CRITICAL MINERALS IN NEW MEXICO

Virginia T. McLemore

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

ACKNOWLEDGEMENTS

- Many colleagues who contributed to and reviewed manuscripts over the years, especially Robert North, Felix Mutschler, Steve Ludington, and Miles Silverman
- Student assistants Haley Dietz, Ethan Haft, Felix Rotich, Nico Harrison, Carmin Vasquez, Evan Owen, and Keith Diegel
- Partial funding by USGS National Geological and Geophysical Data Preservation Program (NGGDPP) and Earth Mapping Resources Initiative (MRI)
- A student grant from New Mexico Geological Society, Society of Economic Geologists, NMT Brightstar Scholarship

Definition of Critical Minerals

are minerals

(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

Critical Minerals

- 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
- May 18, 2018 U.S. Department of Interior published the final list of critical minerals

Elements in Computer Chips
(National Research Council, 2007)

elements needed in 1980s

additional elements needed today

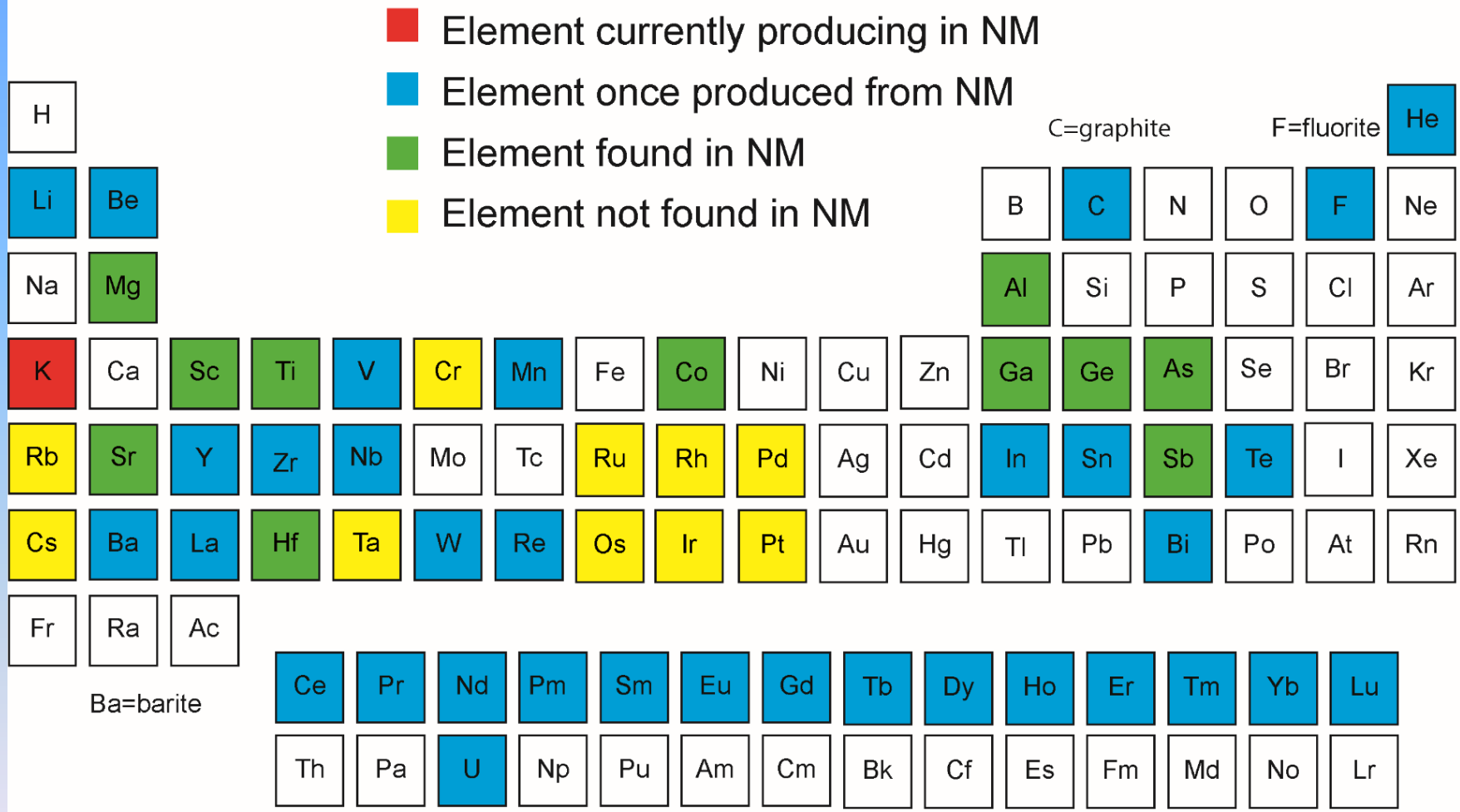
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															
			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

Critical Minerals

- 35 critical minerals were identified
- 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, also contain vanadium
  - 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

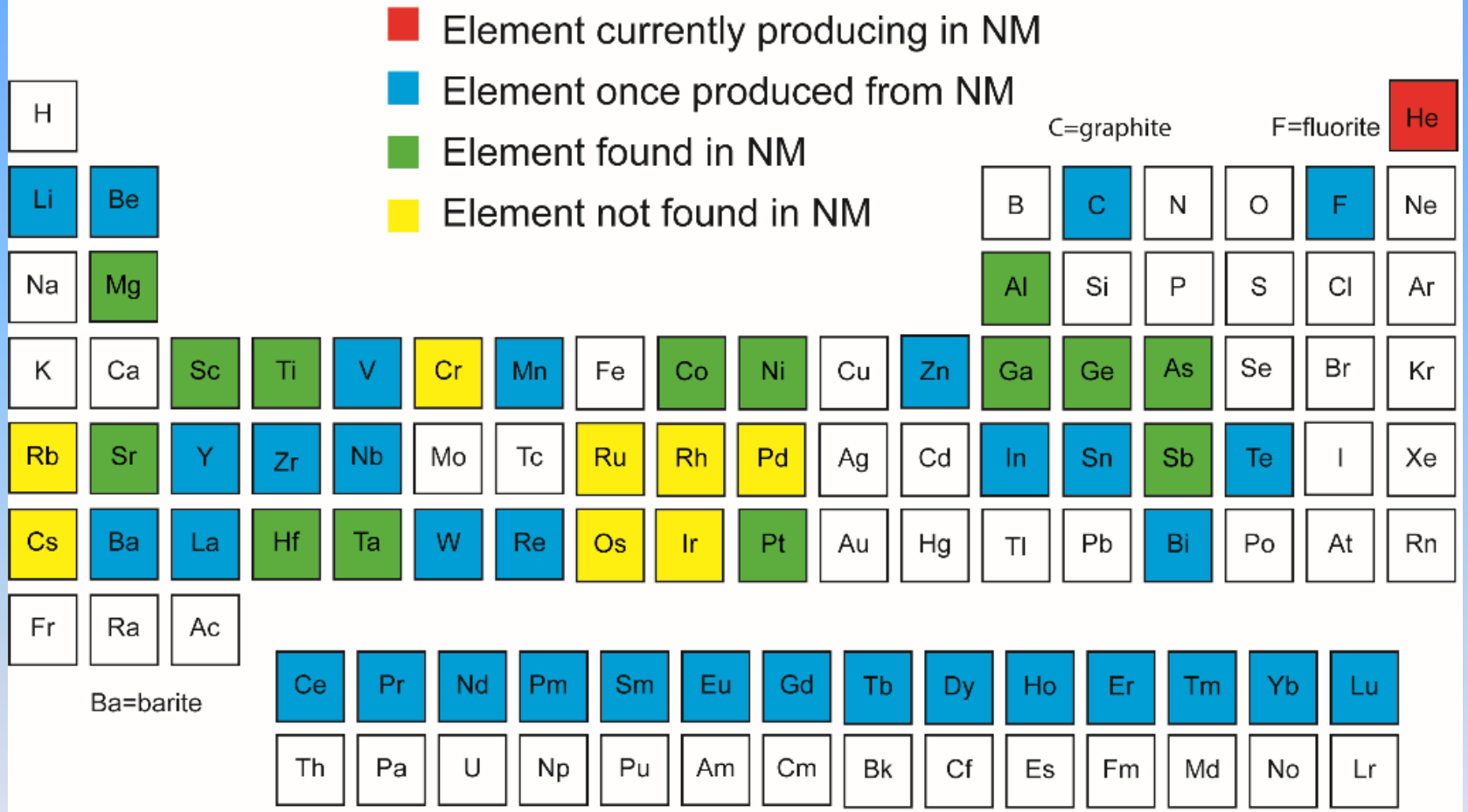
2020



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.

Critical Minerals in New Mexico

2022

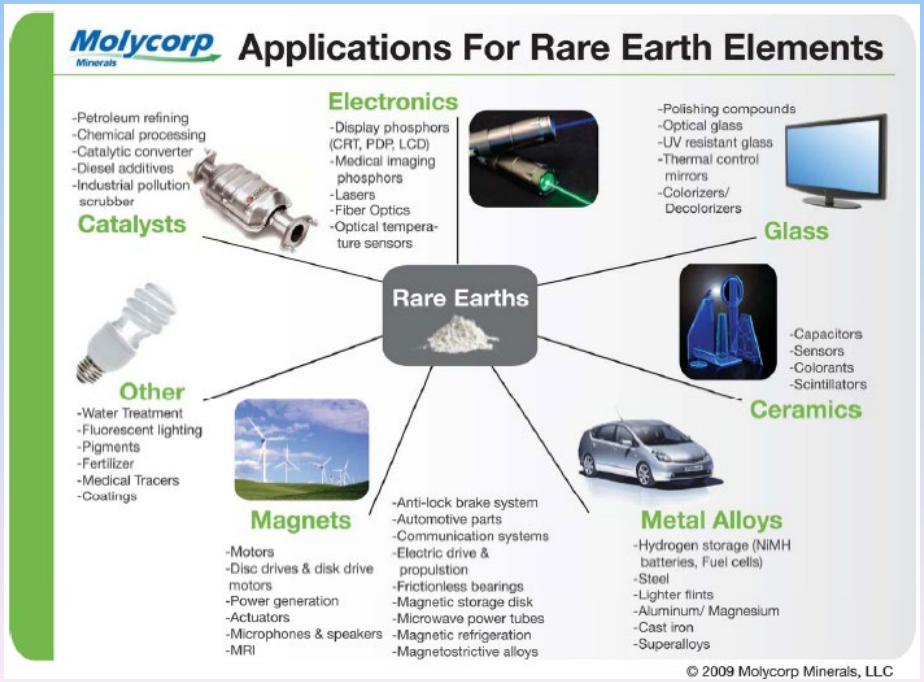


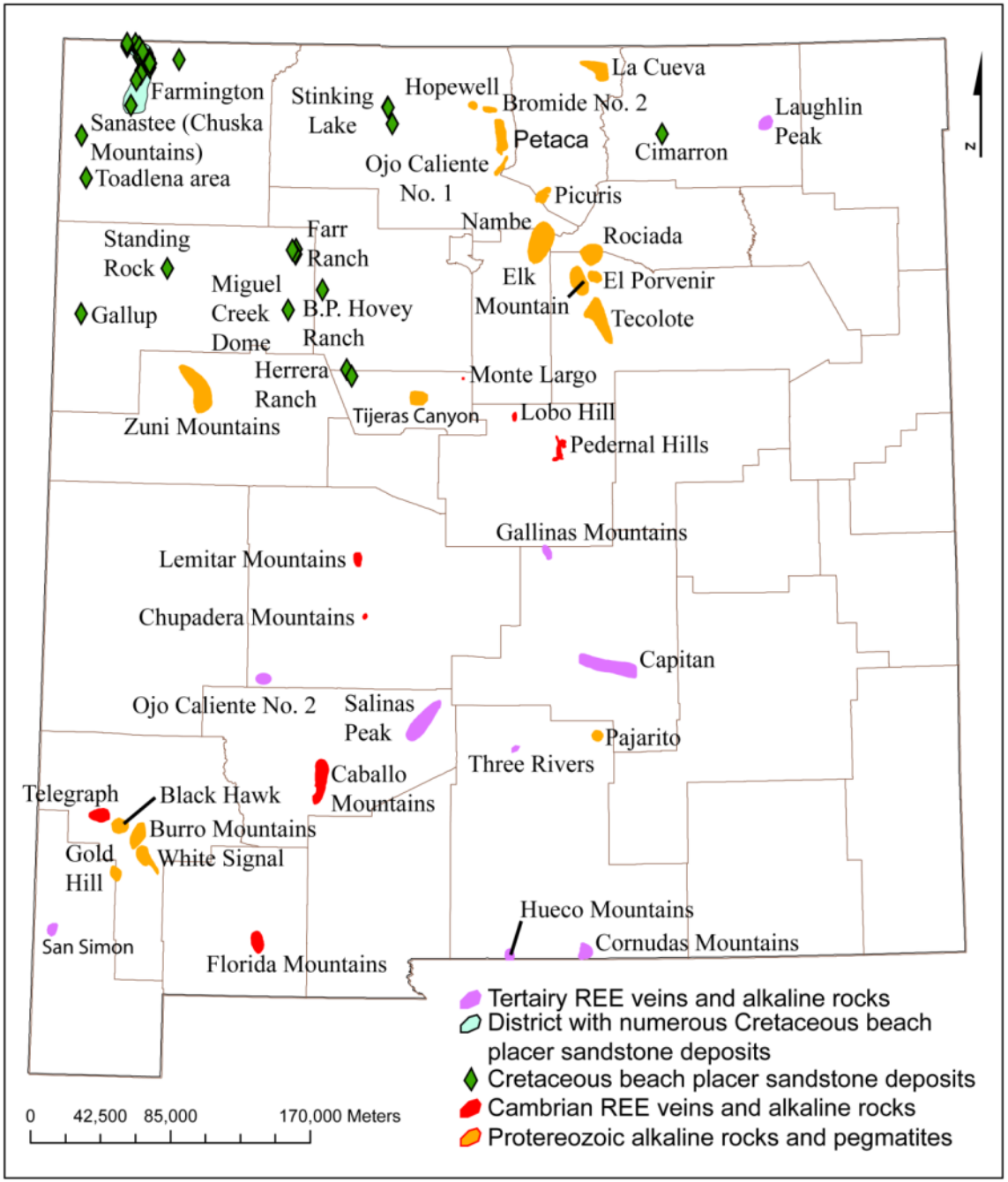
Note that any element or commodity can be considered critical in the future depending upon use and availability. Coal contains several of these critical elements.

U and K (potash) were removed from the critical minerals list in 2021 and Zn and Ni wee added.

Rare Earth Elements

Rare earth elements (REE) are a group of critical minerals that are used to manufacture most of our electronic devices, wind turbines, solar panels, magnets, electric and hybrid cars, and many other products. New Mexico has an abundance of REE deposits, although none are currently in production.

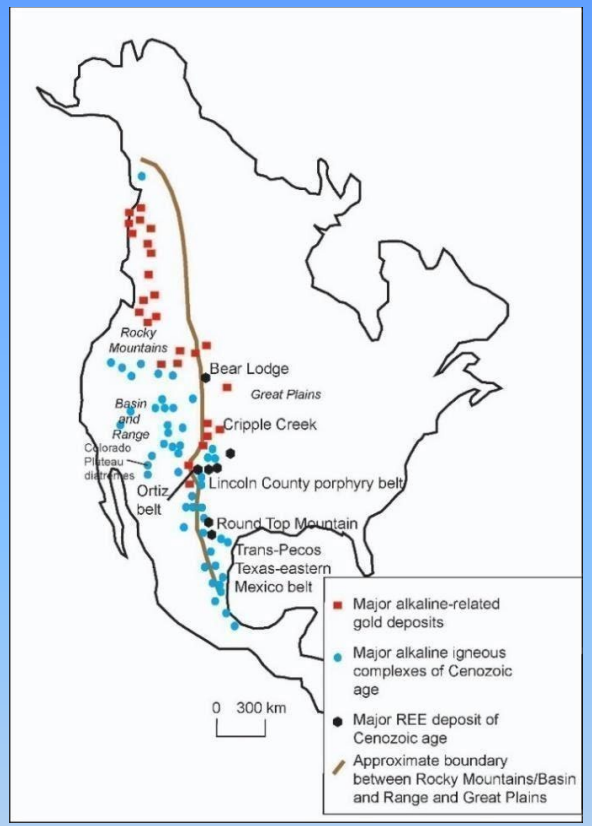




Occurrences of Rare Earth Elements (REE) in New Mexico

Tertiary alkaline igneous-related REE deposits in New Mexico

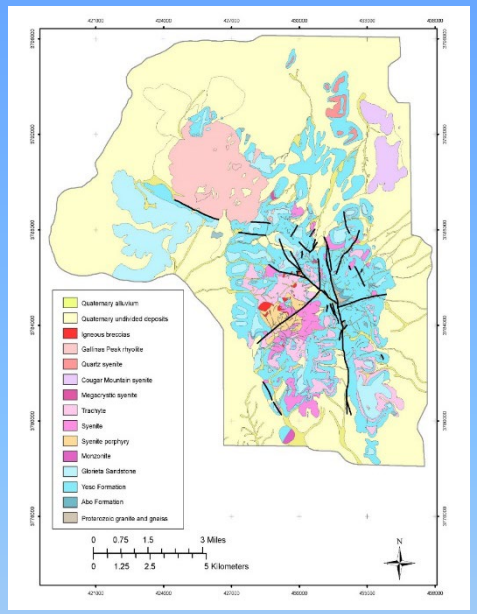
- Part of a belt of alkaline-igneous rocks
- Extends along the eastern edge of the Rocky Mountains and Basin And Range Provinces
- From Alaska And British Columbia southward into New Mexico, Trans-Pecos Texas, And Eastern Mexico
- These alkaline rocks contain relatively large quantities of important commodities such as, gold, fluorine, zirconium, rare earth elements (REE), tellurium, gallium, and other critical minerals

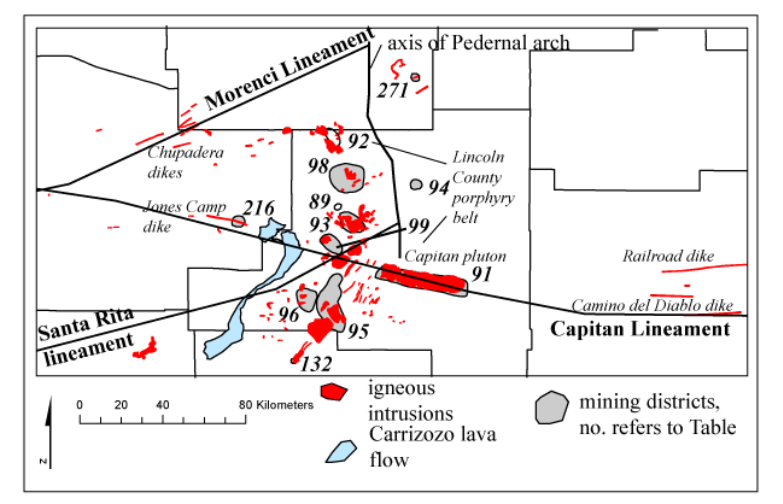


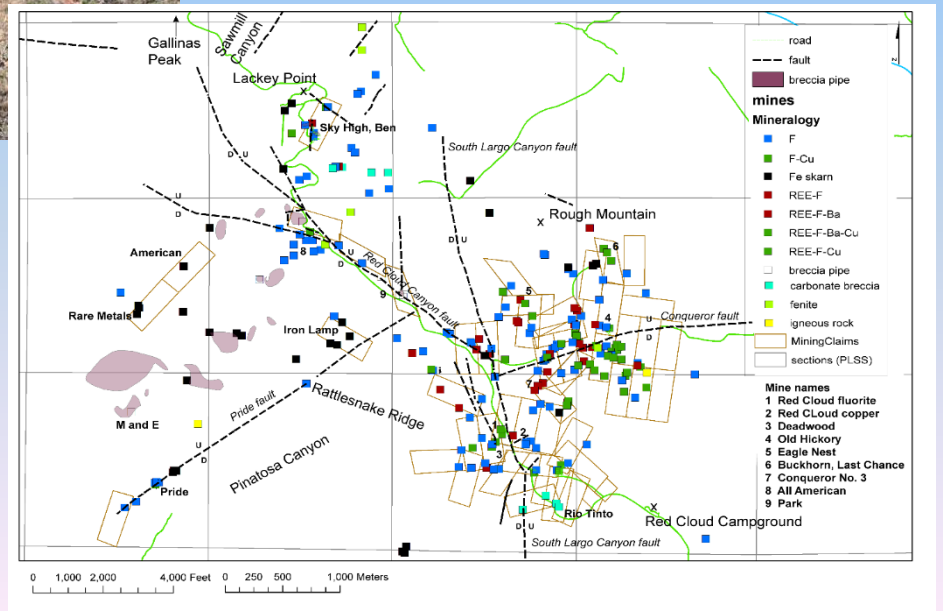
Tertiary carbonatites are found in the North American Cordilleran alkaline-igneous belt in Bear Lodge (WY), Laughlin Peaks (NM), and eastern Mexico

Extent of the North American Cordilleran alkaline-igneous belt (Woolley, 1987; Mutschler et al., 1991; McLemore, 1996, 2018).

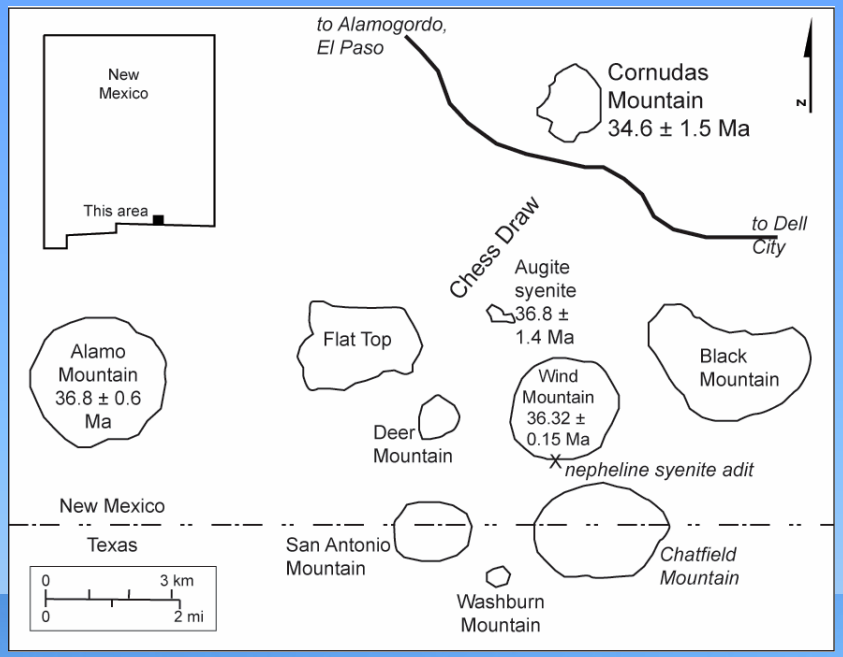
REE in Gallinas Mountains, Lincoln County

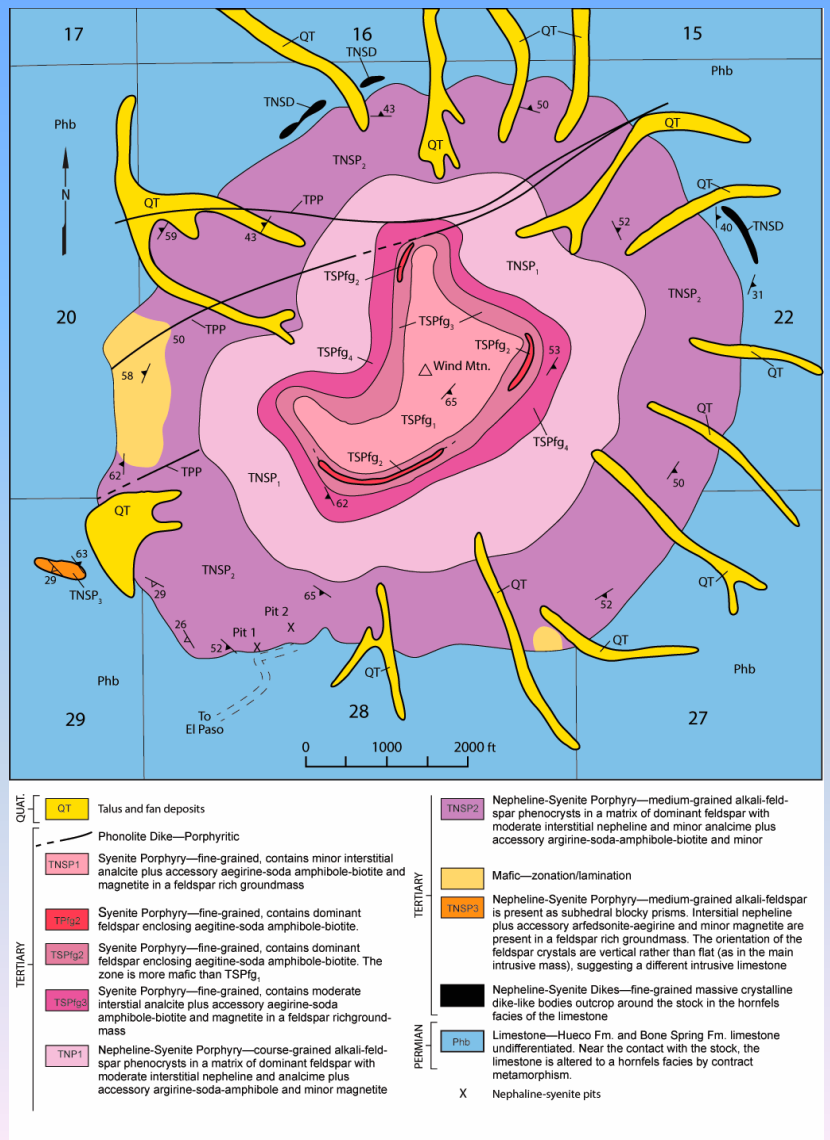


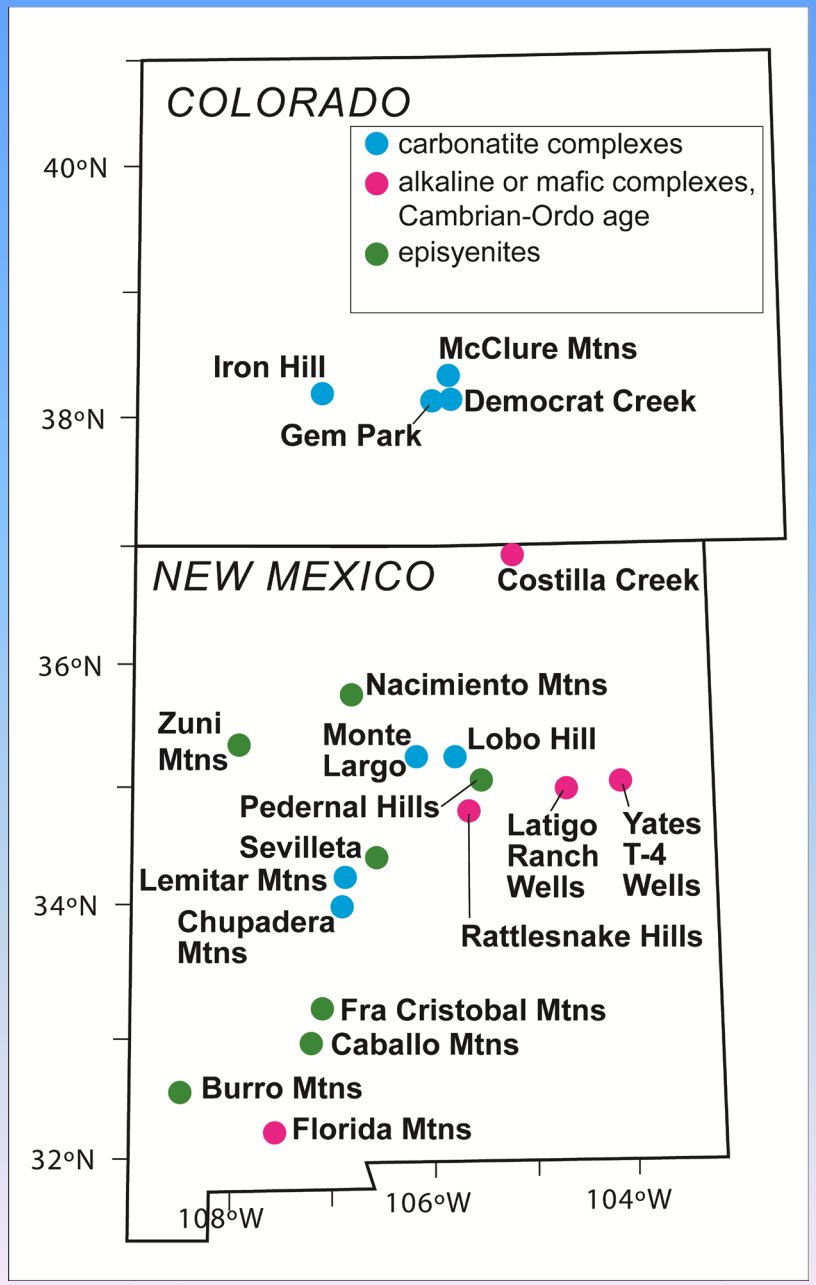




REE in Cornudas Mountains, Otero County



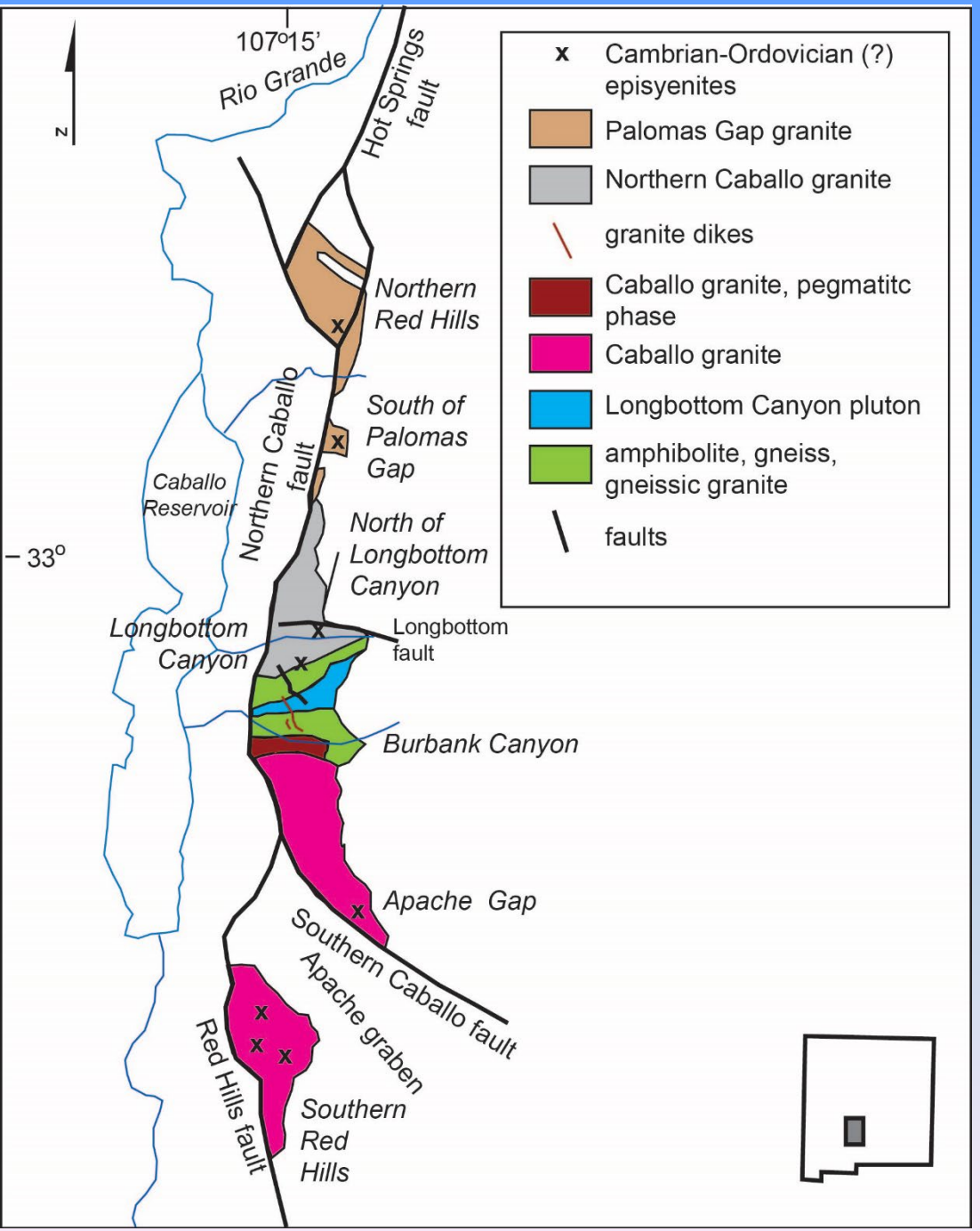




Carbonatites and Episyenites (or metasomatic rocks) in New Mexico and Colorado

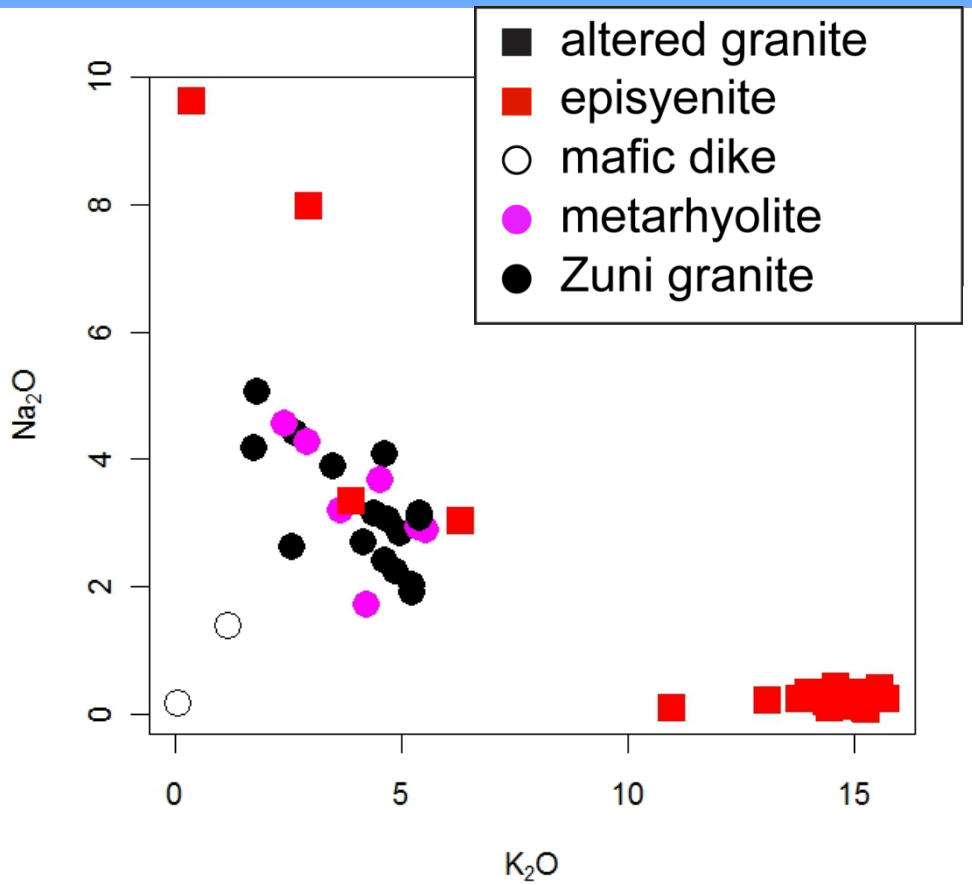
Episyenite is a term used to describe altered rocks that were desilicated and metasomatized by alkali-rich fluids solutions

Episyenites in Longbottom Canyon, Caballo Mountains

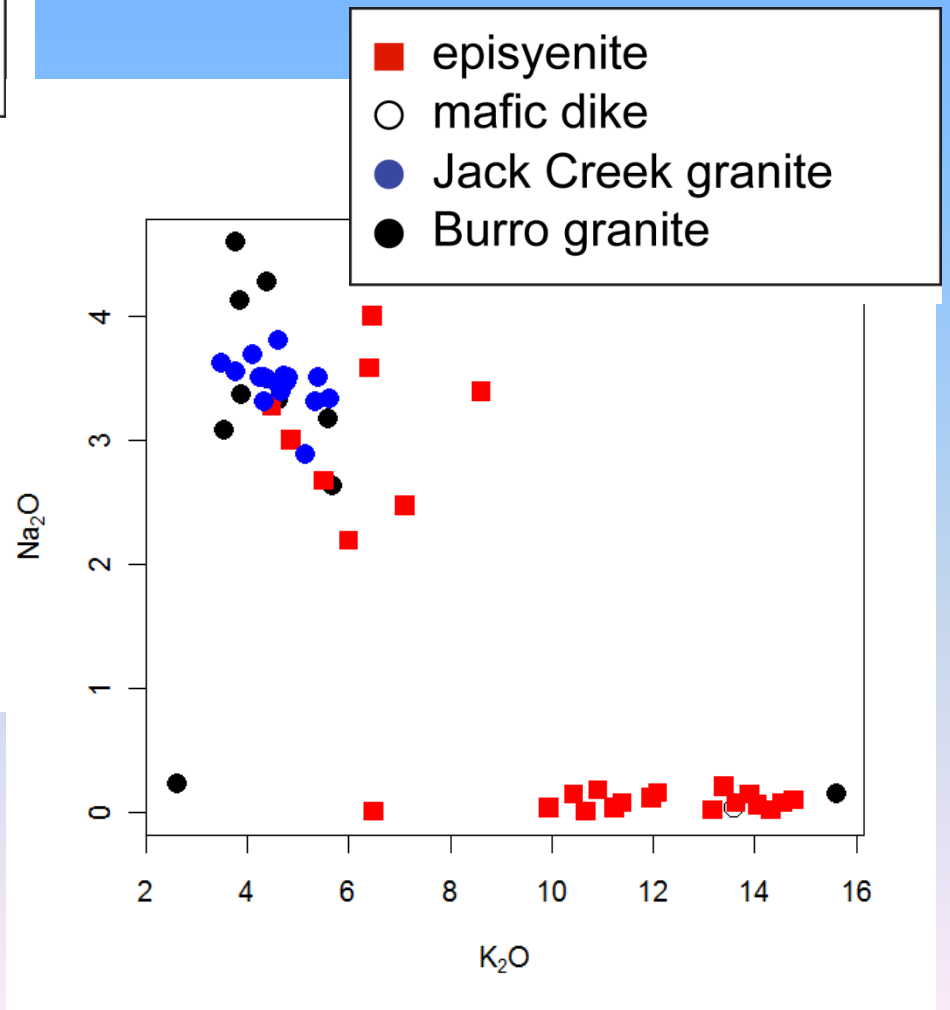


Geologic map of the Caballo Mountains, New Mexico

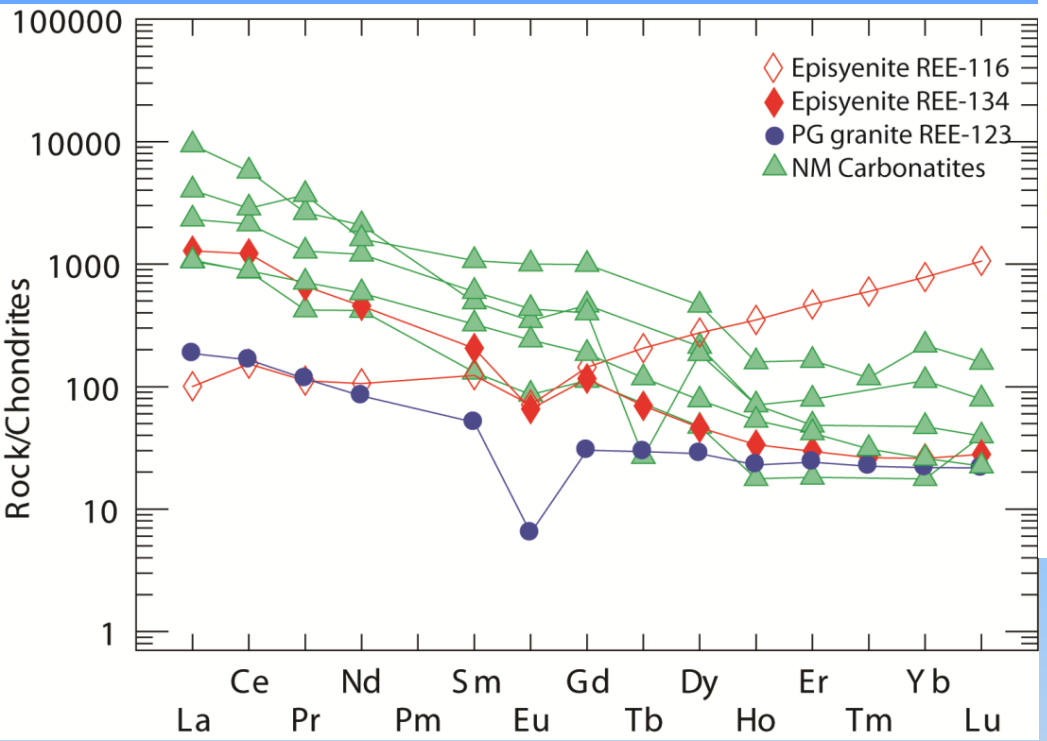
HIGH K_2O

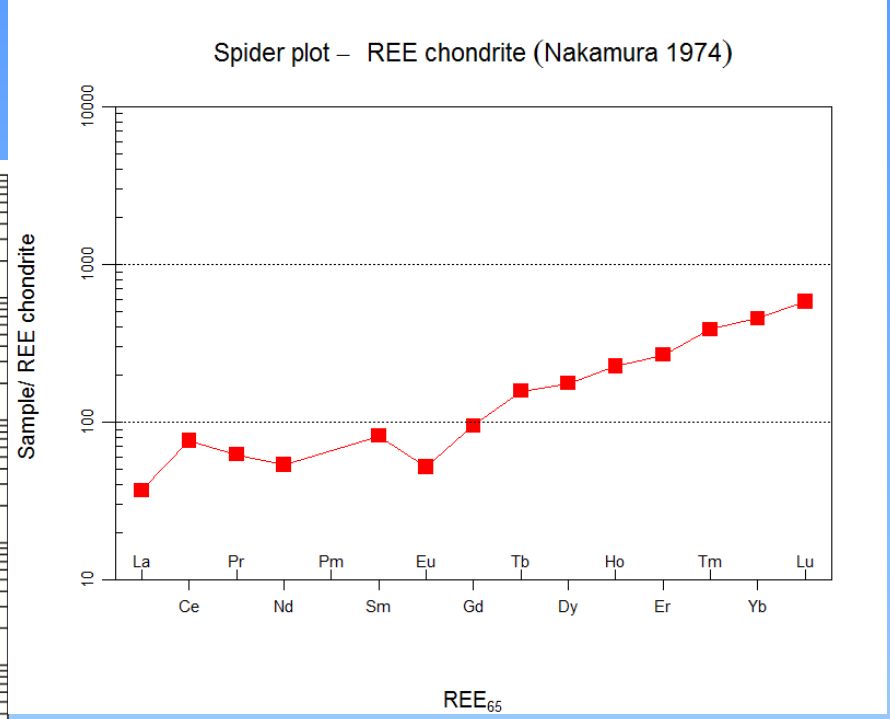


Zuni Mountains



Burro Mountains

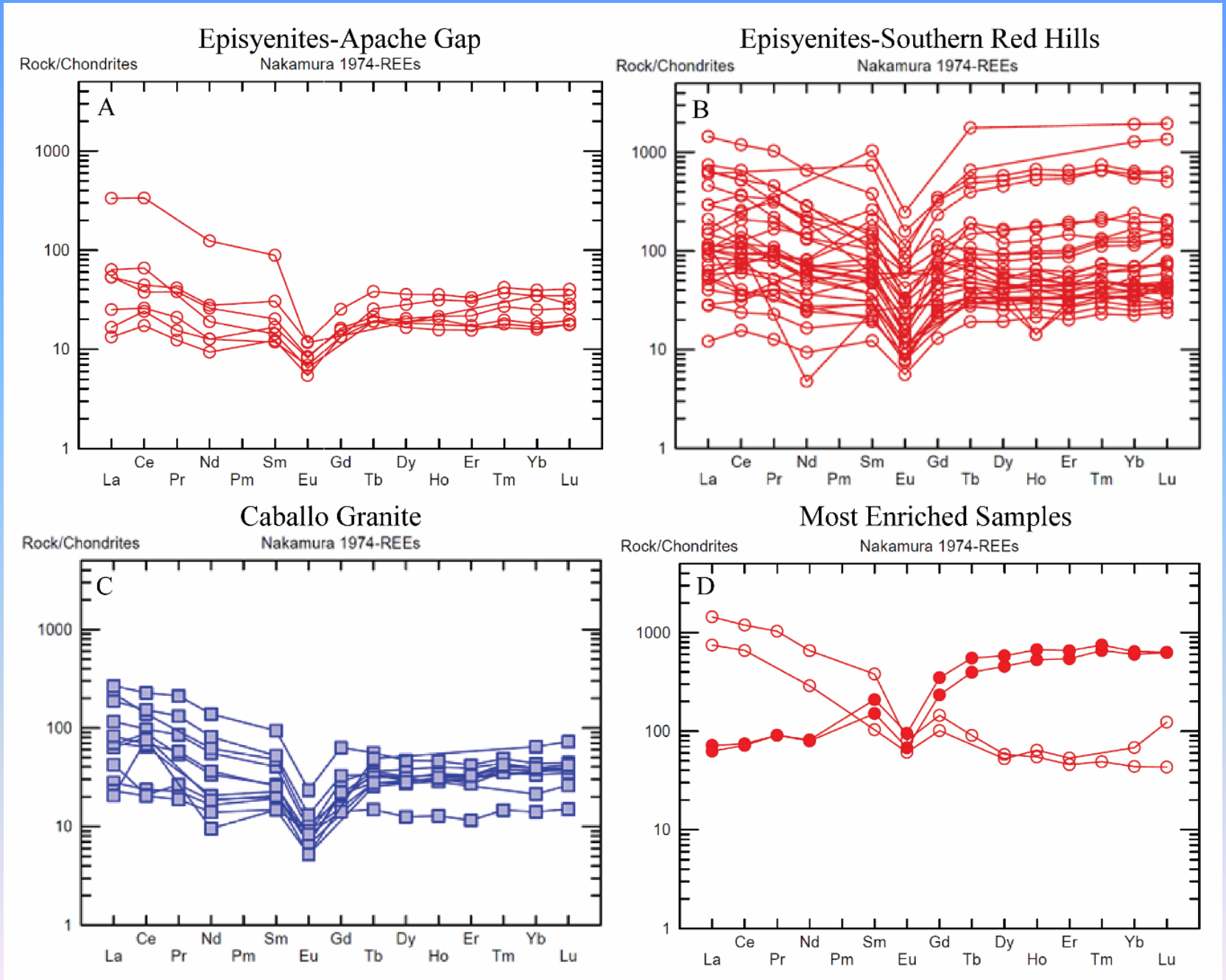




Some episyenites are HREE-enriched

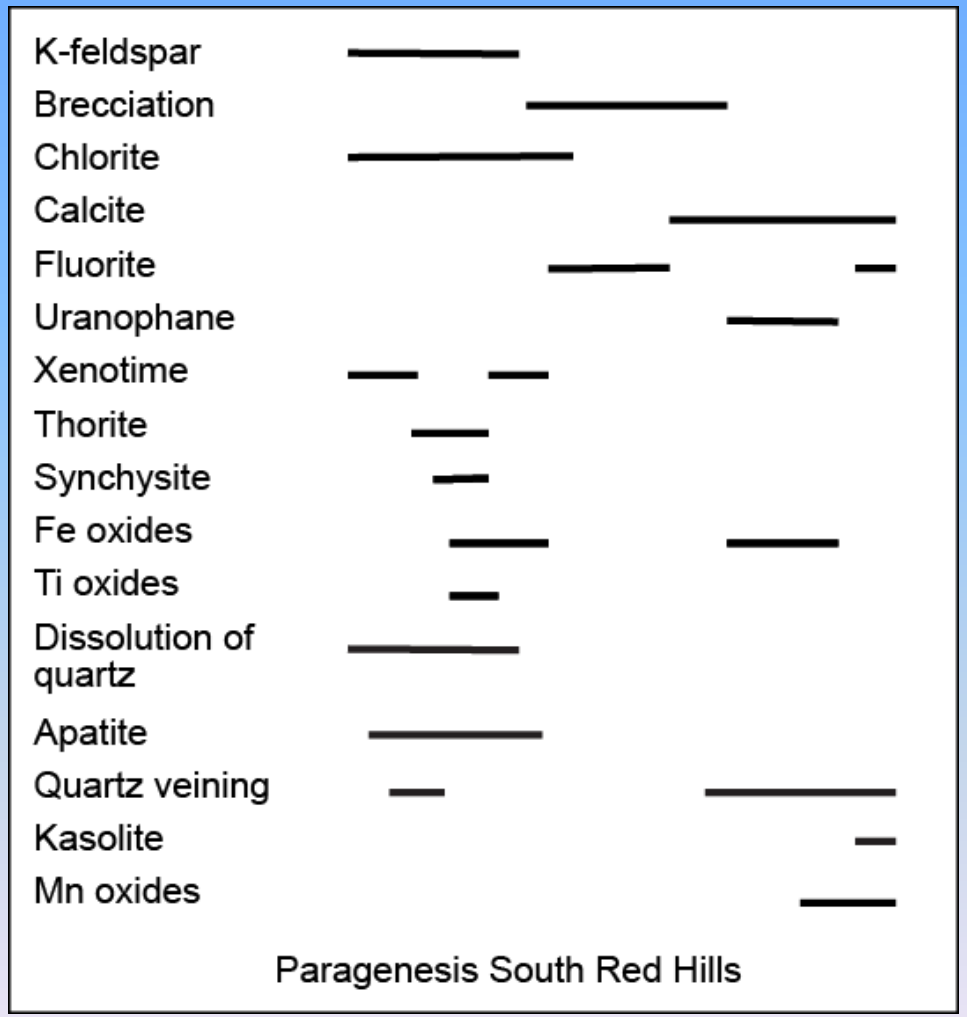
As much as 133 ppm Yb, 179 ppm Dy

They are interpreted to be related to carbonatite or alkaline fluids altering the host granite, similar to fenitization

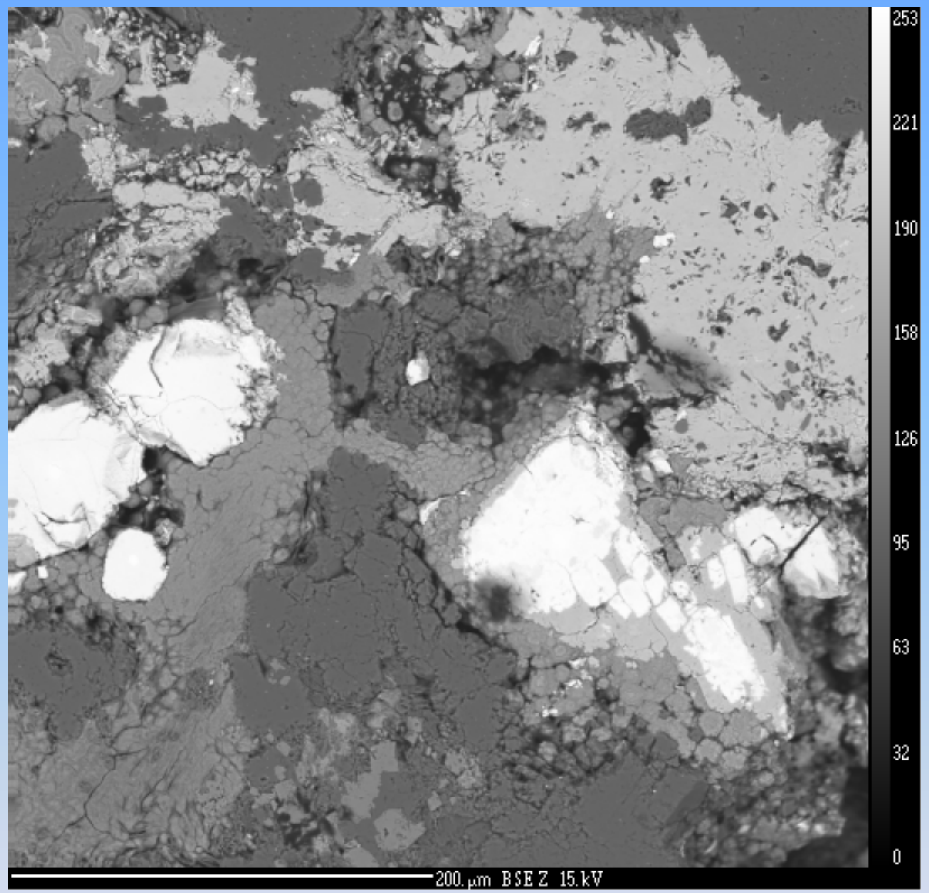

Episyenites-Apache Gap
Rock/Chondrites
Nakamura 1974-REEs
A
1000
100
10
1
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Episyenites-Southern Red Hills
Rock/Chondrites
Nakamura 1974-REEs
B
1000
100
10
1
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Caballo Granite
Rock/Chondrites
Nakamura 1974-REEs
C
1000
100
10
1
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Most Enriched Samples
Rock/Chondrites
Nakamura 1974-REEs
D
1000
100
10
1
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

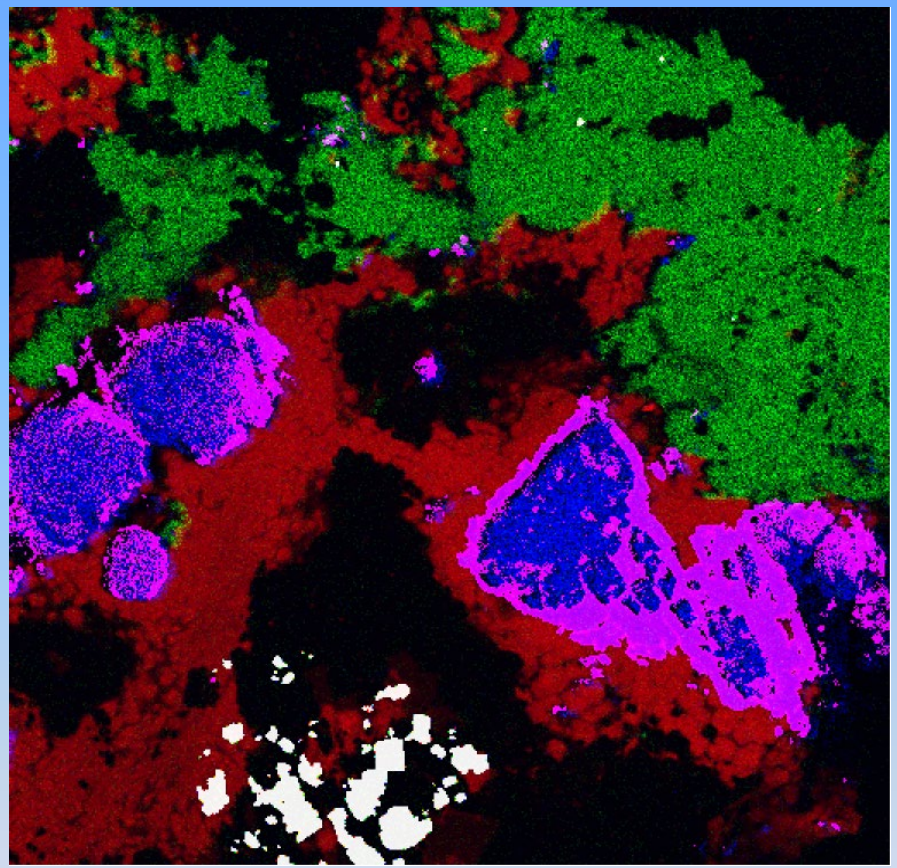
Complex mineralogy

- Synchysite (63 wt.% LREE)
- Aeschynite (9 wt.% HREE)
- Xenotime (16 wt.% HREE)
- Thorite
- Uranophane
- Bastnaesite



Backscatter electron image (electron microprobe) of an episyenite sample





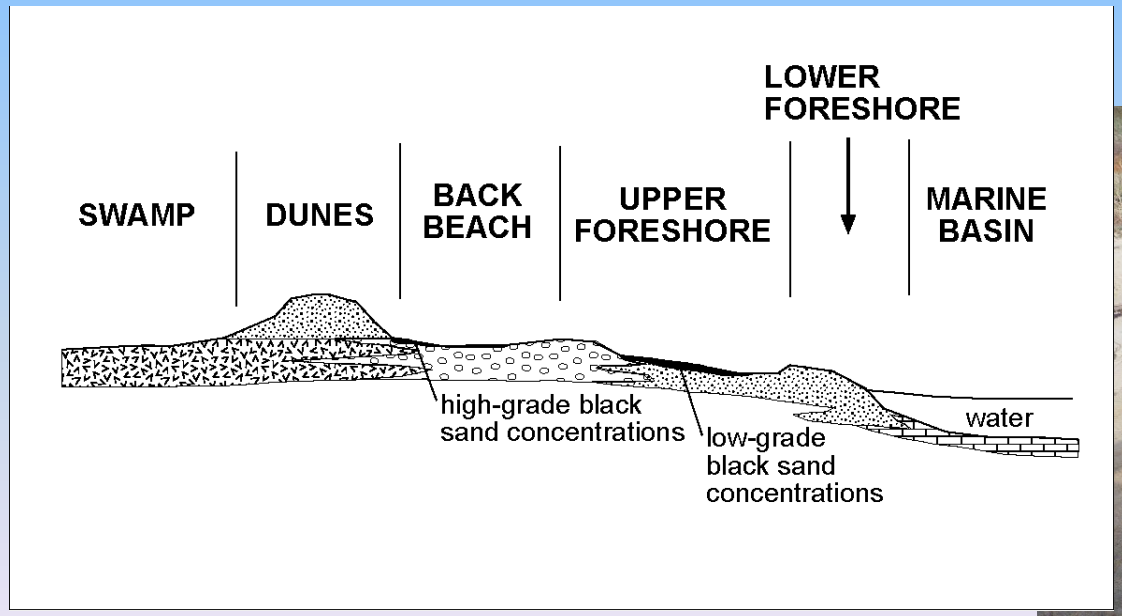
Synchysite
$Ca(LREE)(CO_3)2F$

Thorite
$(Th,U)SiO_4$

Xenotime
YPO_4

Beach-placer sandstone deposits

- Accumulations of heavy, resistant minerals (i.e. high specific gravity) that form on upper regions of beaches or in long-shore bars in a marginal-marine environment
- Known in the industry as mineral sands



Modern beach-placer sandstone deposits in Virginia

Beach-placer sandstone deposits

- Formed by mechanical concentration (i.e. settling) of heavy minerals by the action of waves, currents, and winds
- Composed of rutile, titanite, ilmenite, zircon, magnetite, monazite, apatite, xenotime, garnet, and allanite, among other minerals
- Ti, Zr, Fe are important economically
- Nb, Th, U, Sc, Y, and REE also can be important

Modern beach-placer sandstone deposits in Virginia

Modern examples

- Atlantic Coast, USA
- southeastern Australia
- Andhra Pradesh, India

- Mined for titanium, zircon, and monazite (a Ce-bearing REE mineral)

Stony Creek beach-placer sandstone deposit, Virginia

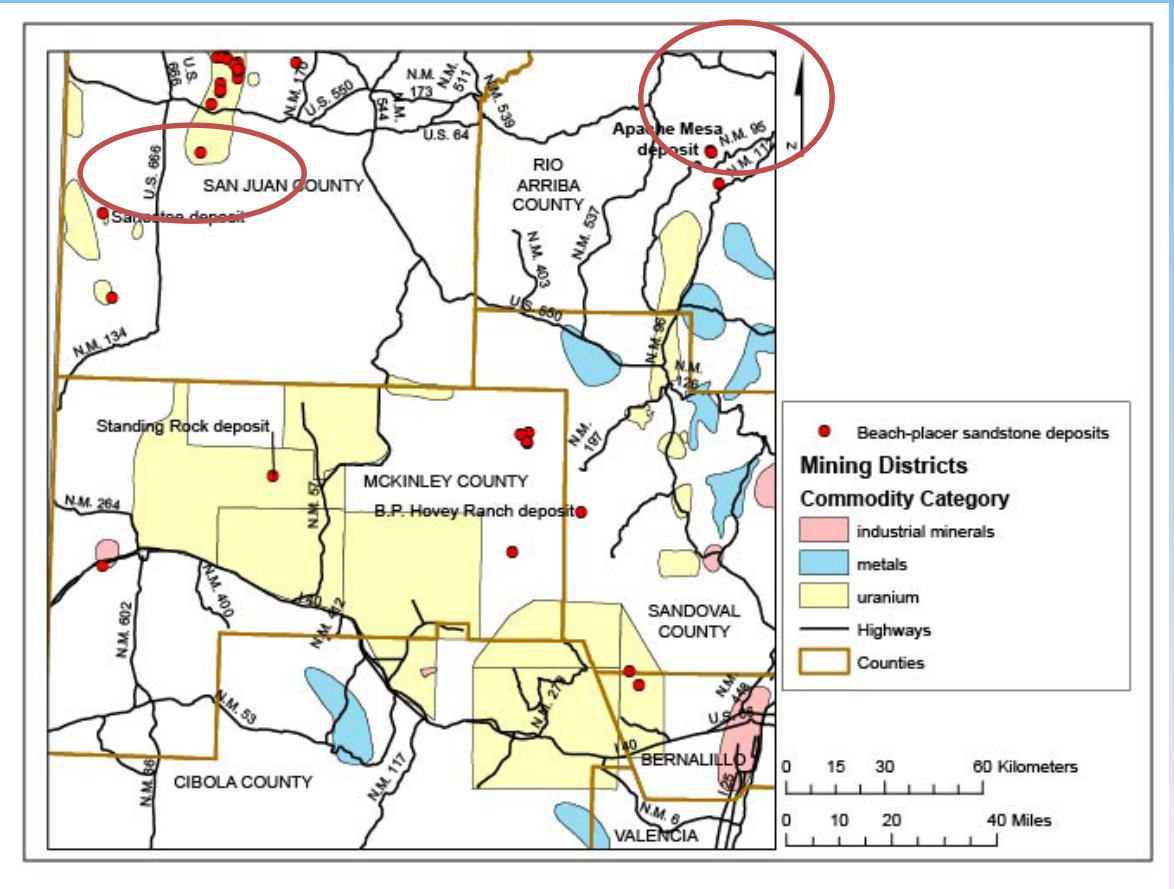
Economics of modern mineral sands

- Economic deposits are 10 million tons of >2% heavy minerals

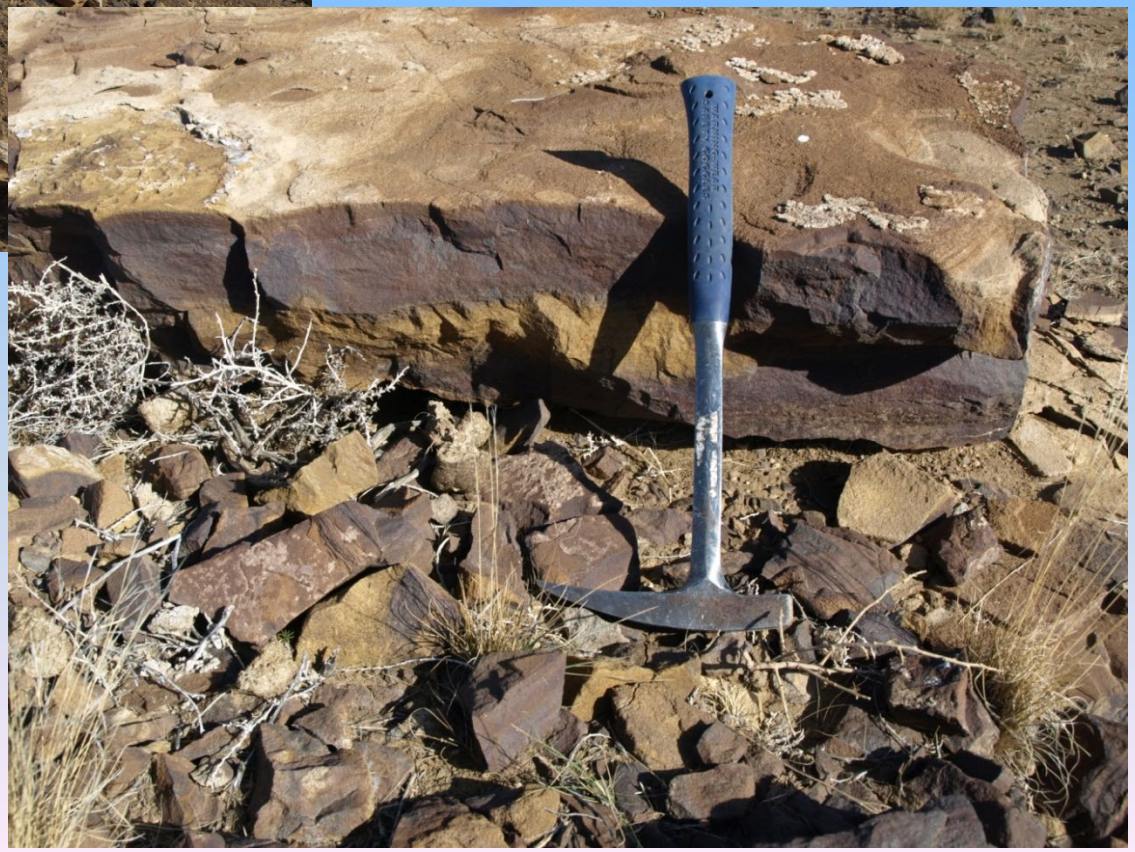
- Zirconium as zircon (1-50%)
  - Ceramic tiles, bricks used to line steel making furnaces, alloying agent in steel, laboratory crucibles
- Titanium as ilmenite (10-60%), rutile, leucoxene (titanium, 5-25%)
  - alloys in aircraft, white pigment found in toothpaste, paint, paper, glazes, and some plastics, heat exchangers in desalination plants, welding rods
- REE as monazite $(Ce,La,Y,Th)PO_4$) (<15%)
  - Catalyst, glass, polishing, re-chargeable batteries, magnets, lasers, glass, TV color phosphors, wind turbines
- Other minerals
  - Garnet, starolite, kyanite trace-50%

New Mexico

Beach-placer sandstone deposits in the San Juan Basin are restricted to Late Cretaceous rocks belonging to the Gallup, Dalton, Point Lookout, and Pictured Cliffs Sandstones

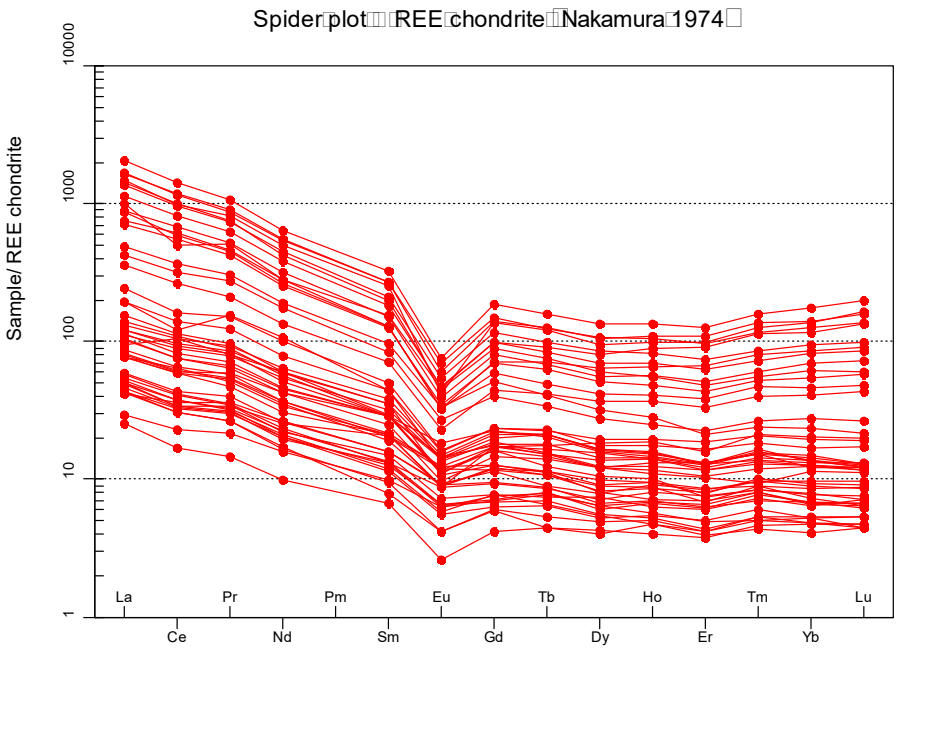


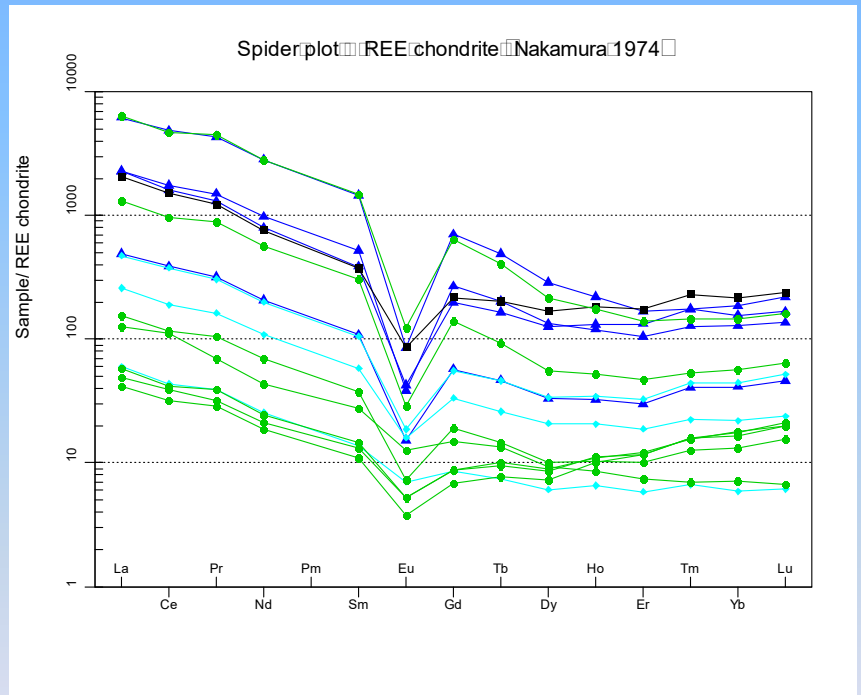
Resources are estimated by the USBM as 4,741,200 short tons of ore containing 12.8% TiO_2, 2.1% Zr, 15.5% Fe and less than 0.10 ThO_2 with some REE (USBM files)



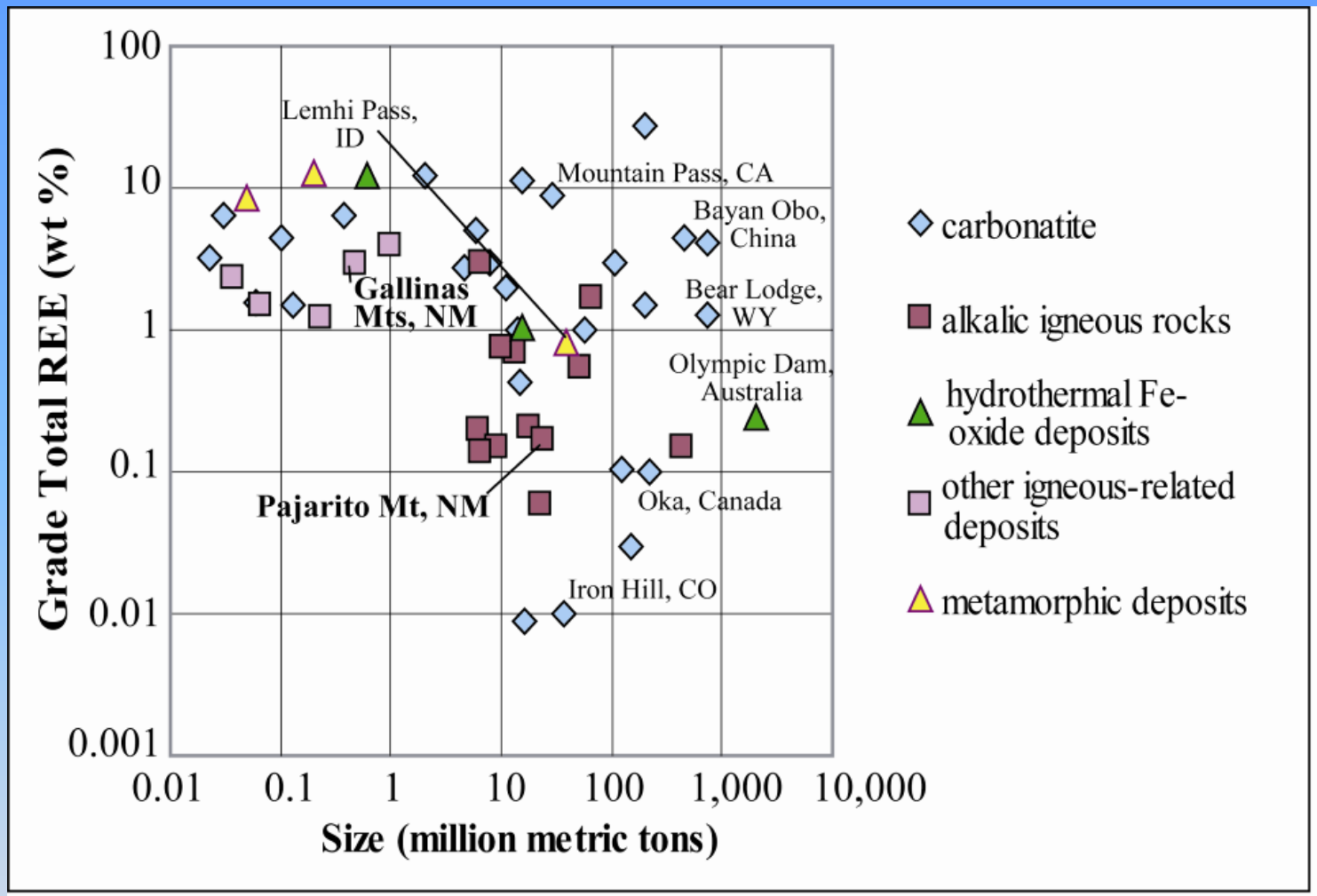
Sanostee deposit, San Juan County

GEOCHEMISTRY





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



Grade and size (tonnage) of selected REE deposits, using data from Oris and Grauch (2002) and resources data from Jackson and Christiansen (1993). Deposits in bold are located in New Mexico.

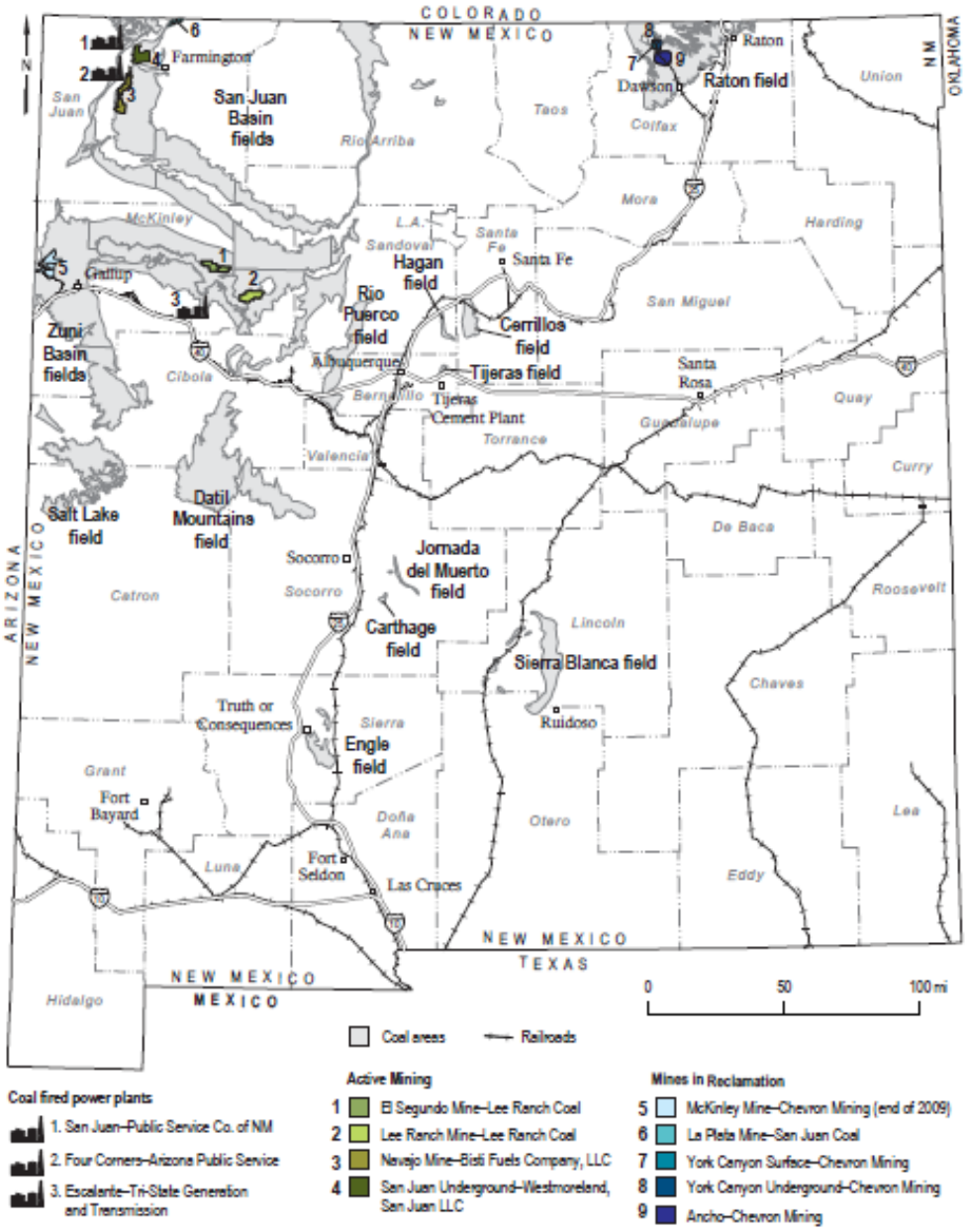
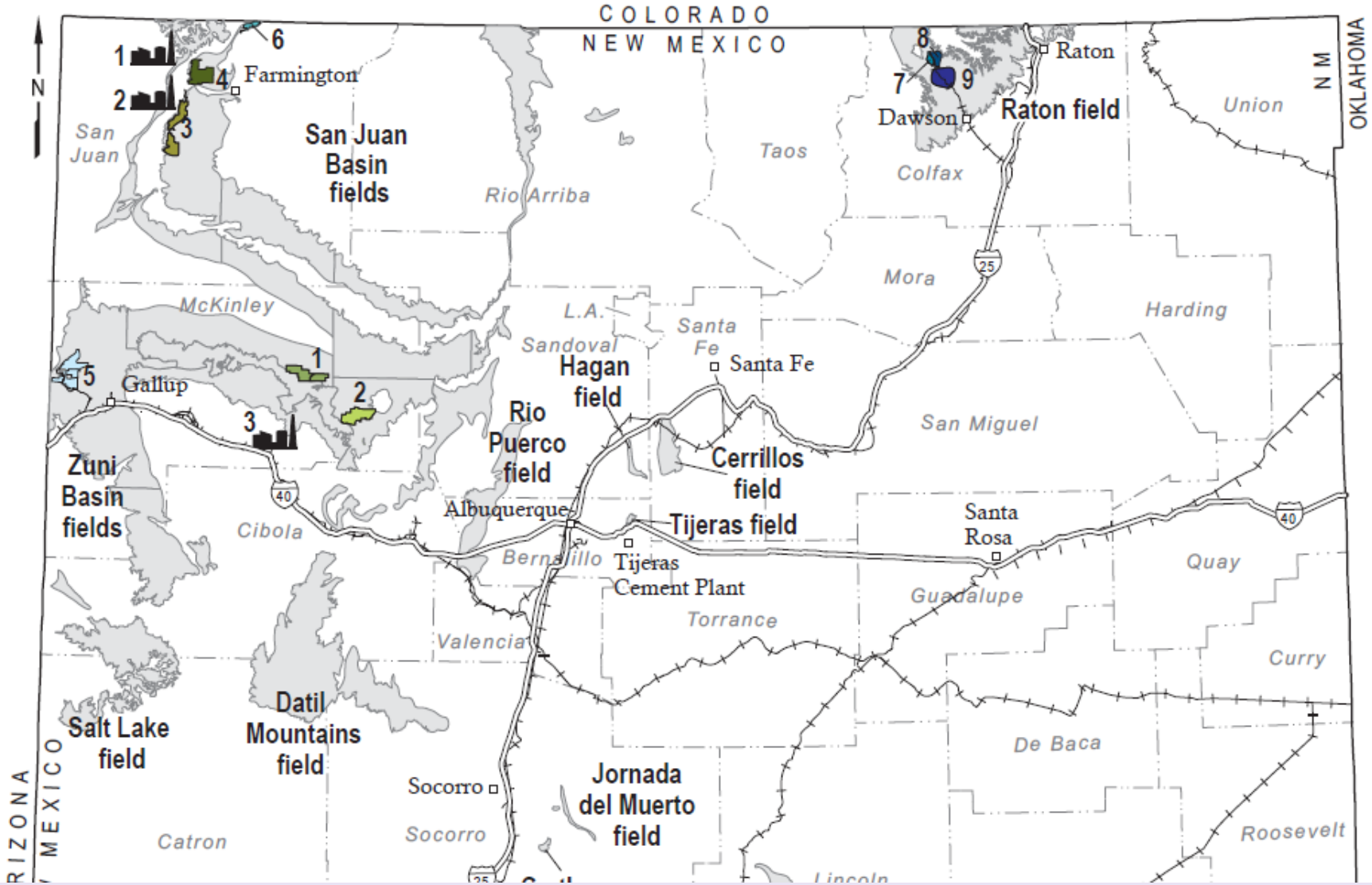
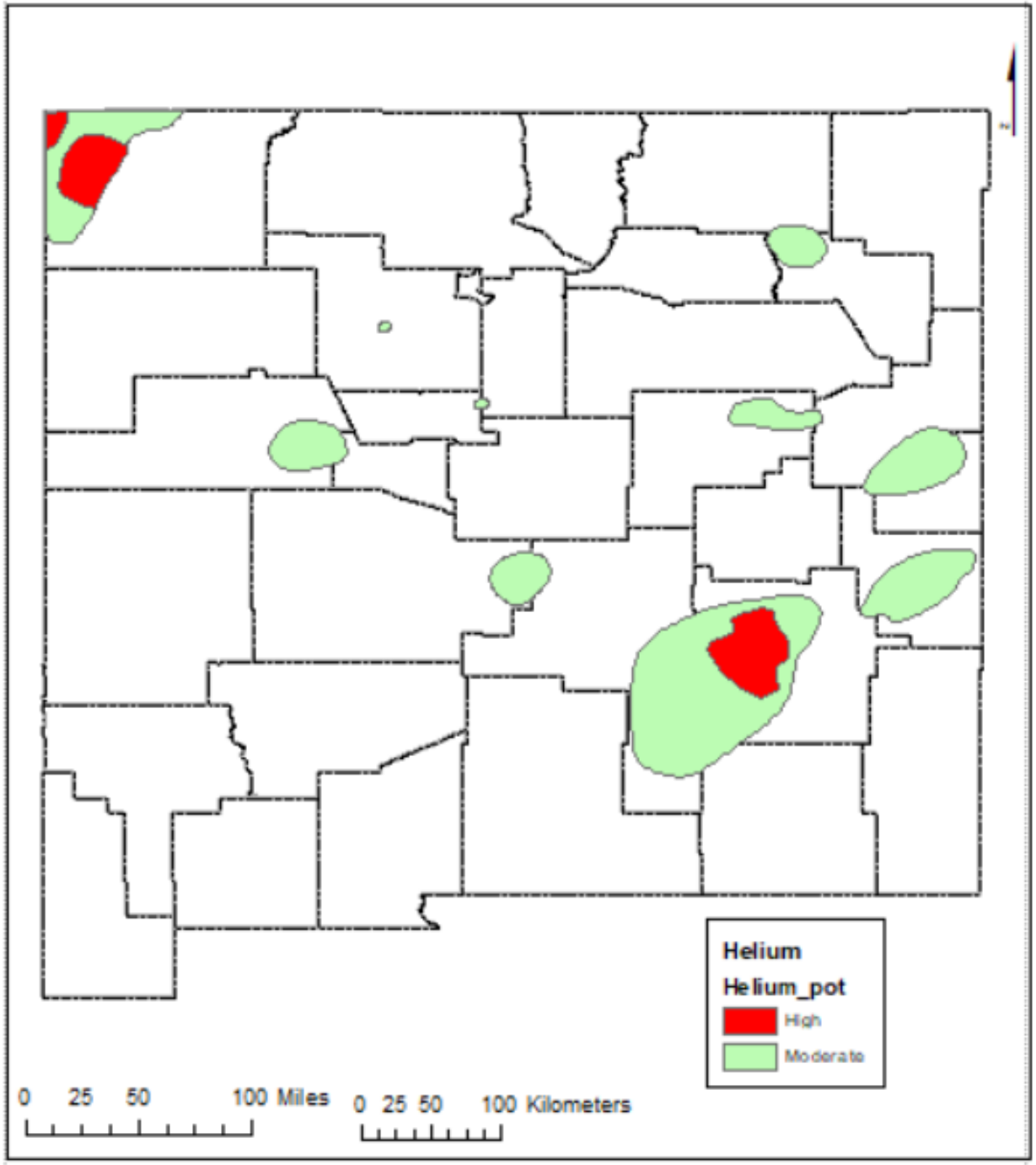


Figure 3. Coal fields of New Mexico, from Hoffman et al. (2009). Mines are surface operation unless specifically noted in legend. Lee Ranch Mining suspended in 2016.

New project awarded by the DOE—REE and other critical minerals in coal deposits



Coal has potential for REE, Co, Ga, Ge, and other CM



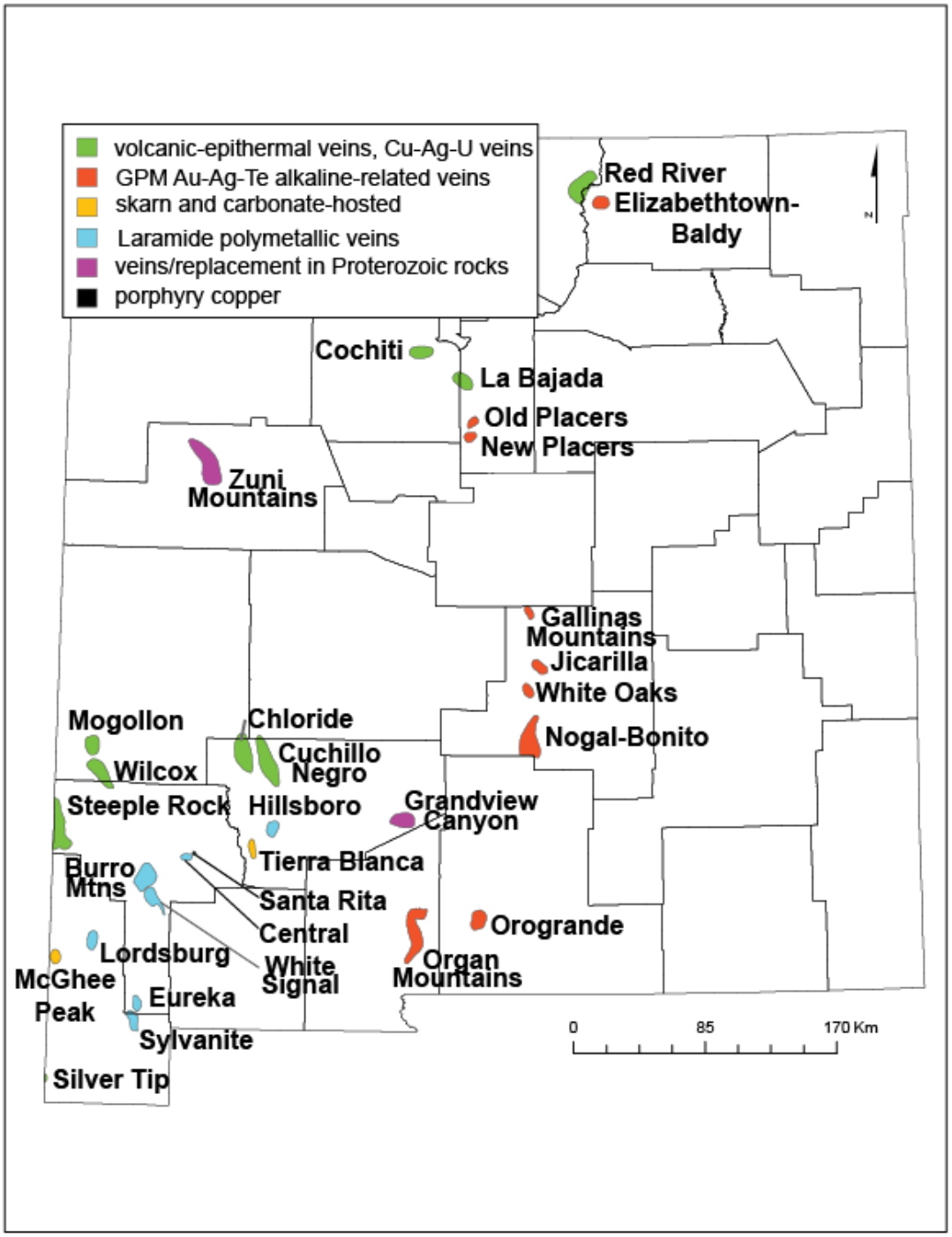
Helium potential in New Mexico

Uses of Tellurium

- Alloying additive in steel to improve machining characteristics
- Processing of rubber
- As a component of catalysts for synthetic fiber production
- As pigments to produce various colors in glass and ceramics
- **Thermal imaging devices**
- Thermoelectric cooling devices, such as summertime beverage coolers
- Thermoelectronics
- **Solar panels/cells**

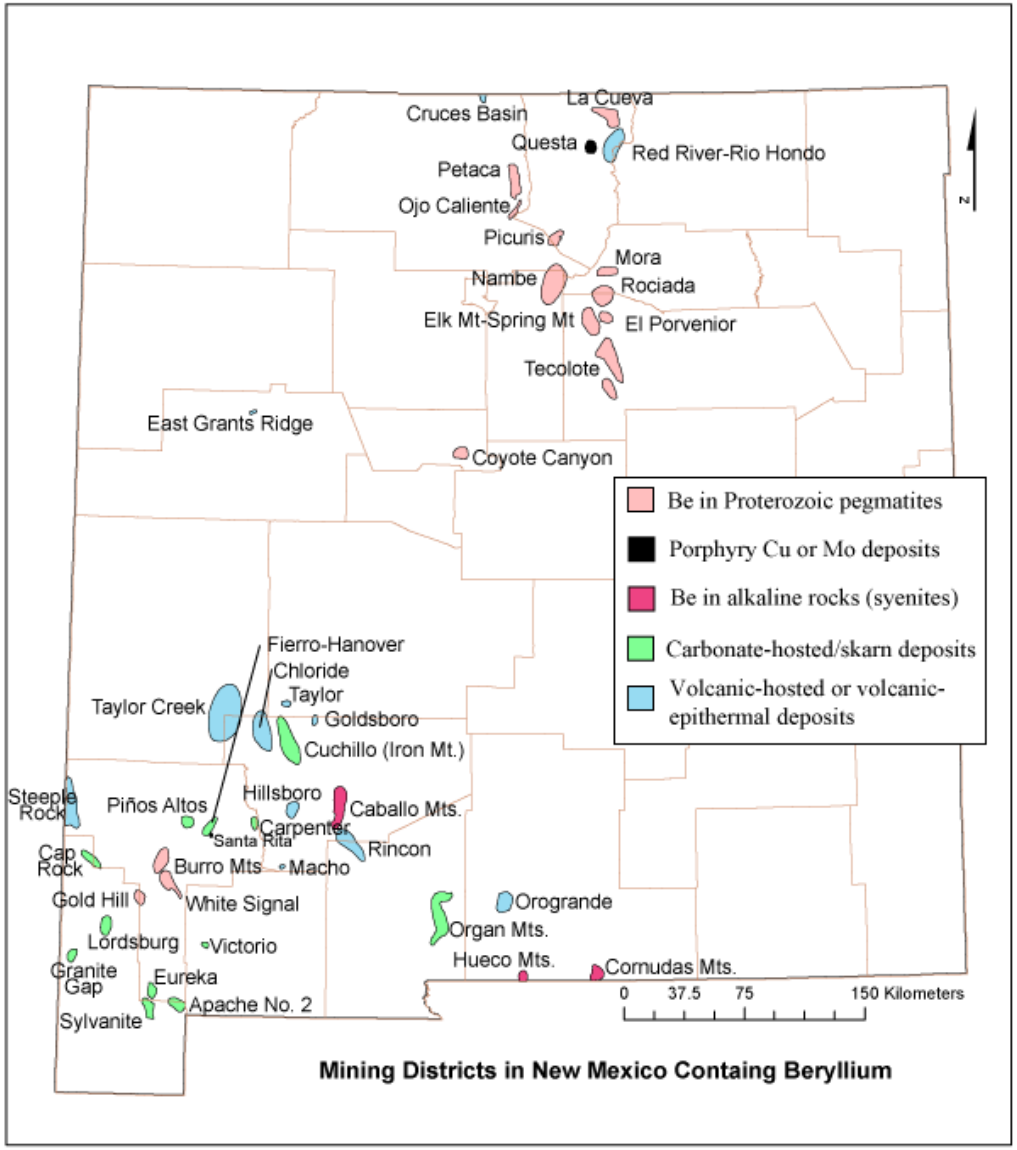
Tellurium

- Production—byproduct of copper refining (refinery in Texas)
- Lone Pine, Catron County produced 5 tons of Te from Au-Te volcanic-epithermal veins



Mining districts in New Mexico with tellurium minerals or chemical assays >20 ppm Te

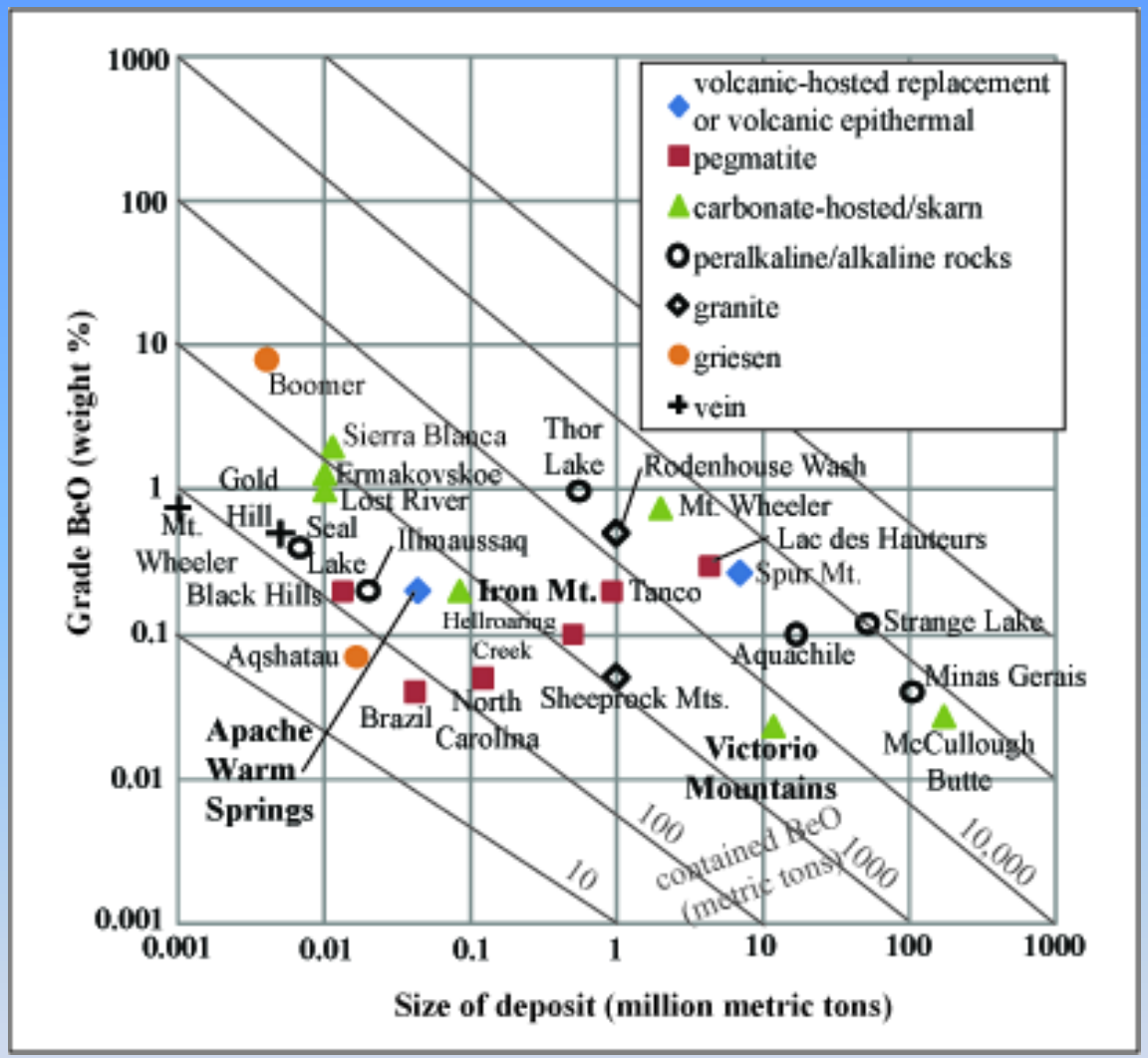
Lone Pine, Wilcox district, Catron County—volcanic epithermal vein



Mining Districts in New Mexico Containg Beryllium

- Defense
- Telecommunications
- Nuclear energy industries
- Shielding in some of our nuclear, medical, and other equipment
- Many of our electronic devices

Beryllium in New Mexico



Grade-tonnage of beryllium deposits (modified from Barton and Young, 2002). Deposits in bold are located in New Mexico.

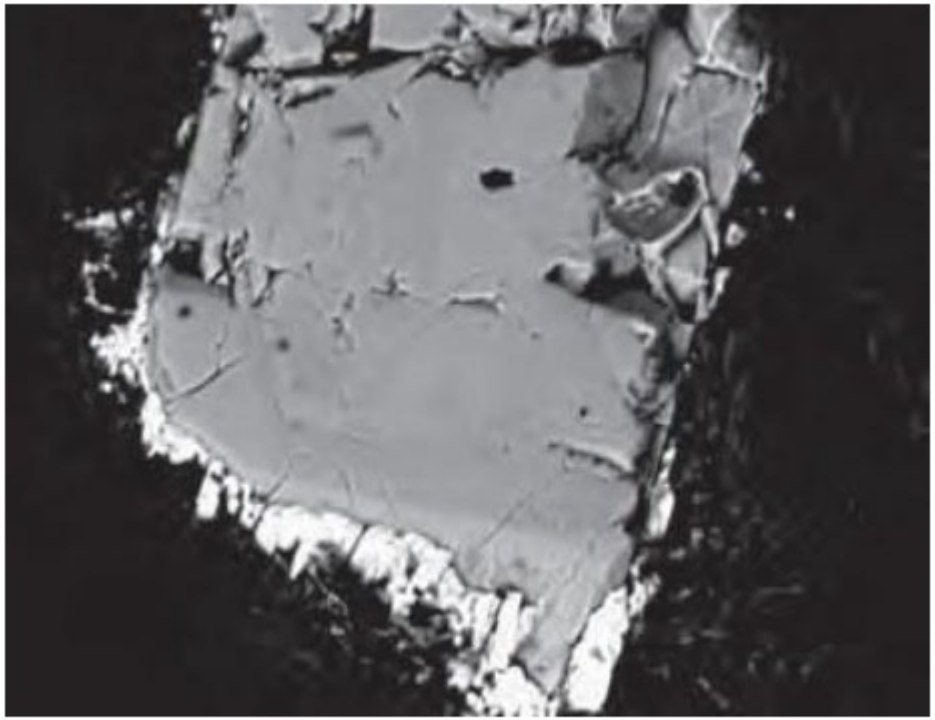
Apache Warm Springs beryllium deposit (Be), as determined from trenching and drilling, looking northeast (N section 6, T9S, R7W).

Mine wastes

Mine wastes

- Tailings
- Mine waste dumps
- Slags
- Smelter

Another potential source are mine wastes (mine rock piles, coal ash, tailings, acid mine drainage, etc.) at inactive mines and abandoned mine lands likely have potential for Critical Minerals, including REE, that could be recovered and pay for cleanup costs



Backscattered electron image of an REE-rich overgrowth (clearly visible here as a bright white band) on a zoned magmatic zircon. Field of view is 150 micrometers (0.15 mm).

What are the challenges in producing critical minerals?

- Meeting the demand (quick change in supply and demand difficult for mines to meet)
- Permitting
- Fear that producing a byproduct could jeopardize production of major commodity
- Environmental issues
  - Many are associated with U/Th (radioactivity)
- Financing for both exploration/mining and development of new products
- Social license to operate
- Local infrastructure challenges

The main challenge is provide society with its needs, protect future resources, limit alteration of the landscape, and affect local communities as little as possible (i.e. sustainable development).

GENERAL COMMENTS

- Many of the critical minerals do not require the tonnages we are used to mine for metals like Fe, Cu, Pb, Zn—i.e. smaller deposits
- Some of these minerals are found in only 1-3 deposits in the world
- Some of these minerals are found in areas of the world that may not be economically unstable or particularly friendly to the U.S.
  - Minerals that provide major revenue to armed fractions for violence, such as that occurring in the Democratic Republic of Congo (GSA, Nov. 2010)
- Some of these minerals come only from the refining of metal deposits and are dependent upon that production
  - Many Cu and Au deposits utilize heap leach technology, which leaves other potential minerals unrecovered in the heap leach

Summary

- New Mexico is currently producing potash
- New Mexico has produced many of the critical minerals and has potential for future production
  - Uranium—2nd in the US in resources
- Exploration for several critical minerals ongoing in NM
  - REE, Te, Co, Li, Be
- Coal deposits in NM could have potential for critical minerals

QUESTIONS?