RARE EARTH ELEMENTS (REE) IN PROTEROZOIC PERALKALINE IGNEOUS ROCKS (PAJARITO MOUNTAIN) AND PEGMATITES IN NEW MEXICO

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Critical Minerals

• IN 2017, 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
Definition of Critical Minerals

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
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

- Red: Element currently producing in NM
- Blue: Element once produced from NM
- Green: Element found in NM
- Yellow: Element not found in NM

C=graphite  F=fluorite  He
B  C  N  O  F  Ne
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

Ba=barite

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.
Occurrences of Rare Earth Elements (REE) in New Mexico
**DISTRICT NAME** | **PRODUCTION**
---|---
Gallinas Mountains | 146,000 lbs of bastnasite concentrate
Petaca | 112 lbs of samarskite, few hundred lbs of monazite, 12,000 lbs of Ta-Nb-REE ore
Elk Mountain | 500 lbs of Ta-U-REE concentrate
Rociada | Several thousand tons of REE-Ta ore
Tecolote | $10,000 worth of beryl, tantalite-columbite and monazite
Gold Hill | REE production in the 1950s

*Production of rare earth elements (REE) in New Mexico, to date.*
Proterozoic
Pajarito Mountain
Proterozoic Pajarito Mountain
Mineralogy Proterozoic Pajarito Mountain (Berger, 2018)

- Eudialyte
  \[ \text{Na}_4(\text{Ca,Ce})_2(\text{Fe}^{++},\text{Mn,Y})\text{ZrSi}_8\text{O}_{22}(\text{OH,Cl})_2 \]
- Fluorite \( \text{CaF}_2 \)
- Apatite \( \text{Ca}_5(\text{PO}_4)_3(\text{OH,F,Cl}) \) (with U, Th)
- Zircon \( \text{ZrSiO}_4 \) (with U, REE)
- 2 REE-bearing silicates
In 1990, Molycorp, Inc. reported historic resources of 2.7 million short tons grading 0.18% Y$_2$O$_3$ and 1.2% ZrO$_2$ as disseminated eudialyte.

Historic REE resources—537,000 short tons of 2.95% total REE (Jackson and Christiansen, 1993)
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.
Costilla massif, La Cueva district, Taos County

- Radioactive pegmatites intrude the granite and both intrude a complex Proterozoic metamorphic terrain of metamorphic and igneous rocks.
- The granitic rocks are subalkaline, metaluminous to peraluminous.
- 1560 ppm Ce and 625 ppm La
Mineralogy of Costilla massif (Zelenka, 1984)

- Uraninite $\text{UO}_2$ (with Ce)
- Thorite $\text{ThSiO}_4$ (with Ce)
- Uranothorite $(\text{Th},U)\text{SiO}_4$
- Magnetite $\text{Fe}_3\text{O}_4$ (with U, Th)
- Zircon $\text{ZrSiO}_4$ (with U, REE)
- Allanite $(\text{Ce},\text{Ca},\text{Y})_2(\text{Al},\text{Fe}^{+++})_3(\text{SiO}_4)_3(\text{OH})$
- Apatite $\text{Ca}_5(\text{PO}_4)_3(\text{OH},\text{F},\text{Cl})$ (with U, Th)
- Titanite $\text{CaTiSiO}_5$ (with U, Th)
- Thorogummite $\text{Th}(\text{SiO}_4)_{1-x}(\text{OH})_{4x}$
- Uranophane $\text{Ca}(\text{UO}_2)_2\text{SiO}_3(\text{OH})_2\cdot5(\text{H}_2\text{O})$
Tajo Granite, Chupadero district, Socorro County

- **Mineralogy**
  - Hematite
  - Fluorite
  - Uranophane?

- **Chemistry**
  - 0.4350% U$_3$O$_8$
  - <1200 ppm Y
Tajo Granite
Pegmatites

Coarse-grained igneous rocks, lenses, or veins with granitic composition, contains essential quartz and feldspar, and represent the last and most hydrous phase of crystallizing magmas.
PEGMATITITES

Burro Mountains

Petaca
Pegmatites

Production from the Petaca and Ojo Caliente No. 1 mining districts, Rio Arriba County w=production data withheld.

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Production</th>
<th>Years of production</th>
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<tbody>
<tr>
<td>Beryl</td>
<td>12,748</td>
<td></td>
</tr>
<tr>
<td>Columbite-tantalite (lbs)</td>
<td>5,092-12,000</td>
<td></td>
</tr>
<tr>
<td>Sheet mica (lbs)</td>
<td>604,927</td>
<td></td>
</tr>
<tr>
<td>Scrap mica (short tons)</td>
<td>15,191</td>
<td>1899-1963</td>
</tr>
<tr>
<td>Feldspar</td>
<td>w</td>
<td></td>
</tr>
<tr>
<td>Lithium (short tons)</td>
<td>w</td>
<td>1920-1963</td>
</tr>
<tr>
<td>Bismuth (lbs)</td>
<td>100</td>
<td>1943</td>
</tr>
<tr>
<td>Rare earth elements (samarskite) (lbs)</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>Kyanite (short tons)</td>
<td>1,500</td>
<td>1928</td>
</tr>
<tr>
<td>Uranium</td>
<td>2 lbs</td>
<td>1954</td>
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PEGMATITES

Elk Mountain
<table>
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<tr>
<th>REE minerals in pegmatites</th>
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<tbody>
<tr>
<td>• Garnet</td>
</tr>
<tr>
<td>• Fluorite</td>
</tr>
<tr>
<td>• Columbite</td>
</tr>
<tr>
<td>• Beryl</td>
</tr>
<tr>
<td>• Gadolinite</td>
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<tr>
<td>• Euxenite</td>
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<tr>
<td>• Uraninite</td>
</tr>
<tr>
<td>• Microlite</td>
</tr>
<tr>
<td>• Allanite</td>
</tr>
<tr>
<td>• samarkite</td>
</tr>
<tr>
<td>• Cyrtolite</td>
</tr>
<tr>
<td>• Zircon</td>
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<tr>
<td>• Monazite</td>
</tr>
</tbody>
</table>
Paragenesis, Globe pegmatite (Petaca)
Summary

• The best potential for REE deposits in Proterozoic rocks in New Mexico—disseminated REE-Y-Zr deposits in alkaline rocks found at Pajarito Mountain, Otero County

• Additional areas
  – Proterozoic granite
    • Tajo Granite in Socorro County
    • La Cueva Granite in Taos County
    • Tusas Granite in Rio Arriba County
  – but additional geochemical studies and ultimately drilling are needed to determine the economic potential of these areas

• Most pegmatites in New Mexico probably will not constitute an economic resource because of low grade, small size, and the expensive hand-sorting techniques required in order to recover any of the commodities
CONCLUSIONS

• REE are important for green technologies as well as our entire lifestyle and new uses will be found because of their unique properties

• REE are found in specific locations based on favorable geology and there is sufficient supply for the near future

• Some of the REE required for these green technologies are found in New Mexico

• Need for understanding the mineralogy and distribution of these minerals in known ore deposits
SME has a new journal with Springer, Mining, Metallurgy, and Exploration

• Special issue in October 2019, Feb 2020 on Critical Minerals
• New articles welcome
QUESTIONS?