EW) plants
  - 1 addition mines in permitting stage
  - Several exploration
- 2 gold mines and 1 mill (active but not producing)
- 1 iron mine
- 1 uranium mine (active but not producing)
- 31 industrial minerals mines, 18 mills
- ~302 aggregate/stone



Not all aggregate mines are shown

From NM Mining and Minerals Div. database

SELECTED ACTIVE EXPLORATION SITES IN NEW MEXICO 2019-2022 (EXCLUDING U)



Most of these exploration sites have been known for >20 yrs

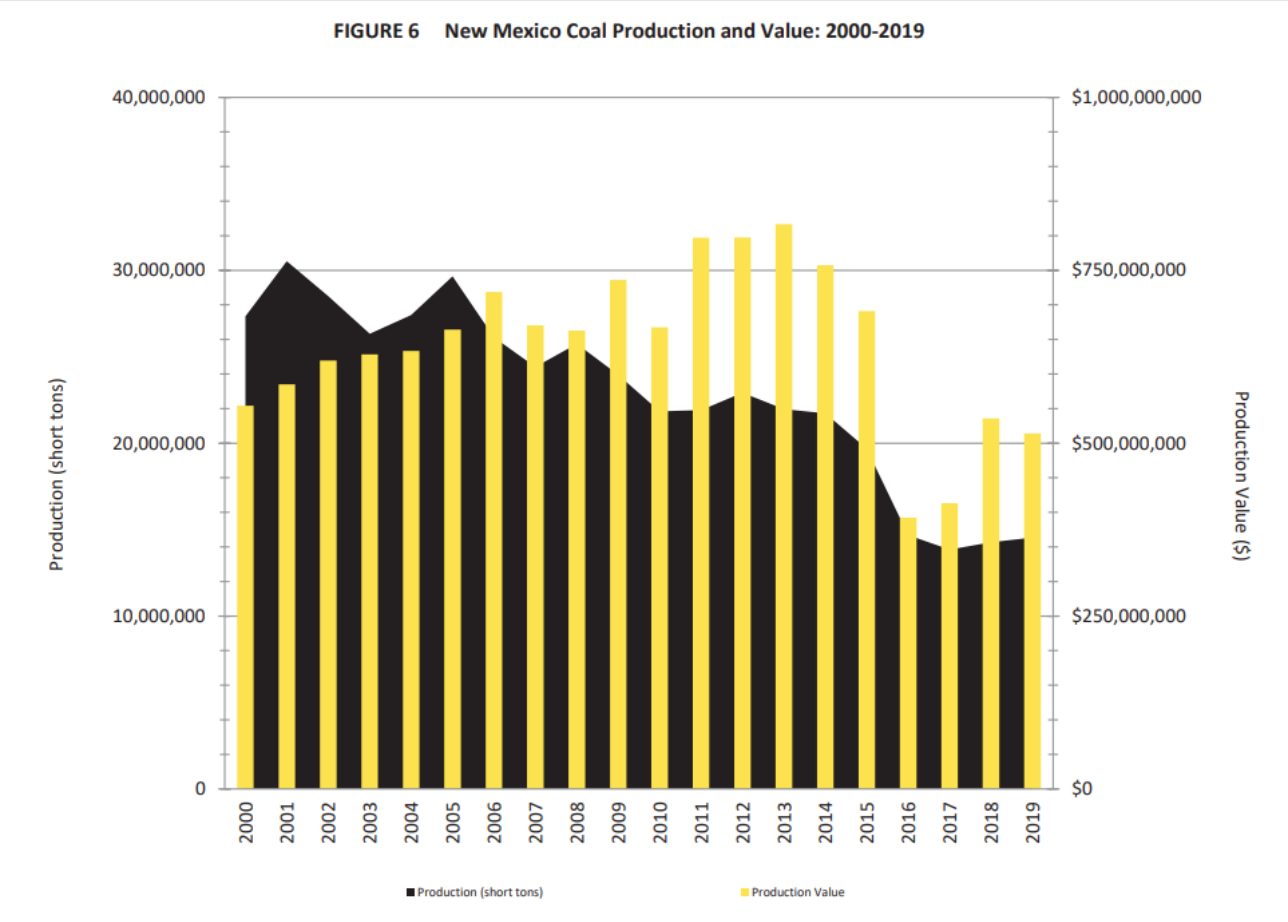
Industrial minerals deposits sometimes can be permitted within a few yrs but not metal mines

From NM Mining and Minerals Div. and NMBGMR databases, company web sites

COAL

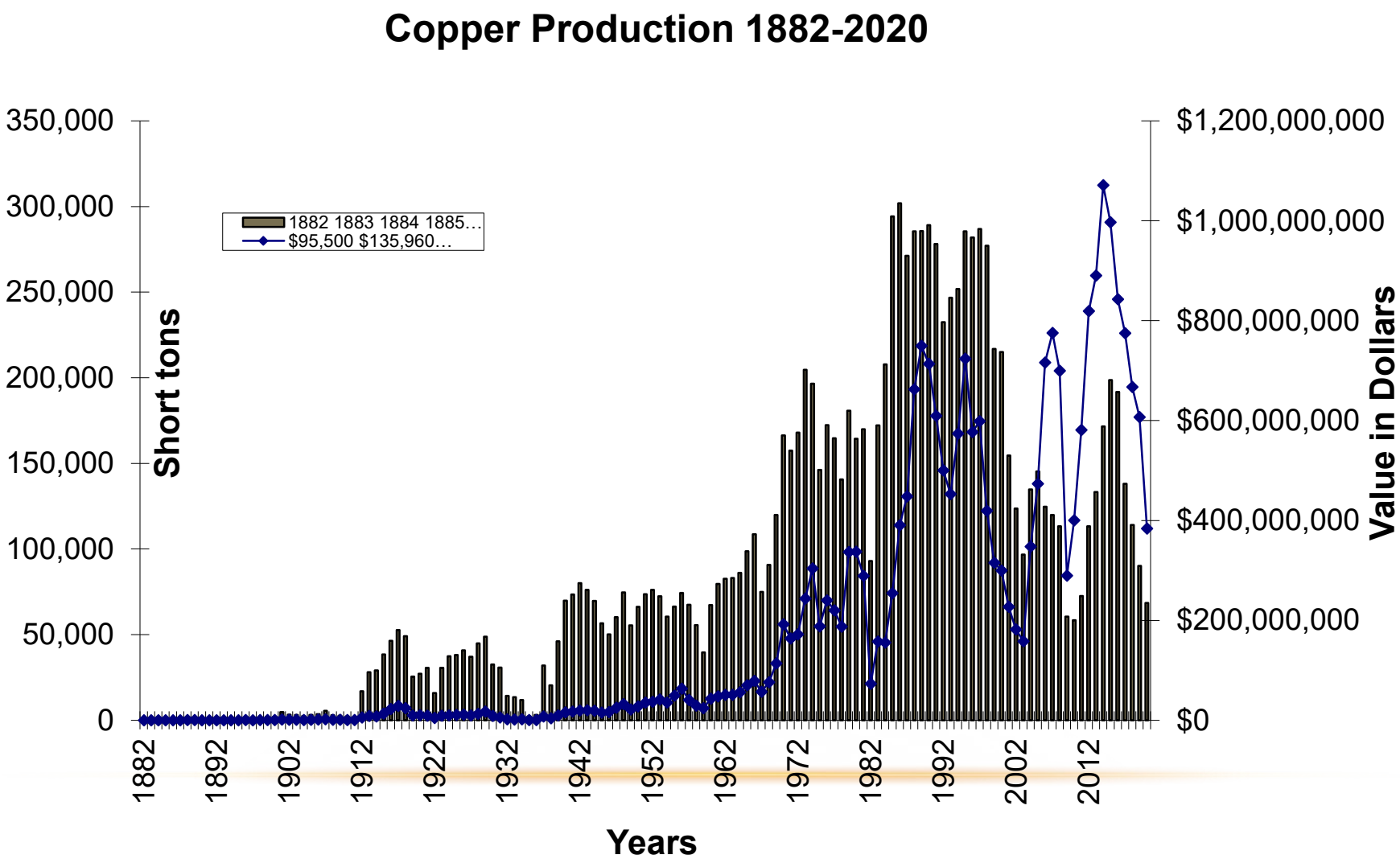
- Fuels 3 electrical generating plants in NM and others in Az
- 3 surface mines and 1 underground mine in San Juan Basin
- Resources at Raton, Carrizozo
- 12th in production in U.S. in 2020
  - 15th in estimated reserves
  - 65 million short tons of recoverable reserves
- San Juan generating station in the Farmington is scheduled to close in the near future

COAL PRODUCTION IN NEW MEXICO 2000-2019



EMNRD_AnnualReport_2020.pdf (nm.gov)

Metals—3rd in copper production in 2020 (Chino, Tyrone)

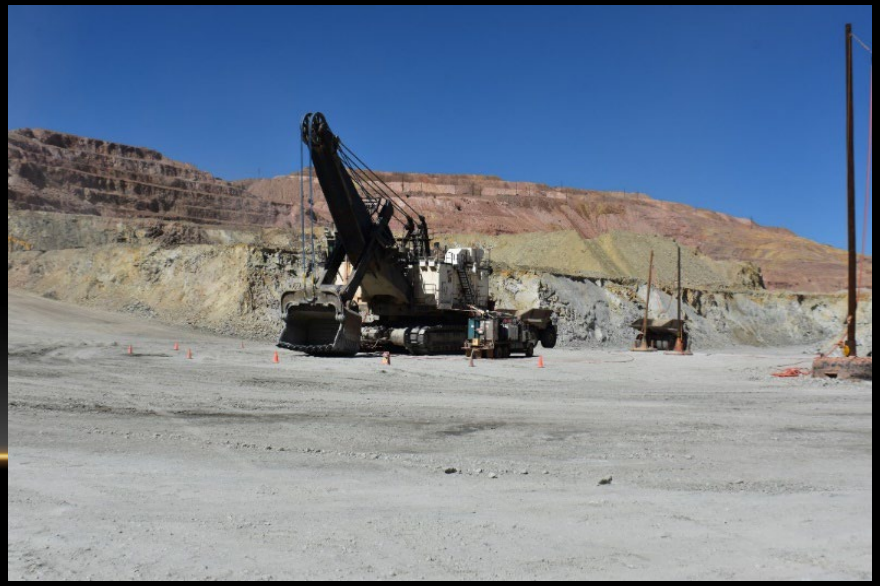


CHINO MINE

- In operation since 1910
- 36,000 metric ton-per-day concentrator and 150 million pound-per-year SX/EW plant
- Closed in April 2020 in response to COVID
- Reopened in January 2021
- Production was 92 million pounds in 2020, 175 million pounds in 2019
- Mine life is 2039
- Updating of permits for planned expansion underway

TYRONE MINE

- In operation since 1967
- 100 million pound-per-year SX/EW plant
- Production 45 million pounds in 2020, 48 million pounds in 2019
- Mine life is 2027
- Updating of permits for planned expansion underway
- Exploration at the Emma deposit

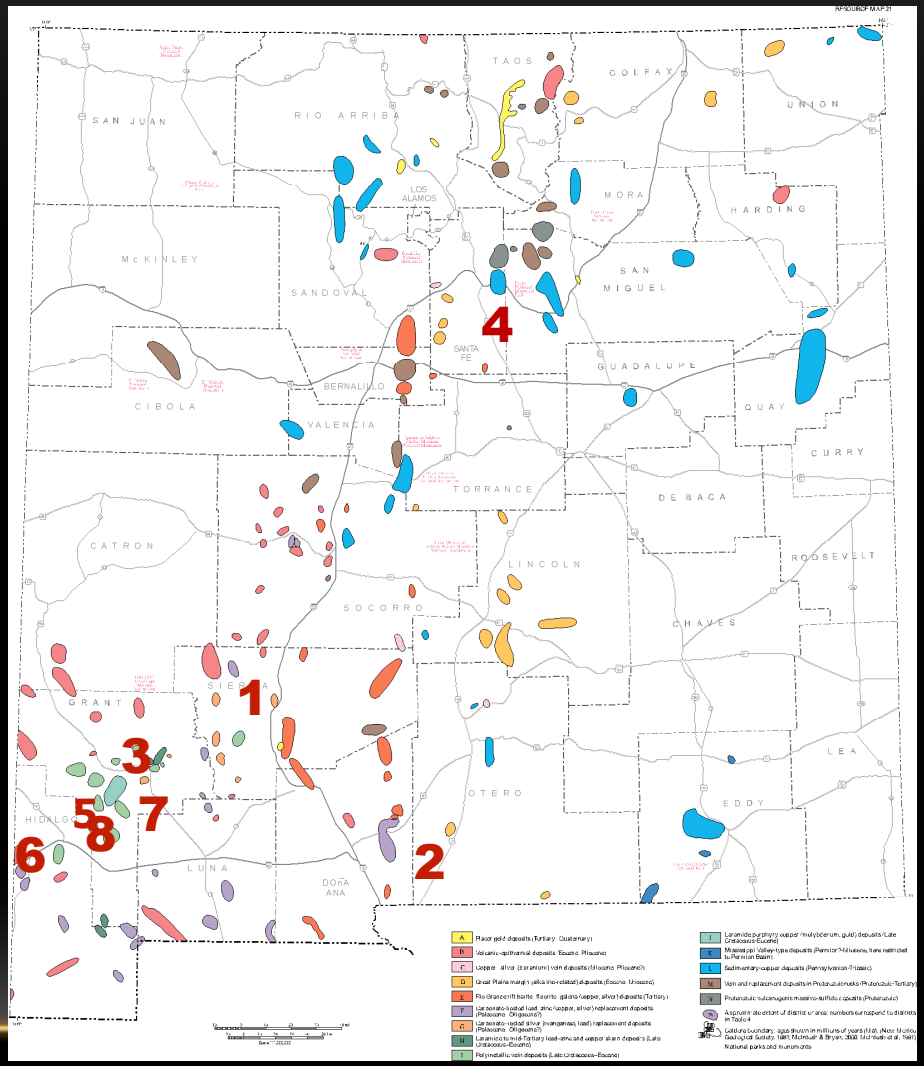


COPPER RESERVES—2020

- Reserves are decreasing
- Chino (incl. Hanover, Cobre, Continental)
  - milling reserves are 213 million metric tons of 0.51% copper, 0.05 g/t gold, 0.9 g/t silver and 0.01% molybdenum
  - leaching reserves are 100 million tons of 0.28% Cu
- Tyrone (incl. Little Rock)
  - leaching reserves are estimated as 33 million metric tons of ore grading 0.27% Cu

POTENTIAL COPPER DEPOSITS

1. Copper Flat (98.1 million short tons at 0.31% Cu, 0.009% Mo, 0.003 oz/short ton Au, and 0.07 oz/ short ton Ag)
2. Orogrande
3. Hanover Mountain (80 mill st reserves at 0.38% Cu)
4. Copper Hill, Picuris district (46.5 mill st of ore at 0.42% Cu)
5. Lone Mountain (7.5 mill st at 2-3% Cu, 1.2% Pb, 4-5% Zn, 203 opt Ag, .01-.02 opt Au)
6. McGhee Peak, Pelloncillo Mountains
7. Mimbres, Grant Co
8. Oak Grove, Grant Co

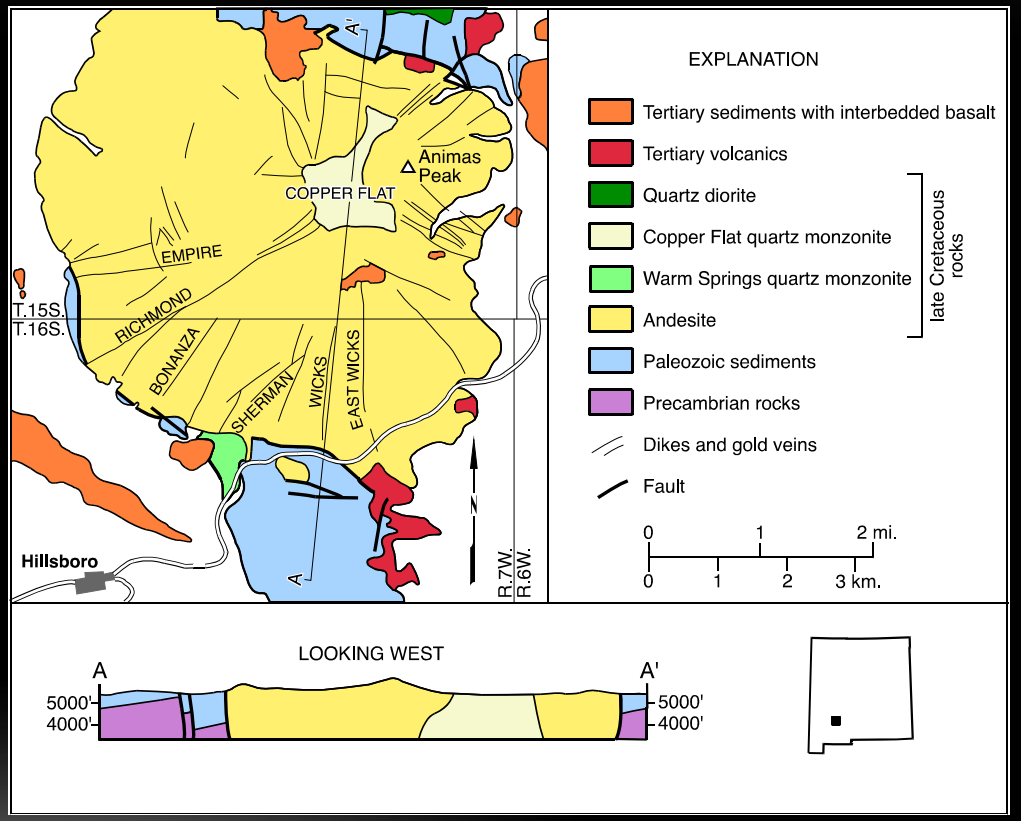


Copper Flat, Themax Resources

Planned production per year for ~15 yrs

50.76 mill lbs Cu
1.01 mill lbs Mo
12,750 oz Au
455,390 oz Ag

Start in 2020s?

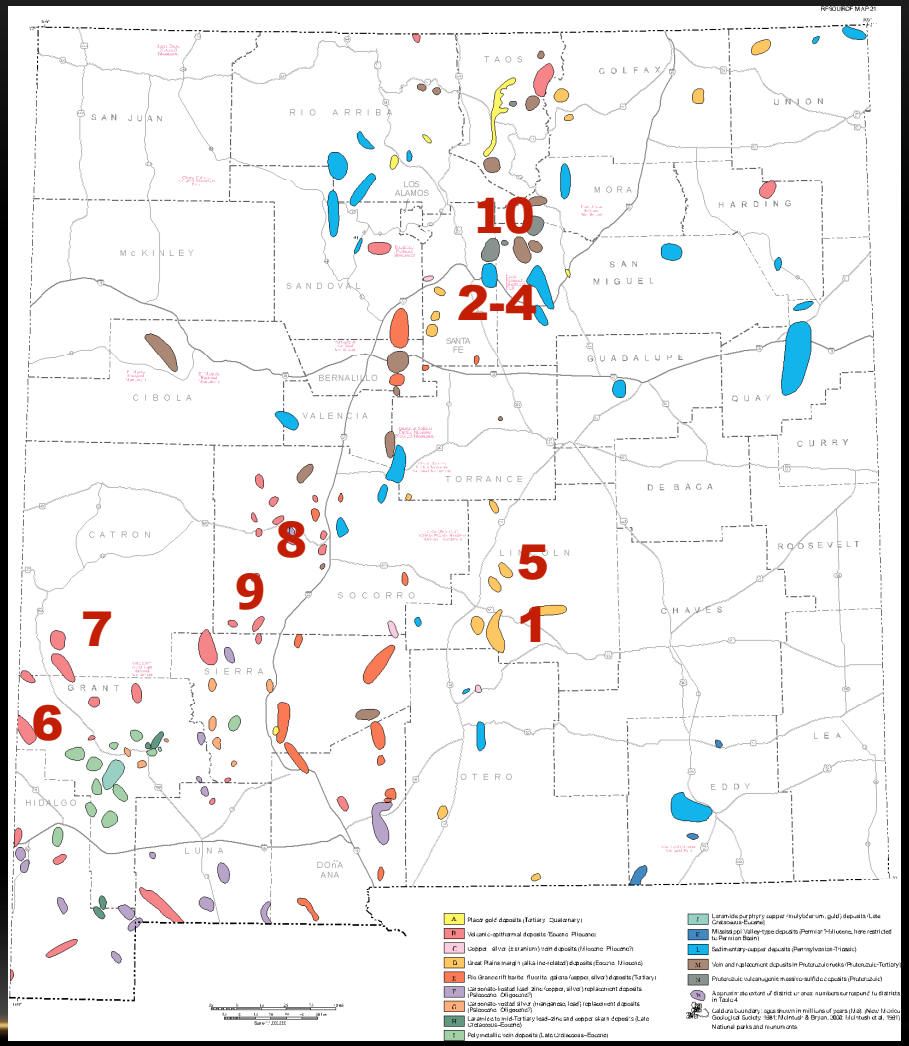


GOLD AND SILVER PRODUCTION

- In 2004-2022 as a byproduct of copper production from the Ivanhoe concentrator (Freeport-McMoRan)
- 9th in gold production
- 10th in silver production

GOLD AND SILVER

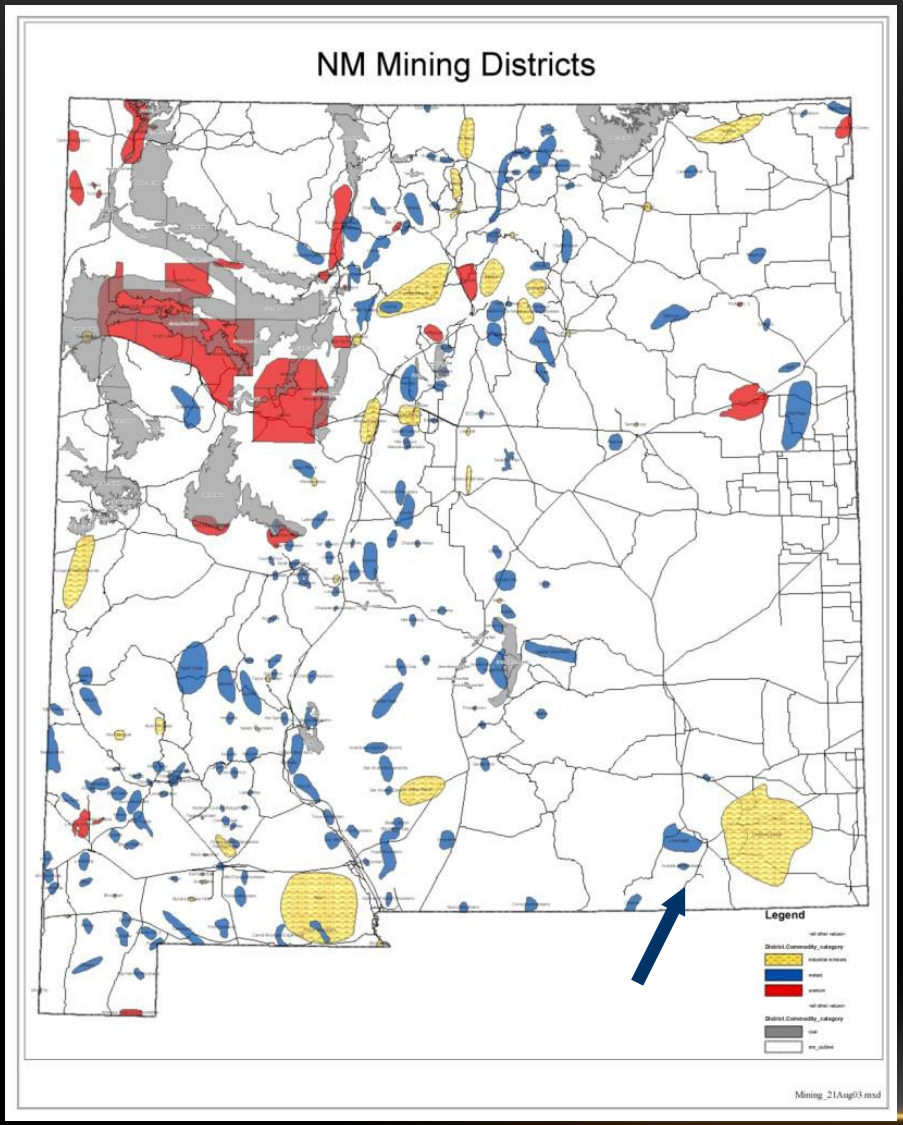
1. Vera Cruz, Lincoln Co
2. Carache Canyon, Santa Fe Co
3. Lukas Canyon, Santa Fe Co
4. San Lazarus, Santa Fe Co
5. Jicarilla Au placers
6. Steeple Rock district
7. Mogollon, Catron Co
8. Magdalena, Socorro Co
9. Rosedale, Socorro Co
10. Terrero, Santa Fe



INDUSTRIAL MINERALS

Any rock, mineral, or other naturally occurring material of economic value, excluding metals, energy minerals, and gemstones, generally nonmetallic

Many critical minerals are considered industrial minerals



Potash Production

1st in US

1951-2020 123 million tons worth >$17 billion

Reserves in Carlsbad District

Potash (>553 million tons)

Potash is used in fertilizers among other uses

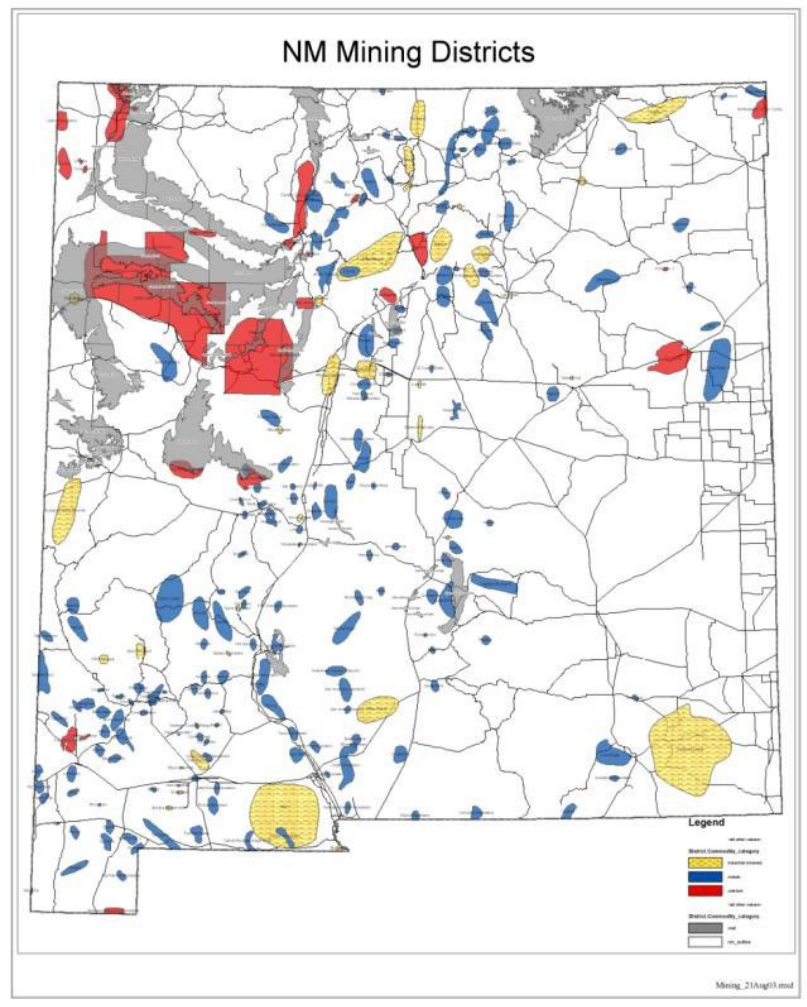
Intrepid closed one mine

Competition from Canadian deposits

- Intercontinental Potash Corp. (IPC) plans are on hold to mine polyhalite at the Ochoa deposit SE of the district
- Intrepid Mining NM LLC is using solution mining techniques at the HB Solar Solution mine (old potash workings)

1ST IN POTASH IN 2021 (MOSAIC, INTREPID MINING)

ADDITIONAL INDUSTRIAL MINERALS IN NEW MEXICO



- 1st in zeolite (St. Cloud, Sierra County)
- 5th in pumice (6 operations)
- 1st in perlite (4 operations)
- 11th in salt (4 operations, Carlsbad)
- Humate is important and expanding

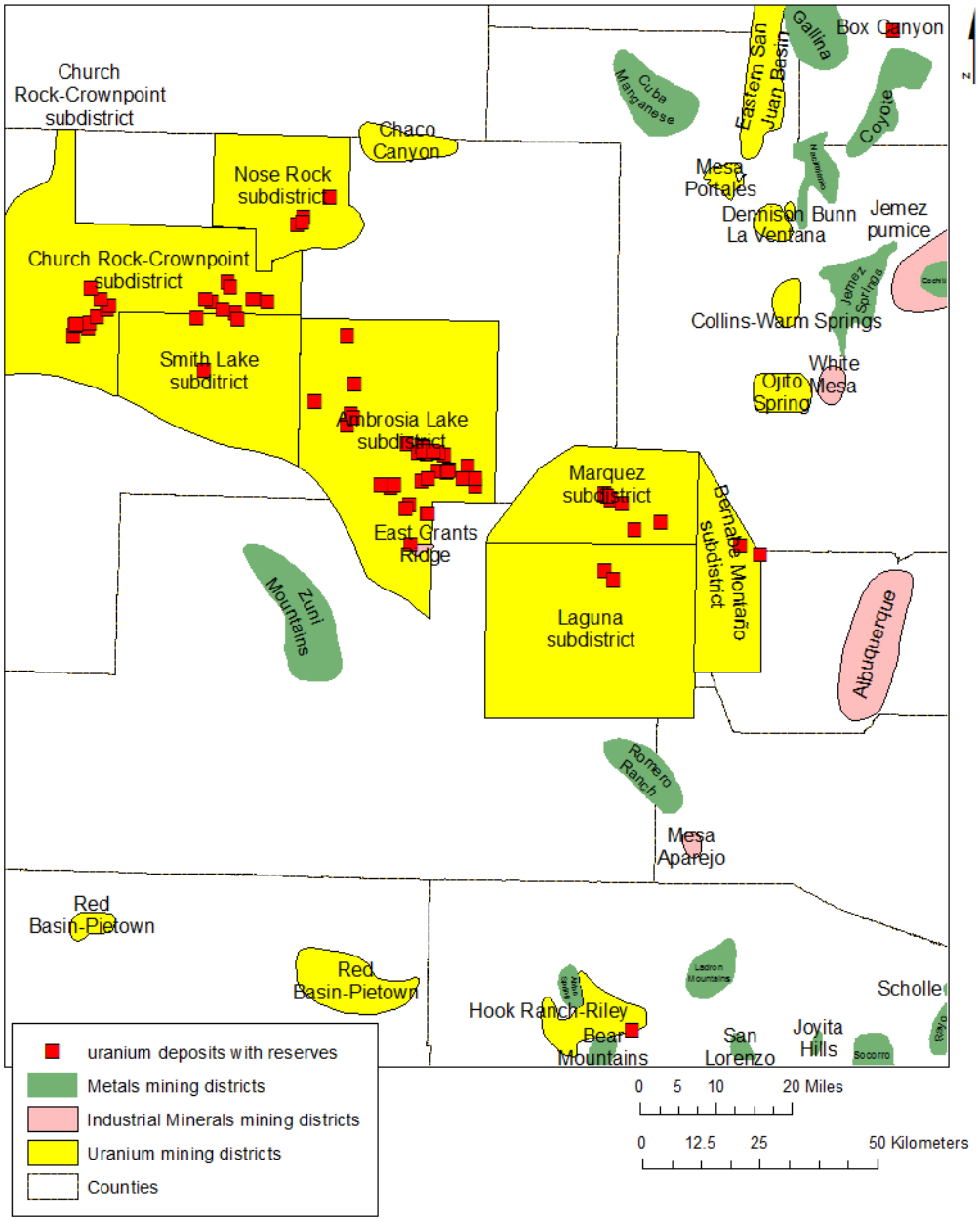
OTHER INDUSTRIAL MINERALS DEPOSITS

- Aggregates
- Gypsum for wallboard
- Brick and clay in El Paso, Albuquerque areas
- Cement in Tijeras Canyon
- Humate in the San Juan Basin
- Sulfur, helium, carbon dioxide
- Travertine (dimension stone), Meso del Oro, west of Belen
  - 477.6 million tons of travertine

URANIUM IN NEW MEXICO 2022

- 2nd in uranium resources 15 million tons ore at 0.277% U3O8 (84 million lbs U3O8) at $30/lb (DOE estimates in 2002)
- Numerous companies have acquired properties (Strathmore, Energy Minerals, Laramide Resources, among others)
- Energy Fuels acquired Strathmore in 2013 and is now permitting the Roca Honda mine
- HRI, Inc. awaiting permits for in situ leach in Church Rock, Ambrosia Lake areas
- Several exploration permits approved or in progress
- Mt. Taylor mine changed status from active to reclamation


Mount Taylor head frame, 2006



Deposits with uranium resources in New Mexico (McLemore and Chenoweth, 2019). Only major mines and deposits are included here.

CRITICAL MINERALS IN NEW MEXICO

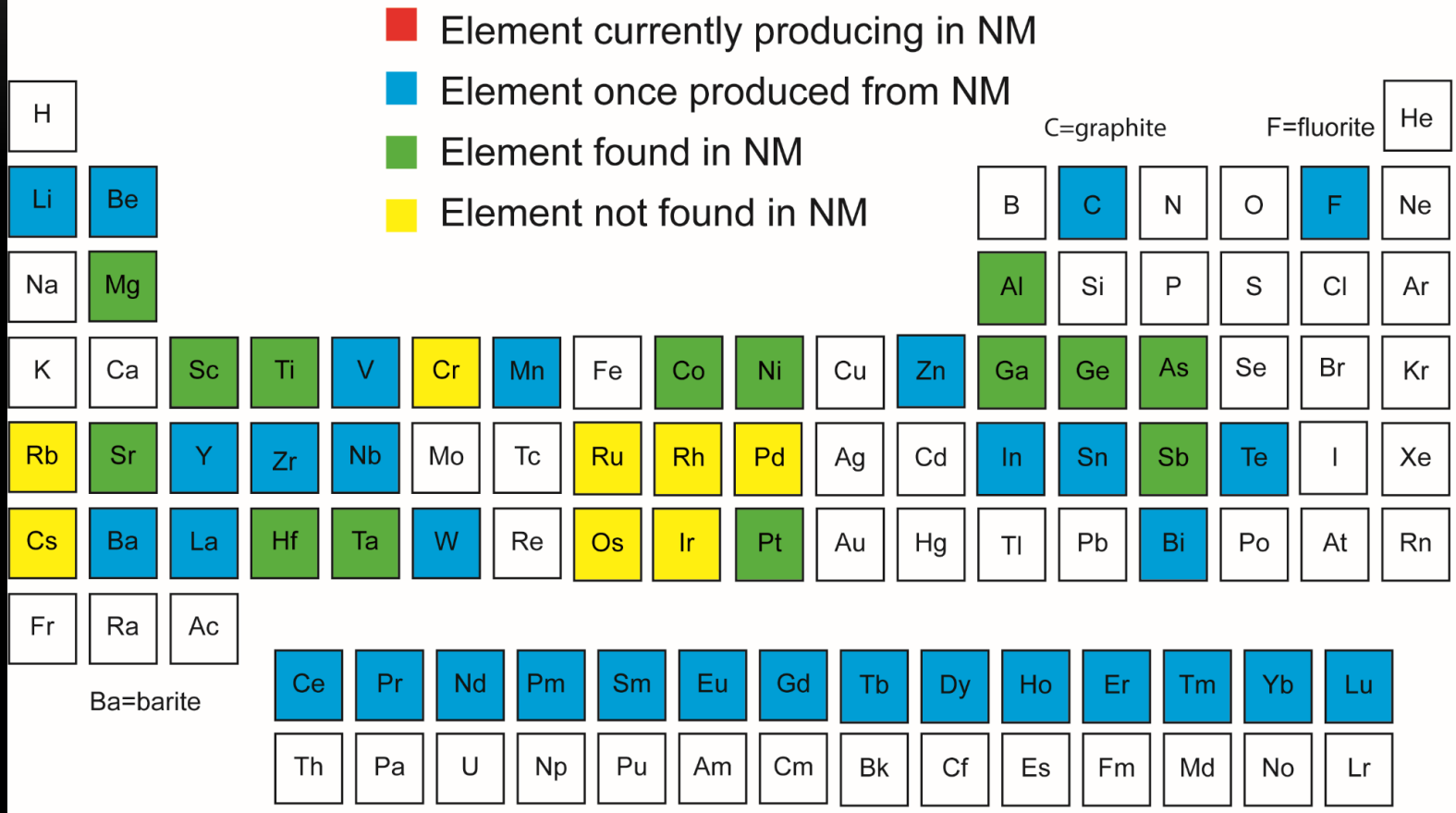
CRITICAL MINERAL

- *is a mineral (1) identified to be a nonfuel mineral or mineral material essential to the economic and national security of the United States, (2) from a supply chain that is vulnerable to disruption, and (3) that serves an essential function in the manufacturing of a product, the absence of which would have substantial consequences for the U.S. economy or national security*
- President Trump signed an executive order (Presidential Executive Order (EO) No. 13817) that requires the Departments of Interior and Defense to develop a list of critical minerals
- In 2021, the critical minerals list was modified by the Biden administration deleting uranium and potash and adding nickel and zinc

CRITICAL MINERALS

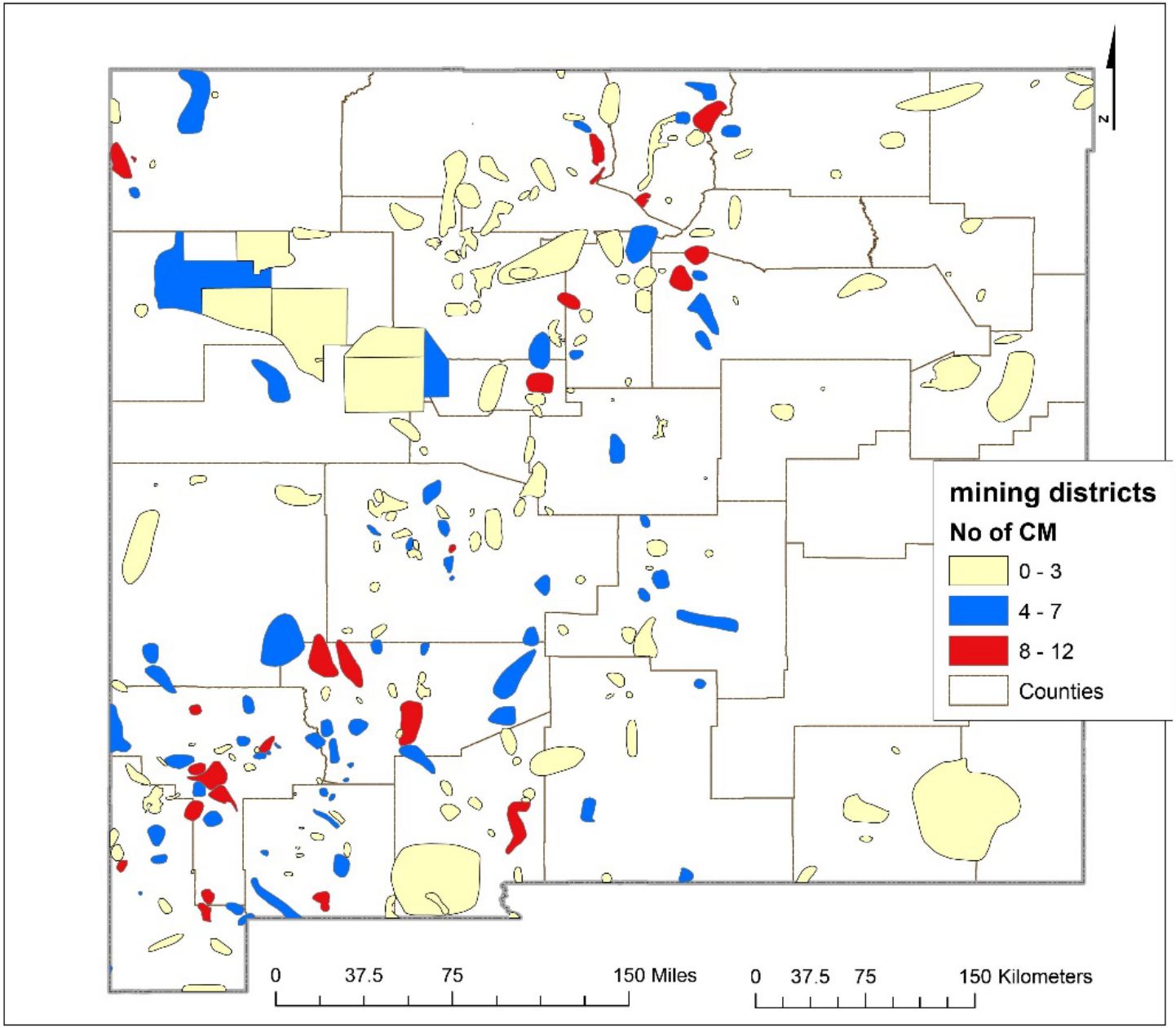
- Over 50 critical minerals are identified
- New Mexico has many of these critical minerals
  - Copper deposits in Grant County contain rhenium, indium, gallium, germanium, and zinc
  - Uranium deposits in the Grants district contain Se, REE, V, Mo
  - Exploration for other critical minerals include REE, tellurium, lithium, beryllium, cobalt
  - Other critical minerals were once produced from New Mexico (tin, vanadium, manganese, fluorspar, barite, graphite, zinc)

Critical Minerals in New Mexico

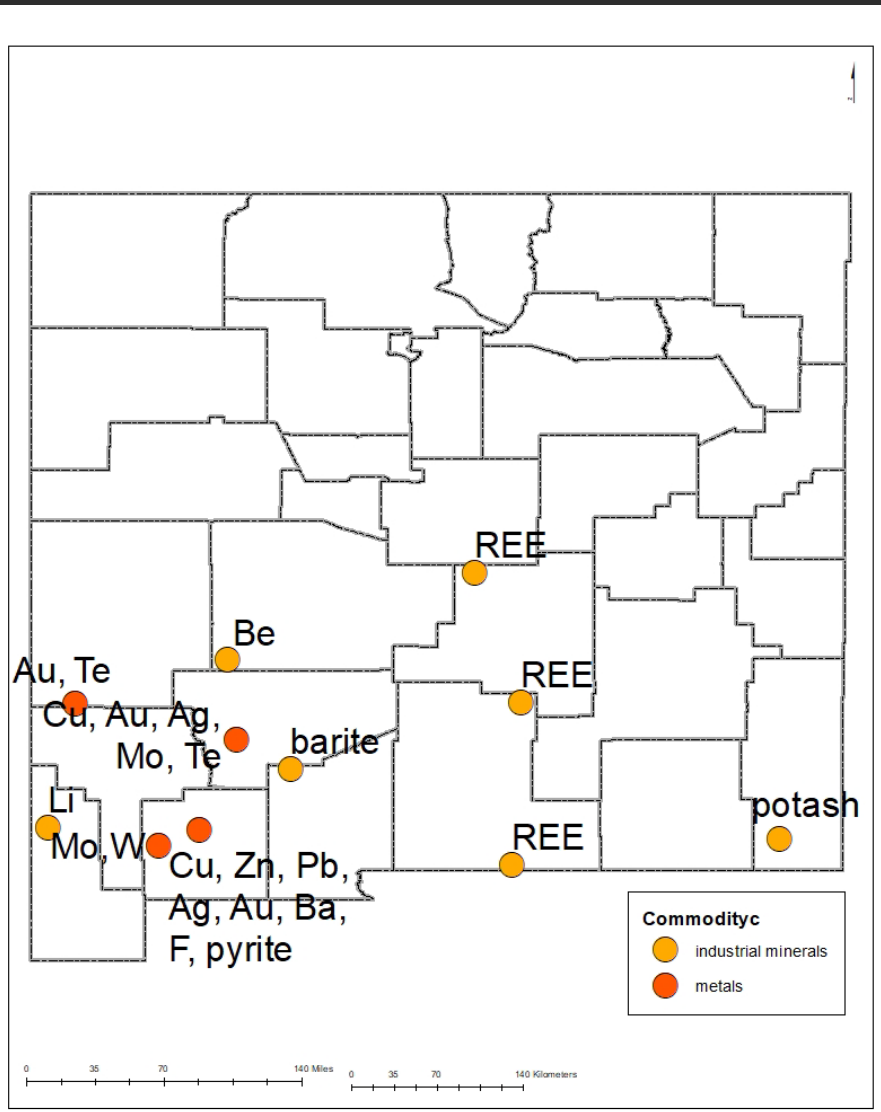


Note that any element or commodity can be considered critical in the future depending upon use and availability. Coal contains several of these critical elements.

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


N
mining districts
No of CM
0 - 3
4 - 7
8 - 12
Counties
0
37.5
75
150 Miles
0
37.5
75
150 Kilometers

SELECTED EXPLORATION SITES OF CRITICAL MINERALS IN NEW MEXICO

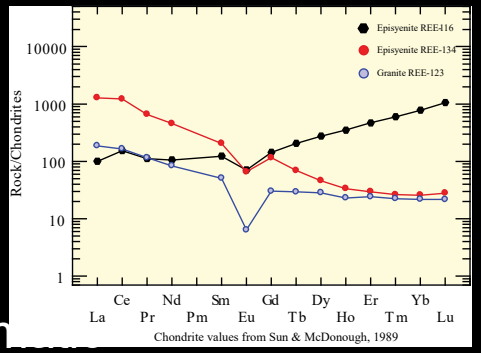


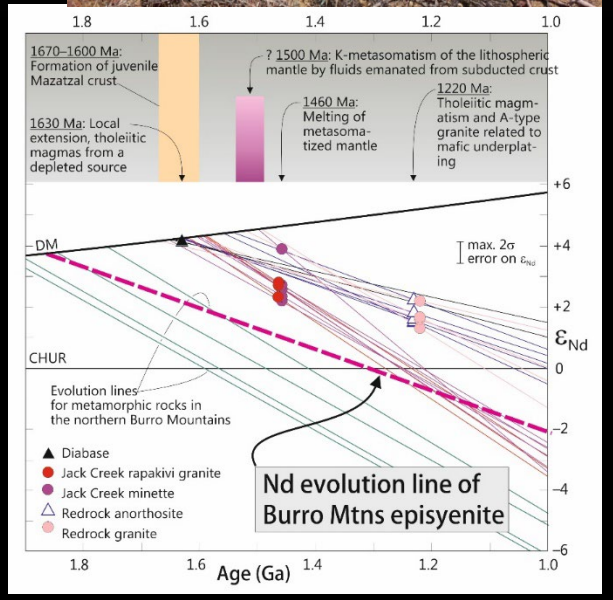
From NM Mining and Minerals Div. and NMBGMR databases, company web sites

RARE EARTH ELEMENTS

USGS MRERP
Mapping and origin of REE in Cambrian-Ordovician Episyenites in the Caballo and Burro Mountains, southern NM (2012-2022)

Annelise Riggins
Nelia Dunbar,
Virginia McLemore
Matthew Heizler
William McIntosh
Kwame Frempong
Adam Smith
Tapani Ramo (Univ Helsinki)





- Brick-red episyenites are metasomatic in origin, possibly related to alkaline or carbonatite intrusions at depth
- REE minerals are associated with altered amphiboles, magnetite, secondary chlorite, hematite, zircon, and fluorite
- Samples have low-moderate TREE, Th, and U; but some samples have relatively high HREE

Epsilon Nd versus age diagram showing evolution line of episyenite compared to Redrock gr, Jack Creek gr and metamorphics. The line is between the time-intergrated evolution of the granites and metamorphics, suggesting that the episyenite may comprise a magmatic source and a fluid component from the upper crust Matzazal metamorphics.

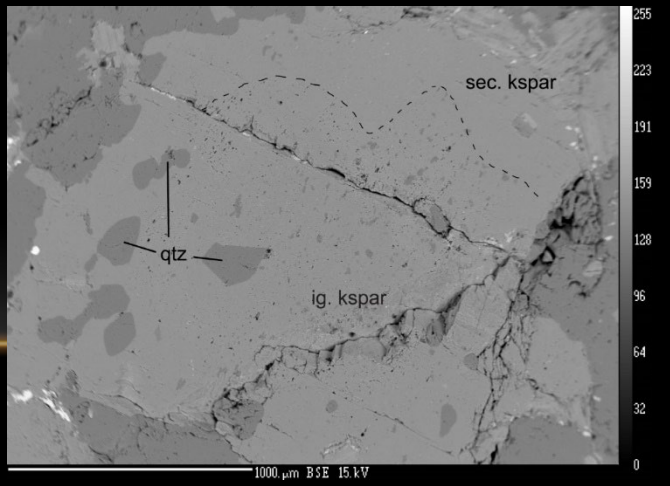
Conclusions from project

- Field relationships and whole-rock chemistry (>15% K_2O) suggest episyenites are metasomatic in origin
- Fracture-filling episyenites indicates fluid flow along fractures
- Feldspar compositions suggest low temperature formation

Contact between granitic gneiss and episyenite in Caballo Mtns

Clasts of episyenite in the basal transgressive conglomerate of the Bliss Formation

Backscatter electron image of K-feldspar



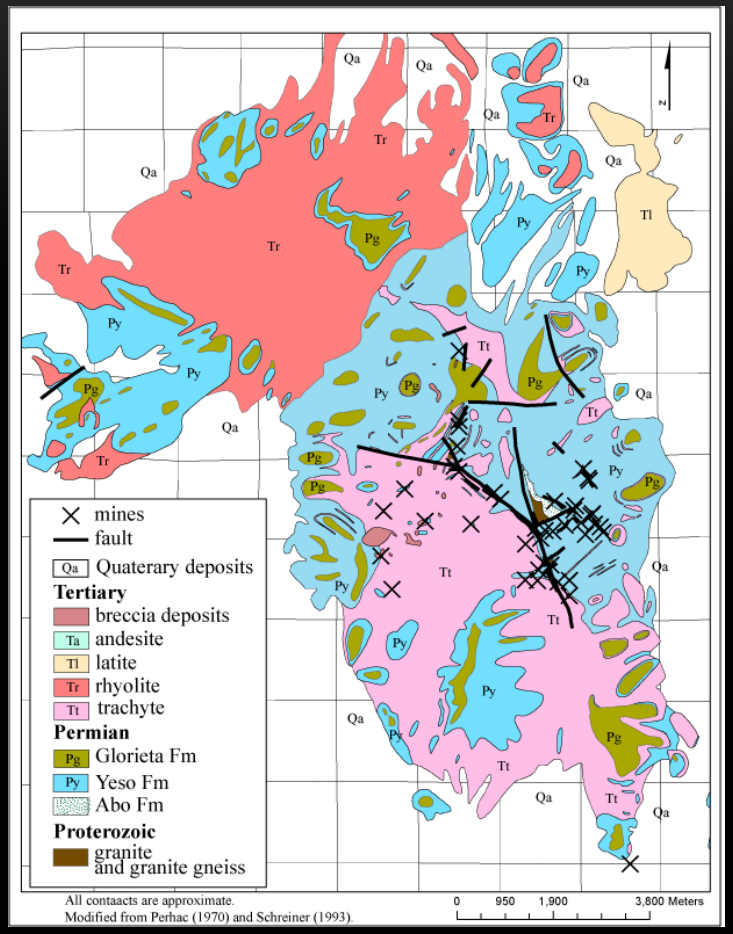
USGS Earth MRI Project Mapping REE in Gallinas Mountains, Lincoln County, NM (2019-2021)

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

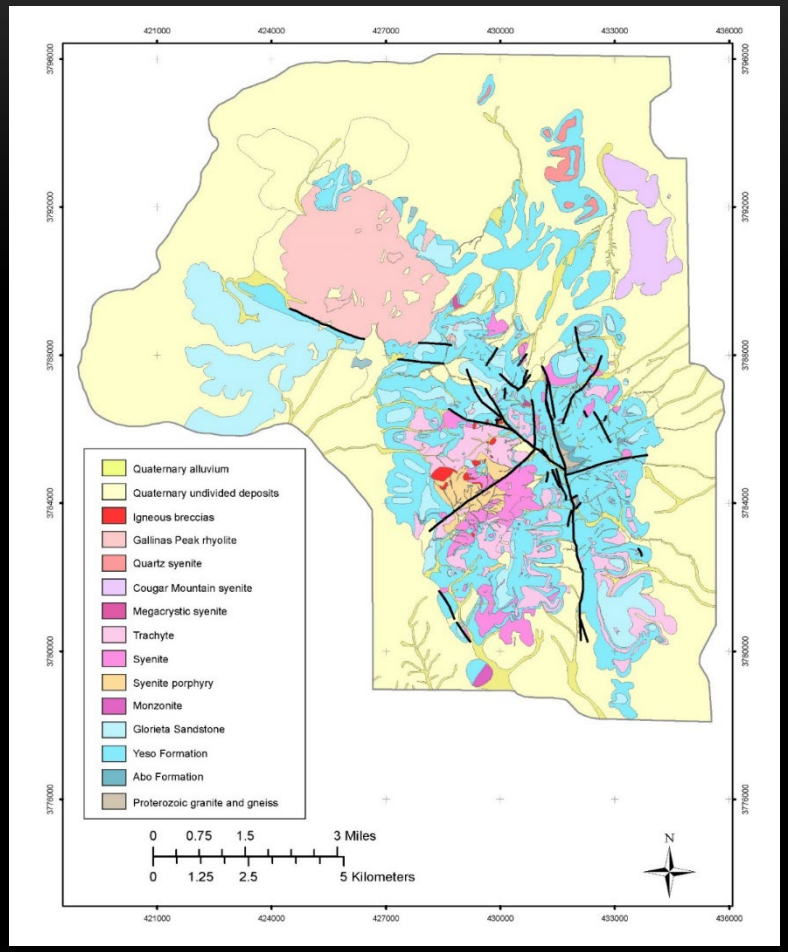
Yellow bastnäsite [(Ce,La)(CO_3)F] in purple fluorite breccia from the Red Cloud mine (length is ~8 mm). Bastnaesite is the most common REE mineral mined in the world today.

$^{40}Ar/^{39}Ar$ 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)



New mapping identified numerous mines and prospects, veins, faults, and subdivided the igneous intrusions



Historic geologic map of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico (Perhac, 1970)

New geologic map of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico

CONCLUSIONS FROM PROJECT

Seven types of mineral deposits (* past production)

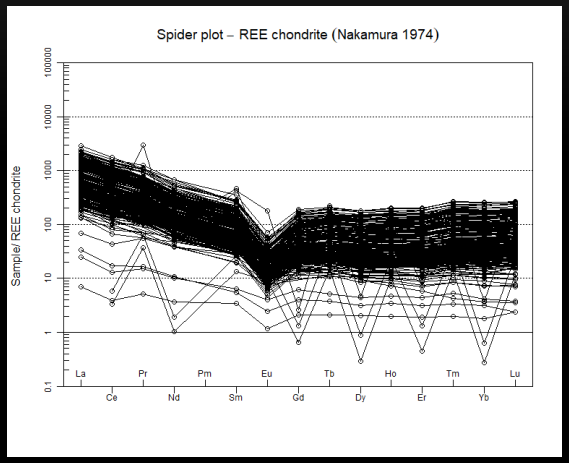
- *Hydrothermal breccia and fissure veins (red)
- F replacements/dissemination s
- Magamtic intrusive breccia pipes (maroon)
- *Fe skarn-contact replacement deposits
- Carbonate breccias
- Hypogene oxidation
- Supergene oxidation

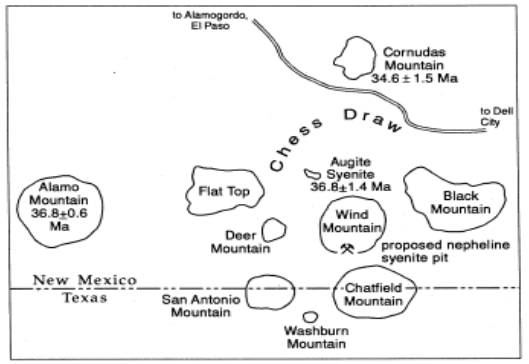
Major faults are not mineralized with the exception of the Pride and Buckhorn faults

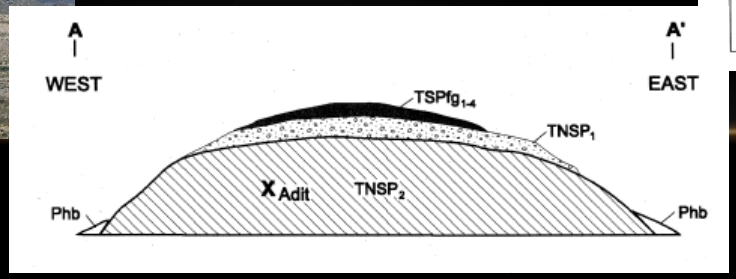
USGS Earth MRI Project
Mapping REE in Cornudas Mountains, Otero County, NM (2020-2022)

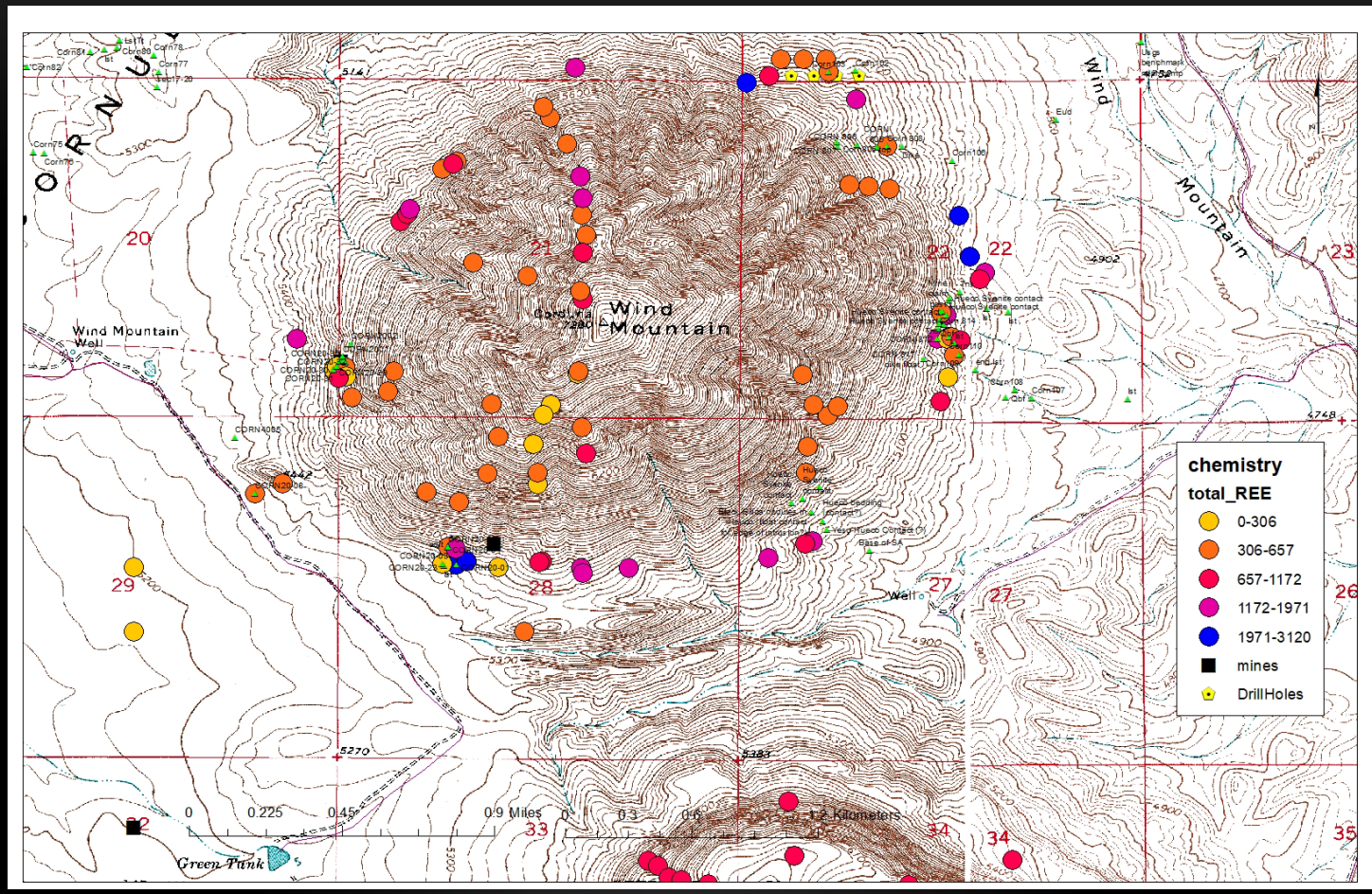
Drs. Virginia McLemore, Nels Iverson, Snir Attia, and students

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





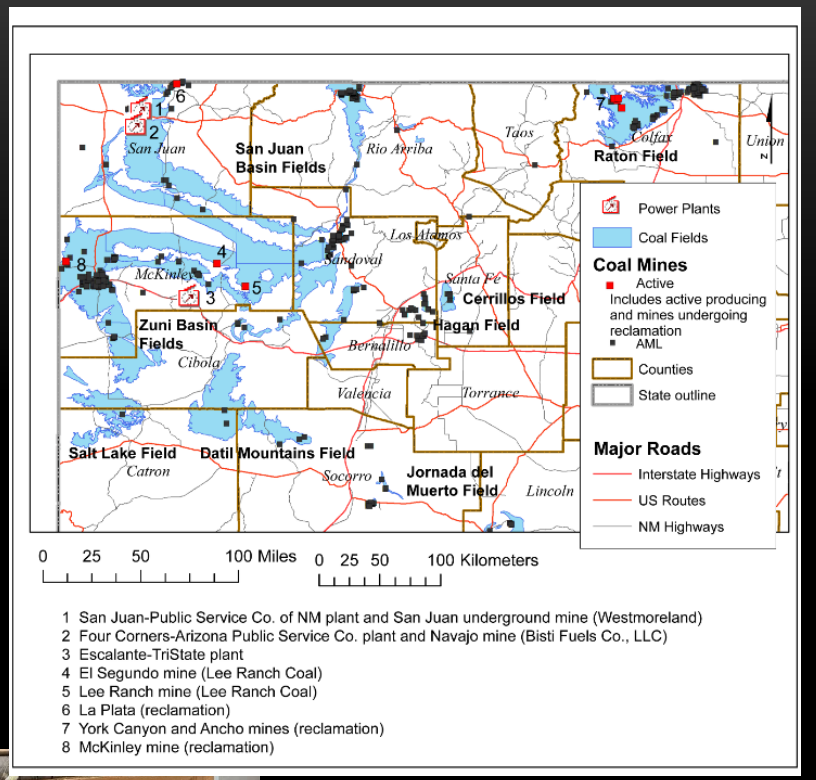




Samples from Wind Mountain

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

- 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



SAN JUAN COLLEGE

New Mexico Tech

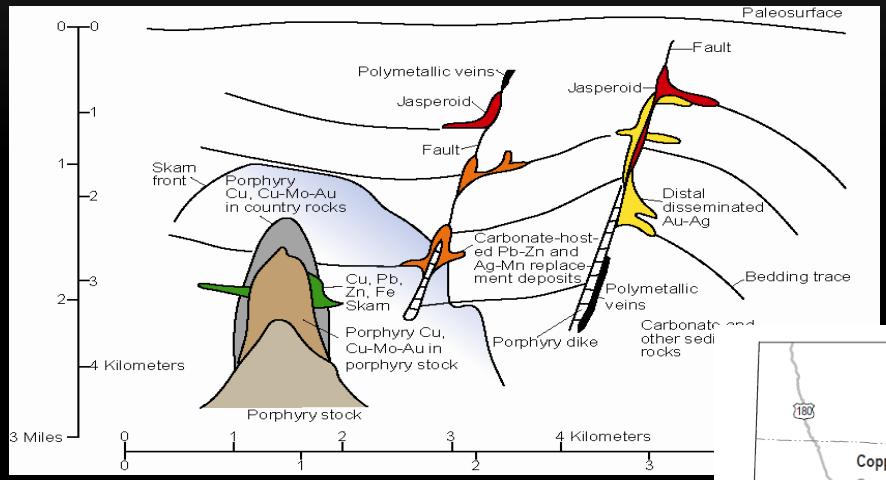
Sandia National Laboratories

Los Alamos NATIONAL LABORATORY EST. 1943

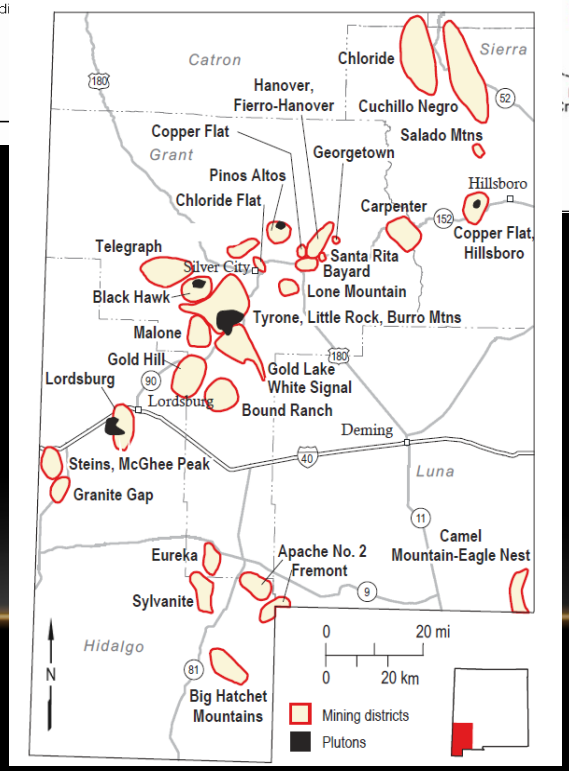
SonoAsh

New Mexico Bureau of Geology and Mineral Resources
New Mexico Tech
Earth Science for the 21st Century

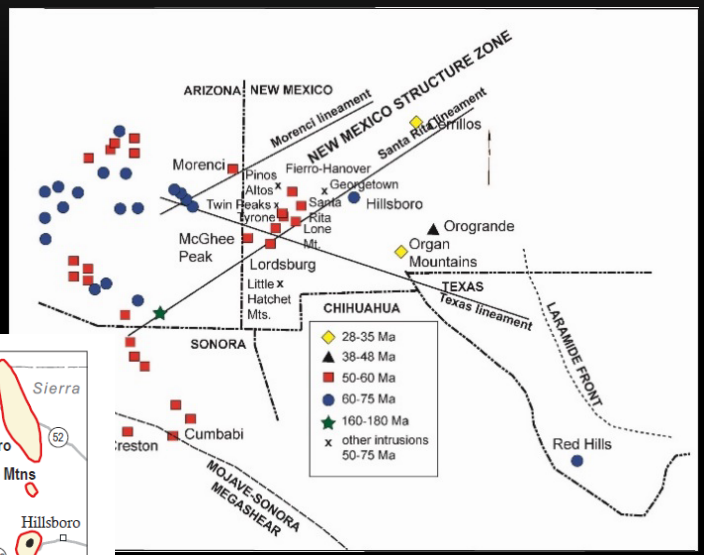
USGS EARTH MRI PROJECT
CRITICAL MINERALS IN LARAMIDE PORPHYRY COPPER DEPOSITS (AUG 2022—JULY 2025



Simplified settings of porphyry copper and associated deposit types (John, 2010).

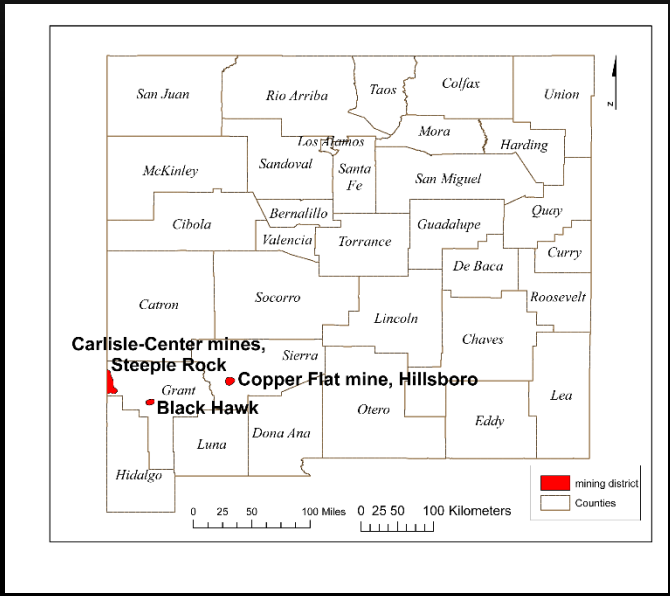


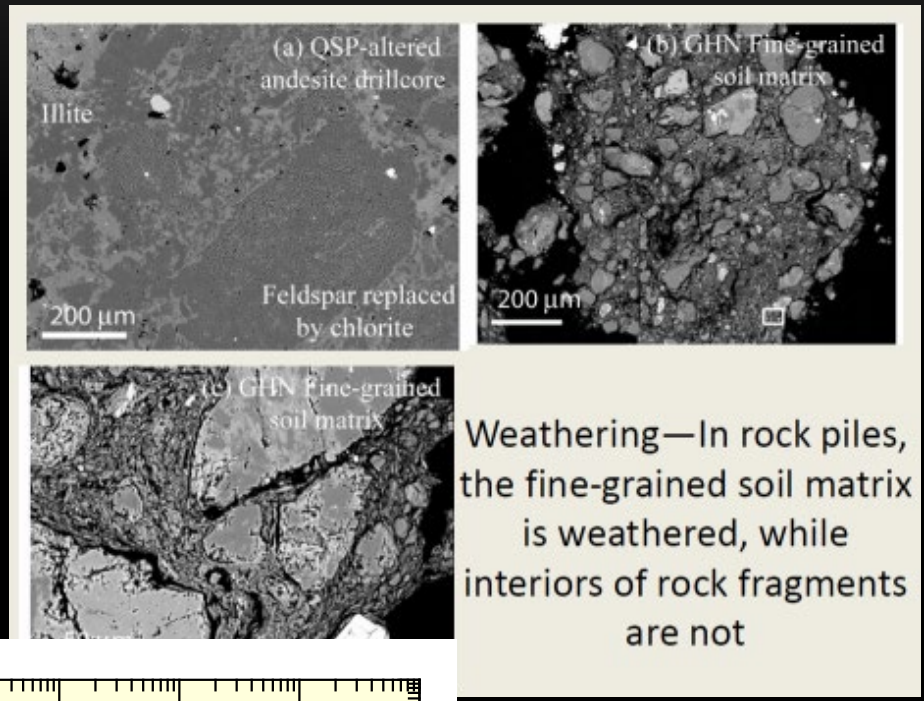
Districts with Laramide deposits and plutons (black) in southwestern New Mexico



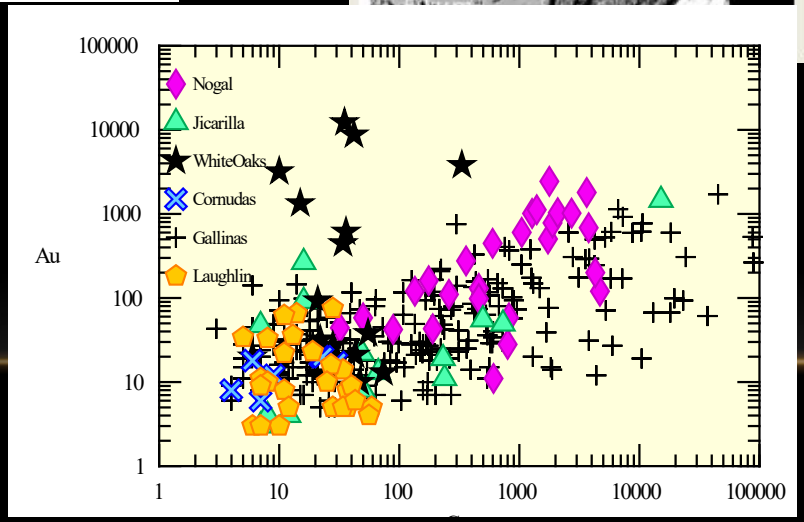
Laramide porphyry copper deposits in southwestern United States and northern Mexico. The Copper Flat porphyry copper deposit is in the Hillsboro district.

USGS EARTH MRI PROJECT
CRITICAL MINERALS FROM MINE WASTES
(AUGUST 2022-JULY 2024)





Weathering—In rock piles, the fine-grained soil matrix is weathered, while interiors of rock fragments are not



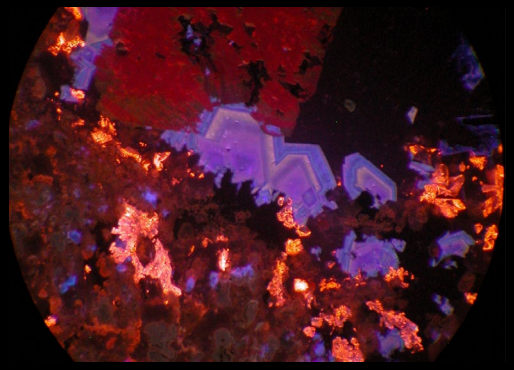
Gold vs copper, alkaline-related deposits, New Mexico

Ore Deposits and Critical Minerals Research Group

Alexander Gysi
NM Bureau of Geology and Mineral Resources
Department of Earth and Environmental Science, NMIMT

Research

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



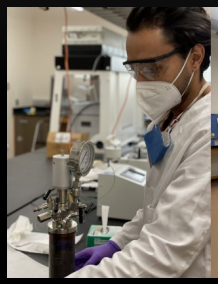
Funding of ~ $3M from DOE and NSF-EAR/-CAREER

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

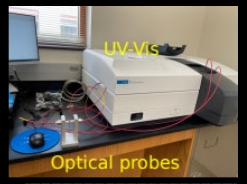
Ore Deposits and Critical Minerals Experimental Lab

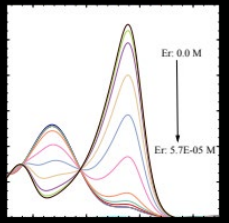
- Hydrothermal fluid-mineral experiments
  - Synthesis/dissolution of REE minerals (xenotime, monazite)
  - REE incorporation into calcite, fluorite, apatite



Thermodynamic properties of critical minerals and their solid solutions

- Hydrothermal solution calorimetry (enthalpy of mixing), heat capacity measurements, and mineral stability

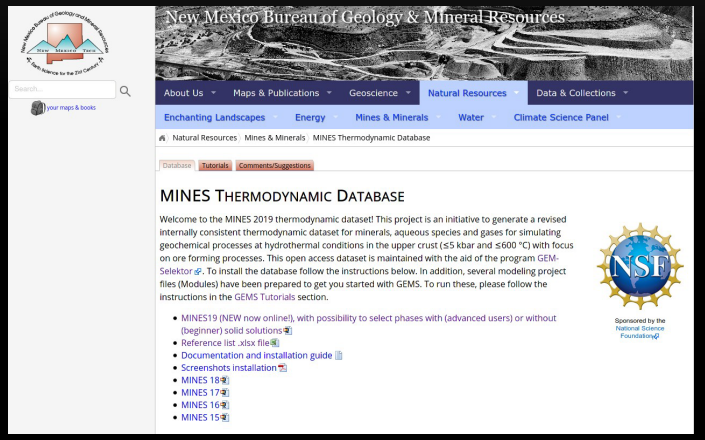




- UV-vis spectrophotometry
  - High temperature complexation of aqueous REE species
  - Flow-through experiments
- NEW Raman laser – hydrothermal diamond anvil cell facility – NSF MRI/DOE research hub

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://apgysi.github.io/gems-mines-tutorial/



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

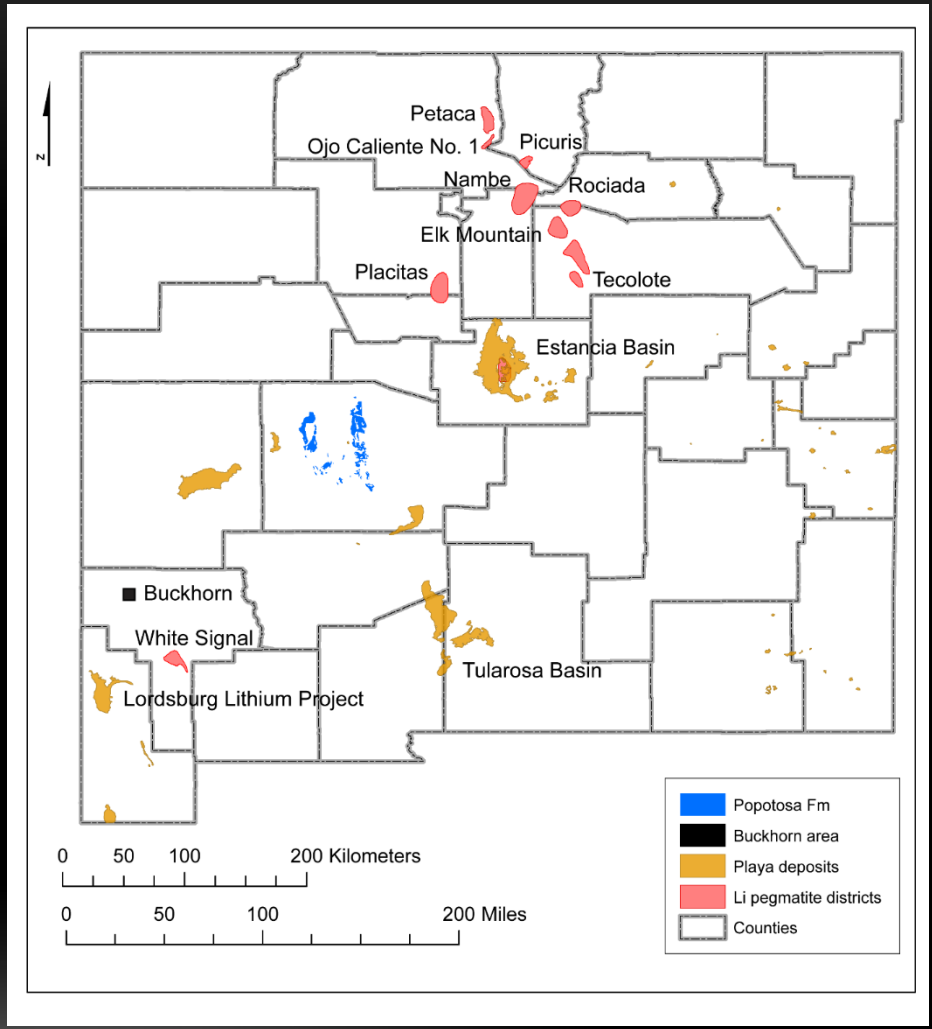
OTHER PROJECTS

- Preserve Geoscience Data and Materials: Priority II Data Preservation of Critical Minerals in New Mexico: Year 3 USGS contract No. G21AP10434 (Aug 2021-July 2022)
  - Undergrad students projects
  - Logging and photographing drill core
  - Database of geochemical analyses
  - Archiving ore and mineralized samples
- Mineral-Resource Potential of Southwestern New Mexico, including critical minerals BLM contract 140L0321P0009-FE (June 2021-Feb 2022)
  - Undergrad students projects
  - Determine the mineral-resource potential for land exchanges

LITHIUM IN NEW MEXICO

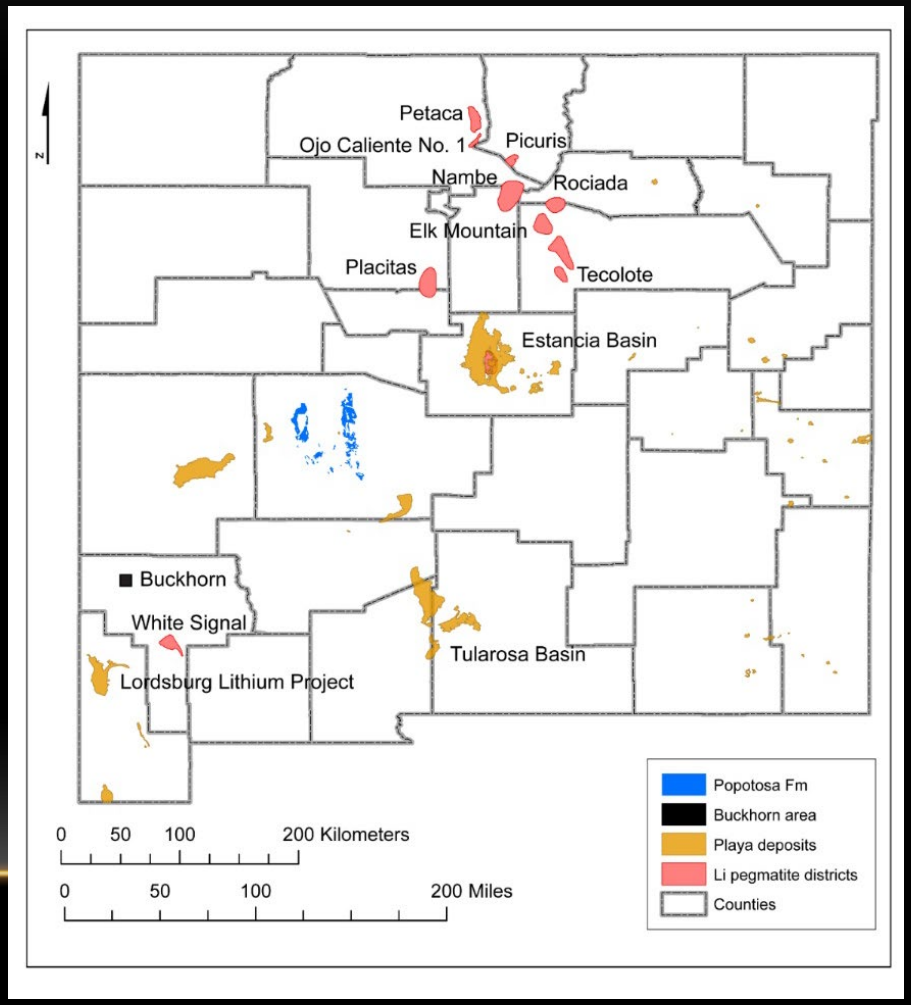
TYPES OF LITHIUM DEPOSITS IN NM

More than 13,000 short tons of lepidolite ore and several hundred short tons of spodumene ore have been produced from pegmatites in New Mexico in 1920-1950.

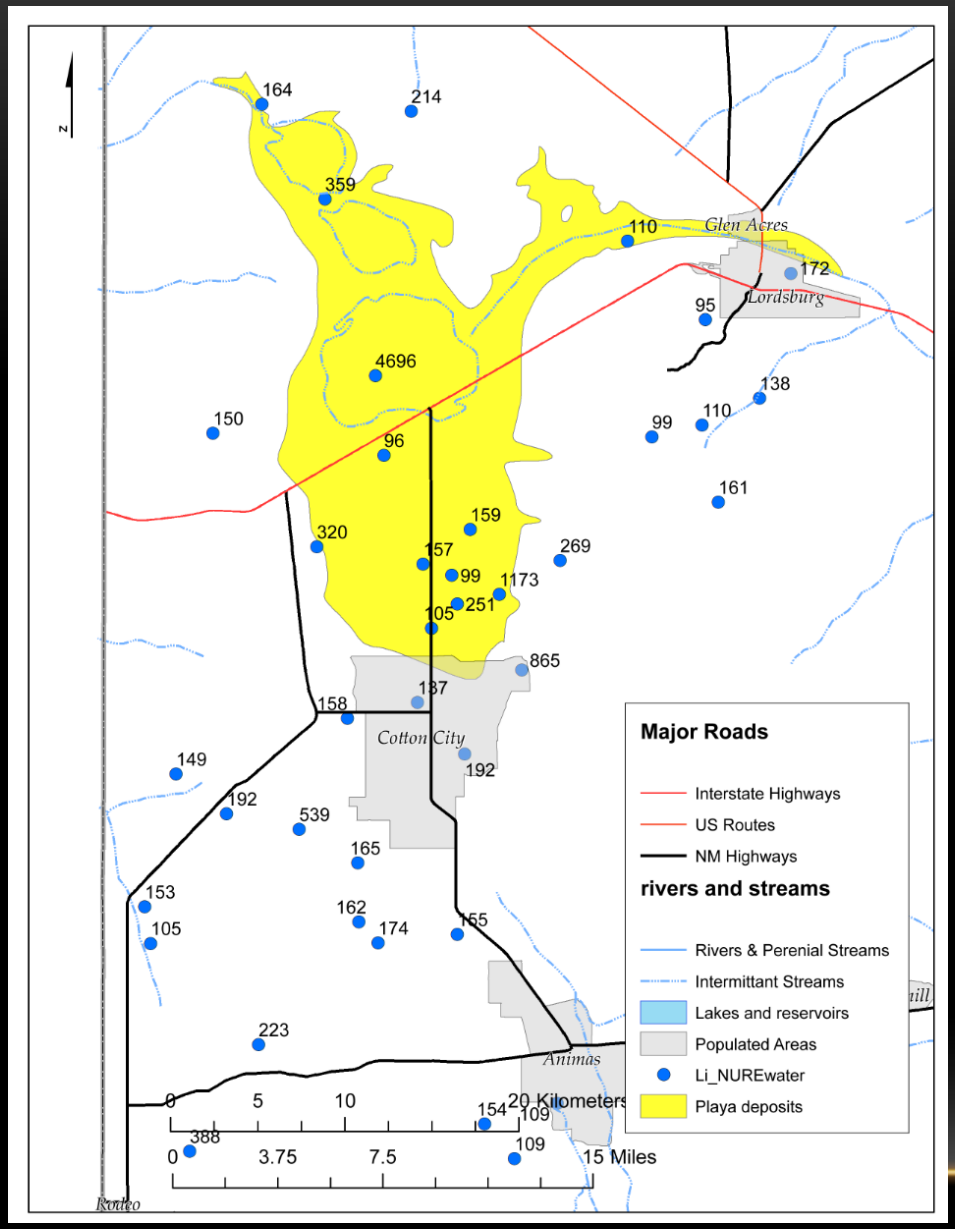


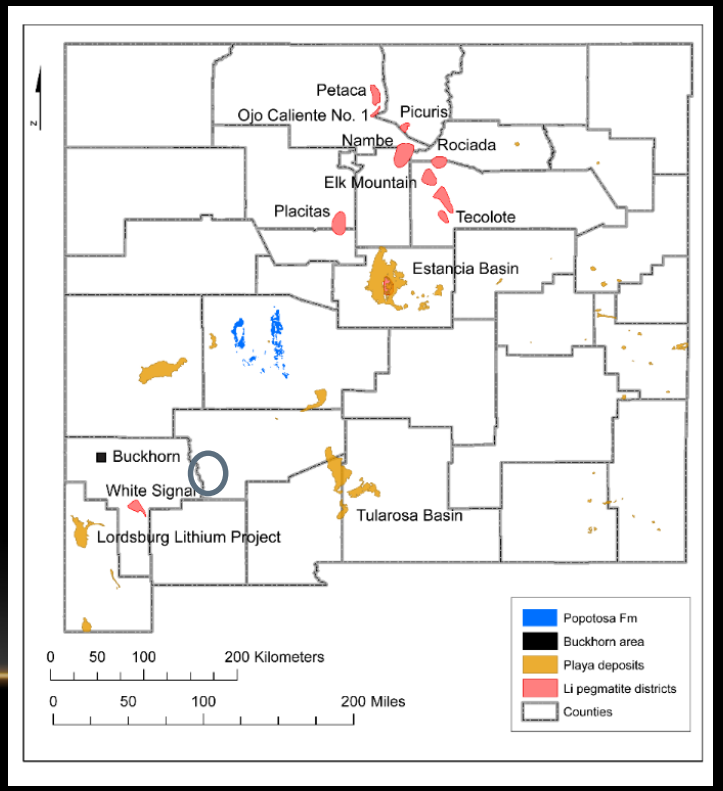
BRINE, HYDROTHERMAL (GEOTHERMAL), AND PLAYA DEPOSITS

- Closed basins
- Derived from weathering of lithium-enriched rhyolite and other volcanic rocks
- Locally associated with geothermal springs and wells

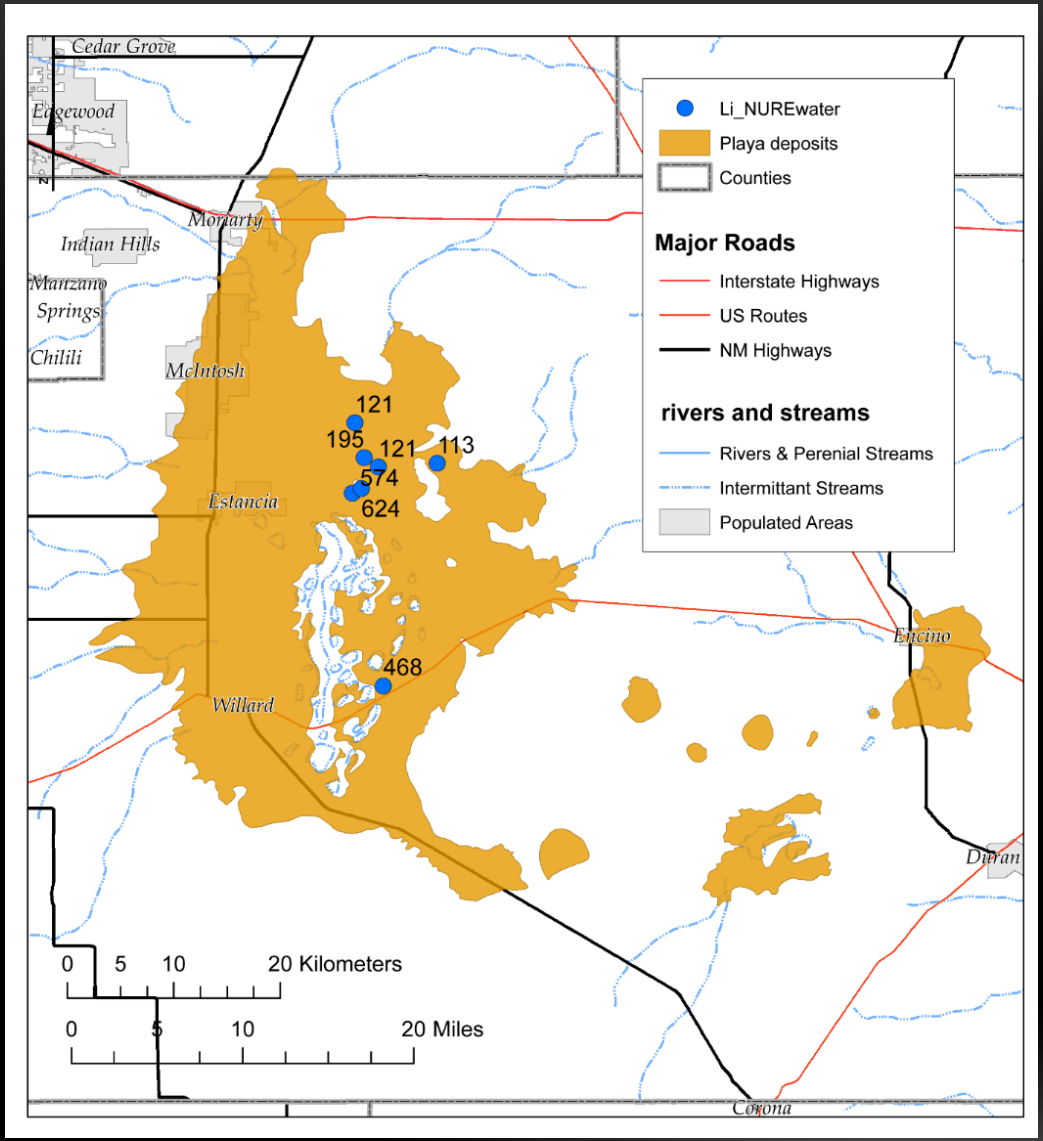


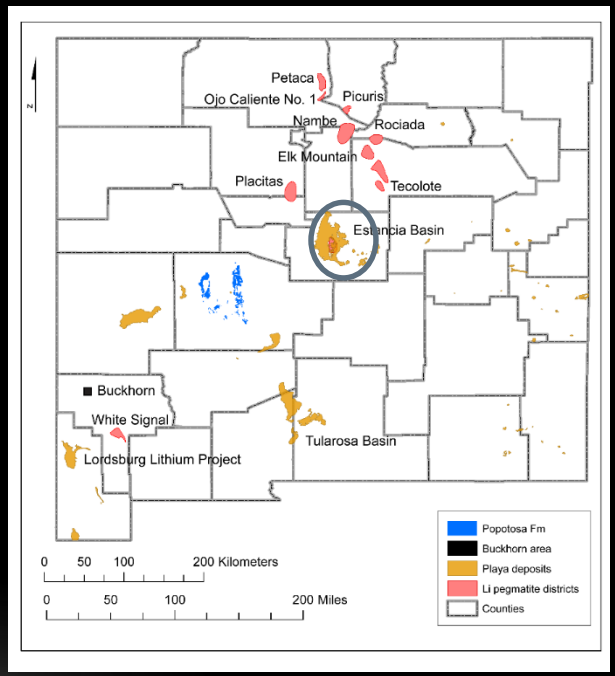
Lordsburg Lithium Deposit, Hidalgo County





Estancia Lake, Torrance County





MINING ISSUES FACING NEW MEXICO

- Many inactive mines still have the potential to contaminate the environment or present a hazard to health and safety
  - Gold King spill
  - AML sites (Abandoned mine lands)
  - Grants uranium district

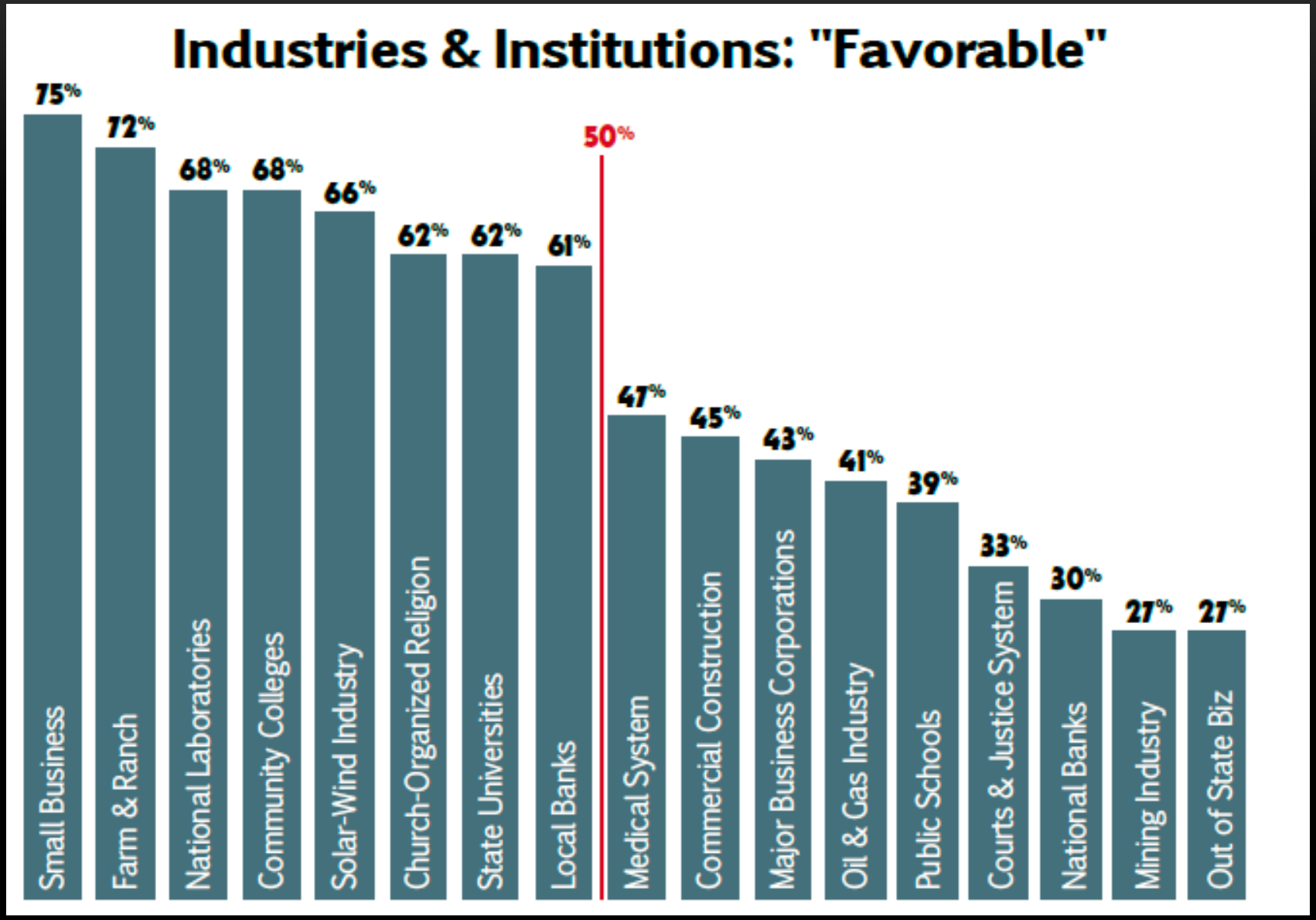
MINING ISSUES FACING NEW MEXICO

- Some current mines are reaching the end of their life and will close over the next decade=decreasing minerals production
- There are not many new mines to replace them
- Mining requires water and their environmental effects must not impact water supplies
- Results in unemployment and decrease in revenues
  - Affects rural economies
  - Affects state revenues
- Legacy issues of past mining activities form negative public perceptions of mining
  - Abandoned or legacy mines, especially Grants uranium district and Questa mine
  - Gold King spill
  - Not in my backyard!!!!!!

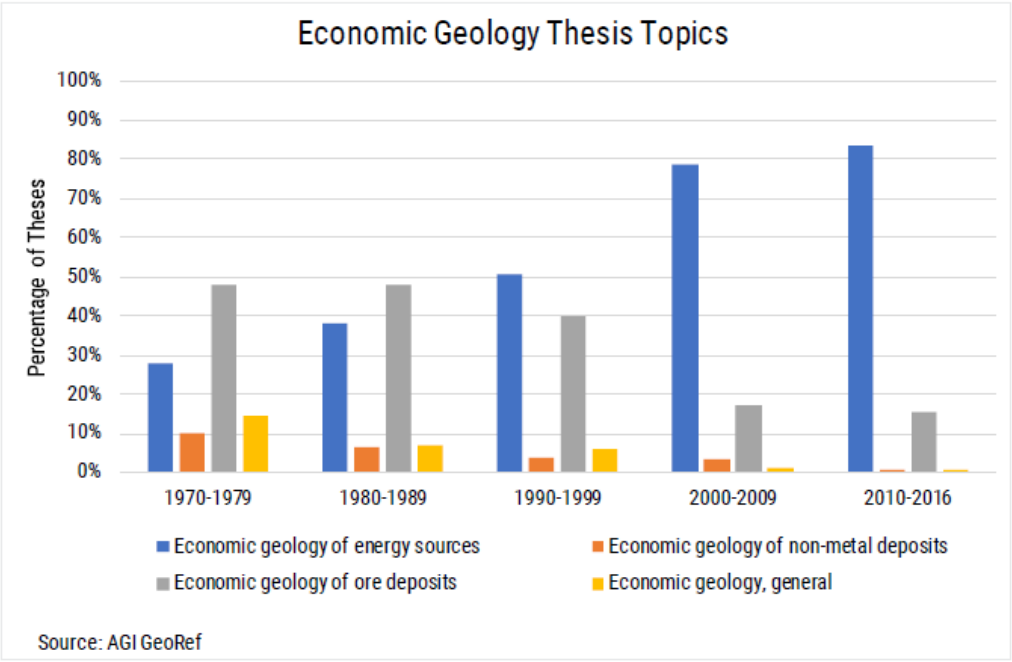
MINING ISSUES FACING NEW MEXICO—CONTINUED

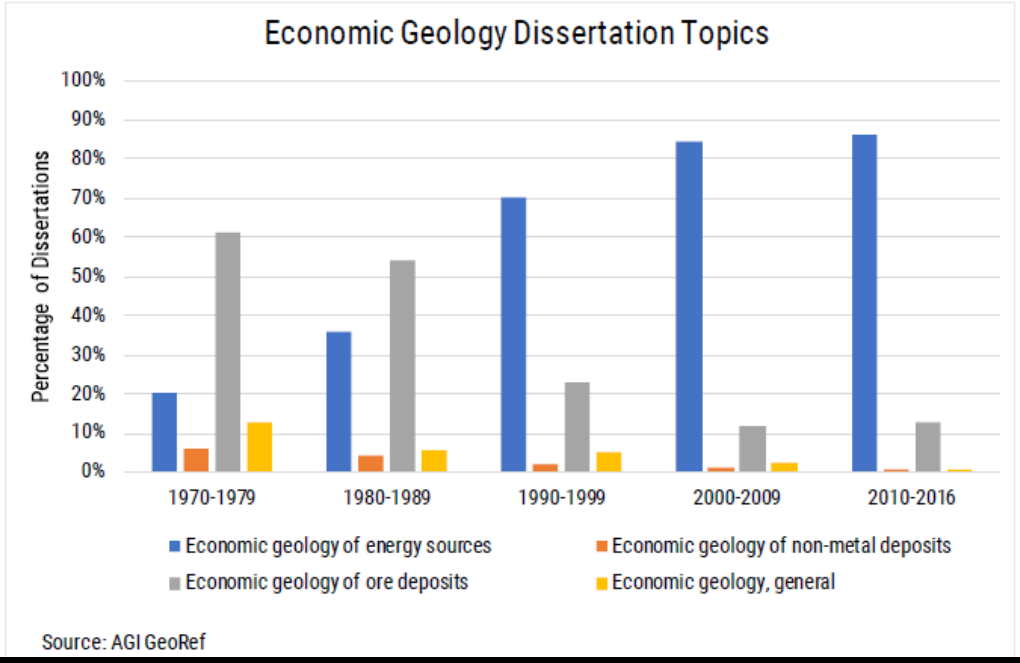
- Global competition is closing some of our mines
- Exploration for new deposits often results in drill targets based upon regulatory minimal impact regulations rather than optimum geological criteria
- Permitting for exploration can take longer than exploration funds are available
- Lower prices=closed mines, little exploration
- In some areas conflicts arise between mining and other activities
  - Grants uranium district
  - Otero Mesa
  - Pecos/Tererro mine
  - **Water, don't want a mine in their backyard**
- Shortage of young geologists and engineers to explore for, develop, mine, permit these commodities and evaluate their effect on the environment—math, science skills critical

Mining is viewed as favorable by only 27% of New Mexicans



http://garritypr.com/sites/default/files/uploads/documents/2017_Garrity_Perception_Survey.pdf





Number of thesis and dissertations on non-energy economic geology has decreased

http://www.multibriefs.com/briefs/aipg/DataBrief_2019_008_EconomicGeologyThesesDissertations.pdf

SUMMARY

- New Mexico has a wealth of mineral resources
- The New Mexico Bureau of Geology and Mineral Resources has a long history in critical minerals research
  - We have a number of ongoing research projects in the broad field of critical minerals, with strong field and laboratory components
- Exploration and permitting takes many years before a deposit can be mined in NM, >10 yrs
- Legacy issues are being addressed
- Negative public perceptions are major issue as is funding
- Global competition is a major challenge
- NMBG/NMT research is addressing some of these issues, as well as actively training future geologists and engineers

MORE INFORMATION

- NM Mines and Minerals Division

  http://www.emnrd.state.nm.us/MMD/

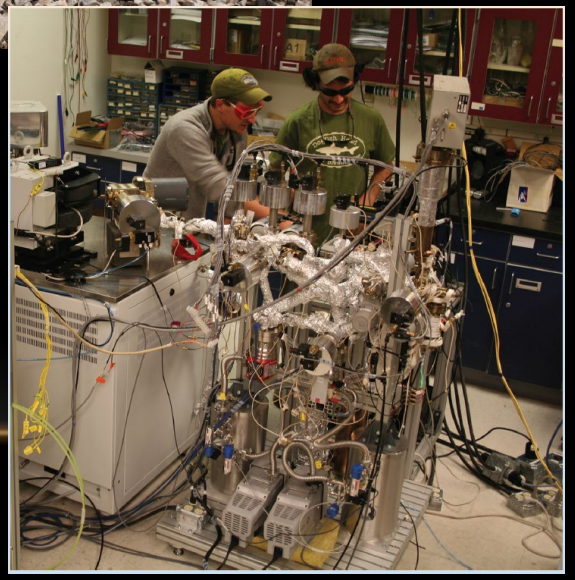
  Virginia McLemore web page

  http://geoinfo.nmt.edu/staff/mclemore/home.html

- New Mexico Bureau of Geology and Mineral Resources

  http://geoinfo.nmt.edu/

RESEARCH



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

QUESTIONS?