



## ***Carbonatites in the Lemitar and Chupadera Mountains, Socorro County, New Mexico***

Virginia T. McLemore

1983, pp. 235-240. <https://doi.org/10.56577/FFC-34.235>

*in:*

*Socorro Region II*, Chapin, C. E.; Callender, J. F.; [eds.], New Mexico Geological Society 34<sup>th</sup> Annual Fall Field Conference Guidebook, 344 p. <https://doi.org/10.56577/FFC-34>

---

*This is one of many related papers that were included in the 1983 NMGS Fall Field Conference Guidebook.*

---

### **Annual NMGS Fall Field Conference Guidebooks**

Every fall since 1950, the New Mexico Geological Society (NMGS) has held an annual [Fall Field Conference](#) that explores some region of New Mexico (or surrounding states). Always well attended, these conferences provide a guidebook to participants. Besides detailed road logs, the guidebooks contain many well written, edited, and peer-reviewed geoscience papers. These books have set the national standard for geologic guidebooks and are an essential geologic reference for anyone working in or around New Mexico.

### **Free Downloads**

NMGS has decided to make peer-reviewed papers from our Fall Field Conference guidebooks available for free download. This is in keeping with our mission of promoting interest, research, and cooperation regarding geology in New Mexico. However, guidebook sales represent a significant proportion of our operating budget. Therefore, only *research papers* are available for download. *Road logs*, *mini-papers*, and other selected content are available only in print for recent guidebooks.

### **Copyright Information**

Publications of the New Mexico Geological Society, printed and electronic, are protected by the copyright laws of the United States. No material from the NMGS website, or printed and electronic publications, may be reprinted or redistributed without NMGS permission. Contact us for permission to reprint portions of any of our publications.

One printed copy of any materials from the NMGS website or our print and electronic publications may be made for individual use without our permission. Teachers and students may make unlimited copies for educational use. Any other use of these materials requires explicit permission.

*This page is intentionally left blank to maintain order of facing pages.*

# CARBONATITES IN THE LEMITAR AND CHUPADERA MOUNTAINS, SOCORRO COUNTY NEW MEXICO

VIRGINIA T. McLEMORE

New Mexico Bureau of Mines and Mineral Resources  
Socorro, New Mexico 87801

## INTRODUCTION

Carbonatites intrude the complex Precambrian terrains exposed in the Lemitar and Chupadera Mountains in central Socorro County (fig. 1). They occur as dikes, veins, and stockworks and exhibit the textures, mineralogy, composition, and associated wall-rock alteration characteristic of other carbonatites.

Carbonatites are unique carbonate-rich rocks of apparent magmatic descent and are characterized by a distinct but variable mineralogy, composition, and associated alteration (Heinrich, 1966). Greater than 50 percent carbonate minerals and varying amounts of apatite, magnetite, pyroxenes, and other accessory minerals are characteristic of carbonatites. These unusual rocks are enriched in total iron, CaO, CO<sub>2</sub>, 13205, and numerous minor and trace elements and depleted in SiO<sub>2</sub> relative to other igneous rock types. One of the remarkable features of

carbonatites is the variation in texture, mineralogy, and chemical composition between carbonatites within the same complex. Carbonatites range from simple monomineralic types to varieties containing complex mineral assemblages and variable compositions. Textures may also be diverse and complex. Late-stage hydrothermal mineralization and alteration products may occur. Economically, carbonatites are important because they may contain large quantities of numerous commodities, including "limestone," iron ore, vermiculite, barite, fluorite, phosphate, rare-earth elements, uranium, thorium, niobium, copper, titanium, strontium, and manganese (Heinrich, 1966).

Most carbonatites occur as one or more plugs or stocks surrounded by cone sheets and ring dikes of carbonatite and alkalic rocks. They generally are associated with alkalic or kimberlite provinces. However, many carbonatite complexes, including those in the Lemitar and Chupadera Mountains, occur as dike swarms with or without any associated alkalic rocks or kimberlites (Heinrich, 1966).

A halo of fenites, produced by fenitization, typically surrounds carbonatites and may be adjacent to carbonatite dikes. Fenitization is a distinct metasomatic alteration associated with carbonatites, kimberlites, and alkalic rocks (Heinrich, 1966; McKie, 1966). Fenites are characterized by alkali feldspars, alkali hornblende, aegirine, apatite, calcite, and the depletion or absence of quartz. Fenitization is locally present adjacent to some Lemitar and Chupadera carbonatites.

## GEOLOGIC SETTING

The geologic and tectonic setting of the Lemitar and Chupadera Mountains are discussed by McLemore (1982) and elsewhere in this guidebook. The Lemitar and Chupadera Mountains form part of the western edge of the Rio Grande graben and are separated by the Socorro cauldron (fig. 1; Eggleston, 1982; Chamberlin, 1981). North-trending faults have exposed portions of a complex Precambrian terrain (see Bowring and others, this guidebook) consisting of metamorphosed sedimentary rocks, mafic dikes, mafic intrusives (Lemitar diorite/gabbro), schists, and granitic rocks (figs. 2 and 3). The Precambrian rocks are overlain or in fault contact with Paleozoic sedimentary rocks and Tertiary sedimentary and volcanic rocks. Carbonatites have intruded only the Precambrian rocks, after their metamorphism. Alkalic rocks are absent in the Precambrian terrain in the Lemitar and Chupadera Mountains. Carbonatites also intrude the Precambrian terrains in the Monte Largo Hills, Bernalillo County (Lambert, 1961), and in southern Colorado at Iron Hill, McClure Mountain, and Gem Park (Heinrich, 1966; Armbrustmacher, 1979).

## GEOLOGY, PETROLOGY, AND MINERALOGY

More than 100 carbonatite dikes and veins intrude the Precambrian terrain in the Lemitar Mountains (fig. 2; McLemore, 1982) and more than a dozen dikes intrude the Precambrian rocks in the Chupadera Mountains (fig. 3; Kent, 1982). The carbonatites range in thickness from less than 1 cm (veins) to more than 1 m (dikes) and a few dikes

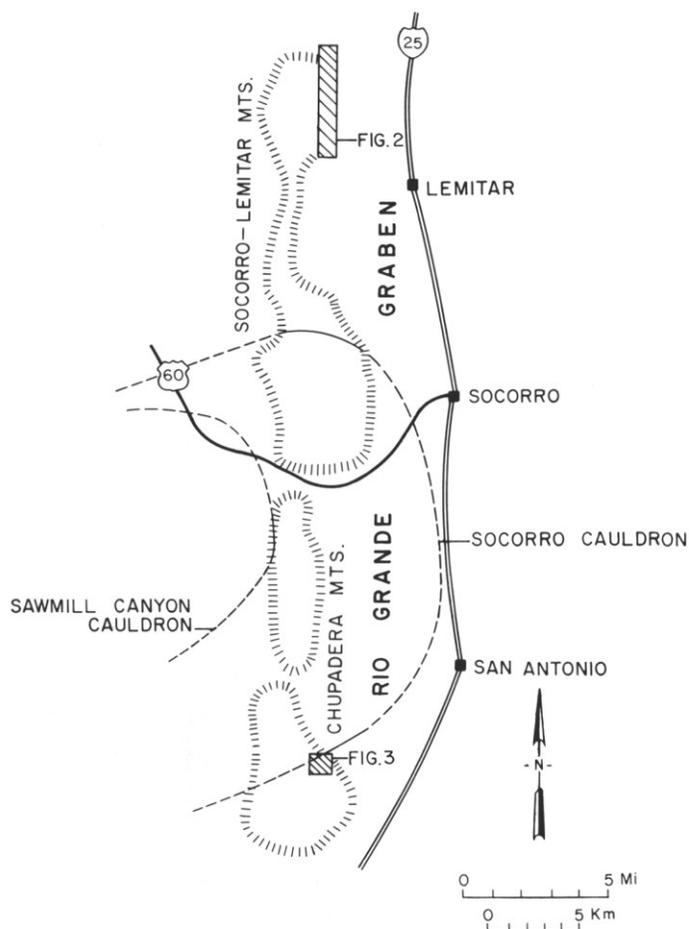


Figure 1. Location map of Lemitar and Chupadera Mountains, central Socorro County. Boundaries of Socorro cauldron from Eggleston (1982), Chamberlin (1981), and G. R. Osburn (personal commun., 1983).

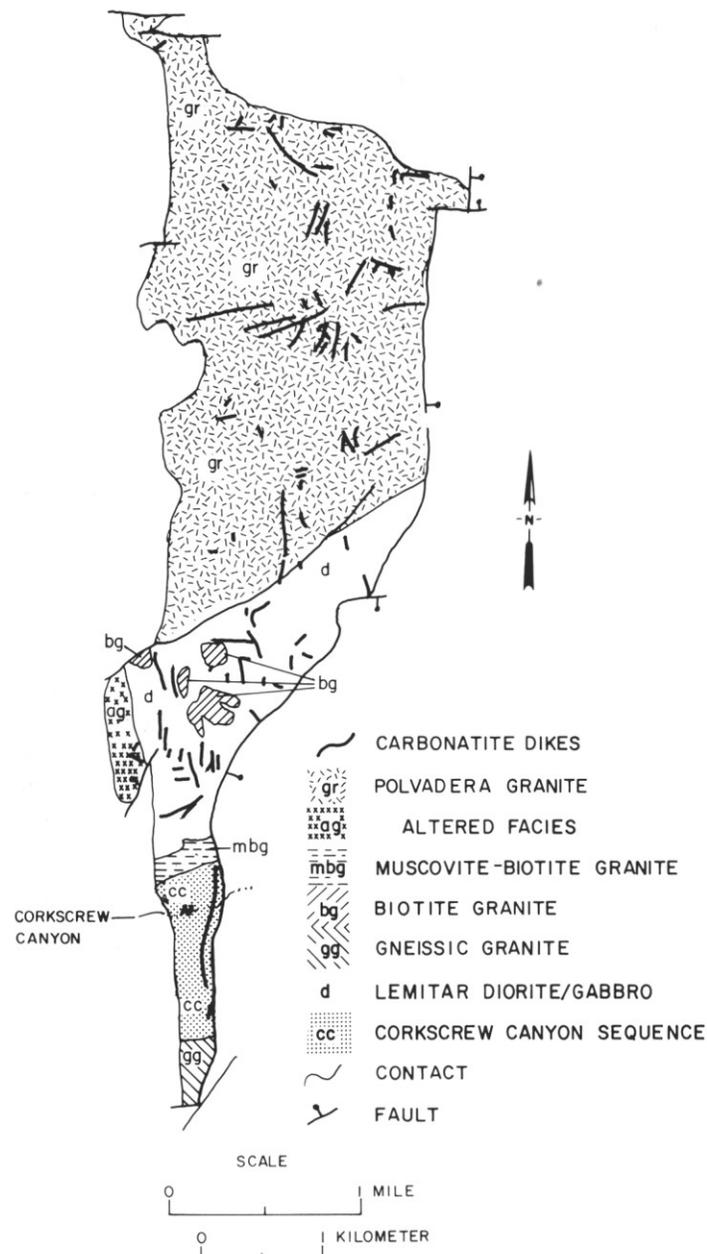


Figure 2. Geologic map of Precambrian rocks in the Lemitar Mountains showing distribution and trends of carbonatite dikes (modified from McLemore, 1982).

can be traced along strike for as much as 600 m (figs. 2 and 3). Some carbonatite dikes locally form subparallel dike swarms. Other dikes pinch and swell and grade into a system of carbonatite veins or stockwork. Alteration, shearing, and brecciation of wall rocks occurs adjacent to some carbonatites; however, other carbonatites intrude otherwise unaltered country rocks. The dikes are fracture-controlled and vary in orientation (figs. 2 and 3).

Many carbonatites are homogeneous and lack internal structure; whereas, other carbonatites are foliated or contain xenoliths or rock fragments of varying size and lithology (McLemore, 1982). Foliation or banding, formed by mineralogic and textural differences, typically is subparallel to dike margins. Fine-grained chilled margins are locally preserved.

In spite of variations in texture of these carbonatites, they can be grouped on the basis of mineralogy and mode of emplacement as silicocarbonatite dikes (figs. 4, 5, and 6); sOvite, rauhaugite, and carbonatite veins (fig. 7); ankeritic-dolomitic carbonatite dikes; and stockwork carbonatites (McLemore, 1982). Silicocarbonatite dikes are light-

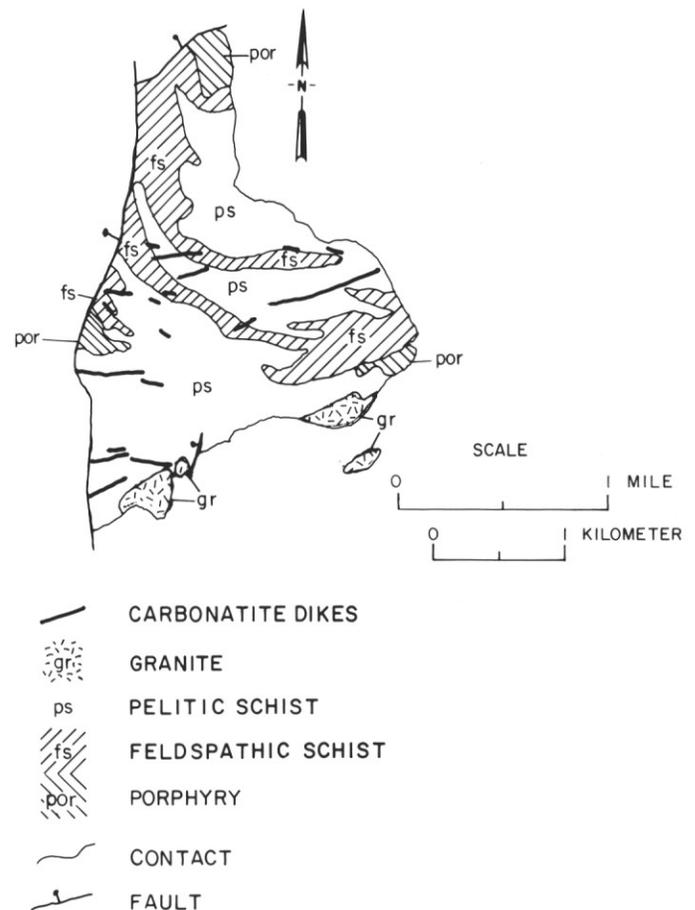


Figure 3. Geologic map of Precambrian rocks in the Chupadera Mountains showing distribution and trends of carbonatite dikes (modified from Kent, 1982).

medium-gray or brown and consist of carbonate matrix (>50% calcite and dolomite), magnetite (5-15%), mica (biotite, phlogopite, muscovite, and chlorite, 10-20%), apatite (5-10%), and various amounts of fluorite, hornblende, quartz, feldspar, barite, ilmenite, pyrite, sphene, sphalerite, galena, pyrrhotite, quartz, and ankerite. Some breccia and microbreccia silicocarbonatite dikes contain as much as 40 percent rock fragments or xenoliths. SOvite (>90% calcite), rauhaugite (>90% dolomite), and carbonatite (>90% calcite and dolomite) veins range in size from less than 1 mm to 5 cm wide and crosscut the silicocarbonatites (fig. 7) and country rocks. Some of these veins are highly radioactive. Ankeritic-dolomitic carbonatite dikes are dusky red to moderate reddish brown and consist of ankerite, dolomite, and calcite (>60%) and varying amounts of quartz, barite, fluorite, biotite, chlorite, hematite/goethite, apatite (trace), pyrite (trace), galena, magnetite (trace), sphalerite, and molybdenite. These dikes are fine- to medium-grained and range in size from 1 cm to more than 1 m wide and as much as 500 m in length. They may intrude or grade into silicocarbonatites. Thin, light-brown, randomly orientated dikelets or veins fill fractures in shattered granite and Lemitar diorite/gabbro forming a boxwork or stockwork pattern (McLemore, 1982). These stockworks consist of ankerite, calcite, dolomite, quartz, feldspar, biotite, and hematite and are adjacent to, or in the vicinity of, silicocarbonatites or ankeritic-dolomitic carbonatites.

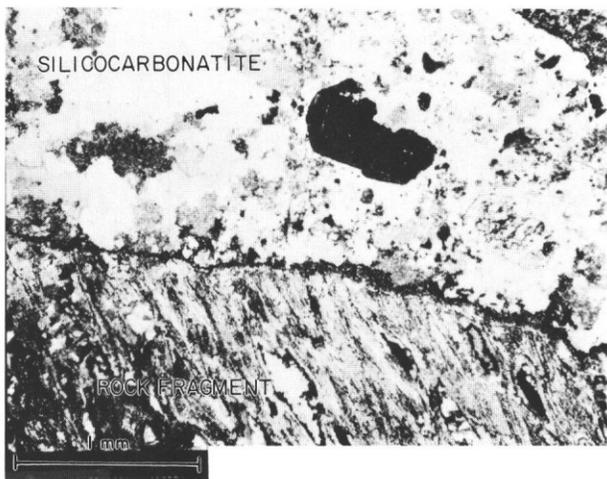


Figure 4. Photomicrograph (crossed nicols) of a primary magmatic silicocarbonatite. Note the reaction rim of mica surrounding the rock fragment (gneissic granite). The large dark grain in the center of the photograph is an apatite crystal.

In thin section, two types of textures dominate in silicocarbonatite dikes: a primary magmatic texture (porphyritic or hypidiomorphic-granular) or a relict replacement texture. Primary magmatic textures are typical of most igneous rocks (fig. 4). Relict replacement textures are preserved by the partial or complete replacement of original feldspar and hornblende phenocrysts by carbonatite minerals. Porphyritic (fig. 5), ophitic to subophitic (fig. 6), and granitic textures are commonly preserved. Replacement carbonatites are not uncommon in the world. They are described from the carbonatite at McClure Mountain in Colorado (Armbrustmacher, 1979) and the carbonatite at Sokli, Finland (Vartiainen and Paarma, 1979).

A mineralogic difference exists between the primary magmatic silicocarbonatites and the replacement silicocarbonatites. Xenoliths or rock fragments occur only in primary magmatic silicocarbonatites. Apatite is more abundant in primary magmatic silicocarbonatites, whereas magnetite is more abundant in replacement silicocarbonatites, although apatite and magnetite may be present in both. Accessory minerals vary in both types. Fluorite, sulfides, sphene, feldspar, and barite tend to be more abundant in primary magmatic silicocarbonatites, whereas hematite, mica, and quartz tend to be more abundant in replacement silicocarbonatites (McLemore, 1982). Furthermore, the Lemitar and

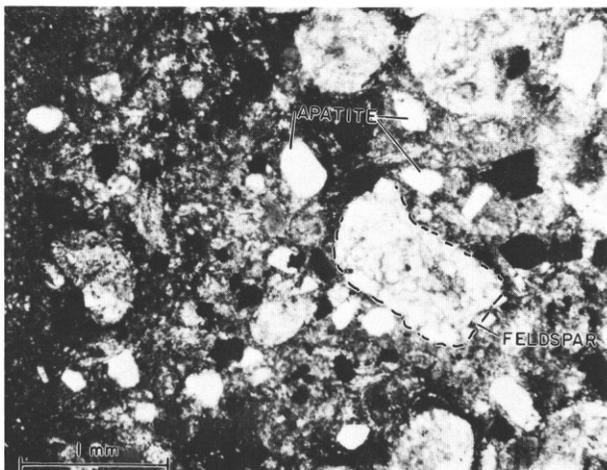


Figure 5. Photomicrograph (plane light) of a replacement silicocarbonatite dike exhibiting relict porphyritic texture. Carbonate has replaced the feldspar crystals. The colorless crystals are apatite.

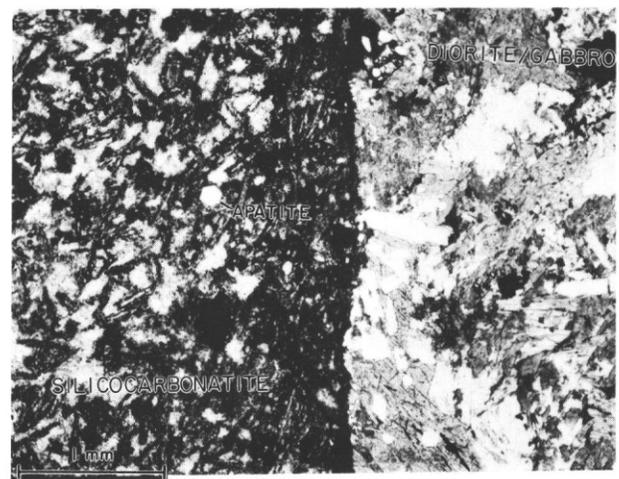


Figure 6. Photomicrograph (plane light) of a replacement silicocarbonatite dike exhibiting subophitic texture and in contact with the Lemitar diorite/gabbro (righthand side). Note colorless hexagonal apatite grain near center of the photograph.

Chupadera primary magmatic and replacement silicocarbonatites are similar in mineralogy to primary magmatic and replacement silicocarbonatites at McClure Mountain, Colorado (McLemore, 1982; Armbrustmacher, 1979).

## GEOCHEMISTRY

The Lemitar and Chupadera carbonatites are significantly enriched in CaO and CO<sub>2</sub> and depleted in SiO<sub>2</sub> relative to normal igneous rocks (Table 1), but are similar in composition to carbonatites in the Monte Largo Hills (Table 1), McClure Mountain, Colorado (Armbrustmacher, 1979), and elsewhere in the world (Heinrich, 1966; Gold, 1966). A chemical difference exists between the various types of carbonatites in the Lemitar and Chupadera Mountains. Replacement silicocarbonatites contain more SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, K<sub>2</sub>O, Li, Nb, Ta, and Th and less CaO, P<sub>2</sub>O<sub>5</sub>, and CO<sub>2</sub> than primary magmatic silicocarbonatites (Table 1). Replacement silicocarbonatites contain more Ni, Sc, Cu, Ba, Cs, and Cr than primary magmatic silicocarbonatites and ankeritic-dolomitic carbonatites. Most of these differences can be attributed to differences in mineralogy and assimilation of country rocks.

The Lemitar and Chupadera silicocarbonatites are similar in chemical composition; however, minor differences are noted (Table 1). The Chu-

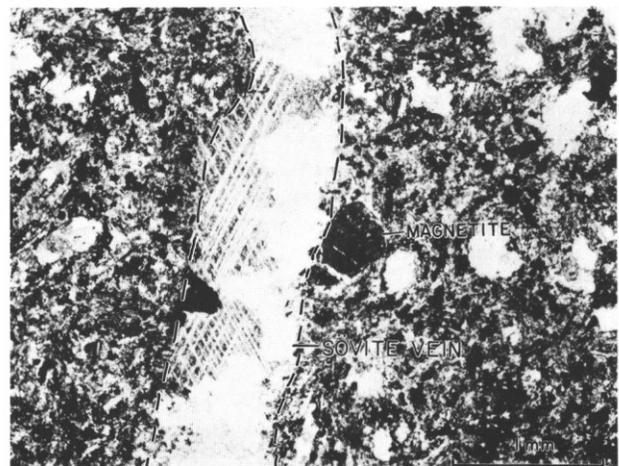


Figure 7. Photomicrograph (crossed nicols) of a coarse-grained sövite vein intruding a replacement silicocarbonatite dike.

Table 1. Chemical analyses of Lemitar, Chupadera, and Monte Largo carbonatites. Oxide totals do not equal 100% because of large concentrations of trace elements. Oxides are in percent and trace elements are in parts per million.

Oxides (%)	1	2	3	4	5	6	7	8
SiO <sub>2</sub>	12.5	24.2	8.27	39.02	7.02	13.03	10.3	5.47
TiO <sub>2</sub>	0.47	1.78	0.57	1.10	1.93	1.52	0.73	0.50
Al <sub>2</sub> O <sub>3</sub>	2.72	4.98	1.11	7.67	2.30	2.53	3.29	1.77
Fe <sub>2</sub> O <sub>3</sub>	3.74	7.68	6.78	2.17	2.01	5.78	3.46	3.88
FeO	4.63	6.87	6.49	4.92	7.59	3.81	3.60	3.71
MgO	8.23	6.80	7.29	4.16	6.29	5.79	5.79	6.10
CaO	31.5	17.2	30.4	19.16	33.73	32.05	36.1	37.06
Na <sub>2</sub> O	0.34	0.75	0.02	1.40	0.04	0.59	0.42	1.09
K <sub>2</sub> O	0.67	1.51	0.26	1.87	0.08	0.15	1.36	0.87
MnO	0.60	0.35	0.84	0.33	0.81	0.60	0.68	0.78
P <sub>2</sub> O <sub>5</sub>	3.16	1.32	0.23	1.76	6.11	4.21	2.09	1.73
CO <sub>2</sub>	27.4	17.8	36.0	14.63	27.60	26.37	28.5	31.16
total oxides	95.96	91.24	98.26	98.19	95.51	96.43	96.32	95.32
trace elements (ppm)								
Li	29	<10	<5	38	10	21	--	15
Sc	11	24	9	--	--	--	--	10
Ni	38	286	--	73	63	40	8	32
Cu	12	63	28	28	20	82	2.5	88
Zn	218	275	194	87	667	567	--	160
Sr	368	355	71	364	782	1,114	--	7,500
Ba	333	953	599	665	215	680	450- 1,120	4,000
Cs	2.5	11	0.6	--	--	--	--	--
Cr	16	231	15	80	43	27	48	102
Co	36	64	54	43	70	45	17	19
Nb	442	308	--	362	565	445	560	--
Ta	26	11	0.9	--	--	--	--	--
Th	62	19	1.4	27	119	30	--	649
U	7.5	8.4	3.2	15	13	42	--	57
number of samples	5	2	6	1	1	1	--	--

- 1 - average primary magmatic silicocarbonatite, Lemitar Mountains (McLemore, 1982)
- 2 - average replacement silicocarbonatite, Lemitar Mountains (McLemore, 1982)
- 3 - average ankeritic-dolomitic carbonatite, Lemitar Mountains (McLemore, 1982)
- 4 - replacement silicocarbonatite, Chupadera Mountains (this report)
- 5 - primary magmatic silicocarbonatite, Chupadera Mountains (this report)
- 6 - silicocarbonatite, Monte Largo Hills, Bernalillo County (this report)
- 7 - average carbonatite (Heinrich, 1966)
- 8 - average carbonatite (Gold, 1966)

padera primary magmatic silicocarbonatite contains more TiO<sub>2</sub>, total iron, CaO, and 13205 and less SiO<sub>2</sub>, MgO, Na<sub>2</sub>O, and K<sub>2</sub>O than the average Lemitar primary magmatic silicocarbonatites. The Chupadera replacement silicocarbonatite contains more SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, CaO, and 13205 and less total iron and MgO than the average Lemitar replacement silicocarbonatite. These differences are typical of carbonatite complexes and may be related to differences in the assimilated country rock.

Eight carbonatites from the Lemitar Mountains were analyzed for rare-earth elements (fig. 8; McLemore, 1982). The primary magmatic and replacement silicocarbonatites are noticeably enriched in rare-earth elements and display steep, light-rare-earth-element-enriched chondrite-normalized patterns (fig. 8); such patterns are characteristic of carbonatites throughout the world (Moller and others, 1980; Mitchell and Brunfelt, 1975; Loubet and others, 1972). However, the ankeritic-dolomitic carbonatites are relatively depleted in rare-earth elements and displays a rare-earth-element pattern similar to granitic rocks (fig. 8). The Lemitar primary magmatic silicocarbonatites are more enriched in rare-earth elements than the replacement silicocarbonatites and the ankeritic-dolomitic carbonatites (fig. 8; McLemore, 1982). The ankeritic-dolomitic carbonatite rare-earth-elements pattern is atypical of carbonatite patterns in that it is relatively depleted in rare-earth elements. This may be due to the replacement of granitic rocks. Anomalous rare-earth-

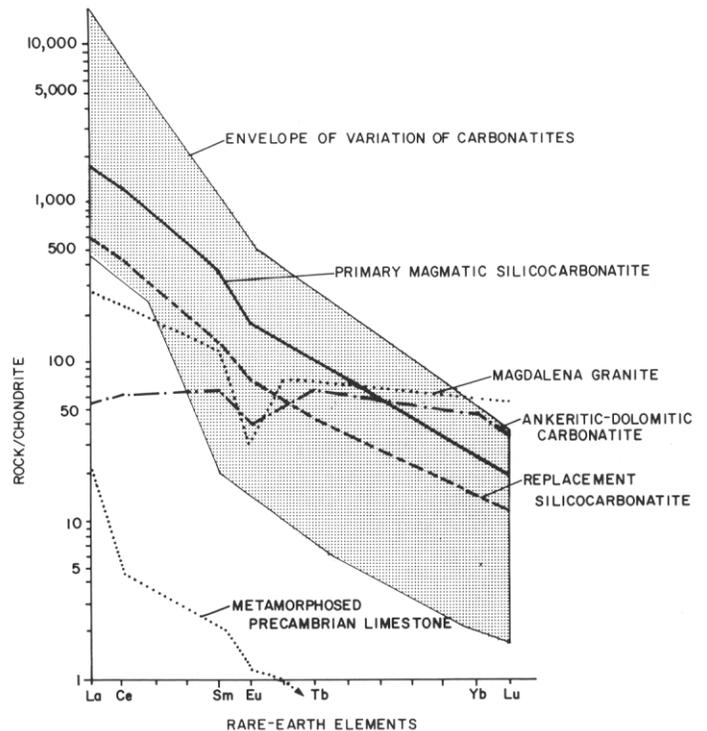


Figure 8. Chondrite-normalized rare-earth-element patterns of the Lemitar carbonatites. Shaded field represents an envelope of variation of carbonatites from throughout the world (miscellaneous analyses compiled by the author). Granite analysis (Precambrian Magdalena granite) from Condie and Budding (1979). Precambrian metamorphosed limestone analysis from Loubet and others (1972). Chondrite values from Haskin and others (1968). Primary magmatic silicocarbonatite trend line is an average of four samples. Replacement silicocarbonatite and ankeritic-dolomitic carbonatite trend lines are averages of two samples each (McLemore, 1982).

element patterns are typical of late-stage carbonatites (McLemore, 1982; Mitchell and Brunfelt, 1975; Möller and others, 1980; Loubet and others, 1972).

### AGE OF THE CARBONATITES

A primary magmatic silicocarbonatite dike from the Lemitar Mountains was dated as 449 ± 16 my. by K/Ar methods on a biotite separate (McLemore, 1982). This age is consistent with field observations. The similarity in emplacement, texture, mineralogy, and chemical composition between the carbonatites in the Lemitar and Chupadera Mountains suggest a similar age for these rocks. Carbonatites in southern Colorado range in age from 506 m.y. to 578 m.y. (Fenton and Faure, 1970; Olson and others, 1977) further supporting an early Paleozoic age.

### ALTERATION

A thin, discontinuous zone of fenitization is locally pronounced adjacent to some carbonatite dikes, although alteration of country rocks adjacent to many carbonatites is negligible. Hematitization, carbonatization, and sericitization may be pronounced adjacent to some carbonatite dikes, although these types of alteration are common in Precambrian terrains in New Mexico (Condie and Budding, 1979). The zone of fenitization ranges in width from <10 cm in the Lemitar diorite/gabbro to <1 m in granites and schists. The fenitization zone is characterized by large, orange-pink albite crystals. Feldspars in unaltered

rocks in the Chupadera and Lemitar Mountains tend to be white to light-pink crystals with labradorite to andesine compositions. Potassium feldspars are common in altered and unaltered rocks. In thin section, small disseminations of iron oxides coat the fenitized feldspars, thereby producing the red color.

Chemical variations during fenitization are variable and affect mafic and salic rocks differently (McKie, 1966; Verwoerd, 1966; Currie and Ferguson, 1971, 1972). At the Callander Bay complex in Canada, increase in fenitization of mafic rocks is accompanied by increases in SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, and 1/20 and decreases in TiO<sub>2</sub>, MgO, CaO, and total iron. In contrast, increase in fenitization of salic rocks is accompanied by an increase in SiO<sub>2</sub>, and decreases in Na<sub>2</sub>O, Al<sub>2</sub>O<sub>3</sub>, MgO, CaO, and total iron (Currie and Ferguson, 1971, 1972). Preliminary chemical analyses of the Lemitar diorite/gabbro and Lemitar granitic rocks show similar chemical trends as seen at Callander Bay; although fenitization is not as pronounced in the Lemitar samples (Table 2, fig. 9; McLemore, 1982; Currie and Ferguson, 1971, 1972). The fenitized diorite/gabbro samples exhibit an increase in Na<sub>2</sub>O and a decrease in CaO relative to unaltered diorite/gabbro samples (fig. 9). The fenitized Polvadera granite samples exhibit an increase in MgO and decreases in SiO<sub>2</sub>, CaO, and Na<sub>2</sub>O (Table 2, fig. 9). Changes in other oxide concentrations are not as pronounced. Additional chemical analyses of the Lemitar rocks are required to adequately define chemical trends due to fenitization.

ECONOMIC GEOLOGY

Carbonatites may contain economic concentrations of rare-earth elements, uranium, thorium, niobium, copper, iron, titanium, barite, and fluorite. An unknown amount of barite was produced from the ankeritic-dolomitic carbonatites in the Lemitar Mountains in 1979-1981. Barite occurs in veins and replacements adjacent to and within the ankeritic-dolomitic carbonatites (McLemore, 1982). The Lemitar and Chupadera carbonatites are also enriched in phosphate (5-10% apatite), uranium (0.001-0.25% U308), thorium (as much as 0.20% Th), rare-earth ele-

Table 2. Chemical analyses of fenitized and unaltered granites and diorite/gabbro in the Lemitar Mountains. Analyses of unaltered granites, unaltered diorite/gabbro, and fenitized diorite/gabbro from McLemore (1980). X-ray fluorescence analyses of fenitized granite provided by K. B. Faris (New Mexico Bureau of Mines and Mineral Resources).

Oxides (%)	1	2	3	4	5	6	7	8
SiO <sub>2</sub>	69.8	68.0	74.2	73.5	70.3	69.7	53.4	56.6
TiO <sub>2</sub>	0.79	0.78	0.46	0.45	0.58	0.53	2.16	1.23
Al <sub>2</sub> O <sub>3</sub>	12.2	14.3	13.6	13.1	12.7	13.1	11.0	12.5
Fe <sub>2</sub> O <sub>3</sub> *	8.05	6.46	3.66	4.43	5.82	4.18	18.3	14.6
MgO	0.93	1.05	0.47	0.45	1.23	0.88	2.15	2.50
CaO	1.98	2.02	1.07	1.04	0.46	0.62	6.89	4.36
Na <sub>2</sub> O	3.04	3.69	3.45	3.03	2.29	1.87	2.39	3.46
K <sub>2</sub> O	3.85	3.94	4.40	5.20	4.40	7.00	1.72	1.56
MnO	0.11	0.09	0.05	0.08	0.06	0.03	0.28	--
trace elements (ppm)								
Sr	110	226	71	78	55	45	150	478
Rb	147	140	168	218	148	415	47	61
number of samples	2	3	3	2	1	1	5	2

\* Total iron calculated as Fe<sub>2</sub>O<sub>3</sub>  
 1 - Group 1 granite, average gneissic granite of McLemore (1980)  
 2 - Group 1 granite, average biotite granite of McLemore (1980)  
 3 - Group 2 granite, average muscovite-biotite granite of McLemore (1980)  
 4 - Group 2 granite, average Polvadera granite of McLemore (1980)  
 5 - Fenitized granite (altered facies of Polvadera granite, this report)  
 6 - Fenitized granite (Polvadera granite, this report)  
 7 - average Lemitar diorite/gabbro of McLemore (1980)  
 8 - average fenitized diorite/gabbro (McLemore, 1980)

ments (as much as 0.19%), and niobium (0.04% Nb; this report; McLemore, 1982; Pierson and others, 1982), although concentrations of economic grade are discontinuous and localized. The subsurface potential is unknown.

CONCLUSIONS

The Lemitar and Chupadera carbonatites are similar in age, texture, mineralogy, and chemical composition to the carbonatites in southern Colorado, which suggests a similar origin. Strontium-, carbon-, and oxygen-isotope studies of carbonatites in Colorado indicate an upper mantle source (Olson and others, 1977; Fenton and Faure, 1970; Armbrustmacher, 1979). Carbonatites may be derived from: (1) a primary carbonatite magma, (2) differentiation of one of several primary parent magmas (ijolite, peridotite, nephelinite, nephelite-basalt), (3) fractional crystallization of an alkalic magma, (4) metasomatism of alkalic rocks, and (5) immiscibility during later stages of silicate magmas (Heinrich, 1966). Experimental evidence confirms that magmas of a variety of compositions can produce the wide variance in composition found in the Lemitar and Chupadera carbonatites (Wyllie, 1966; Heinrich, 1966). The strong fractionation and enrichment of light rare-earth elements in the Lemitar carbonatites (fig. 8) supports fractionation or metasomatism of an upper mantle source.

ACKNOWLEDGMENTS

This paper is a summary of on-going research of carbonatites in New Mexico and is supported by the New Mexico Bureau of Mines and Mineral Resources. Chemical analyses of samples were provided by the author, Lynn Brandvold and associates, and K. B. Faris (New Mexico Bureau of Mines and Mineral Resources). Rare-earth element analyses were provided by K. C. Condie and associates (New Mexico Institute of Mining and Technology). James McLemore (Petroleum Recovery and Research Center) and Richard Chamberlin (New Mexico Bureau of Mines and Mineral Resources) assisted in sample collecting. Kent C. Condie (New Mexico Institute of Mining and Technology) critically reviewed the manuscript and Frank Kottlowski (Director, New Mexico Bureau of Mines and Mineral Resources) authorized its publication.

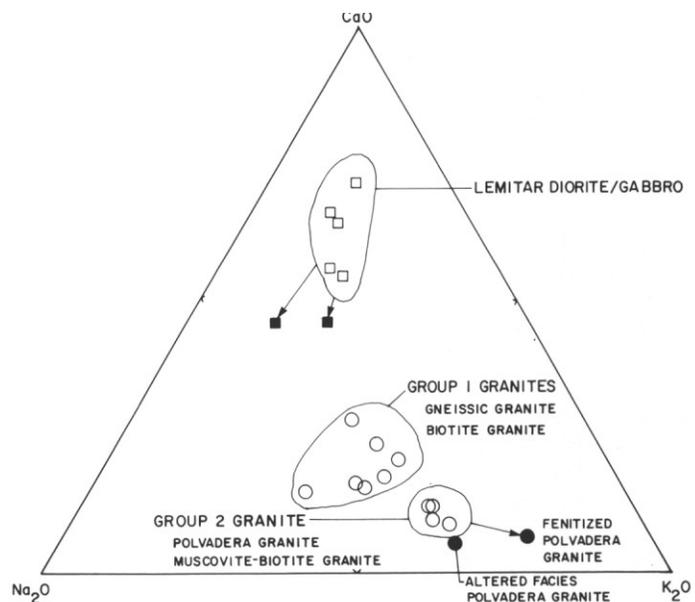
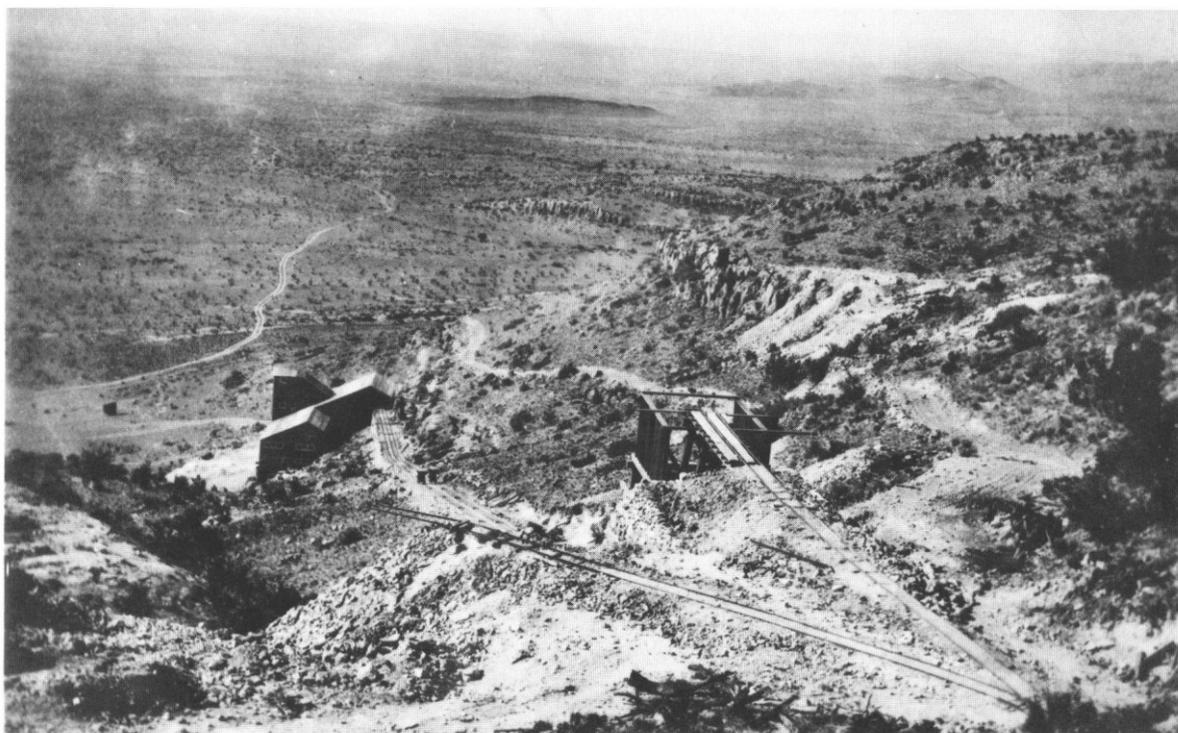


Figure 9. CaO-Na<sub>2</sub>O-K<sub>2</sub>O plot of the effect of fenitization on the Lemitar diorite/gabbro and Lemitar granite. Open symbols represent unaltered samples; closed symbols represent fenitized samples. Arrow is in direction of fenitization. Group 1 and Group 2 granites are from McLemore (1980).

## REFERENCES

- Amibrustmacher, T. J., 1979, Replacement and primary magmatic carbonatites from the Wet Mountains area, Fremont and Custer Counties, Colorado: *Economic Geology*, v. 74, p. 888-901.
- Chamberlin, R. M., 1981, Cenozoic stratigraphy and structure of the Socorro Peak volcanic center, central New Mexico: *New Mexico Geology*, v. 3, no. 2, p. 22-24.
- Condie, K. C. and Budding, A. J., 1979, Geology and geochemistry of Precambrian rocks, central and south-central New Mexico: *New Mexico Bureau of Mines and Mineral Resources Memoir 35*, 58 p.
- Currie, K. L. and Ferguson, J., 1971, A study of fenitization around the alkaline carbonatite complex at Callander Bay, Ontario, Canada: *Canadian Journal of Earth Sciences*, v. 8, p. 498-517.
- , 1972, A study of fenitization in mafic rocks, with special reference to the Callander Bay complex: *Canadian Journal of Earth Sciences*, v. 9, p. 1,254-1,261.
- Eggleston, T. L., 1982, Geology of the central Chupadera Mountains, Socorro County, New Mexico [M.S. thesis]: Socorro, New Mexico Institute of Mining and Technology, 162 p.
- Fenton, M. D. and Faure, G., 1970, Rb-Sr whole-rock age determinations of the Iron Hill and McClure Mountain carbonatite-alkalic complexes, Colorado: *The Mountain Geologist*, v. 7, no. 4, p. 269-275.
- Gold, D. P., 1966, The average and typical chemical composition of carbonatites: *Mineralogical Society of India, International Mineralogical Association Volume*, p. 83-91.
- Haskin, L. A., Haskin, M. A., Frey, F. A., and Wildenan, T. R., 1968, Relative and absolute terrestrial abundances of the rare earths, in Ahrens, L. H., ed., *Origin and distribution of the elements*: London, Pergamon Press, p. 891-912.
- Heinrich, E. W., 1966, *The geology of carbonatites* (reprinted in 1980): Chicago, Rand McNally and Company, 555 p.
- Kent, S., 1982, Geologic maps of Precambrian rocks in the Magdalena and Chupadera Mountains, Socorro County, New Mexico: *New Mexico Bureau of Mines and Mineral Resources Open-file Report OF-170*, scale 1:24,000, 2 plates.
- Lambert, P. W., 1961, Petrology of the Precambrian rocks of part of the Monte Largo area, New Mexico [M.S. thesis]: Albuquerque, University of New Mexico, 91 p.
- Loubet, M., Bernat, M., Javoy, M., and Allegre, C. J., 1972, Rare-earth contents in carbonatites: *Earth and Planetary Science Letters*, v. 14, p. 226-232.
- McKie, D., 1966, Fenitization, in Tuttle, O. F. and Gittins, J., eds., *Carbonatites*: New York, Interscience Publishing, p. 261-294.
- McLemore, V. T., 1980, Geology of the Precambrian rocks of the Lemitar Mountains, Socorro County, New Mexico [M.S. thesis]: Socorro, New Mexico Institute of Mining and Technology, 169 p.
- , 1982, Geology and geochemistry of Ordovician carbonatite dikes in the Lemitar Mountains, Socorro County, New Mexico: *New Mexico Bureau of Mines and Mineral Resources Open-file Report OF-158*, 104 p.
- Mitchell, R. H. and Brunfelt, A. D., 1975, Rare-earth-element geochemistry of the Fen alkaline complex, Norway: *Contributions to Mineralogy and Petrology*, v. 52, p. 247-259.
- Moller, F., Morteani, G., and Schley, F., 1980, Discussion of REE distribution patterns of carbonatites and alkalic rocks: *Lithos*, v. 13, p. 171-179.
- Olson, J. C., Marvin, R. F., Parker, R. L., and Mehnert, H. H., 1977, Age and tectonic setting of lower Paleozoic alkalic and mafic rocks, carbonatites, and thorium veins in south-central Colorado: *U.S. Geological Survey Journal of Research*, v. 5, p. 673-687.
- Pierson, C. T., Wenrich-Verbeek, K. J., Hannigan, B. J., and Machette, M. N., 1982, National uranium resource evaluation, Socorro quadrangle, New Mexico: U.S. Department of Energy Report PGJ/F-068 (82), 45 p.
- Vartiainen, H. and Paarma, H., 1979, Geological characteristics of the Sokli carbonatite complex, Finland: *Economic Geology*, v. 74, p. 1,296-1,306.
- Verwoerd, W., 1966, Fenitization of basic igneous rocks, in Tuttle, O. F. and Gittins, J., eds., *Carbonatites*: New York, Interscience Publishing, p. 295-308.
- Wyllie, P. J., 1966, Experimental studies of carbonatite problems; the origin and differentiation of carbonatite magmas, in Tuttle, O. F. and Gittins, J., eds., *Carbonatites*: New York, Interscience Publishing, p. 311-352.



*Some sense of the remoteness of many early-day New Mexico mining camps is projected by the above view of Western Mineral Products mill at Hansonburg, ca. 1917. No railroad ever passed through this region although at least two were proposed. The closest railhead was more than 20 miles away at Carthage. The only link with the outside world was provided by the Socorro-White Oaks stage road here winding past the mill on its way up Hansonburg (now North) Canyon toward Ozanne. Also in this view to the north-northwest are the ore and waste tracks from the Rimrock tunnel, ore-storage bins, and the gravity-plane rail tramway to the mill. Photo courtesy St. Joe American Corp., Tucson, Arizona; New Mexico Bureau of Mines and Mineral Resources collection.*