Lemitar Field Trip Handout February 17, 2023

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Carbonatites are carbonate-rich rocks (>50% CaO; <20% SiO_2) of apparent magmatic derivation and typically contain disseminated REE, uranium, thorium, niobium, tantalum, zirconium, hafnium, iron, titanium, vanadium, copper, apatite, vermiculite, and barite. Carbonatites are commonly associated with REE-Th-U veins and alkali-metasomatism, known as fenitization (LeBas, 2008) and (Fig. 8). In New Mexico, Cambrian-Ordovician carbonatites occur as dikes and associated veins and stockworks in five areas in New Mexico: Lemitar (506 Ma, Haft et al., 2022, $^{40}Ar/^{39}Ar$ data on phlogopite), Chupadera Mountains, Lobo Hill, Caballo Mountains and the Monte Largo area in the Sandia Mountains (Fig. 2). A fifth Oligocene carbonatite locality in New Mexico occurs at Laughlin Peak in the Chico Hills, Colfax County (see Great Plains Margin, GPM, deposit type). Carbonatites could be in the subsurface in the Gallinas Mountains as suggested by alteration, geochemistry, and previous drilling, but no samples have been obtained for precise determination of the lithology.

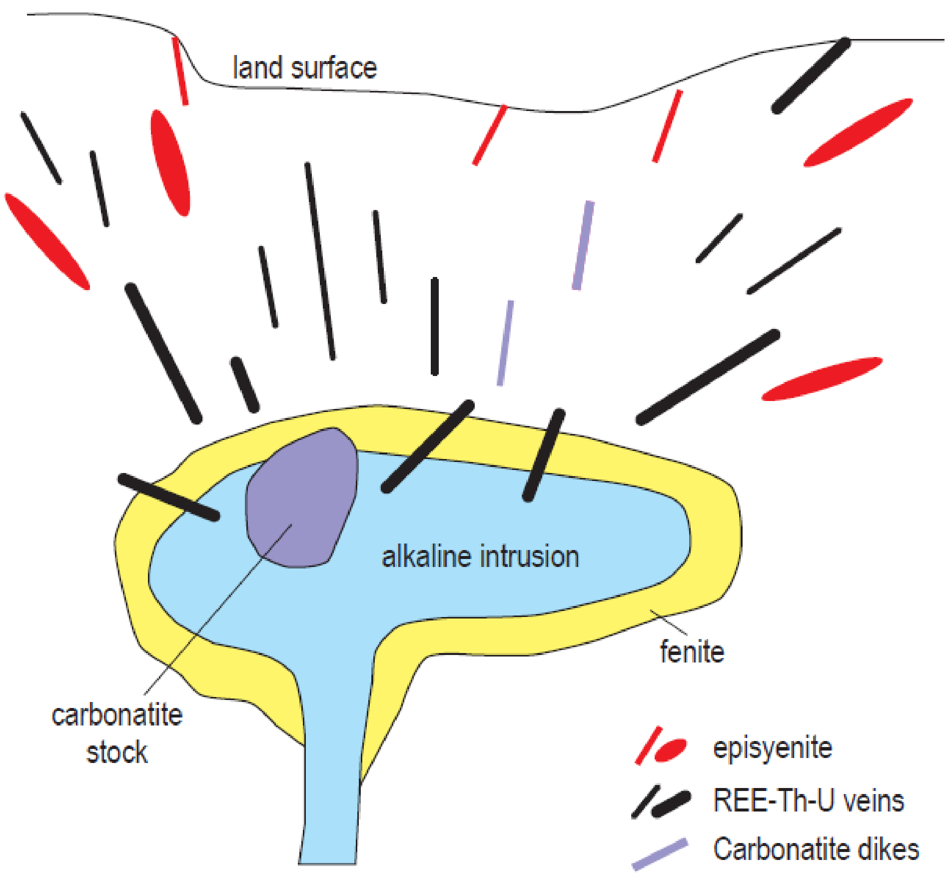


Figure 8. Relationship of REE-Th-U veins, fenites, and episyenites to alkaline rocks and carbonatites. Fenite is an alkali metasomatic alteration that surrounds the alkaline and carbonatite intrusions.

More than 100 carbonatite dikes intruded a complex Proterozoic granitic and metamorphic terrain in the Lemitar Mountains, central New Mexico (Fig. 3; McLemore, 1982, 1983, 1987, McLemore and Modreski, 1990; Haft et al., 2022). There are no alkaline igneous rocks found in the Lemitar Mountains. Compositionally, the Lemitar carbonatites are silicocarbonatite, sövite, and rauhaugite. Carbonatite dikes are typically 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. The silicocarboantites consist of greater than 50% calcite and dolomite, 5-15% magnetite, 10-20% biotite, phlogopite, muscovite, and chlorite, 5-10% apatite, and various amounts of accessory minerals (bastnaesite, fluorite, barite). The sövites consist mostly of calcite and dolomite with few accessory minerals. Rauhaugites (called ferrocarbonatites by McLemore and Modreski, 1990) intruded the sövite and silicocarboantite dikes and consist of dolomite, ankerite, hematite, and goethite and lesser amounts of calcite, dolomite, barite, fluorite, and quartz. The Lemitar carbonatites exhibit igneous textures, the most obvious is a porphyritic texture defined by phenocrysts of phlogopite and apatite. Fine-grained chilled margins are found along the edges of the larger dikes. Thin discontinuous zones of potassic and sodic-potassic fenitization, carbonatitzation, and hematization alter the surrounding host diorite/gabbro and granite. K-Ar geochronology on phlogopite yielded an age of 449±15 Ma (McLemore, 1987) and recent $^{40}Ar/^{39}Ar$ geochronology records an age of ~504 Ma (unpublished).

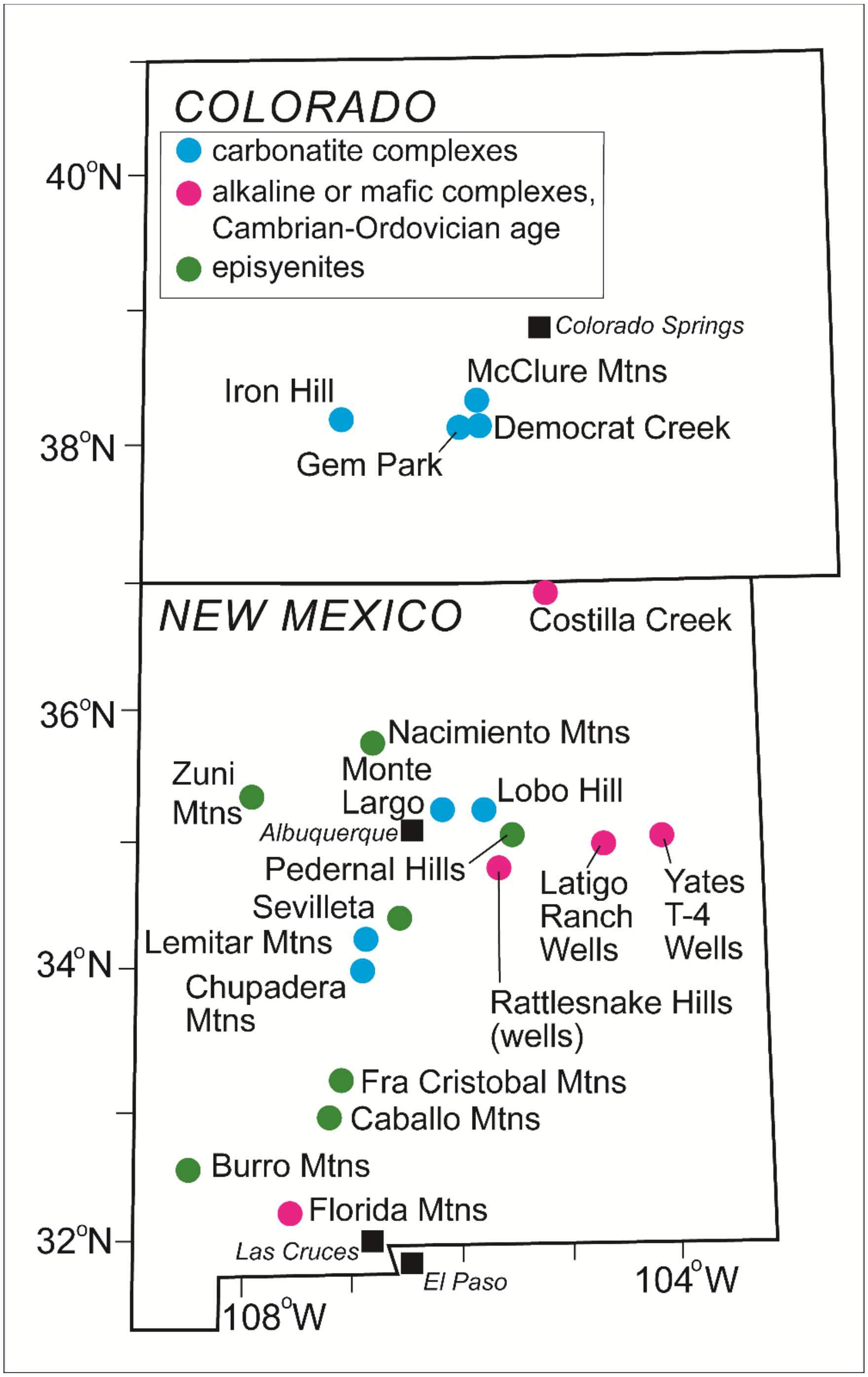


FIGURE 2. Cambrian-Ordovician carbonatites, episyenites, and syenites and other alkaline complexes in southern Colorado and New Mexico.

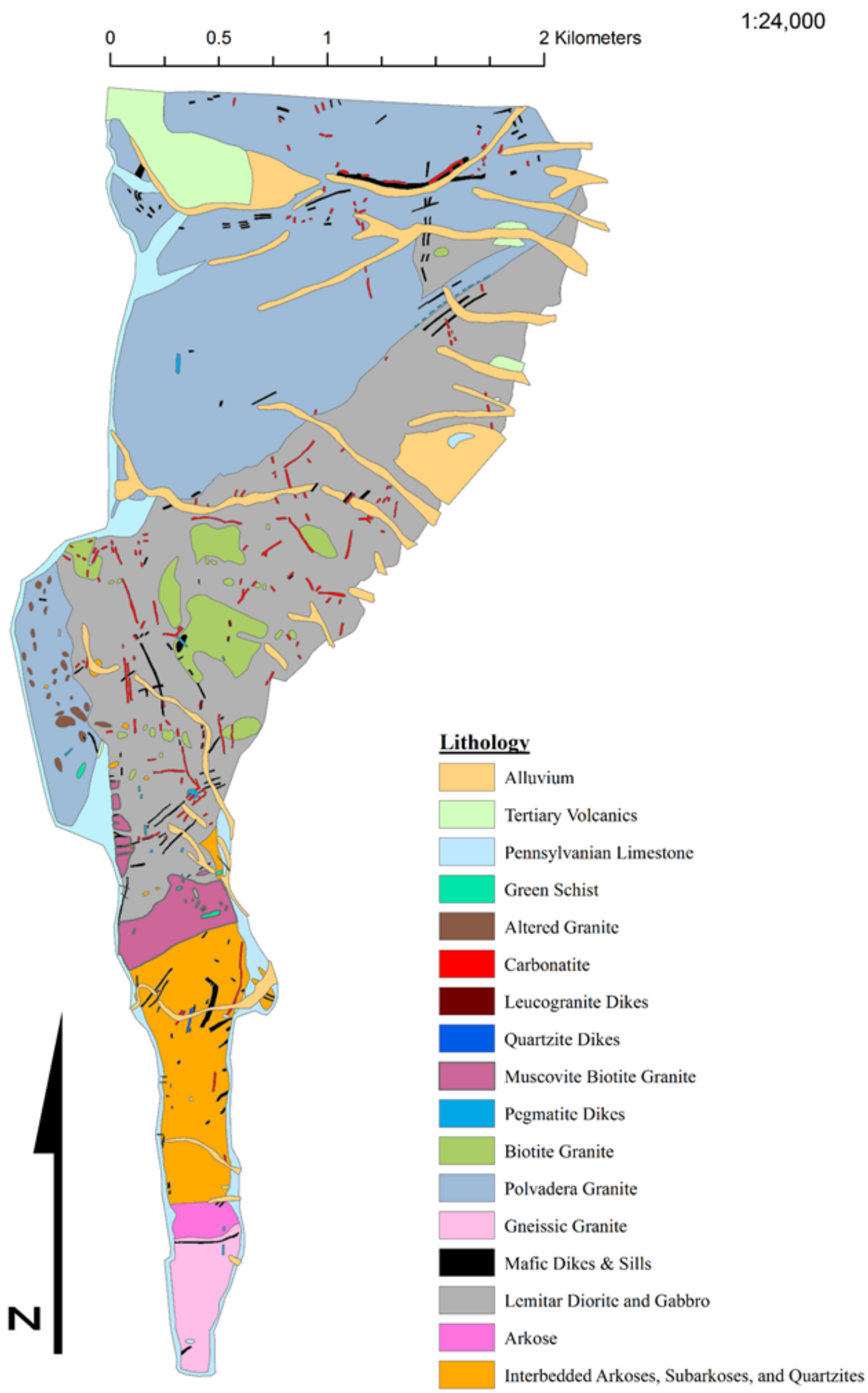


FIGURE 3. Geologic map of Lemitar carbonatites (McLemore, 1980, 1982).

Importance of the Lemitar carbonatites is that they could be an economic source of REE (Fig. 2.2).

57	58	59	60	62	63	64	65	66	67	68	69	70	71	39
La	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	**Y**
138.91	140.12	140.91	144.24	150.36	151.96	157.25	158.93	162.5	164.93	167.26	168.93	173.04	174.97	88.906

Light rare earths **Heavy rare earths**

La - Lanthanum	Eu - Europium	Er - Erbium
Ce - Cerium	Gd - Gadolinium	Tm - Thulium
Pr - Praseodymium	Tb - Terbium	Yb - Ytterbium
Nd - Neodymium	Dy - Dysprosium	Lu - Lutetium
Sm - Samarium	Ho - Holmium	Y - Yttrium

Figure 2.2: Sub-groups of the rare-earth metals, per industry (not scientific) norms (sources: TMR, industry sources).

If we plotted the REE according to concentration, you would get a jagged pattern like Figure 1 that is difficult to interpret.

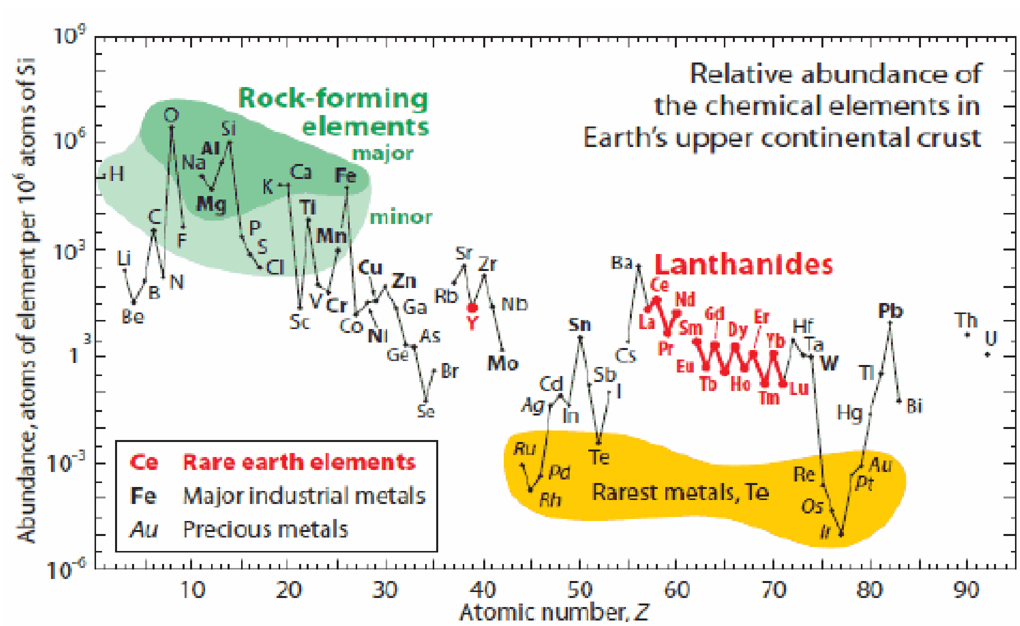


Figure 1 Relative abundance of rare earths (highlighted in red). Figure courtesy of Gordon Haxel, USGS.

So we plot the concentration of the sample (rock)/concentration of chondrite (Fig. 3). We use chondrite simply by convention agreed by geochemists decades ago. I have the paper somewhere. Here you can see chondrite-normalized patterns for many deposits. Mt. Pass is in CA and is the US in production. Byan Obo is the China deposit.

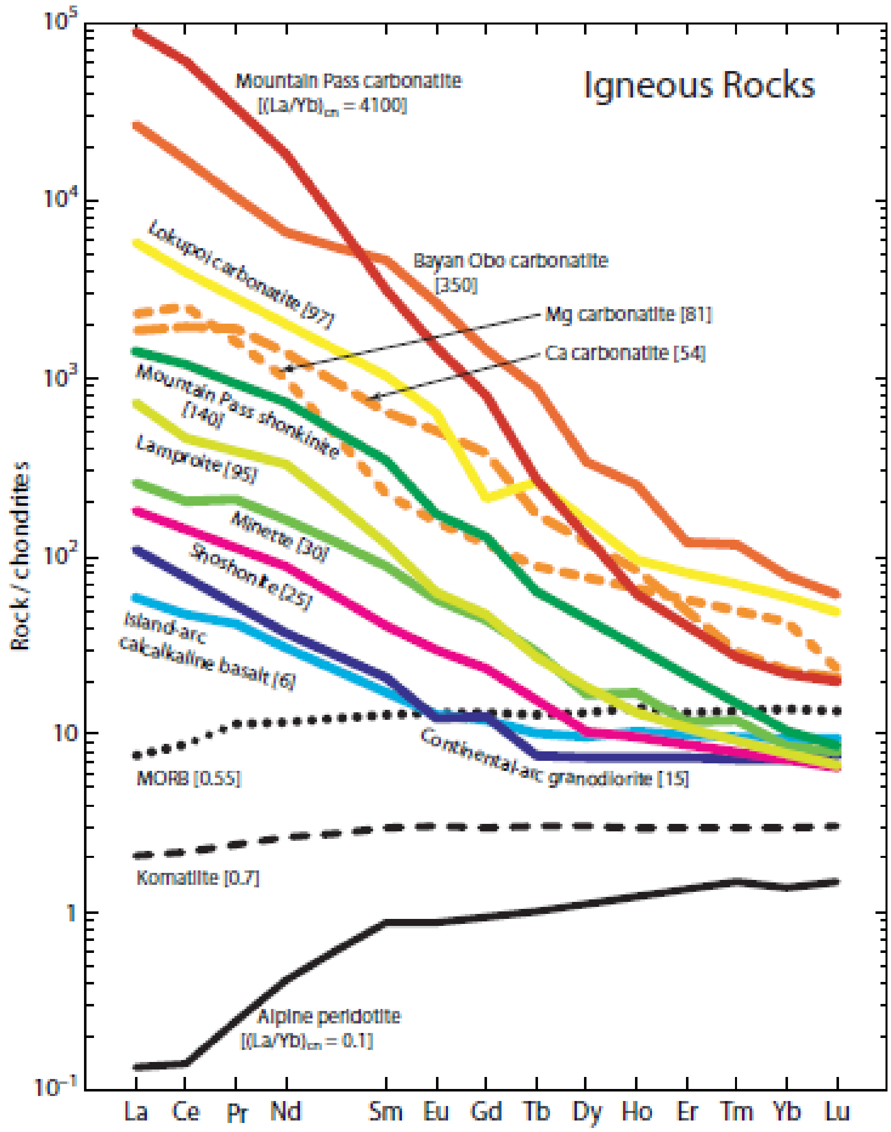
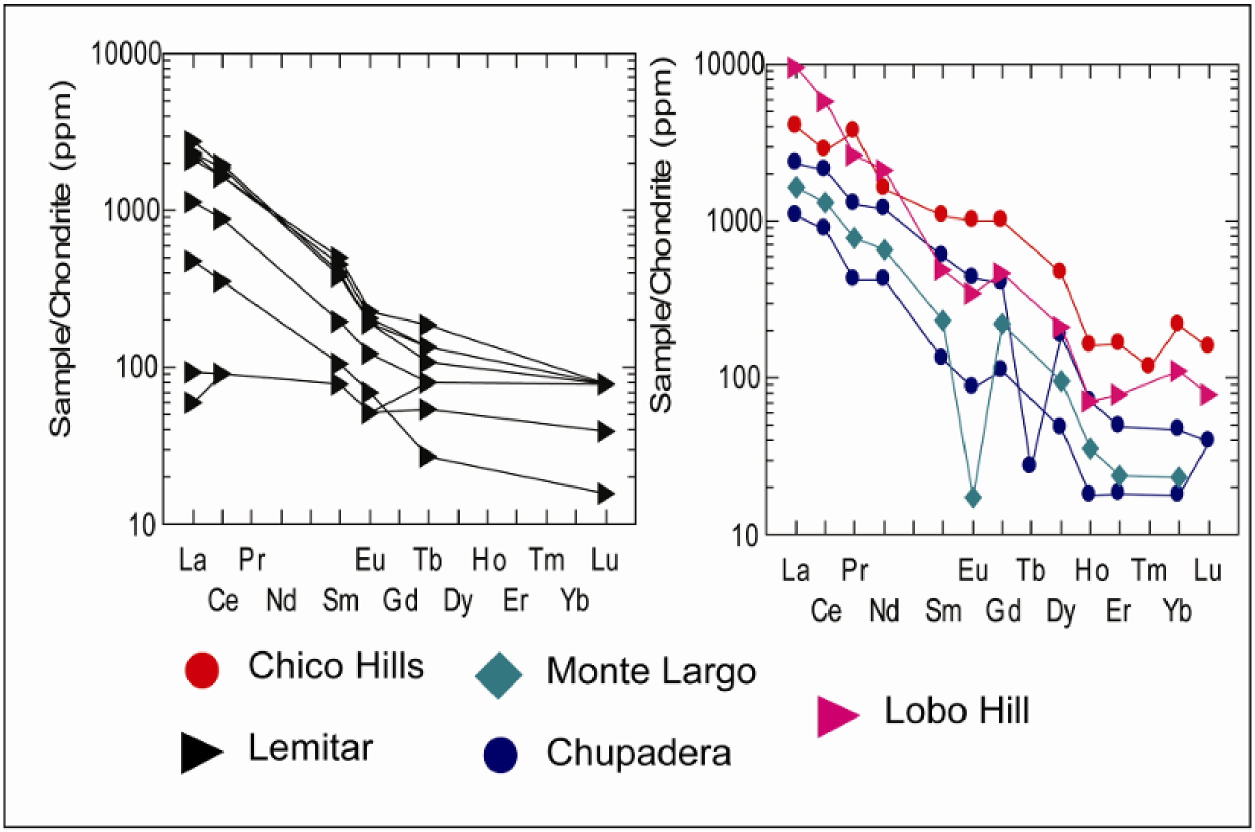


Figure 3. Chondrite-normalized (Table 1; Nakamura, 1974) REE spectra for average (labeled in italic) or representative compositions (labeled in upright type) of several common suites of ultramafic to intermediate, tholeiitic and calcalkaline

Here are the chondrite-normalized diagrams for carbonatites in New Mexico (Fig. 5).



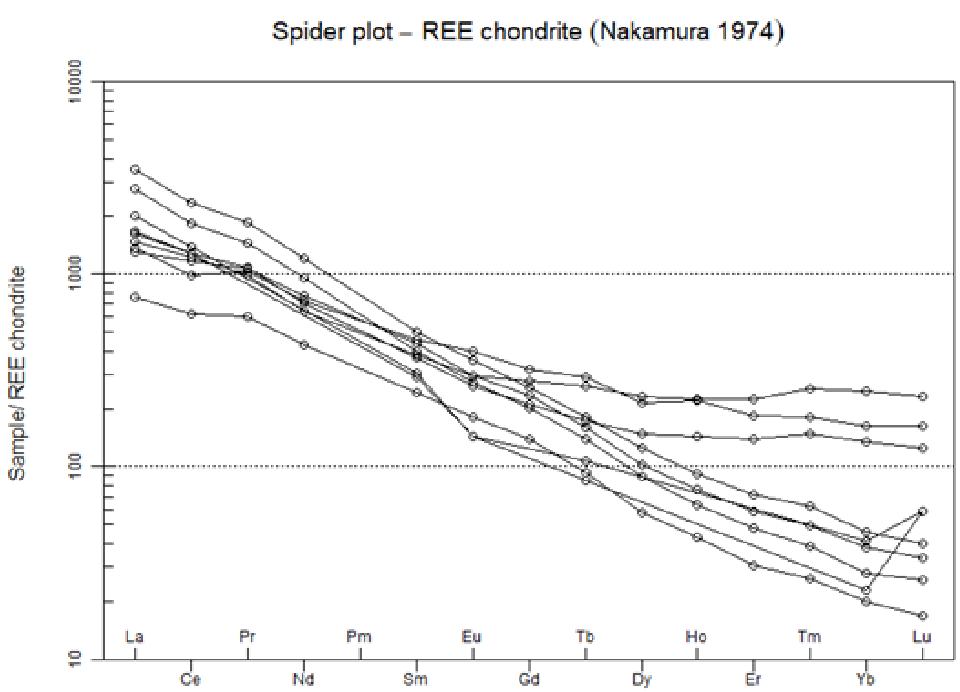


FIGURE 5. REE chondrite-normalized plots of carbonatites in New Mexico, bottom is Lemitar. (Chico Hill is Tertiary in age).

Geologists like to classify rocks. Here is one classification (Fig. 6). Basically you take the oxides and normalize the concentrations to those 3 oxides. The software that I use does that for. Then each field is derived from many analyses from all over the world. So what these diagrams, show that our samples in New Mexico have similar compositions as carbonatites from throughout the world. Each symbol is from different locations.

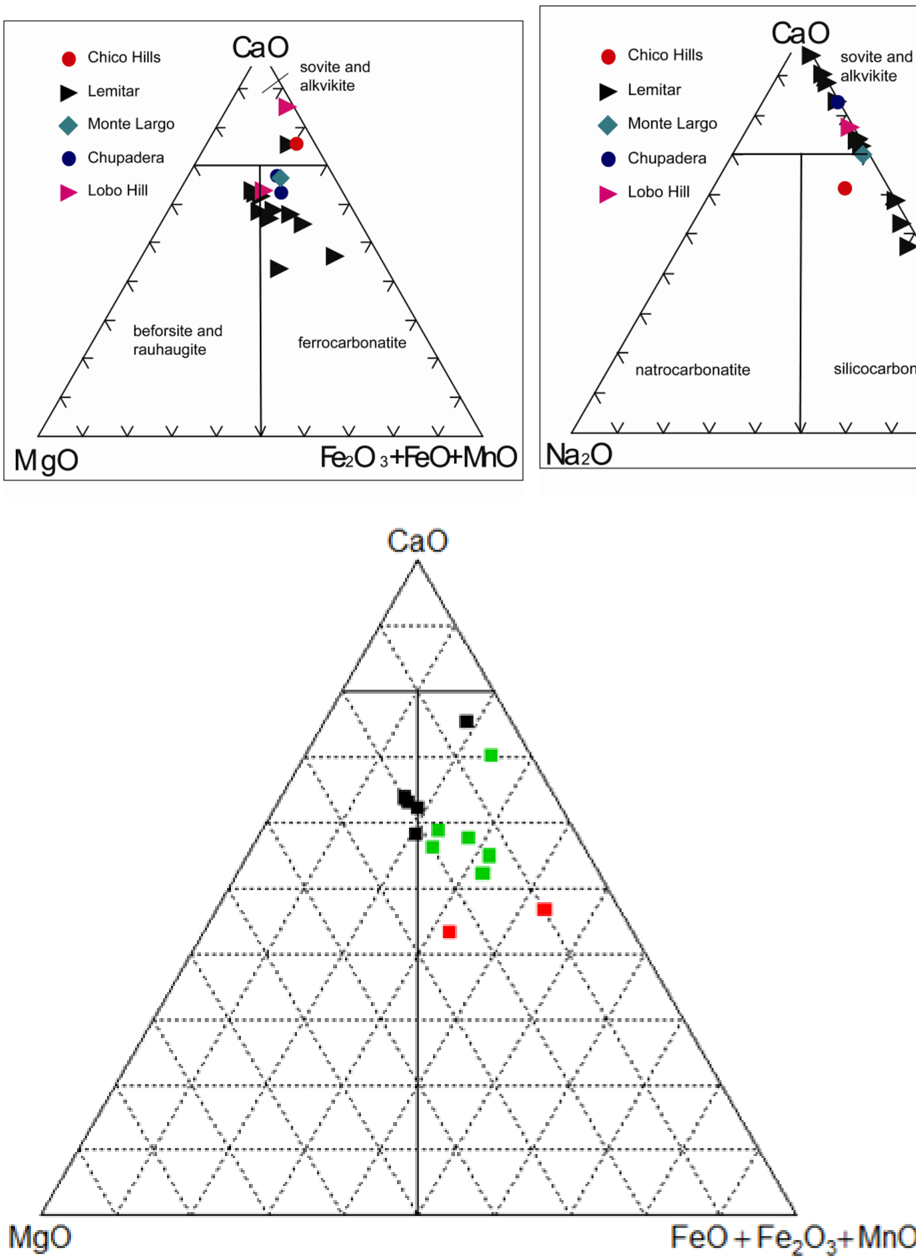


FIGURE 6. Plots of carbonatites in New Mexico, bottom is Lemitar.

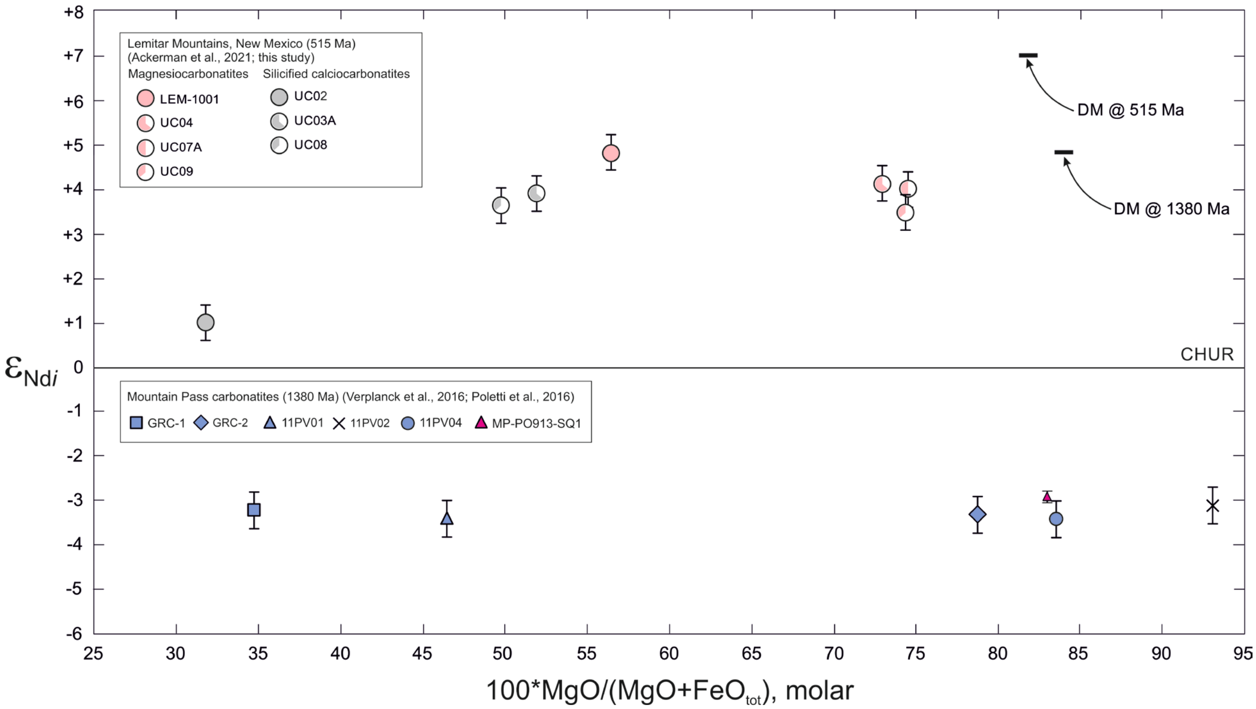


FIGURE 8. Molar 100*MgO/(MgO+FeO_{tot}) vs. e_{Ndi} diagram showing the initial Nd isotope composition of the 515-Ma Lemitar carbonatites (Ackerman and others, 2021; this study) and the 1380-Ma Mountain Pass carbonatite (Verplanck and others, 2016; Poletti and others, 2016). DM is the depleted mantle of DePaolo (1981), with e_{Nd} shown at the two times of interest, CHUR is the Chondritic Uniform Reservoir of DePaolo and Wasserburg (1976). Error bars are 2SD external.

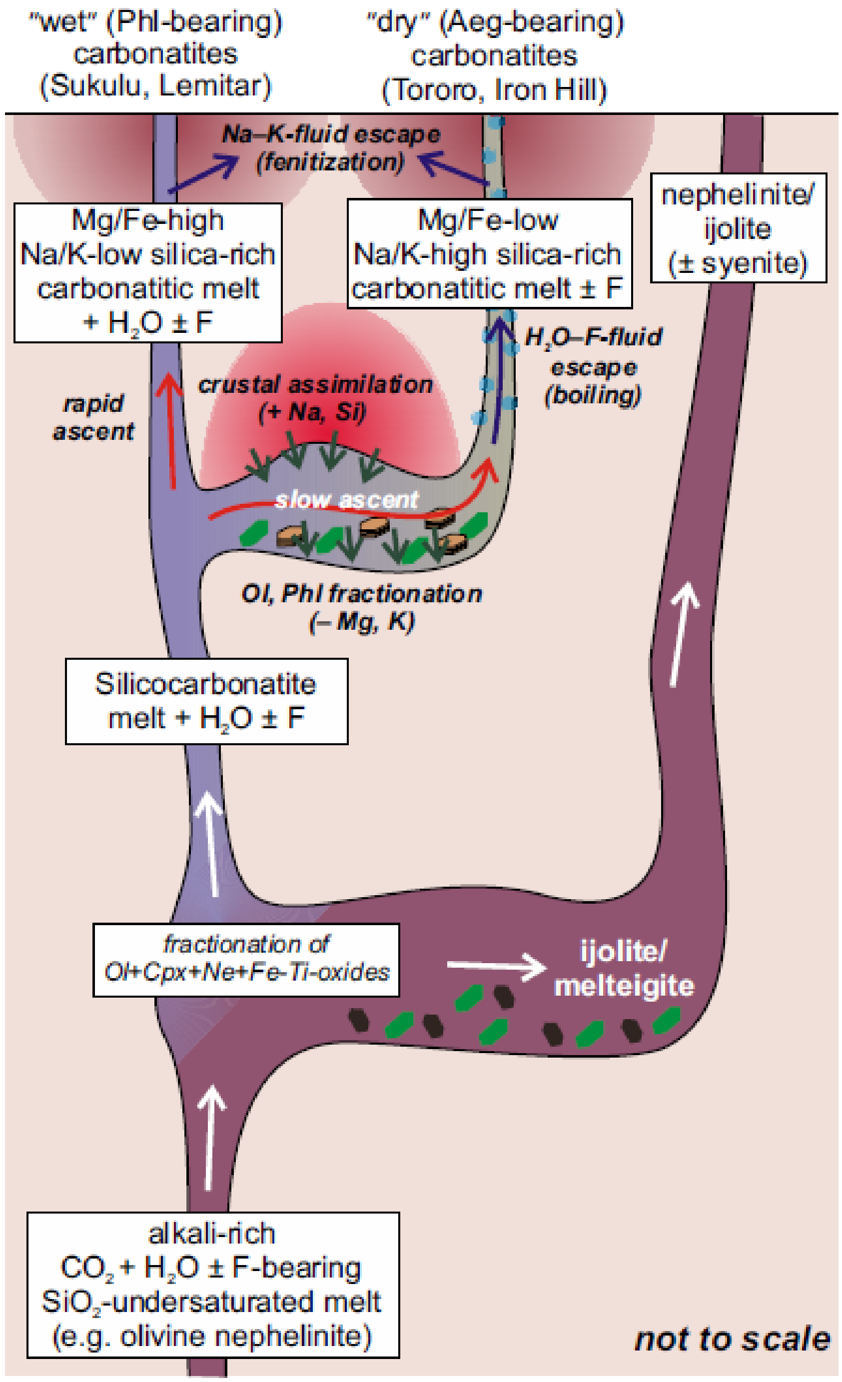


Fig. 10 General model for the petrogenesis of silicocarbonatite–silica-rich carbonatite–carbonatite association. Aeg – aegirine, Cpx – clinopyroxene, Ne – nepheline, Ol – olivine, Phl – phlogopite (Ackerman et al., 2020).

CONCLUSIONS

- The Lemitar carbonatites are magmatic, mantle-derived rocks that are enriched in light REE and Nb (as shown by mineralogy, whole-rock chemistry, isotopic geochemistry).

- The age is about 515 Ma and indicates that the Lemitar carbonatite belongs to the Cambrian-Ordovician magmatic event in New Mexico and Colorado ($^{40}Ar/^{39}Ar$, U/Pb).
- The model presented by Ackerman and others (2021) provides a testable hypothesis for the origin of the Lemitar carbonatites and other magmatic and metasomatic rocks emplaced during the Cambrian-Ordovician magmatic event. Available Nd isotope data points to a relatively radiogenic primary source in the mantle beneath Mazatzal crust.
- The Lemitar carbonatites are not economic at the present time because of small tonnage and low grades. But drilling is required to determine if they increase in REE and Nb concentrations at depth (1.1% total REE in one sample is significant). Detailed geophysics is required to determine if the Lemitar Mountains could have a larger carbonatite intrusive in the subsurface.

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