

RARE EARTH ELEMENTS (REE) POTENTIAL IN THE CORNUDAS MOUNTAINS, SOUTHERN NEW MEXICO

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ABSTRACT

Re-examination of the rare earth elements (REE) deposits in the Cornudas Mountains is warranted in light of today's economic importance of critical minerals, including REE that are essential in most of our electronic devices. New mapping and petrographic, $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology, and geochemical analyses are underway. The Cornudas Mountains form the northern Trans–Pecos alkaline magmatic province in the southern part of the North American Cordilleran alkaline-igneous belt. The igneous rocks in the area were emplaced ~37–27 Ma, just prior to or during the early phases of Rio Grande rift extension, and consist of 1) larger nepheline syenite–syenite laccoliths and plugs, 2) phonolite plug, sills, and dikes, and 3) smaller syenite plugs and dikes that intrude Permian and Cretaceous sedimentary rocks. New USGS geophysical data indicate that some of these intrusions extend deep into the subsurface, with additional intrusions potentially buried in the subsurface. The focus of REE exploration is along the outer edge of the Wind Mountain nepheline syenite laccolith, as well as within syenite–phonolite dikes, plugs and altered areas in Chess Draw. Some samples contain as much as 3110 ppm total REE, hosted in REE-bearing minerals (eudialyte, monazite, bastnäsite, calcioctapleilite). We incorporate whole rock and clinopyroxene chemistry of each intrusion into the clinopyroxene–liquid geothermobarometer (Putirka, 2008; Masotta, 2013) to determine the temperatures and pressures of emplacement. This thermometer provides higher crystallization temperature estimates for the syenite intrusions (857–1028°C) than the phonolite sills (760–869°C). We then use the barometric estimates (0.3–3.3 kbar) to calculate emplacement depths (1.1–12.3 km). Pairing these depths with the new geochronology, we can estimate minimum exhumation rates for intrusions in the Cornudas Mountains that range from 0.03–0.34 mm/yr, with faster exhumation rates for younger intrusions. Estimating crystallization temperatures and exhumation rates provide additional information to aid in developing a model for the formation of REE deposits.

INTRODUCTION

The growing market for alternative technologies like solar panels, wind turbines, batteries, electric cars, desalination plants, and carbon capture and storage require non-traditional elements for their manufacture. Many critical minerals are 100% imported into the United States. These mineral resources are essential to our economy and have supply chains that may be disrupted.

Some of these critical minerals are found in the North American Cordilleran alkaline-igneous belt, a zone of alkaline-igneous rocks that extends from Alaska and British Columbia southward into eastern New Mexico, Trans-Pecos Texas, and eastern Mexico (Fig. 1). These rocks contain relatively large quantities of critical minerals, such as fluorine (F), zirconium (Zr), rare earth elements (REE), niobium (Nb), beryllium (Be), and other commodities, including some of the largest producing gold (Au) deposits. The belt coincides with eastward lithospheric thickening that follows the tectonic boundary between the stable Great Plains and the tectonically active Rocky Mountains and Basin and Range provinces from Colorado to Mexico. Some of the REE, Zr, Nb, and Be resources are located in New Mexico, but they have not been important exploration targets in the past because demand has been met elsewhere.

The Cornudas Mountains are one area containing critical minerals in the North American Cordilleran alkaline-igneous belt. They are located in southern Otero County, New Mexico and northern Huesped County, Texas and form the northern extent of the Trans–Pecos alkaline magmatic province (Fig. 2, 3). This area is part of the Otero Mesa between Rio Grande rift to the west and Salt Basin graben to the east.

The purpose of this study is to re-examine the geology and mineral-resource potential of the Cornudas Mountains by remapping specific mineralized areas along with conducting detailed petrography, geochemistry, mineralogy, and geochronology.

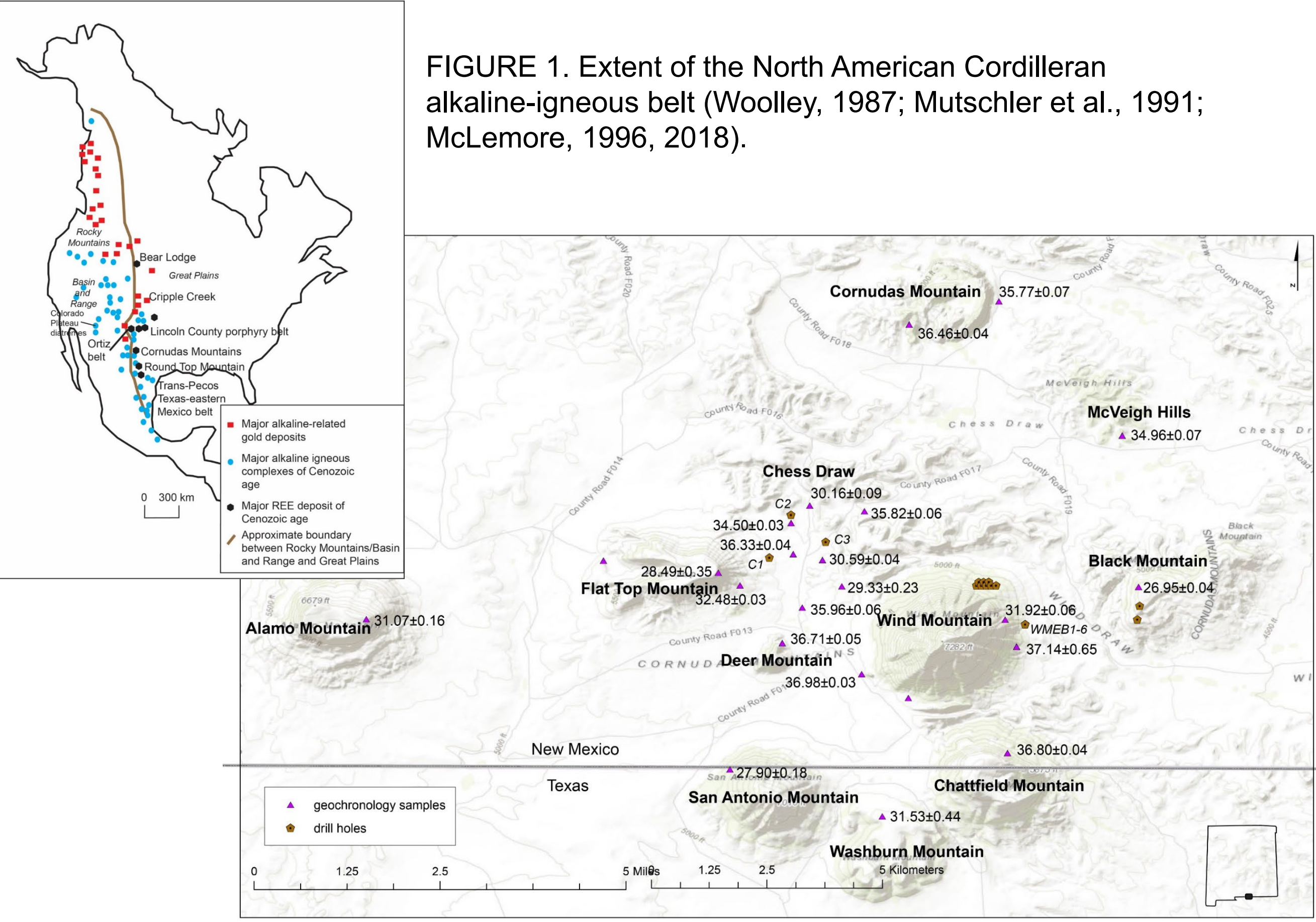


FIGURE 1. Extent of the North American Cordilleran alkaline-igneous belt (Woolley, 1987; Mutschler et al., 1991; McLemore, 1996, 2018).

FIGURE 2. The Cornudas Mountains consist of larger nepheline syenite to syenite laccoliths (Wind Mountain, Deer Mountain, Washburn Mountain, San Antonio Mountain, Cornudas Mountain), phonolite sills (Alamo Mountain, Flat Top Mountains, Chatfield Mountain, and Black Mountain), small syenite to nepheline syenite intrusions, and numerous syenite, volcanic breccia, and phonolite dikes. Ages range from 37–27 (Table 1).

TABLE 1. Intrusive bodies in the Cornudas Mountains (modified from Barker et al., 1977; McLemore, 2018; new mapping). Bold indicate samples (or nearby samples) contain TREE >500 ppm.

Locality, map unit	Predominant lithology	Form	Thickness (km)	Sample	Age (Ma)
Wind Mountain, Ens2	Nepheline syenite to syenite porphyry	Layered laccolith	0.25	McLemore (1996), CORN814	36.8±0.6, 37.14±0.65
Little Windy (W Wind Mountain) Ens2	Nepheline syenite	Laccolith	0.1	CORN4005	36.98±0.03
Chatfield Mountain, Ep	Phonolite	Sill	0.15	CORN4015	36.80±0.04
Deer Mountain (Little Wind Mountain), Ens	Nepheline syenite	Laccolith	0.1	CORN2000	36.71±0.05
Sill west Cornudas Mountain, Es	Quartz syenite to syenite	Sill	0.1	CORN4019	36.46±0.04
Northwest Chess Draw (augite syenite), Eas	Augite syenite inner zone, phonolite outer zone	Plug	0.1	CORN177	36.33±0.04
South Chess Draw, Ens2	Volcanic breccia	dikes	0.02	CORN20-10	35.96±0.06
Chess Draw	Volcanic breccia	dikes	0.01	nd	nd
Dike north of Wind Mountain	Phonolite	dike	0.01	CORN181	35.82±0.06
Cornudas Mountain, Es	Quartz syenite to syenite	Plug or laccolith, sill	0.1	CORN112	35.77±0.07
McVeigh Hills, Es	Quartz syenite to syenite	Top of a laccolith or sill?	?	CORN226	34.96±0.07
Mesquite Hills, Es	phonolite	dike	0.01	CORN4008	34.50±0.03
Dike east of Flat Top	phonolite	dike	0.01	CORN117	32.48±0.03
Wind Mountain dike	phonolite	dike	0.01	CORN805	31.92±0.06
Washburn Mountain, Ons	Nepheline syenite	Sill	0.15	CORN208	31.53±0.44
Alamo Mountain, Op	Phonolite	Discordant sheet or sill	0.25	CORN4002	31.07±0.16
Northeast Chess Draw (unnamed hill), Opp	Phonolite	Plug	0.1	CORN4006	30.59±0.04
Chess Draw dike	phonolite	plug	0.01	CORN4007	30.16±0.09
East Chess Draw syenite	Nepheline syenite	plug	0.01	CORN79	29.33±0.23
Flat Top, Op	Phonolite	Sill (50–75 ft thick)	0.015–0.023	CORN4004	28.49±0.35
San Antonio Mountain, Ons	Nepheline syenite	Laccolith	0.15	CORN4013	27.90±0.18
Black Mountain, Ons	Nepheline syenite	Sill	0.07	CORN4011	26.95±0.04

GEOLOGY, MINERALOGY, AND GEOCHEMISTRY



FIGURE 3. Wind Mountain is a texturally, mineralogical, and chemically zoned laccolith (McLemore et al., 1996).



FIGURE 4. Wind Mountain nepheline syenite at the Addwest adit.



FIGURE 5. Pink eudialyte in black phonolite dike in contact with skarn.



FIGURE 6. Mineralized nepheline syenite containing 1124.23 ppm TREE, 5650 ppm Zr, 362 ppm Nb (drill hole WMEDB-4, 278 ft depth).

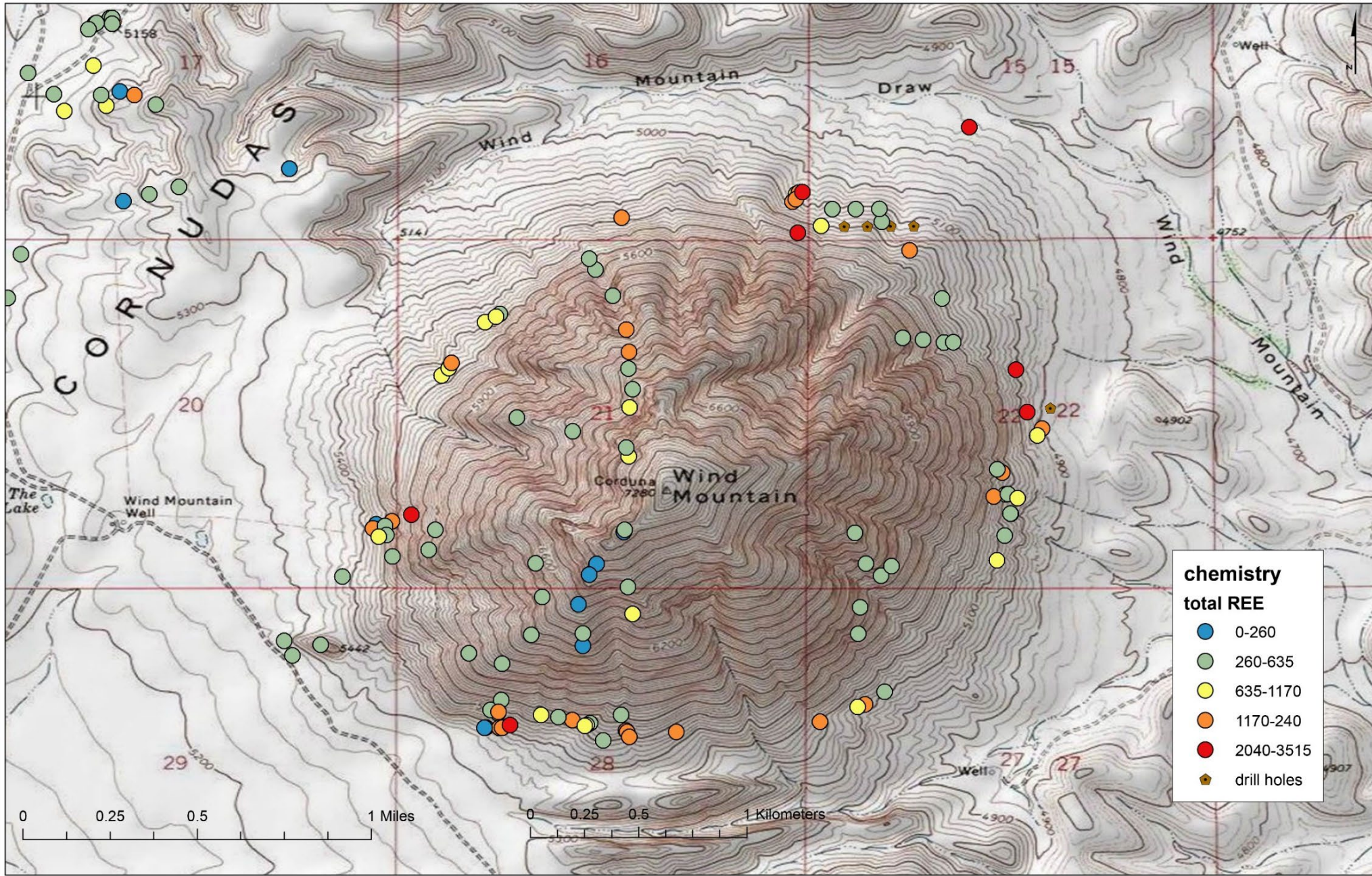


FIGURE 7. The focus of REE-Nb-Zr exploration is along the outer edge of the Wind Mountain nepheline syenite laccolith, as well as within syenite–phonolite dikes, plugs and altered areas in Chess Draw. Samples from Wind Mountain and adjacent Chess Draw are elevated in REE (up to 3313 ppm) and Nb (up to 1750 ppm). Pyrochlore is the predominant Nb mineral. REE are found in bastnäsite, calcioctapleilite, eudialyte, monazite, vitusite, zircon, and xenotime. Most REE minerals are small (under 20 microns), although eudialyte and bastnäsite are coarser and better-crystallized. Note that bastnäsite is the REE-mineral currently being produced at Mt. Pass, Ca and Bayan Obo, China. Zr is up to >10,000 ppm.

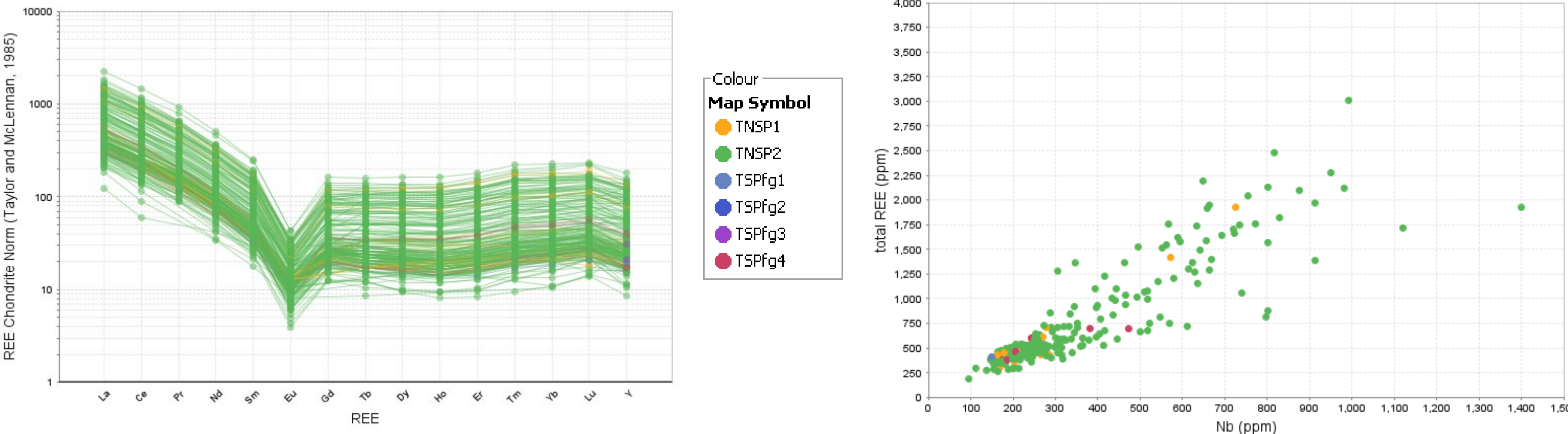


FIGURE 8. Chondrite normalized REE and total REE vs. Nb plots of samples from Wind Mountain laccolith; TNSP2 (green) are from outer margin. Chemical analyses from this study, Geovic, Barker et al. (1977), Schreiner (1994), Potter (1996), and McLemore et al. (1996).

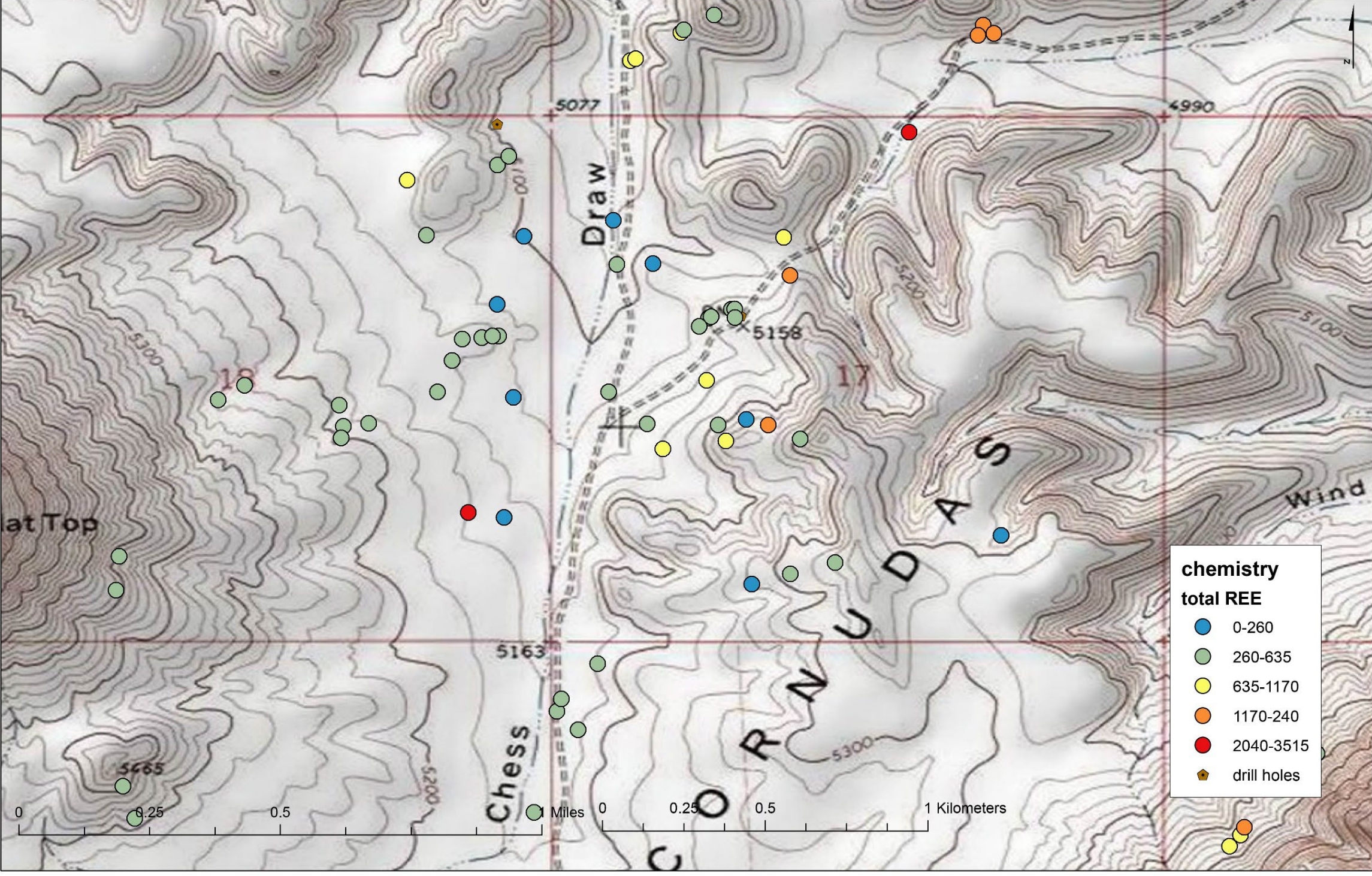


FIGURE 9. Chess Draw is underlain by magnetic anomalies (see Fig. 13). New mapping and previous drilling indicates complex intrusive relationships. Age relationships indicate REE mineralization is between 37 and 30 Ma (Fig. 14; Table 1).



FIGURE 10. Volcanic breccia dike intruding syenite dike (Chess Draw hole C-1, depth 177 ft).



FIGURE 11. Syenite dike intruding trachytic syenite dike (Chess Draw hole C-1, depth 188.5 ft).

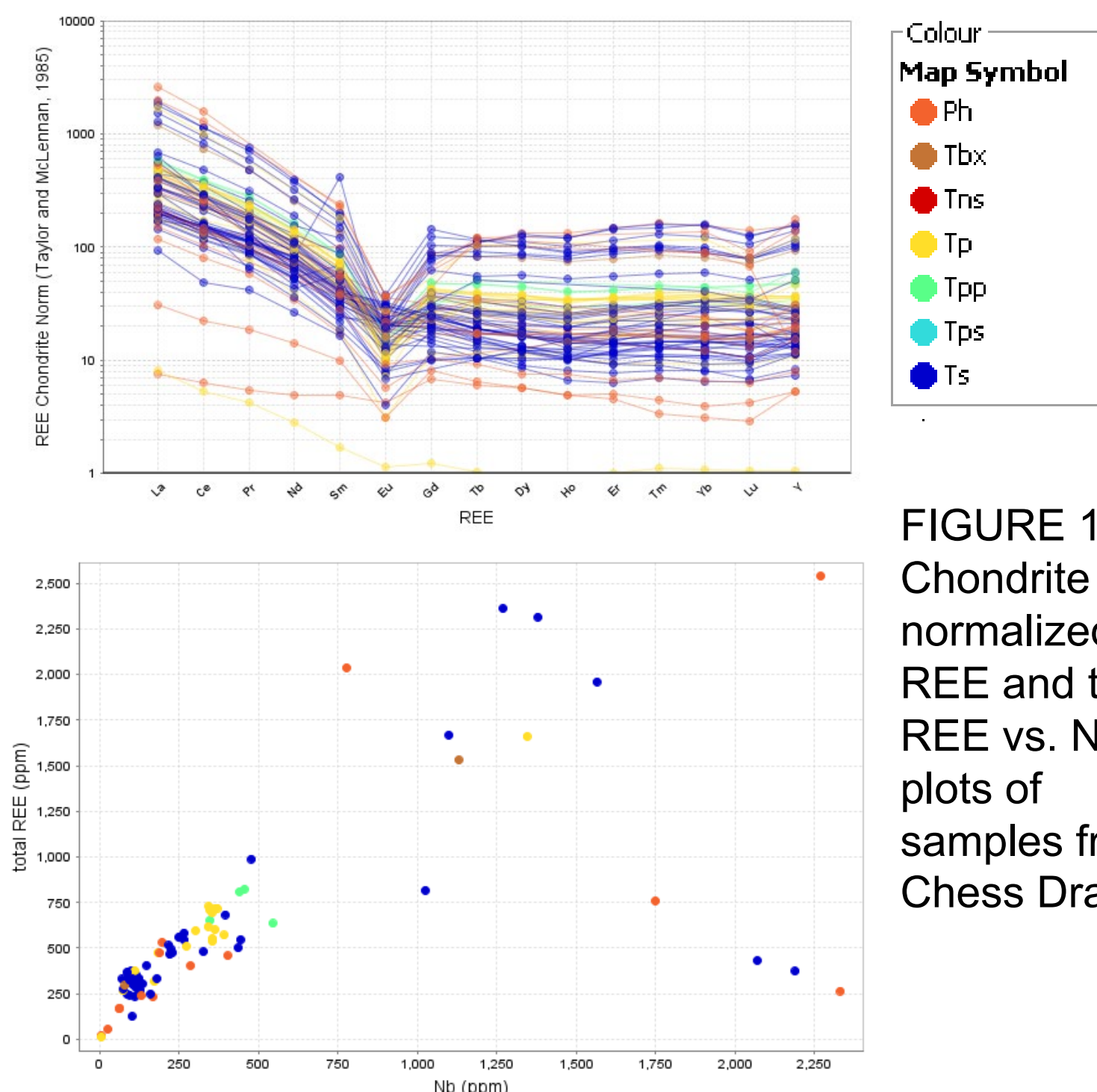


FIGURE 12. Chondrite normalized REE and total REE vs. Nb plots of samples from Chess Draw.

GEOPHYSICS

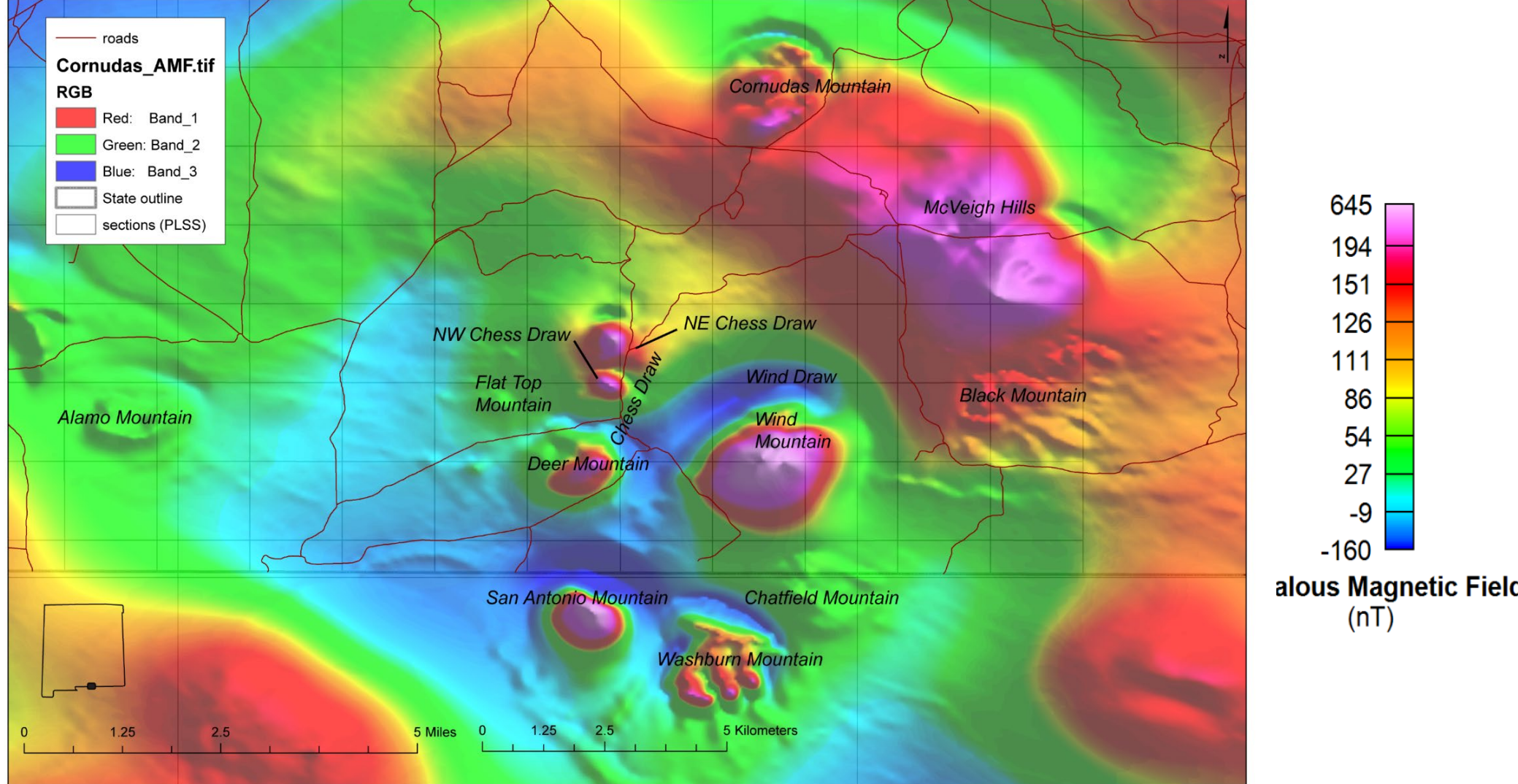


FIGURE 13. Map of the anomalous magnetic field (AMF) of the Cornudas Mountains (Bultman, 2021, 2022) showing intrusive laccoliths and plugs (red anomalies) that extend deep into the subsurface, with additional intrusions potentially buried in the subsurface. New mapping in Chess Draw and McVeigh Hills indicates the anomalies are the top of syenite and phonolite intrusions, possibly as sills, laccoliths, or plugs.

GEOCHRONOLOGY

Intrusion	Updated $^{40}\text{Ar}/^{39}\text{Ar}$ Age (Ma)	Gray: Formerly Reported Ages
Barker et al. (1977)	36.0 ± 1.1–21.8 ± 0.9 Ma (biotite)	Gray: Formerly Reported Ages
McLemore (2018)	36.8 ± 0.6–33.0 ± 1.4 Ma (biotite)	Purple: Laccolith/Plugs
Wind Mountain	37.14 ± 0.65 Ma (amphibole)	Cyan: Sills
Li'l Windy	36.98 ± 0.03 Ma (biotite)	Green: Dikes
Chatfield Mountain	36.80 ± 0.04 Ma (biotite)	
Deer Mtn	36.71 ± 0.05 Ma (biotite)	
Sill West of Cornudas Mountain	36.46 ± 0.04 Ma (groundmass)	
Augite Syenite	36.33 ± 0.04 Ma (biotite)	
South Chess Draw Syenite	35.96 ± 0.06 Ma (biotite)	
Dike North of Wind Mountain	35.82 ± 0.06 Ma (groundmass)	
Cornudas Mountain	35.77 ± 0.07 Ma (biotite)	
McVeigh Hills	34.96 ± 0.07 Ma (groundmass)	
Mesquite Hill	34.50 ± 0.03 Ma (groundmass)	
Dike East of Flat Top	32.48 ± 0.03 Ma (groundmass)	
Wind Mtn Dike	31.92 ± 0.06 Ma (groundmass)	
Washburn Mountain	31.53 ± 0.44 Ma (groundmass)	
Alamo Mountain	31.07 ± 0.16 Ma (groundmass)	
Unnamed Hill	30.59 ± 0.04 Ma (groundmass)	
Chess Draw Dike	30.16 ± 0.09 Ma (groundmass)	
East Chess Draw Syenite	29.33 ± 0.23 Ma (groundmass)	
Flat Top	28.49 ± 0.35 Ma (groundmass)	
San Antonio Mountain	27.90 ± 0.18 Ma (groundmass)	
Black Mountain	26.95 ± 0.04 Ma (groundmass)	

FIGURE 14. $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology results indicate emplacement from 37.14–26.39 Ma, longer than the previously reported K/Ar ages (36.0–31.6 Ma). See table 1 for more details.

PRELIMINARY CONCLUSIONS

- $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology results indicate emplacement from 37–27 Ma, longer than the previously reported K/Ar ages (36.0–31.6 Ma).
- The REE, Zr, and Nb ore controls are magmatic laccoliths and hydrothermal skarns adjacent to the laccoliths, dikes, and plugs.
- New mapping in Chess Draw and McVeigh Hills indicates that syenite and phonolite intrusions, possibly as sills, laccoliths, or plugs form the top of aeromagnetic anomalies. The REE, Zr and Nb potential of these anomalies is unknown; drilling is required.
- REE-Zr exploration is along the edge of Wind Mountain laccolith and in Chess Draw. REE are found in bastnäsite, calcioctapleilite, eudialyte, monazite, vitusite, zircon, and xenotime. None of the other intrusions, except Chess Draw and Wind Mountain have elevated REE, Zr, or Nb.
- Elevated Nb concentrations are found along the western edge of Wind Mountain and Chess Draw. Pyrochlore is the predominant Nb mineral.
- The spatial distribution of REE, Zr and Nb is discontinuous, but drilling in areas of higher REE, Zr and Nb is required to determine if there are enough concentrations for economic development.
- Although the TREE and Zr of the Wind Mountain and Chess Draw intrusions and skarns are below normal economic grades (i.e. <5%TREE), some of these minerals possibly could be separated magnetically, producing a potential economic REE concentrate.
- Calculated emplacement depths are estimated as 1.1–12.3 km.

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