REE-BEARING CAMBRIAN-ORDOVICIAN EPISYENITES AND CARBONATITES IN SOUTHERN AND CENTRAL NEW MEXICO, USA

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- Ethan Haft, Eric Ruggles mineralogy and geochemistry of Lemitar carbonatites
- Emily Perry geochemistry on calcites and modeling
- Nd isotopic studies by O. Tapani Rämö
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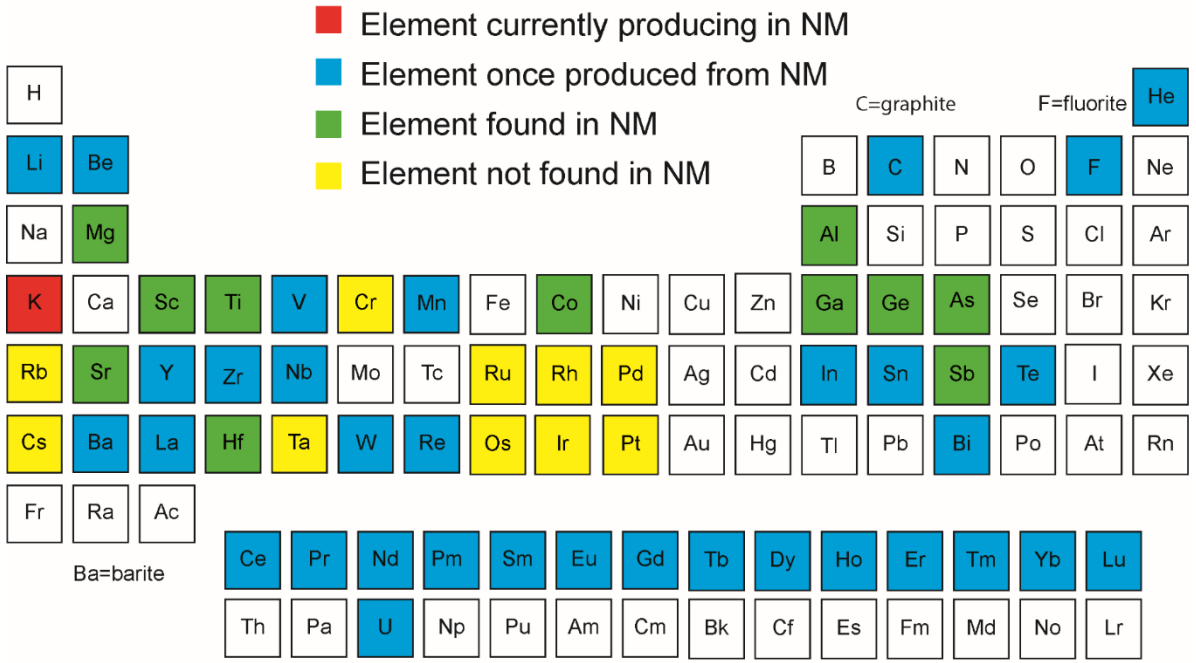
Definitions

Critical Minerals

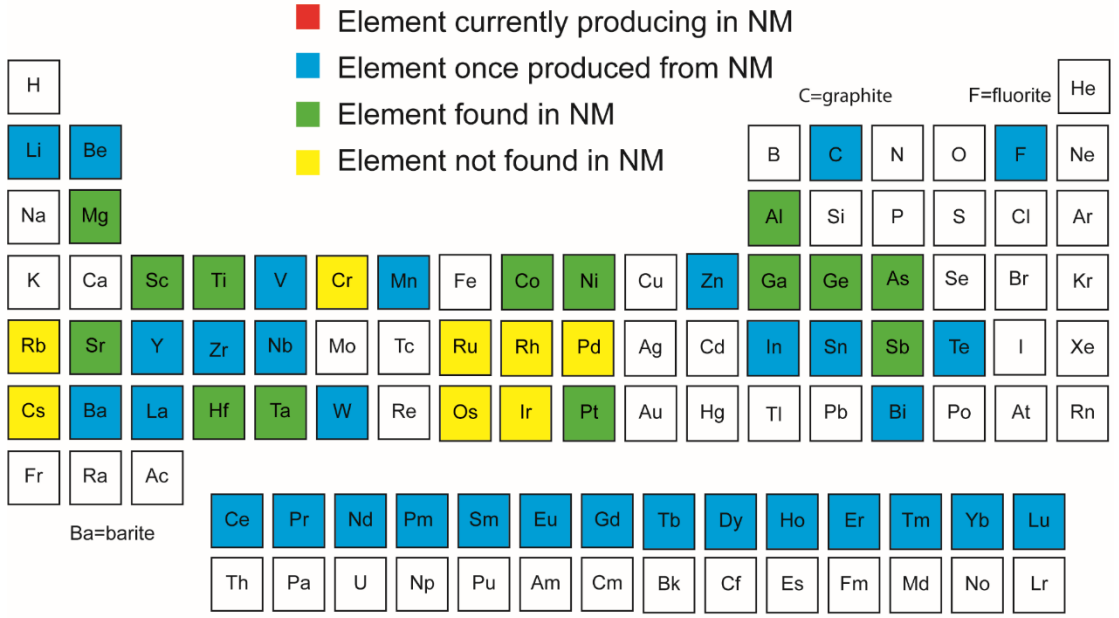
- Minerals needed for military, industrial or commercial purposes that are essential to renewable energy, national defense equipment, medical devices, electronics, agricultural production and common household items
- Minerals that are essential for use but subject to potential supply disruptions
- Minerals that perform an essential function for which few or no satisfactory substitutes exist
- The absence of which would cause economic, national security, or social consequences
- 33-50% minerals are classified as such

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.

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.

DOE recently added Copper (Cu) to their list of critical minerals

Critical minerals change with time and country

- Salt was once a critical mineral, but is now abundant with low supply disruptions
- Copper is considered critical mineral by Japan

minerals

MDPI

Article

Environmental Implications of Resource Security Strategies for Critical Minerals: A Case Study of Copper in Japan

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check for updates

Abstract: In the assessment of critical minerals, environmental impacts have been a focus of a number of methodologies. In the case of resource security for critical minerals, there are a variety of potential strategies that might be used to reduce criticality from the supply risk perspective, but

Episyenites

- The term *episyenite* was originally used to describe metasomatic syenites whose magmatic protolith was not certain (Lacroix, 1920)
- Episyenites are quartz-depleted, K-feldspar-rich altered rocks that were desilicified and metasomatized by alkali-rich fluids
- Episyenites are similar to altered rocks formed by fenitization and would be called fenites by some geologists
- Fenitization is the alkali-metasomatism associated with carbonatites or alkaline igneous activity
- However, we are reluctant to use the term fenite for these rocks studied here because there is no definitive spatial association with carbonatite or alkaline igneous rocks in some areas

Dike-like episyenite in Longbottom Canyon area

Fractures filled with episyenite beneath an episyenite body on the Sevilleta Wildlife range

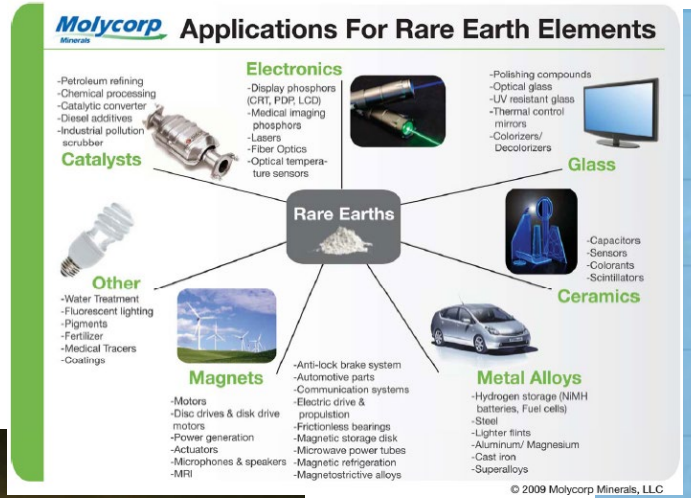
Carbonatites

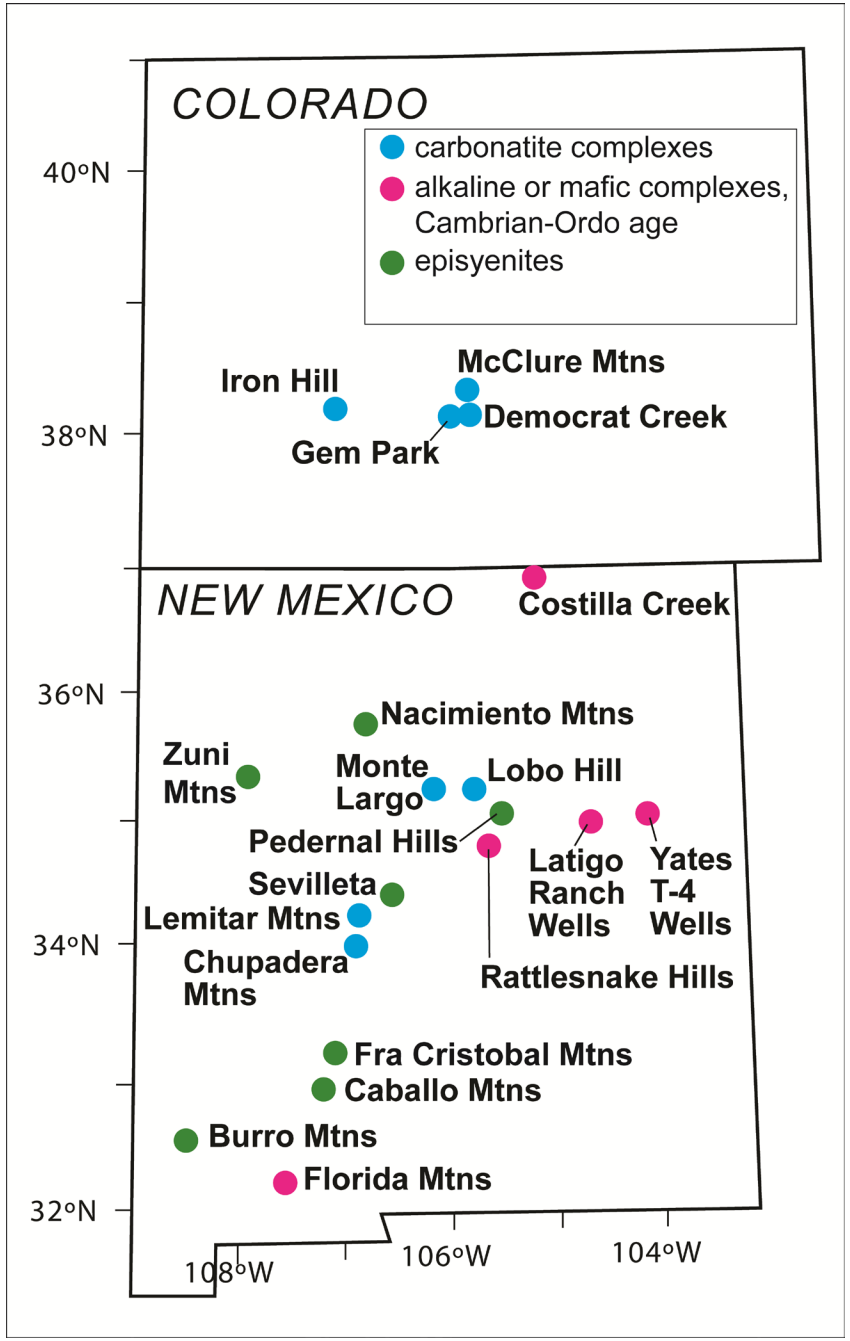
- Carbonate-rich rocks contain >50% magmatic carbonate minerals (calcite, dolomite, siderite, ankerite), apatite, barite
- Less than 20% SiO_2 (silicate minerals)
- Enriched in REE, U, Th, Nb, Ta, Zr, Hf, Fe, Ti, V, Cu, Sr

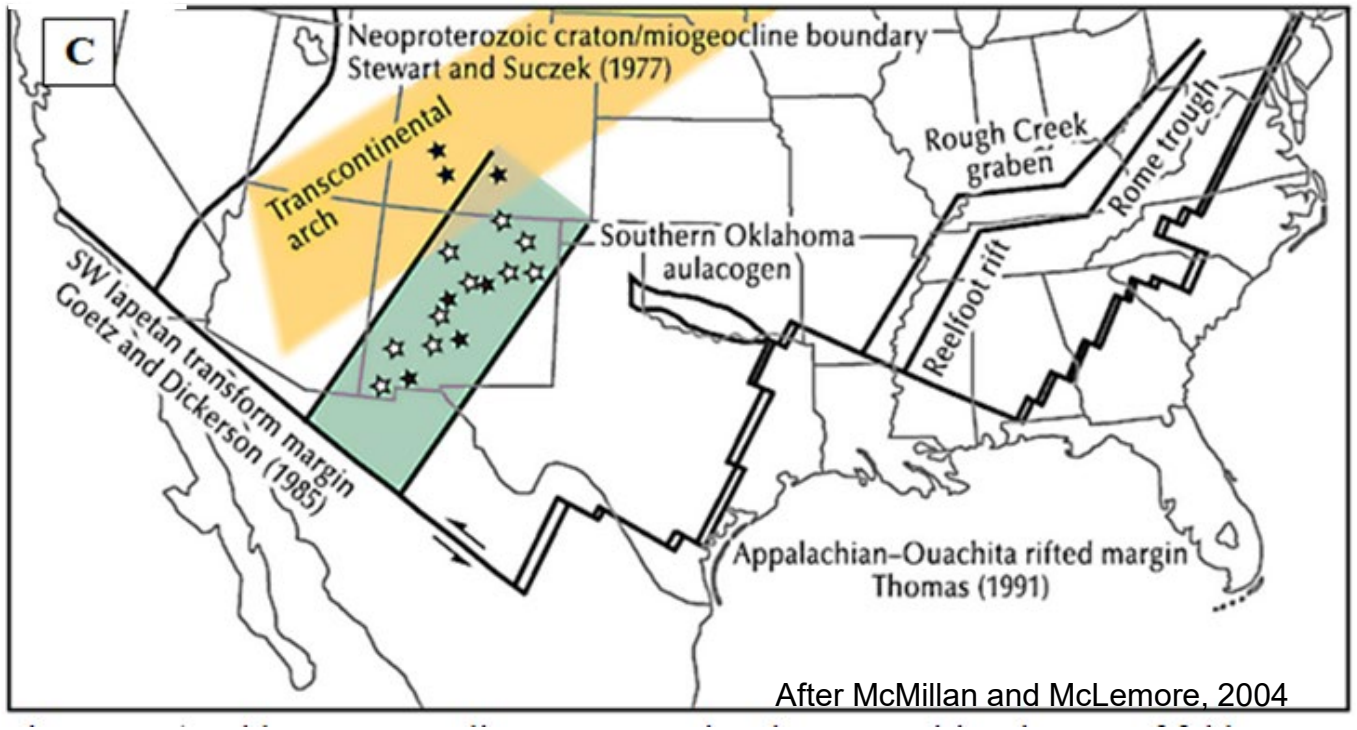
Carbonatites are important because they are an economic source of REE

Mountain Pass Carbonatite, California

- 1.3 Mt in reserves with a grade of 7.98%
  - Bastnaesite (light REEs)





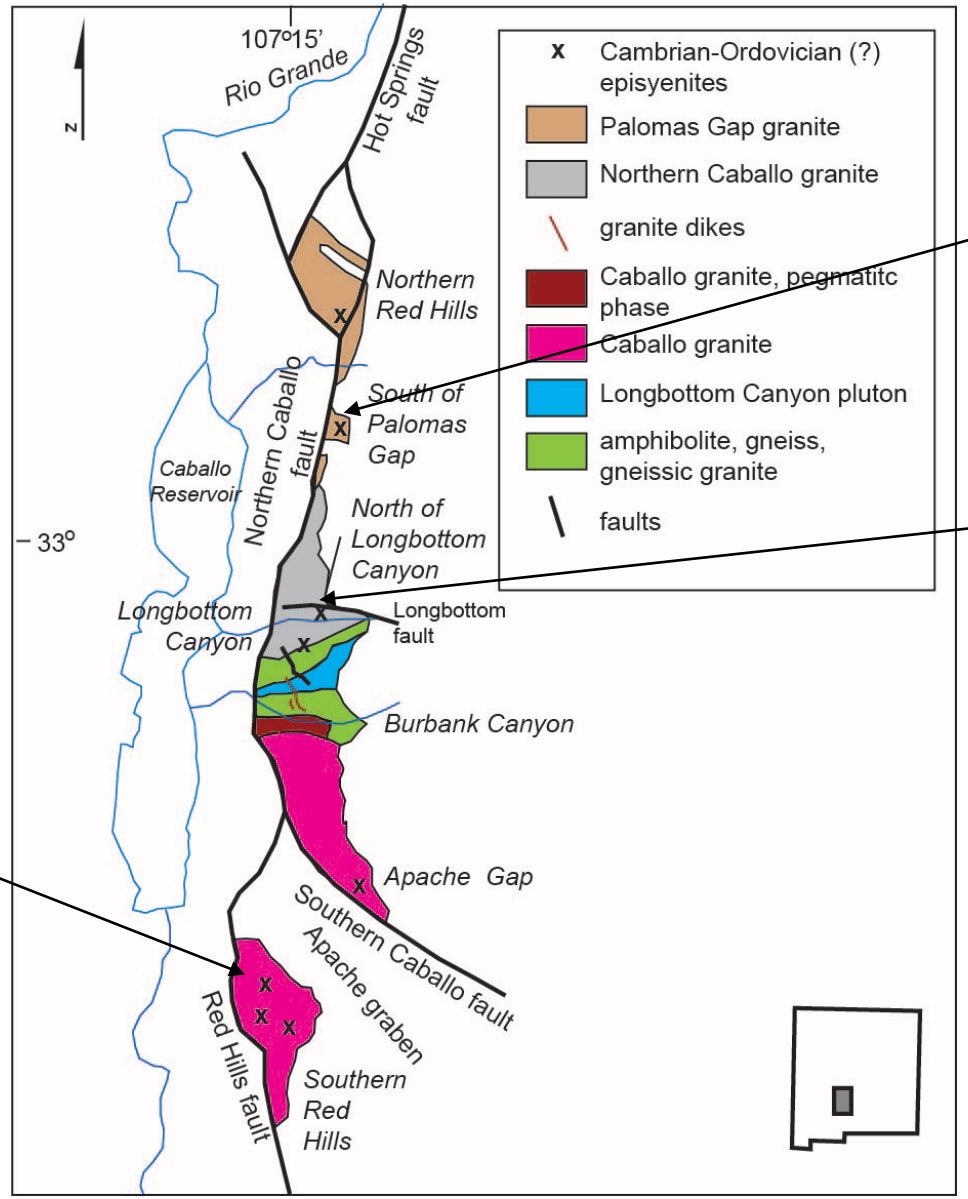


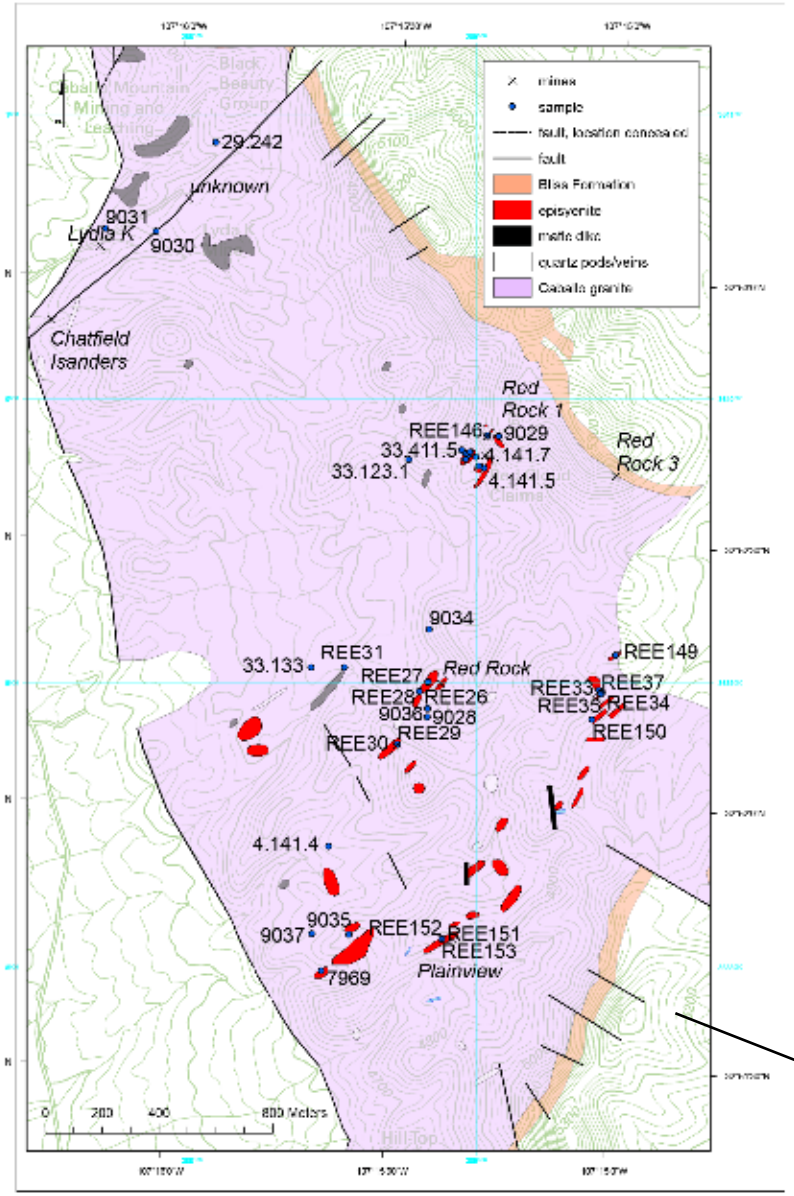
After McMillan and McLemore, 2004

Cambrian-Ordovician magmatic event in New Mexico resulting in carbonatites, syenites, alkali granites, episyenites (metasomatic rocks)

Field Relationships

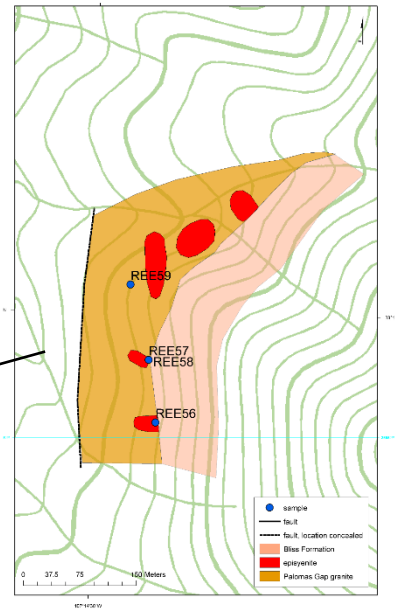
Caballo Mountains



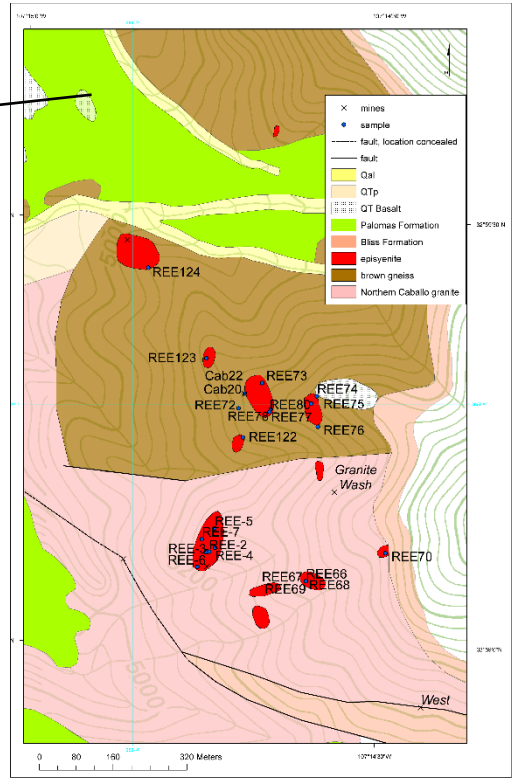


Southern Red Hills

South Palomas Gap



Longbottom Canyon

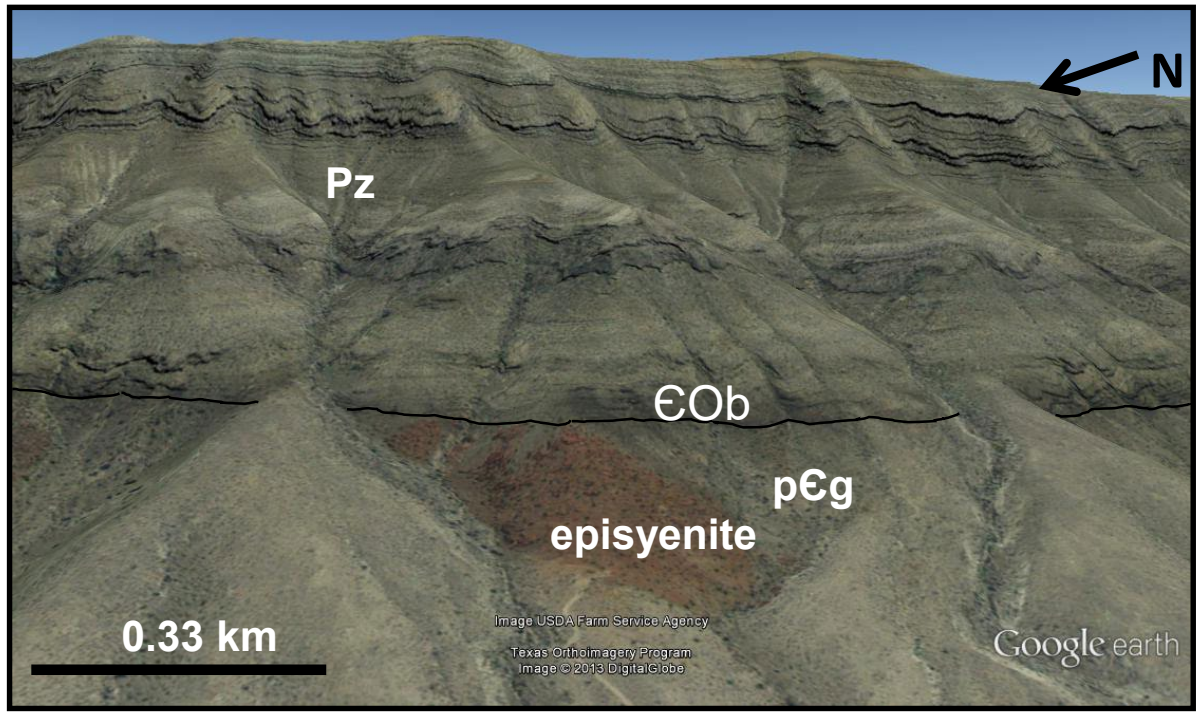


Apache Gap, Caballo Mountains

Quarry, South Red Hills, Caballo Mountains

Jack Creek Rapakivi Granite, Ramsey Saddle area, Wild Horse Mesa area, northern Burro Mountains

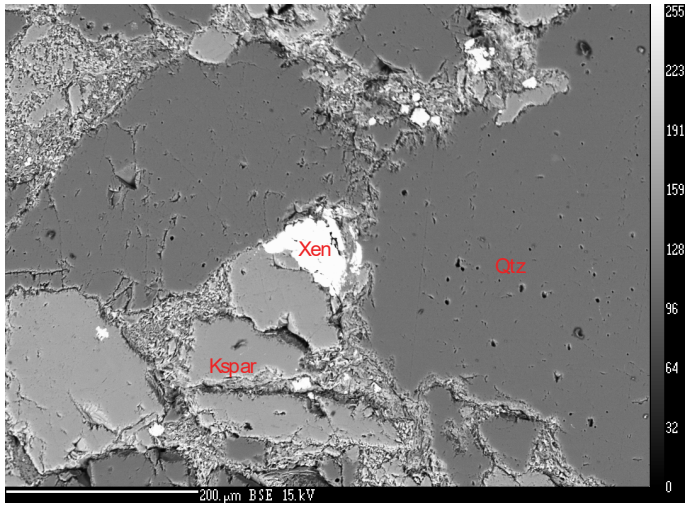
The rapakivi texture is preserved within the episyenite, suggesting a metasomatic origin

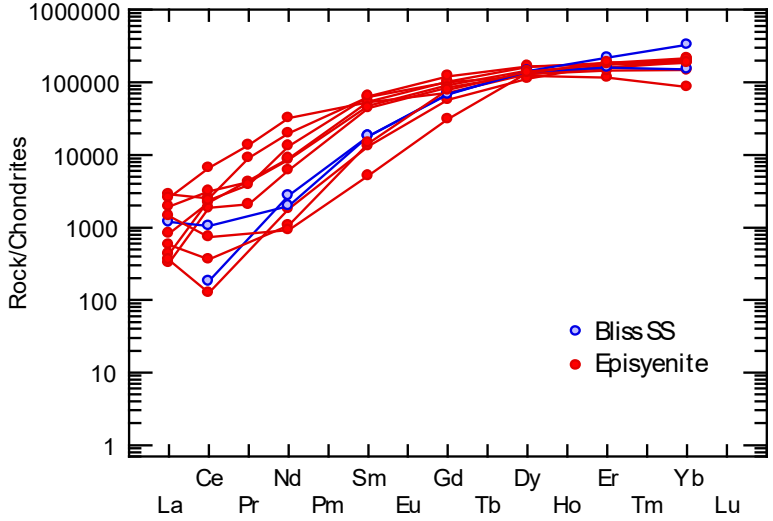


Episyenites South Palomas Gap, Caballo Mountains are unconformably overlain by the Cambrian-Ordovician Bliss Formation (looking west)

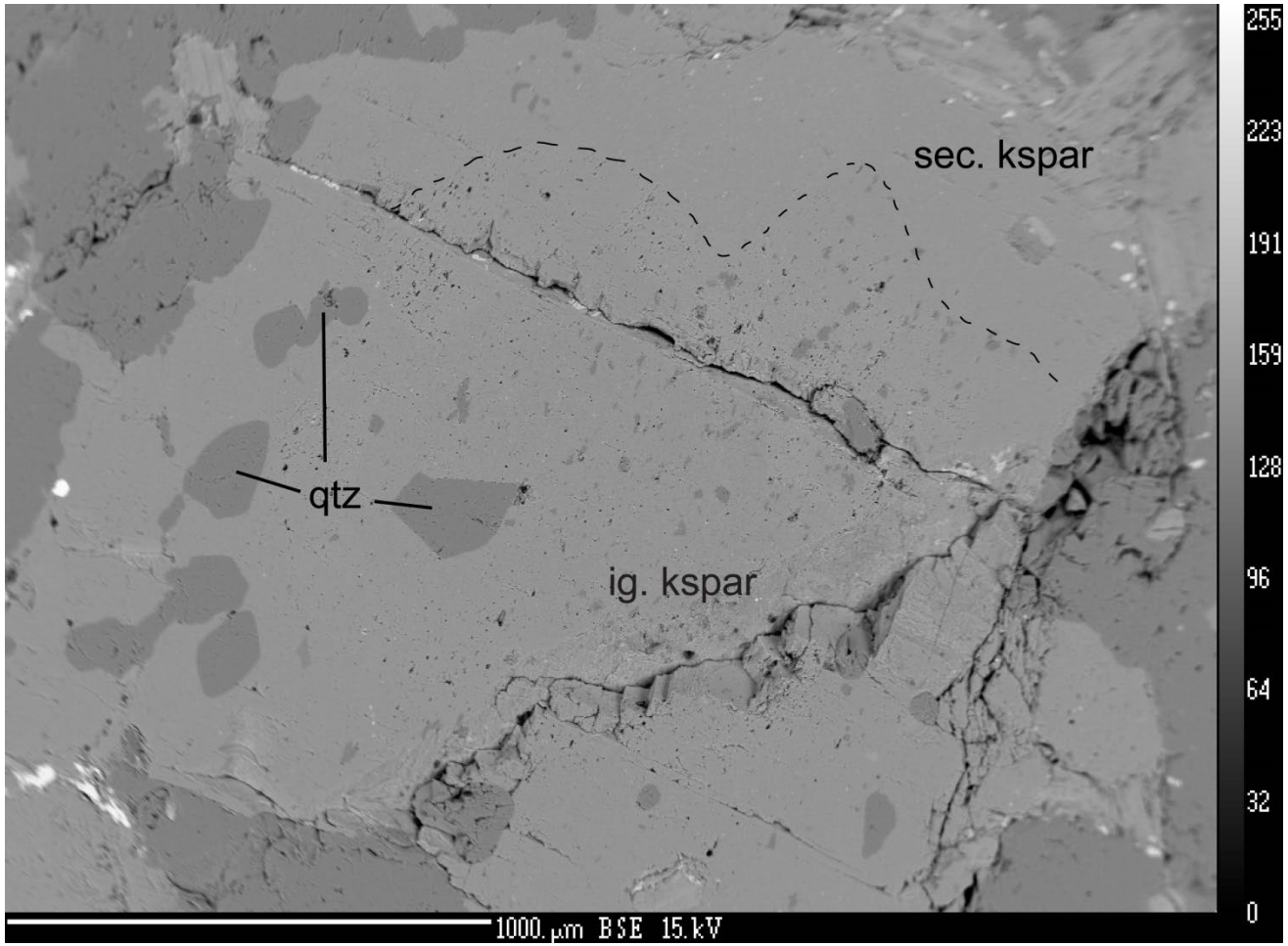
Clasts of episyenite in the basal transgressive conglomerate of the Bliss Formation

Xenotime in the basal Bliss Formation



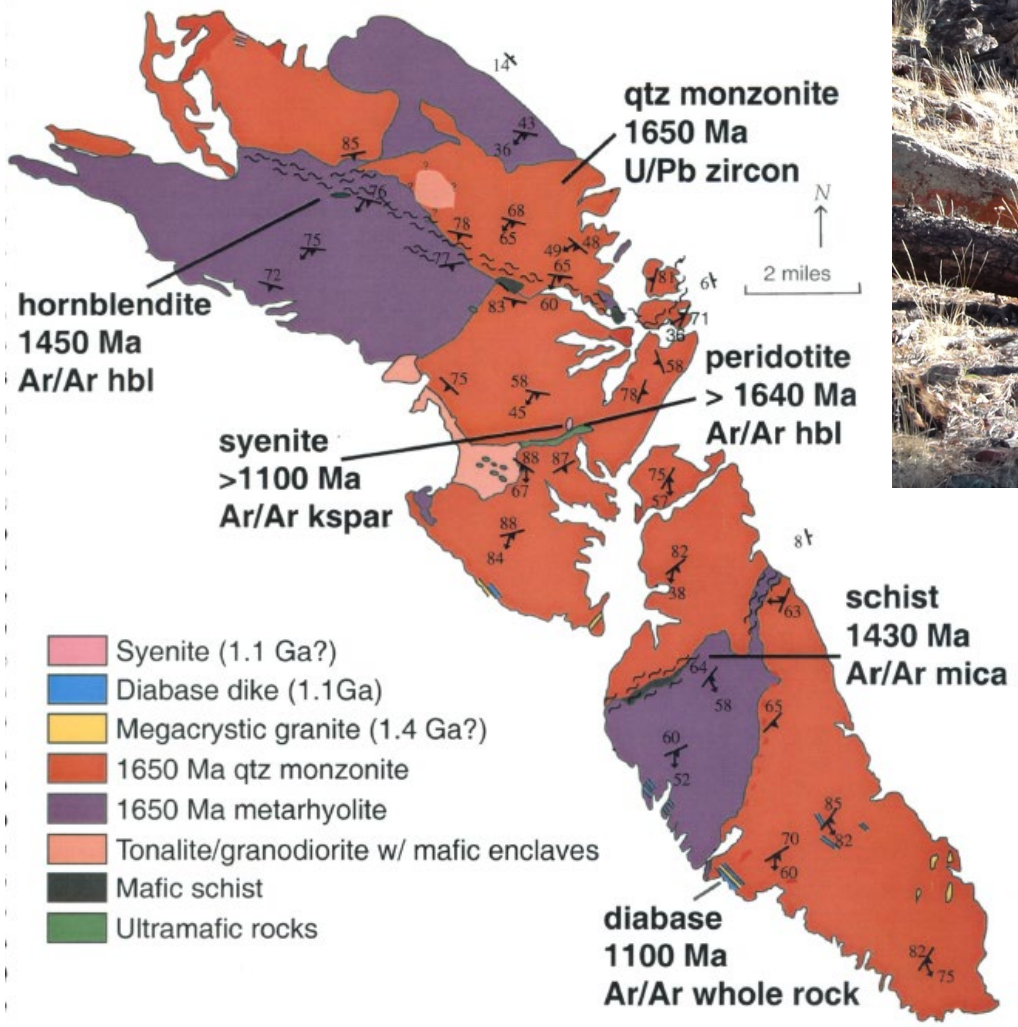


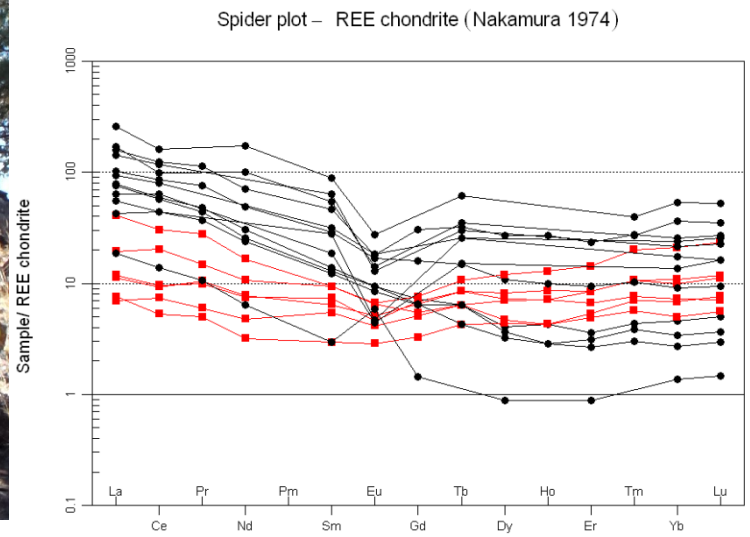
Backscatter electron image of K-feldspar



The feldspars to be dated must be selected carefully

Zuni Mountains

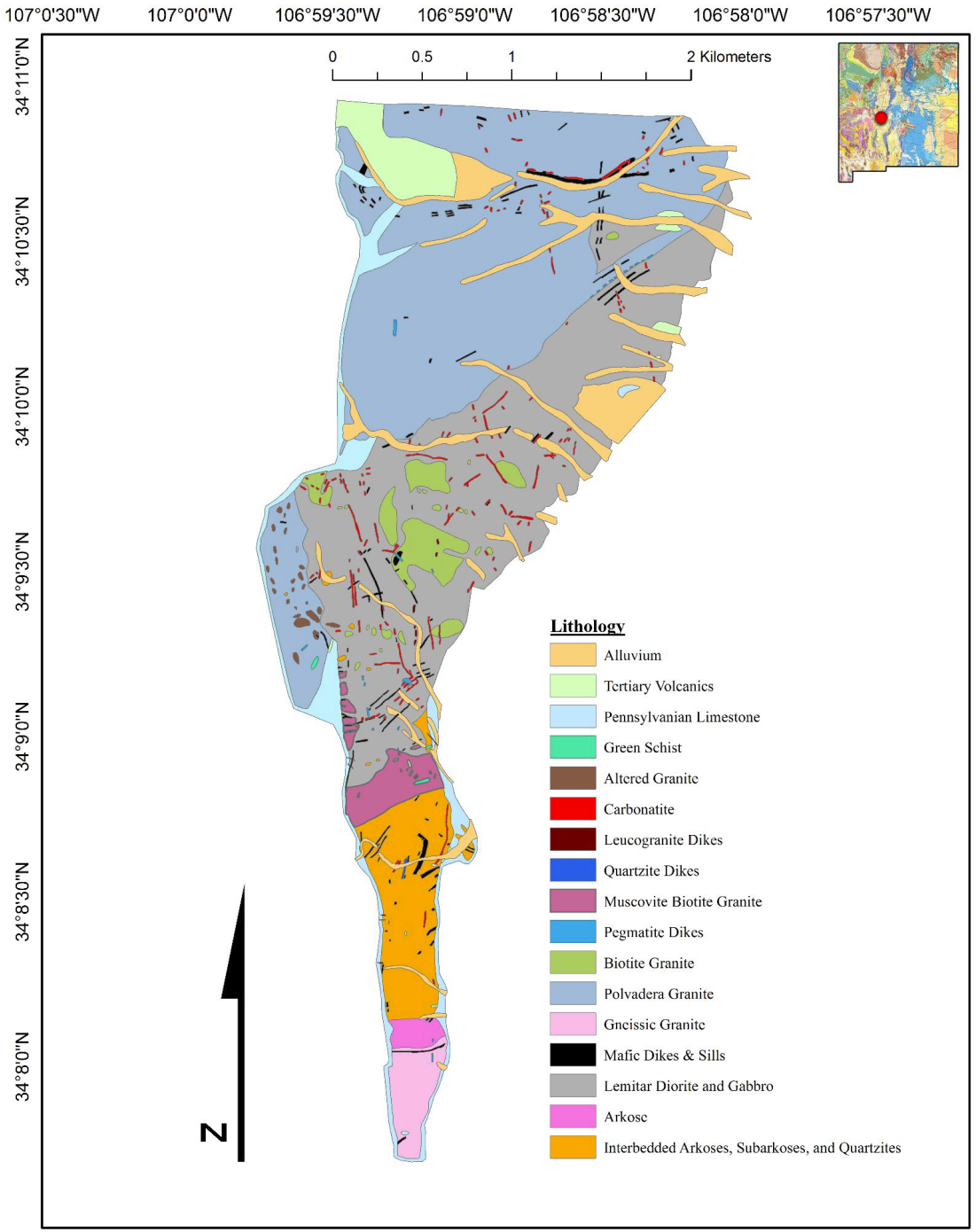




Age dates from Bowing and Condie (1982), Strickland (2000)
Geology from Goddard (1966), Lambert (1983)

Lemitar Mountains

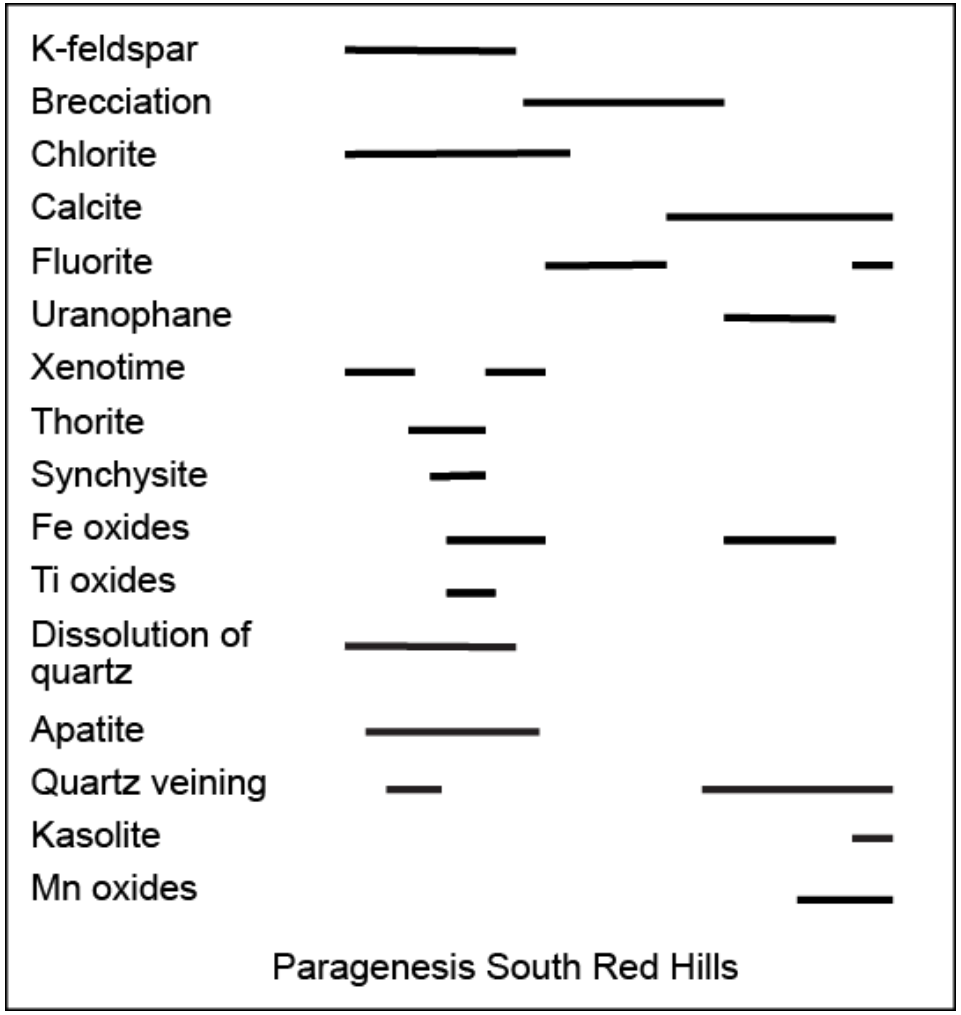
- More than 100 carbonatite dikes intruded a complex Proterozoic granitic and metamorphic terrain in the Lemitar Mountains, central New Mexico
- Dikes are a few centimeters to more than a meter wide and up to 600 m long, and contain anomalously high concentrations of REE, U, Th, and Nb



Chemistry and Mineralogy

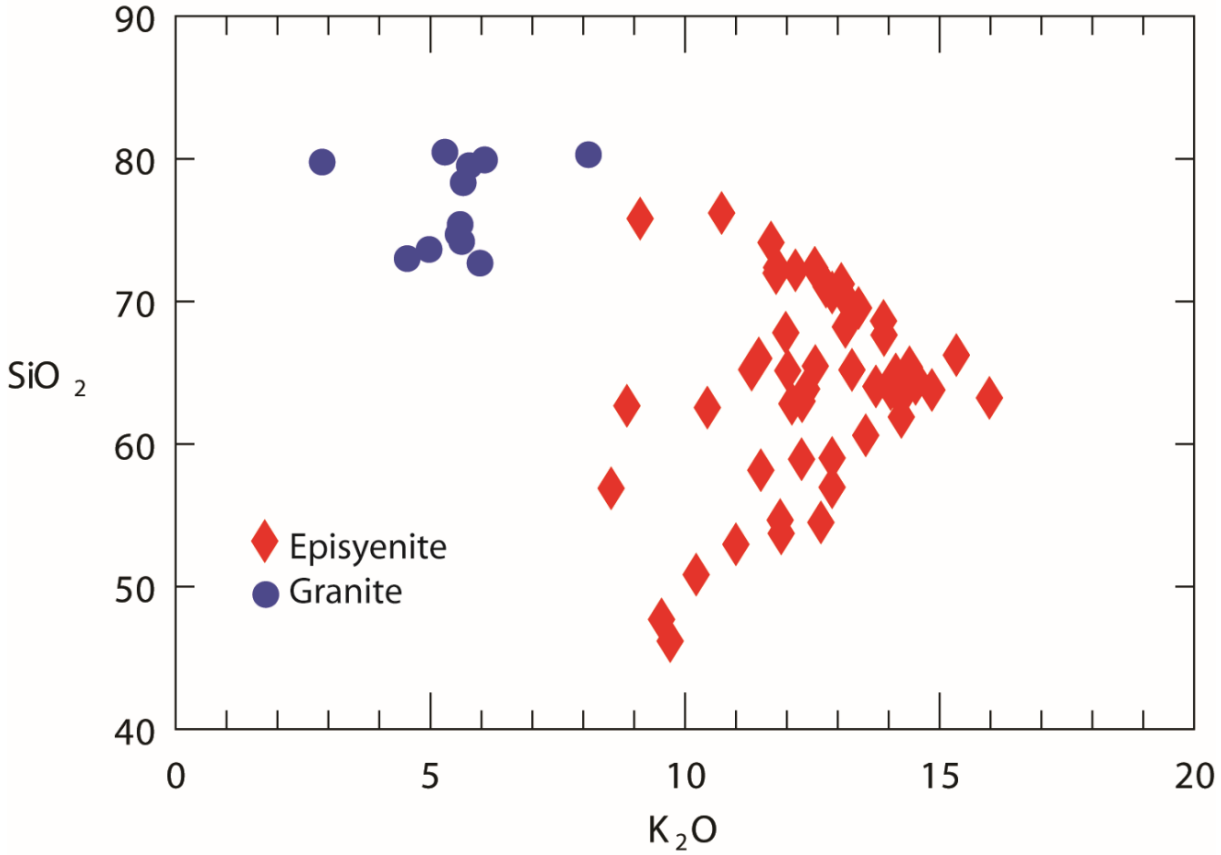
Episyenites have complex mineralogy

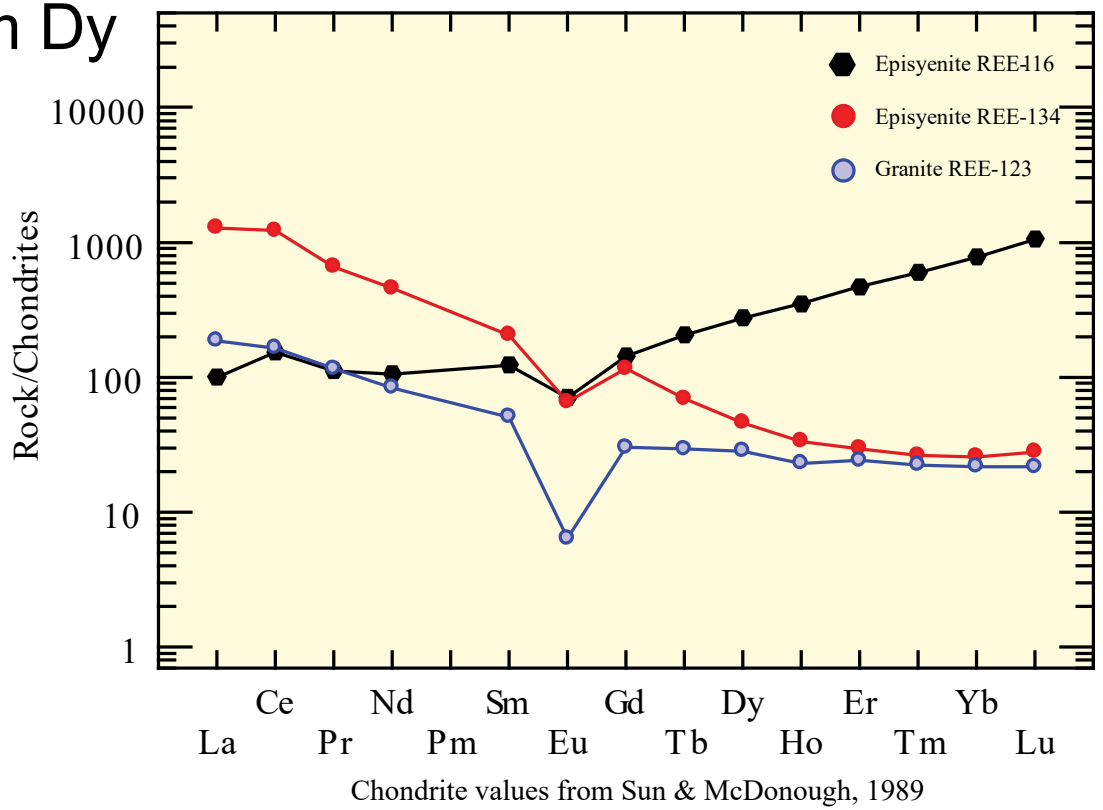
- Synchysite (63 wt.% LREE)
- Aeschynite (9 wt.% HREE)
- Xenotime (16 wt.% HREE)
- Thorite
- Uranophane
- Bastnaesite



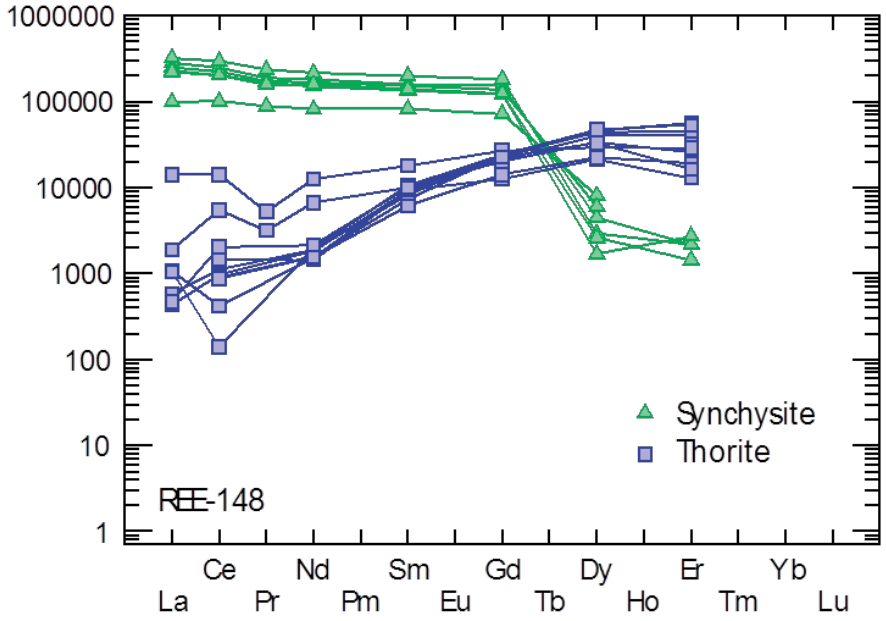
Composition of episyenites

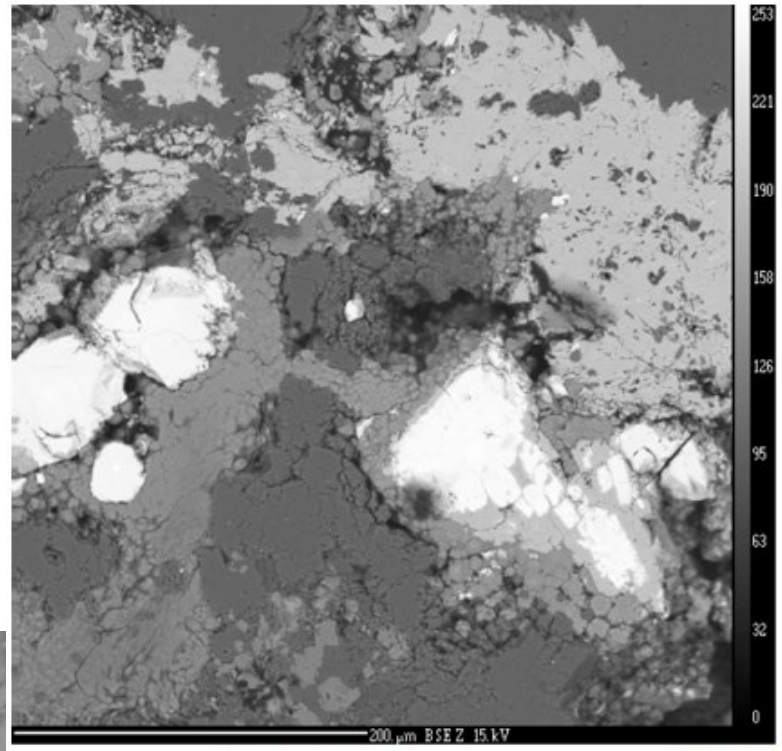
- K-feldspar rich (>16% K_2O) and quartz poor
- Anomalous in U (2,329 ppm), Th (9,721 ppm), TREE (1,378 ppm), Yb (130 ppm) and ppm Dy (180 ppm)

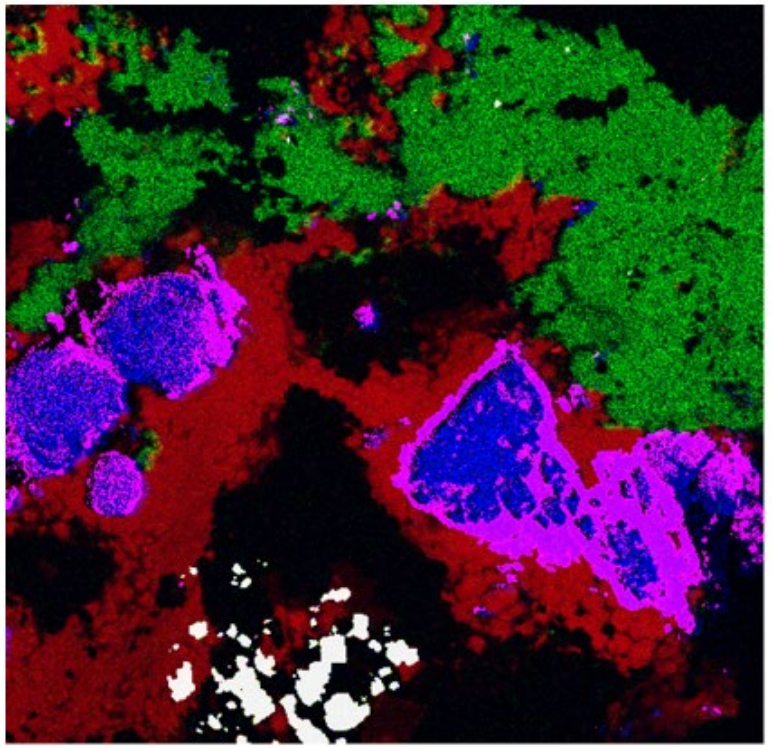




Granite samples typically contain more silica and less K_2O, episyenite endmember orthoclase at 15.60 wt. % K_2O (K-feldspar





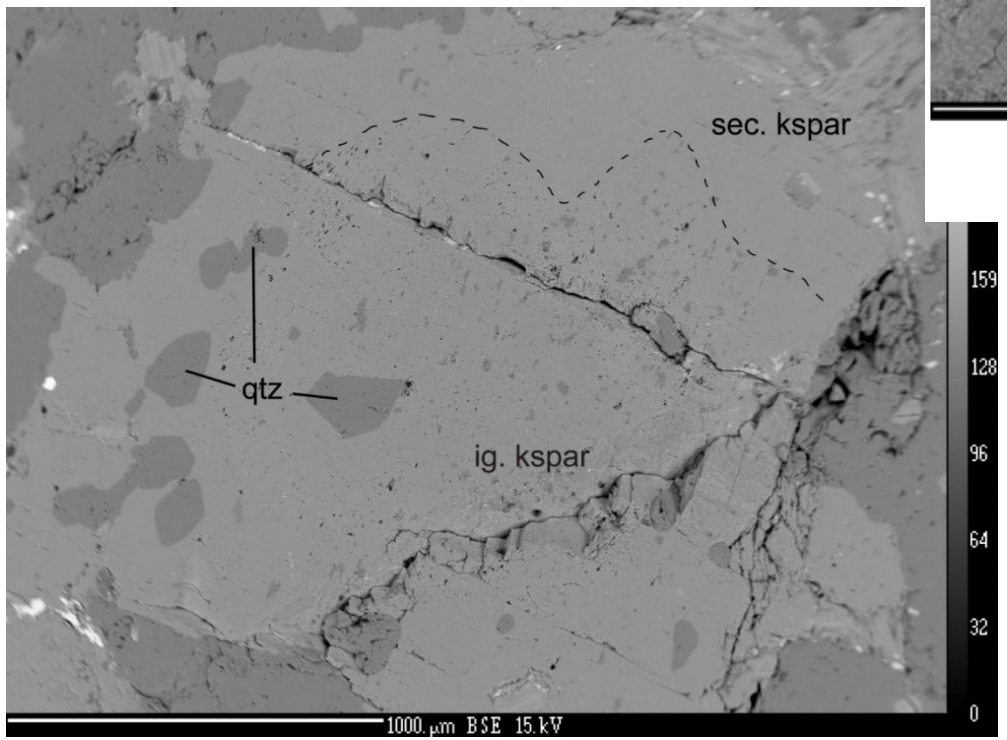


Synchysite $Ca(LREE)(CO_3)2F$

Thorite $(Th,U)SiO_4$

Xenotime YPO_4

Electron microprobe image of minerals in episyenite, Caballo Mountains

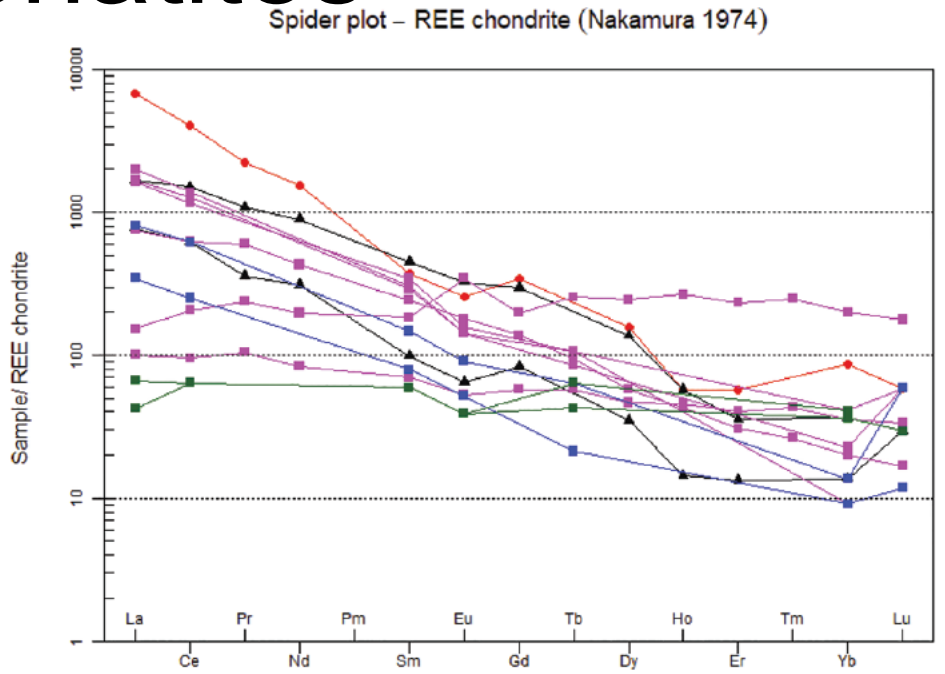


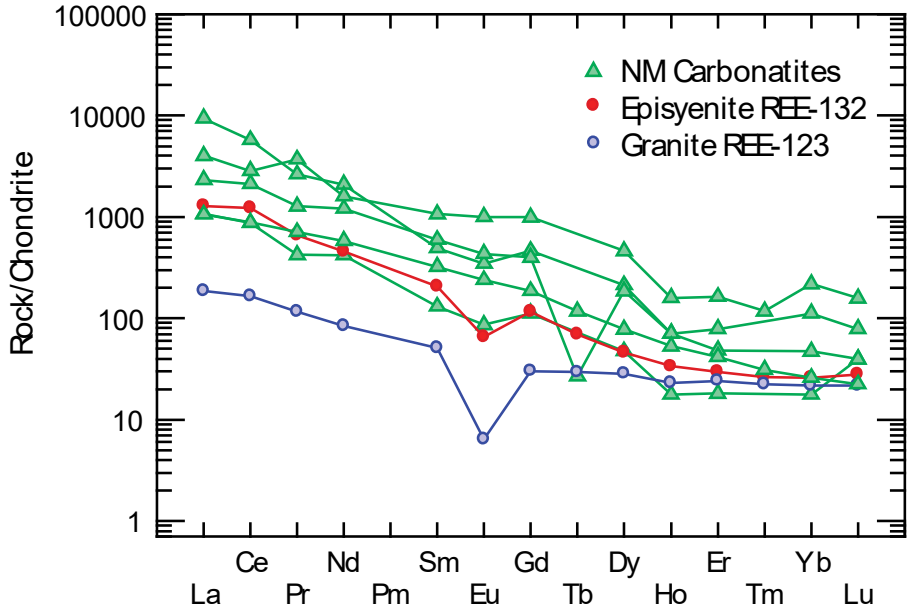
Backscatter electron image of K-feldspar

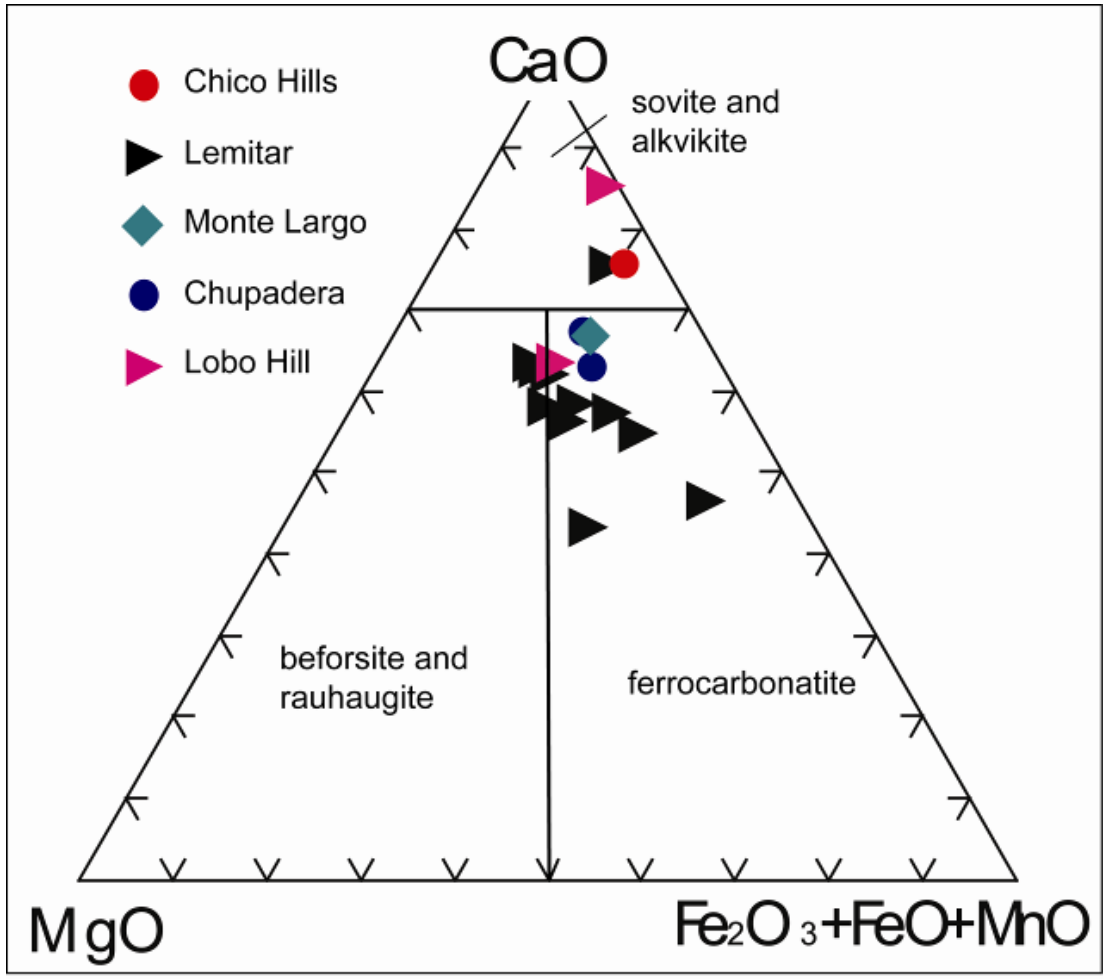
Composition of Lemitar carbonatites

- As much as 11,327 ppm total REE (bastnasite, but more mineralogy is needed)
- As much as 1550 ppm Nb
- As much as 4244 ppm Ba (barite)

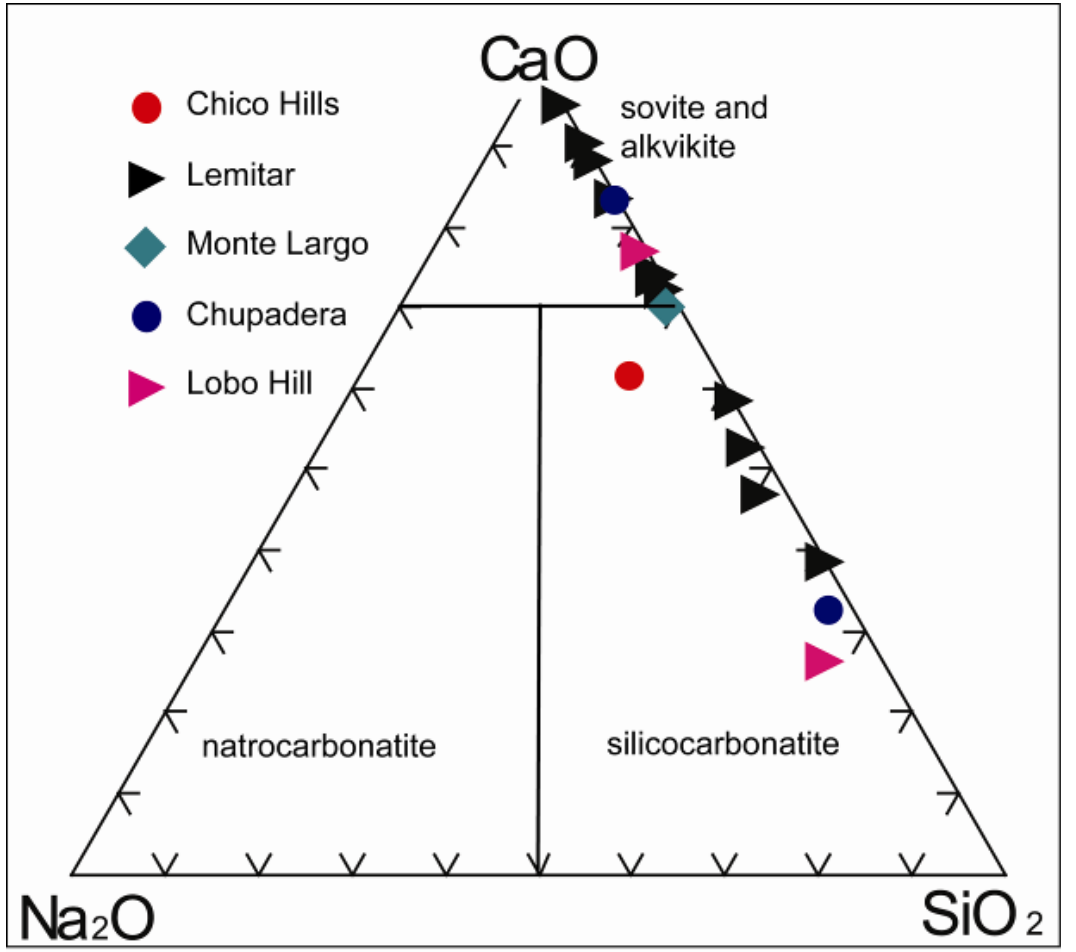
- These concentrations are elevated but are not economic at the present time







These diagrams show that carbonatites in NM have similar compositions to other carbonatites in the world. Each symbol is from different location in New Mexico.



Geologists like to classify rocks. Here are examples of the international classification.

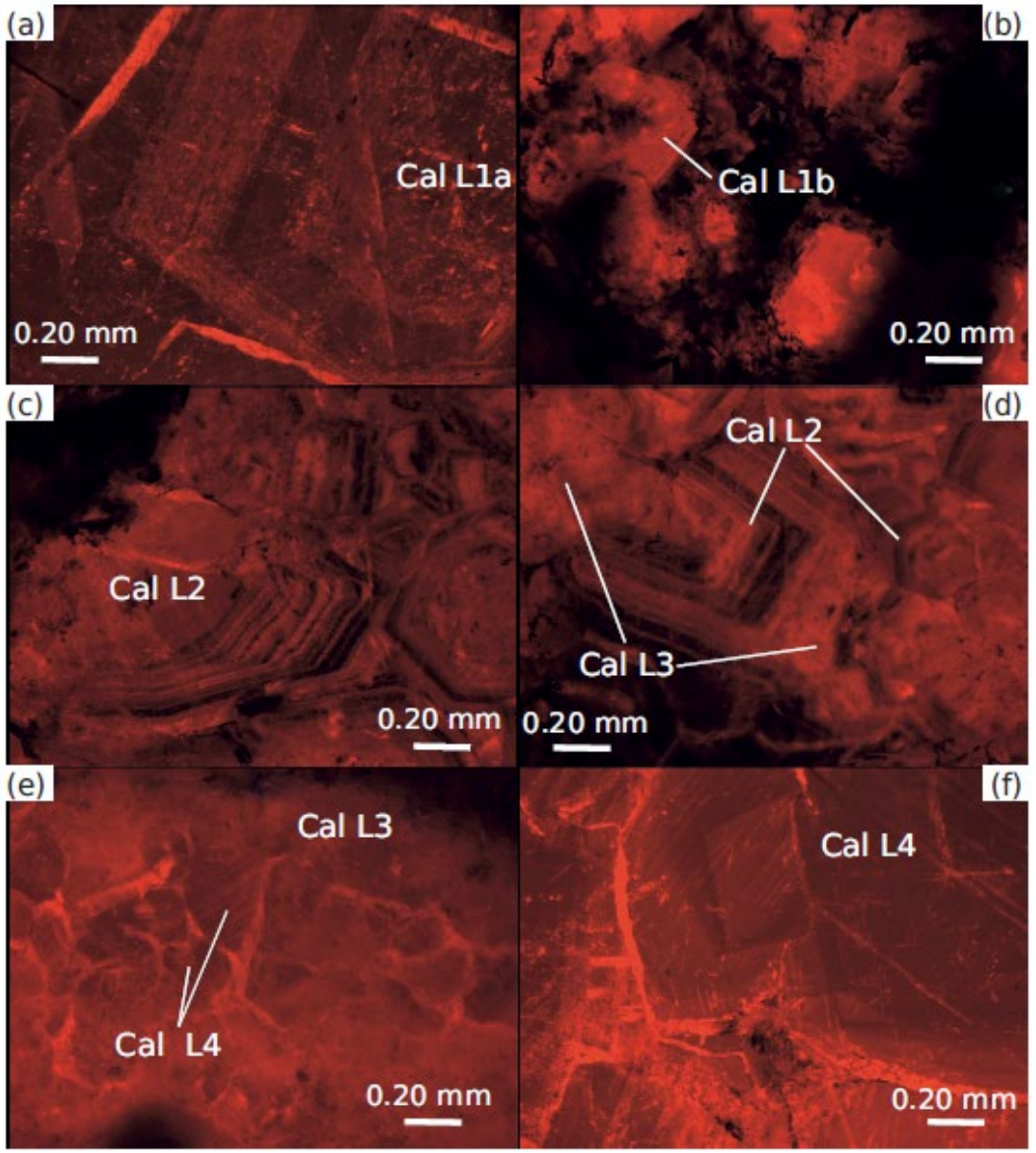
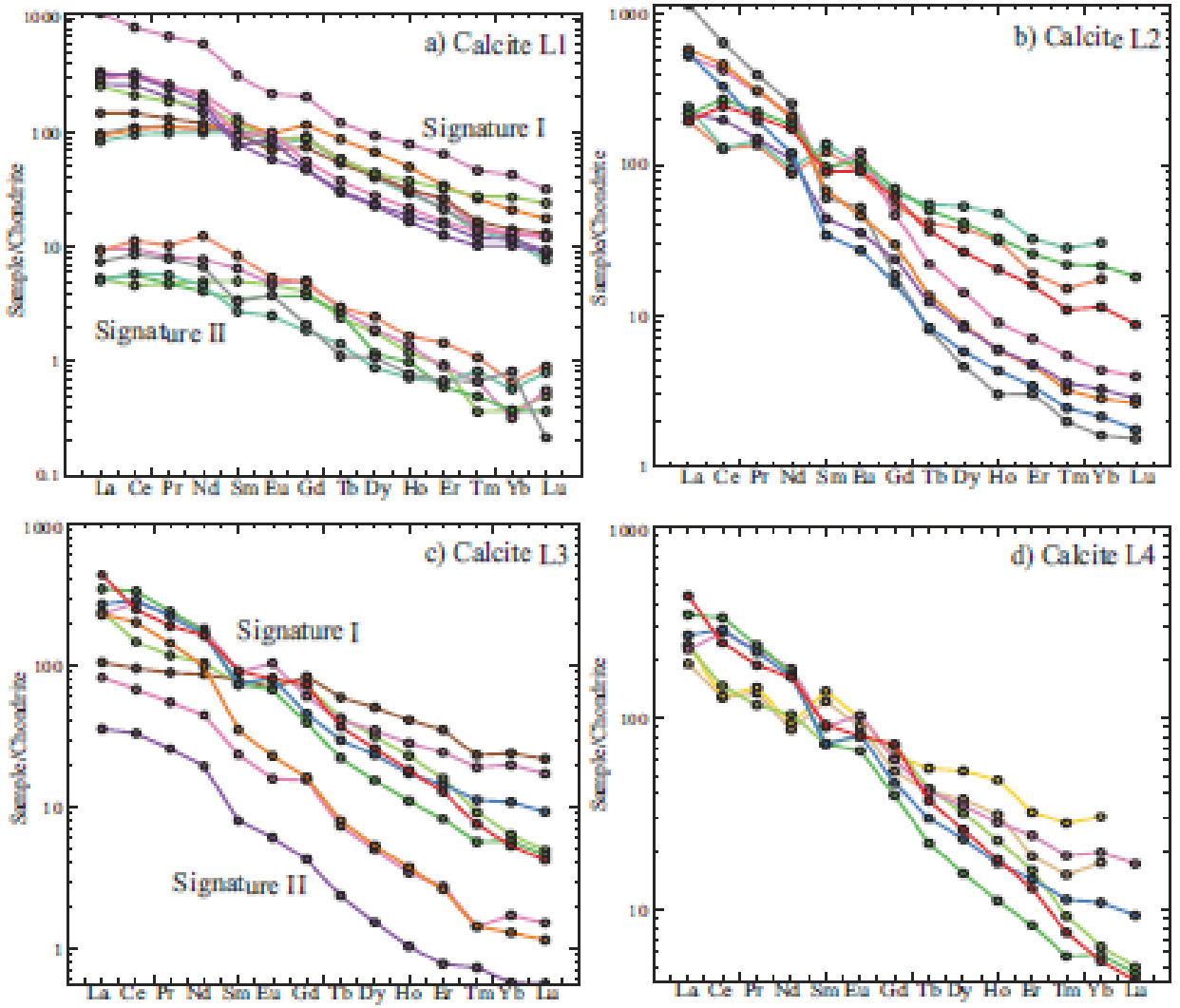


Figure 3.4: CL photomicrographs of Calcite L1-L4 in the Lemitar Mountains carbonatite. a,b) Calcite L1 with irregular oscillatory zoning, pitted cores and/or pervasive alteration. c,d) Calcite L2 with strong oscillatory zoning and overprint by Calcite L3. e) Anhedral clusters of Calcite L3 and euhedral to subhedral calcite L4 with bright CL rim signatures.

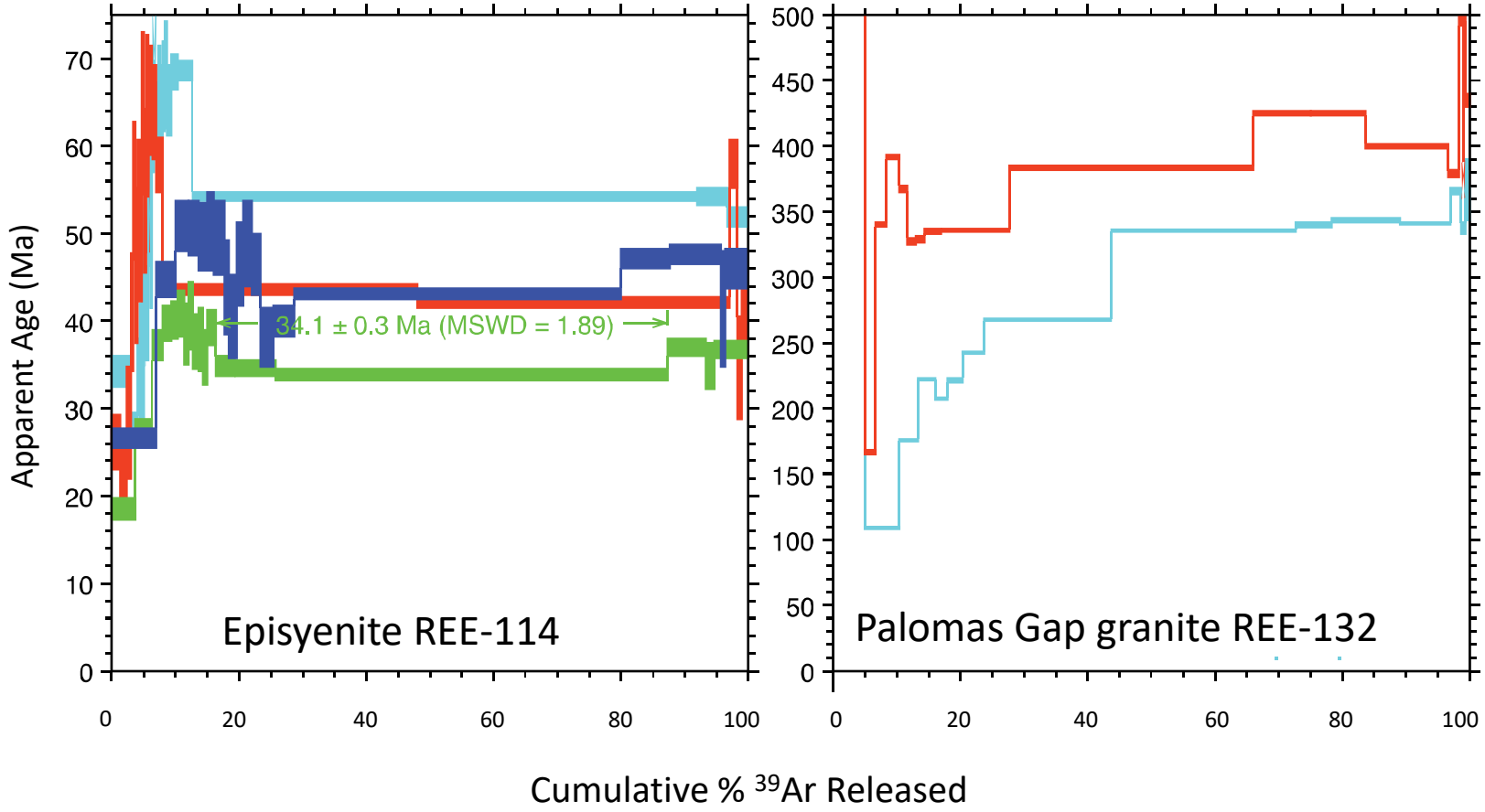


Perry (2019) found at least 4 stages of calcite with varying REE compositions in the Lemitar carbonatites

Geochronology

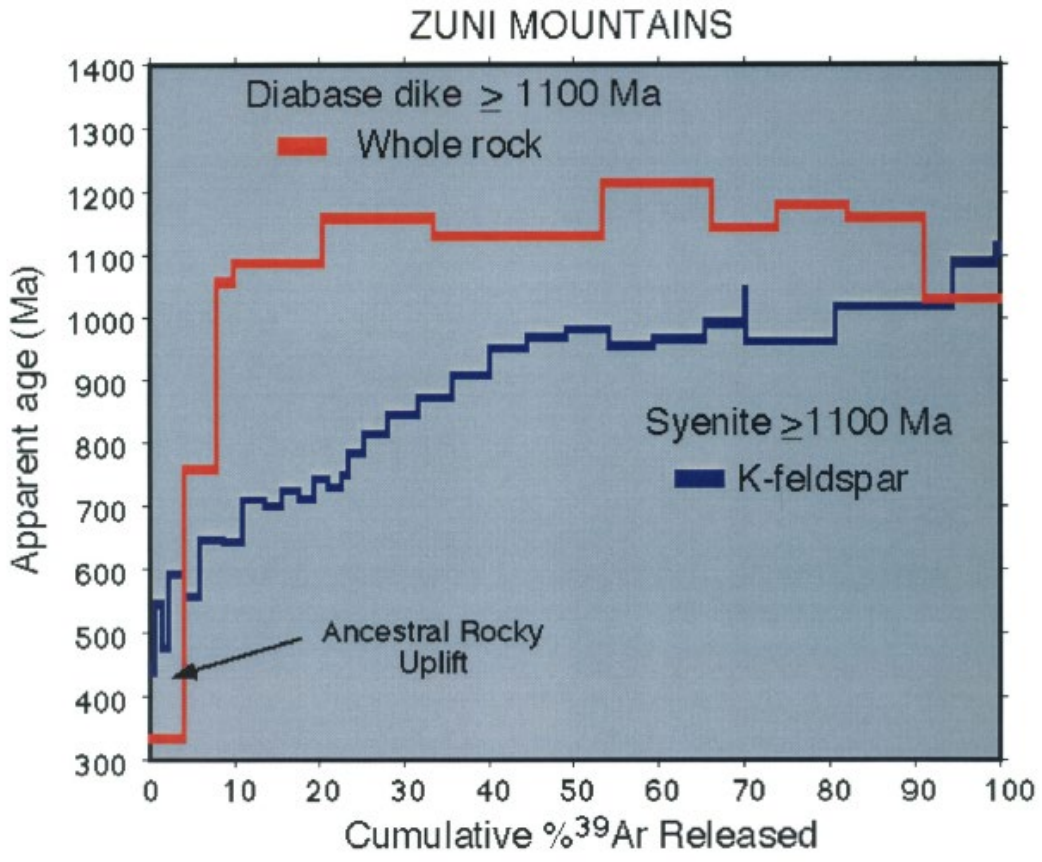
- Annelise M. Riggins, Adam Smith thesis, 40Ar/39Ar dating
- Jonas Kaare-Rasmussen, UC Santa Barbara, U/Pb dating

Caballo Mountains—4 individual K-feldspar fragments from an episyenite from the Northern Red Hills and the Palomas Gap Granite



My interpretation is that altered original feldspar was dated instead of the new metasomatic feldspar.

Zuni Mountains (Strickland, 2000)



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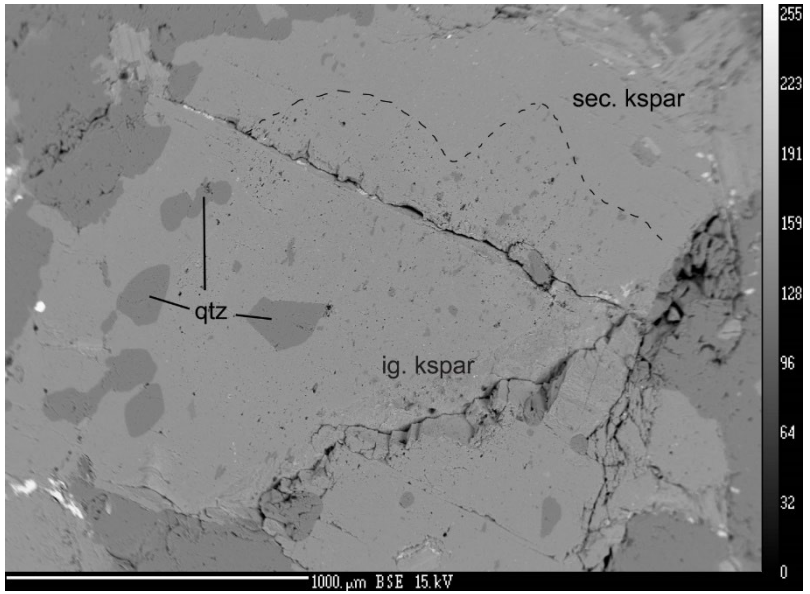
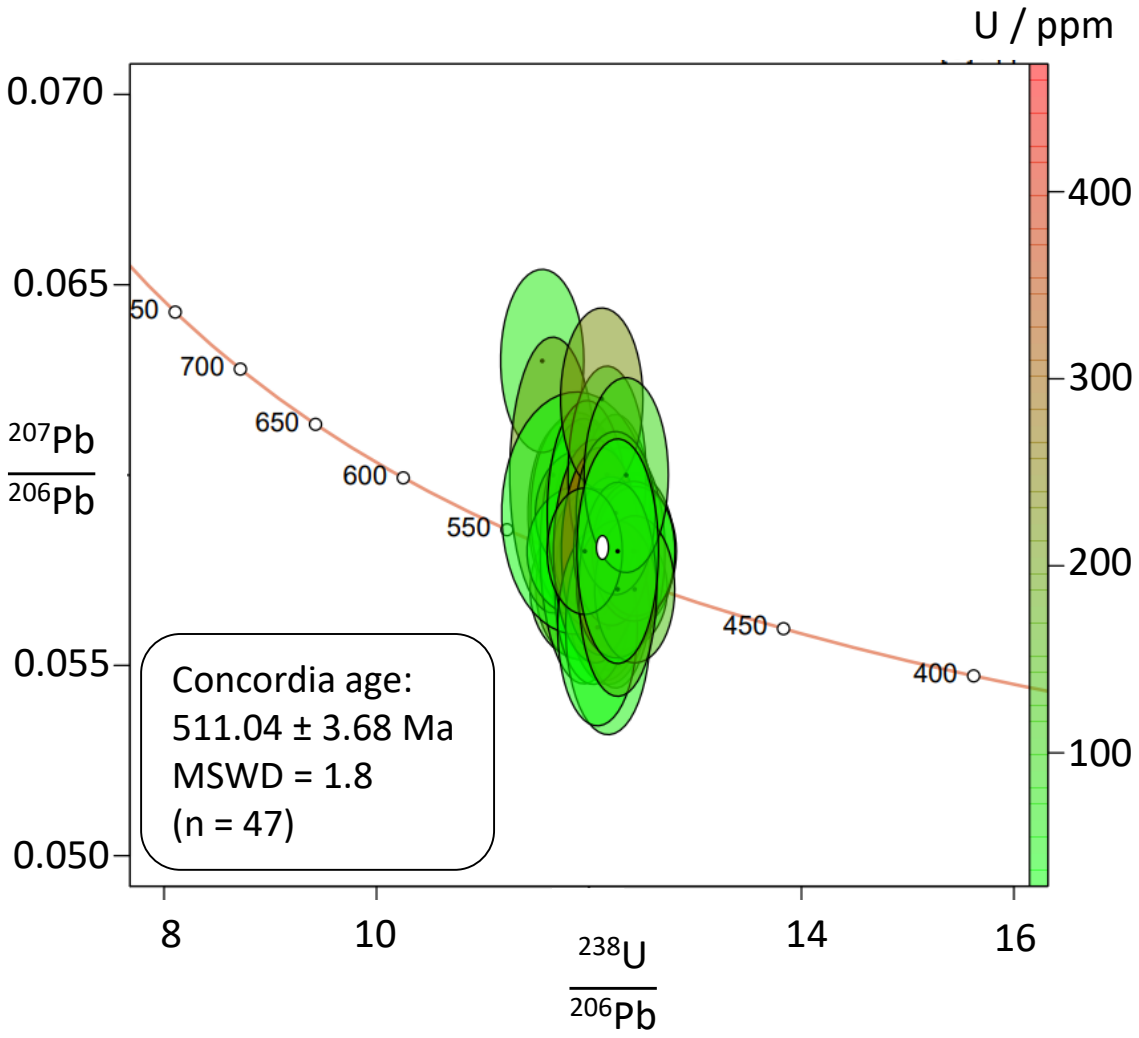
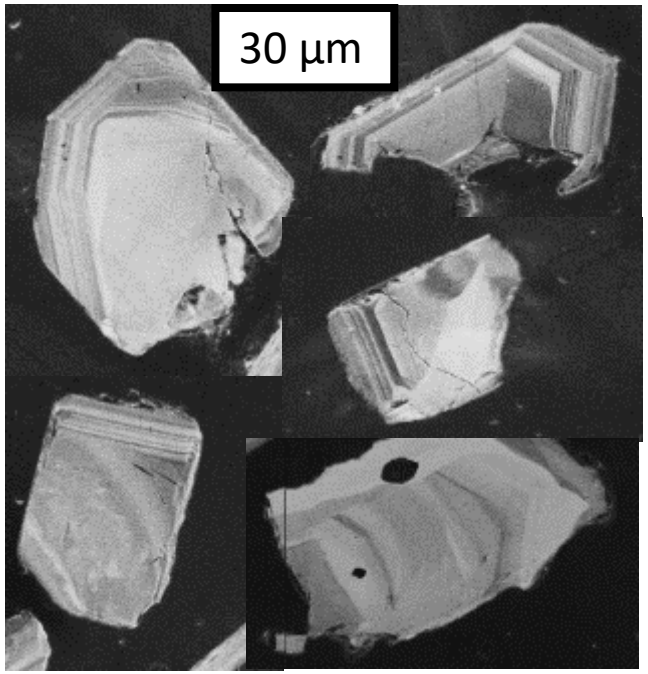


Florida Mountains – magmatic syenite

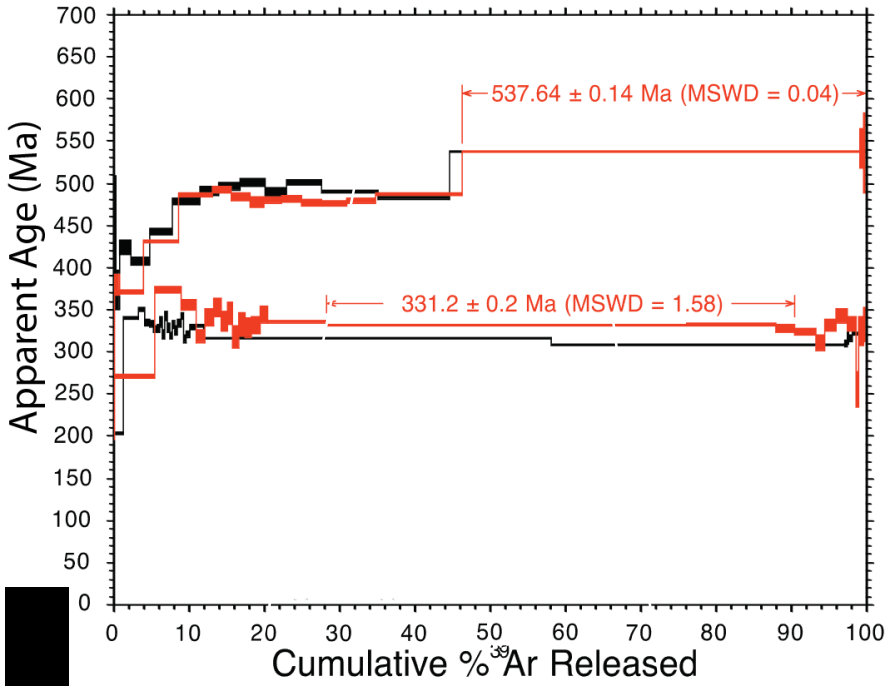


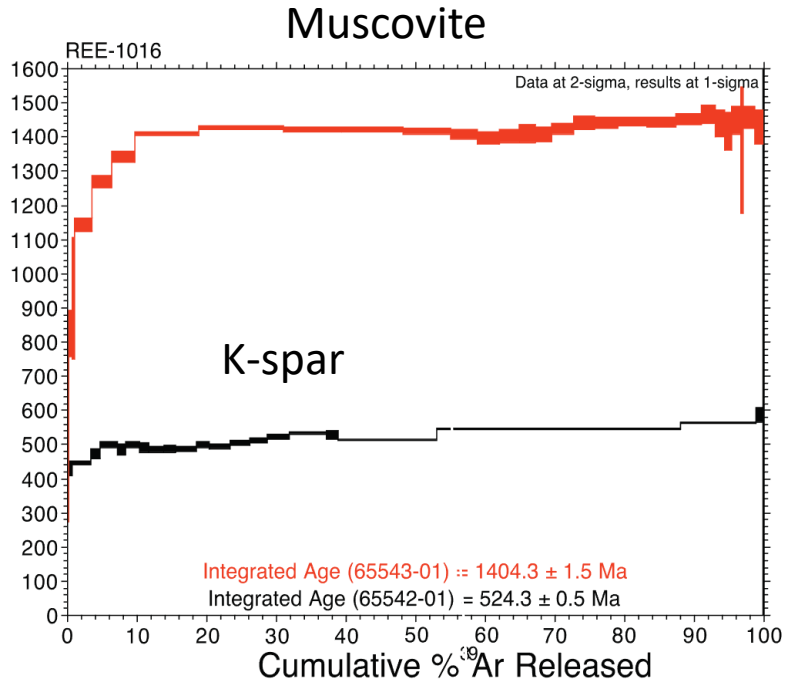


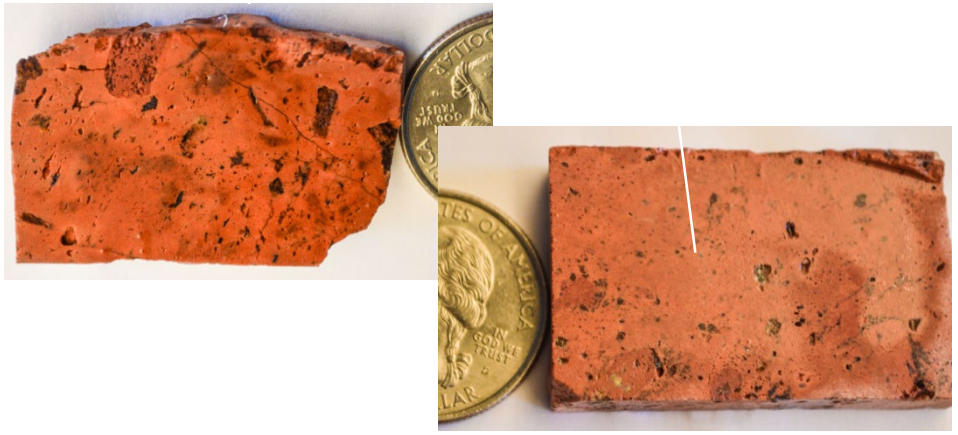
McMillian and McLemore, 2004

503 ± 10 Ma
(from Evans and Clemons, 2006)

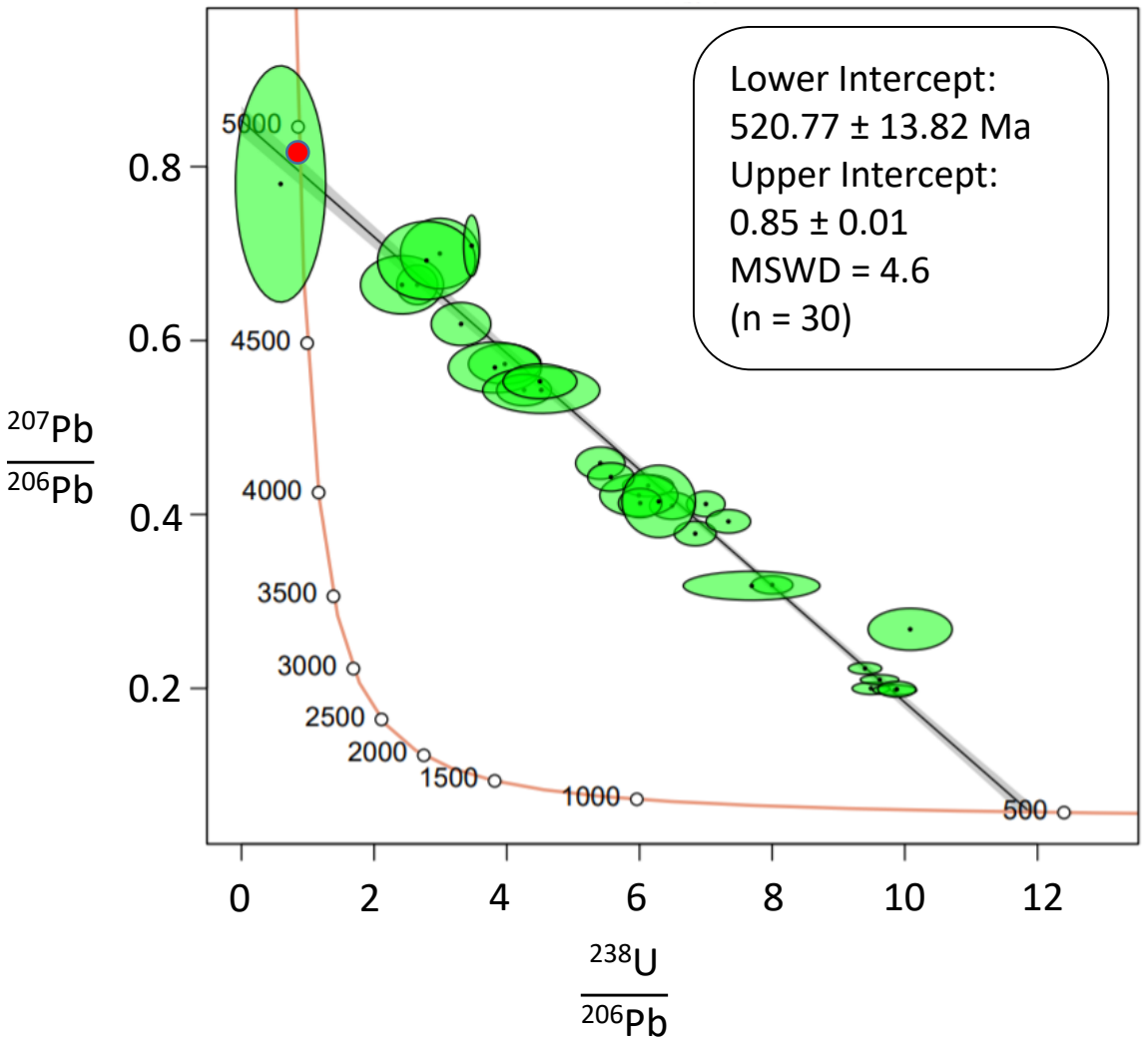
Lobo Hill – episyenites





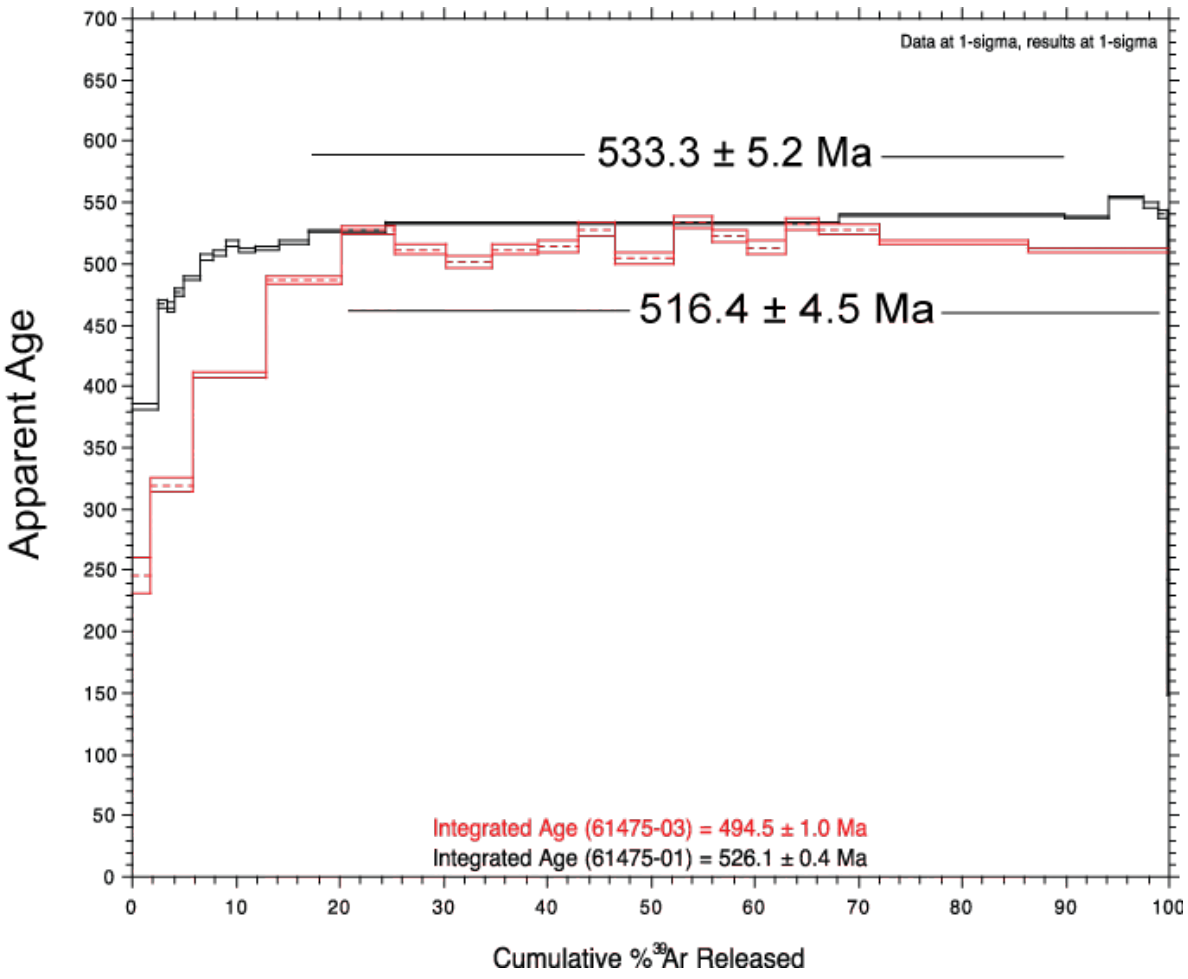


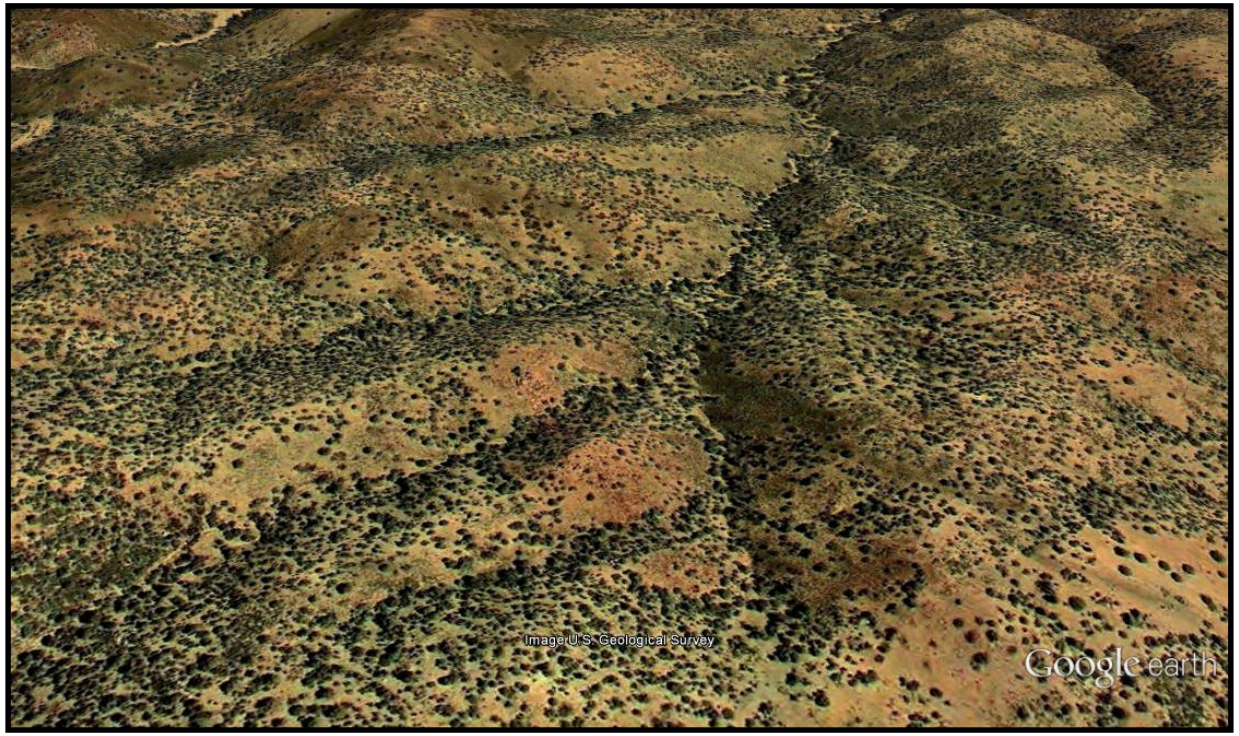
Lobo Hill – episyenites



518 ± 6.7 Ma ($^{40}Ar/^{39}Ar$ – biotite in monzonite) (McLemore et al., 1999)

Burro Mountains

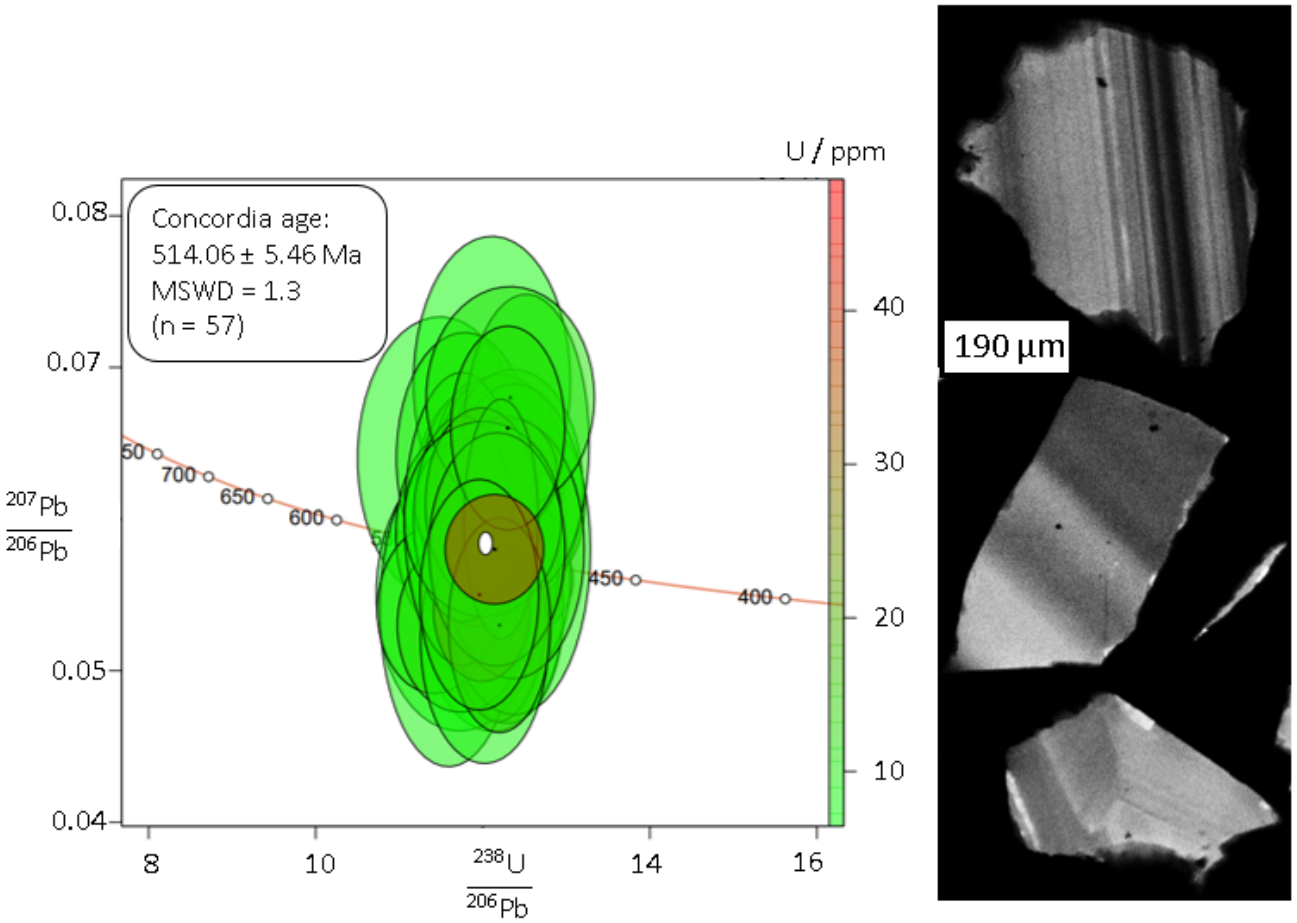


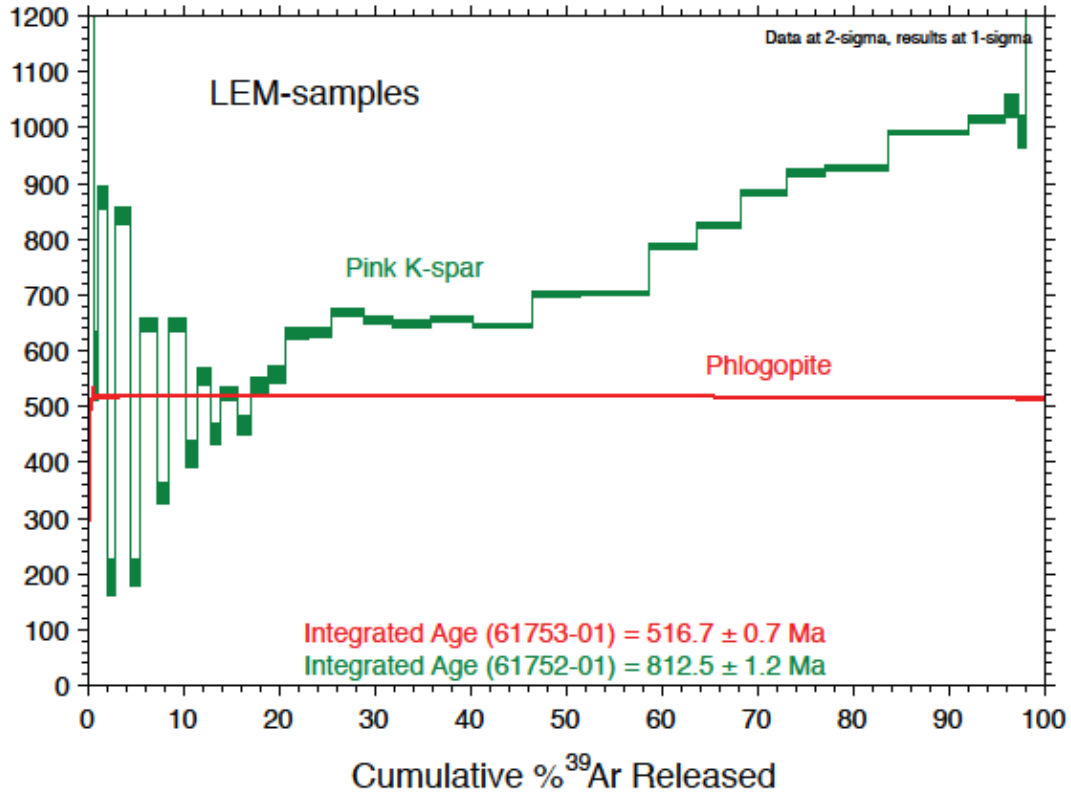


Eveningstar Canyon, Burro Mountains

Burro Mountains yields a $^{40}Ar/^{39}Ar$ plateau age at approximately 540 Ma (feldspar)

Lemitar – carbonatites



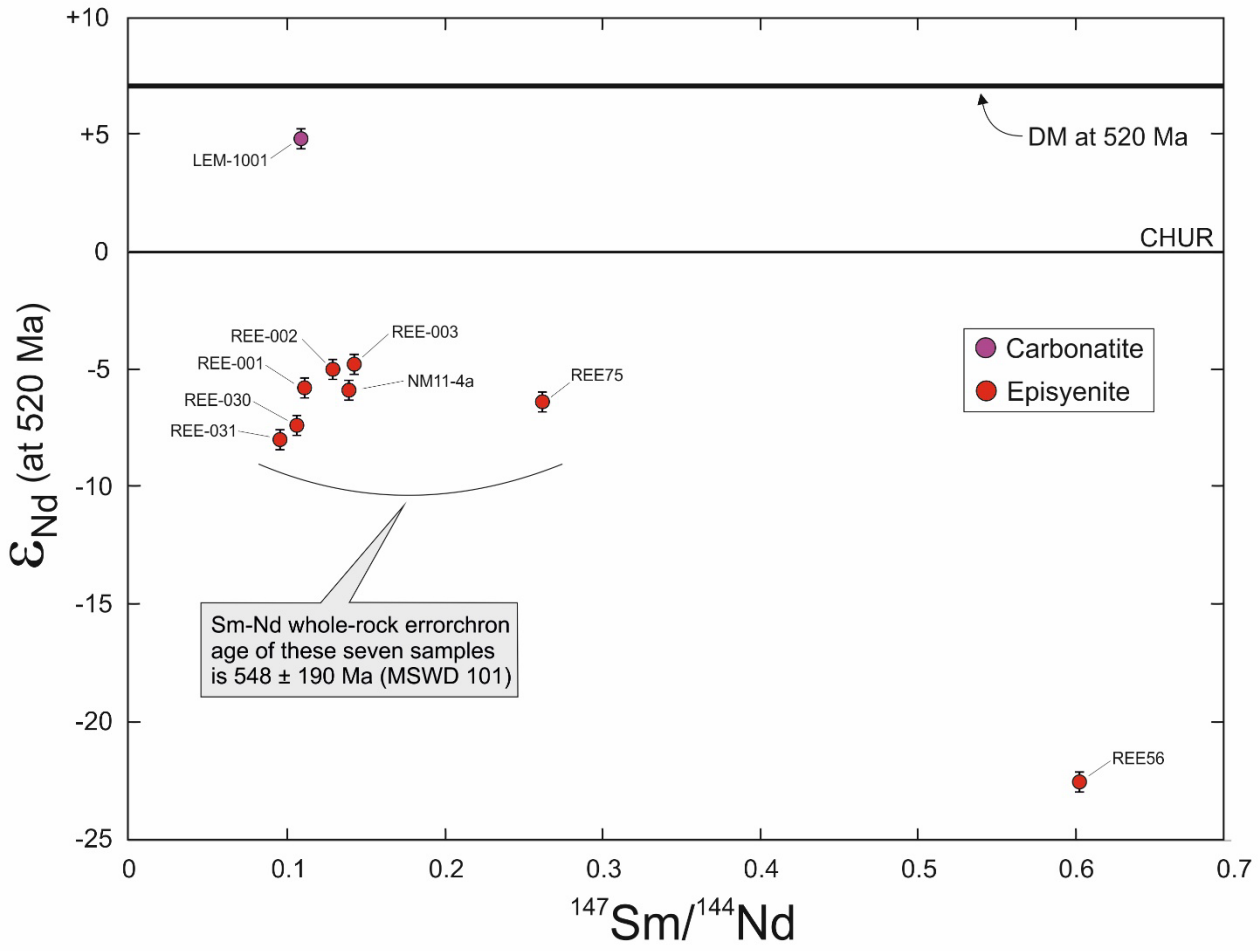


U/Pb, Jonas Kaare-Rasmussen,
UC Santa Barbara, 2021

40Ar-39Ar age on phlogopite
(NMBGMR Argon Lab)
Age is about 516 Ma

Neodynium isotopic data

By O. Tapani Rämö



Lemitar carbonatite is from a relatively strongly depleted mantle (eNd at 520 Ma +4.8, depleted mantle model age 678 Ma) and different source then the episyenites

Caballo episyenites are much less radiogenic (eNd at 520 Ma ca. -5 to -8, model ages ca. 1480-1780 Ma) and record a drastically different, but enriched source (probably cratonic subcontinental lithosphere)

scatter probably implies source variation and open-system processes subsequent to crystallization, especially for REE56

Initial epsilon values (calculated at 520 Ma) for the Caballo and Burro episyenites (in total, 8 samples) and the Lemitar carbonatite. Also shown is depleted mantle composition at 520 Ma, as well as CHUR.

CONCLUSIONS

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- Episyenites and carbonatites in NM and CO are Cambrian-Ordovician and associated with Proterozoic granitic and metamorphic rocks
- Episyenites are metasomatic in origin, whereas carbonatites are magmatic, mantle-derived igneous rocks
- Limited isotopic data suggests that in terms of source, episyenites are probably not related to carbonatites, even though both episyenites and carbonatites are present locally and of similar age
- Episyenites have low-moderate REE (as much as 3167 ppm TREE), Th (as much as 9721 ppm), and U (as much as 2329 ppm), and some samples have relatively high heavy REE (as much as 133 ppm Yb and 179 ppm Dy), which are important economic commodities
  - **Hypothesis—Metasomatism may be a mechanism to concentrate heavy REE**
- Carbonatites contain as much as 1.1% TREE
- The episyenites and carbonatites in NM are not economic at the present time, but drilling is required to determine if they increase in REE and Nb concentrations at depth. The 570 Ma Iron Hill carbonatite in CO is a economic resource for niobium (1.21 kt of 0.057% Nb_2O_5)