GEOLOGY AND REGIONAL IMPLICATIONS OF CARBONATITES IN THE LEMITAR MOUNTAINS, CENTRAL NEW MEXICO[1]

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ABSTRACT

More than 100 carbonatite dikes and veins intrude a complex Precambrian terrain in the Lemitar Mountains, New Mexico. These Ordovician carbonatites are not associated with any alkalic rocks or kimberlites, but they exhibit textures, mineralogy, chemistry, and alteration characteristic of carbonatites. Despite variations in texture, the Lemitar carbonatites can be grouped on the basis of mineralogy, chemistry, and texture as primary-magmatic and replacement silicocarbonatites and rodbergs. The Lemitar silicocarbonatites consist of more than 50% carbonate minerals and varying amounts of accessory minerals, and they are enriched in LREE. The rodbergs consist of more than 50% carbonate minerals, are stained red by hematite, and exhibit flat REE patterns. Carbonate and barite-fluorite-galena veins of uncertain origin are found in the carbonatites and country rocks. Periodic episodes of alkalic magmatism occurred in New Mexico and southern Colorado during the Proterozoic, late Paleozoic, and Tertiary. The Lemitar carbonatites are part of a regional episode of alkalic and carbonatite magmatism which affected New Mexico and southern Colorado during the late Paleozoic. Continental rifting may have occurred during the Precambrian and late Paleozoic in central New Mexico, although exact geographical limits of paleorifts cannot be determined because overlapping periods of tectonism may have affected the area since Paleozoic times.

INTRODUCTION

A large carbonatite dike swarm in the Lemitar Mountains near Socorro, New Mexico (fig. 1), contains more than 100 silicocarbonatite and rodberg dikes and associated veins within a complex Proterozoic metamorphic terrain (fig. 1). While not associated genetically or spatially with any alkalic rocks or kimberlites, their textures, mineralogy, chemistry, and associated alteration are characteristic of carbonatites. Silicocarbonatites consist of mixed carbonate and silicate minerals and are common in many carbonatite complexes (Heinrich 1966). Rodberg is a rare calcite-dolomite carbonatite that is stained red throughout by hematite and is recognized in only a few carbonatite complexes, including the Fen complex, south Norway (Heinrich 1966; Andersen 1984). Carbonatite stocks, plugs, or ring structures, typical of many carbonatite complexes in the world (Heinrich 1966), are absent in the Lemitar Mountains. Hydrothermal carbonate and barite-fluorite-galena veins of uncertain age and genesis occur within the carbonatites and the country rocks. A K-Ar date of 449 ± 16 m.y. was obtained on a biotite separate from a silicocarbonatite (McLemore 1982); therefore the Lemitar carbonatites are probably Ordovician in age. Because igneous activity during Cambrian-Ordovician times has only recently been documented in New Mexico (Brookins 1980; Loring and Armstrong 1980), the presence of Ordovician carbonatites in New Mexico has important regional implications.

GEOLOGIC SETTING

The Lemitar Mountains form part of the western edge of the Rio Grande rift, a north-trending zone of Tertiary crustal extension and possible deep-seated compression. North-trending Miocene and Pliocene faults have exposed portions of a complex Precambrian metamorphic terrain, intruded by the carbonatites (Chamberlin 1982, 1983).

The oldest rocks in the Lemitar Mountains are metamorphosed sedimentary rocks consisting of the Proterozoic Corkscrew Canyon sequence (fig. 2). Lithologies include quartzo-feldspathic schists and quartzites, probably derived from arkoses, subarkoses, and quartz sandstones (McLemore 1980). The Corkscrew Canyon sequence was intruded in succession by gneissic granite, the Lemitar diorite/gabbro, the Polvadera granite, and amphibolite and pegmatite dikes. Zircons from the gneissic granite yielded a U-Pb age of 1648 ± 3 m.y. (Bowring et al. 1983). Carbonatites intruded the Precambrian rocks after metamorphism but prior to depo-

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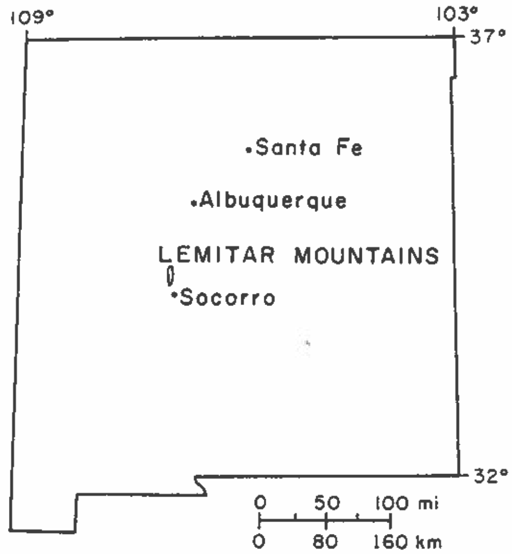

FIG. 1.—Location map of Lemitar Mountains, central New Mexico.

sition of Mississippian and Pennsylvanian sedimentary rocks. Paleozoic sedimentary rocks and Tertiary volcanic and sedimentary rocks overlie or are in fault contact with the Precambrian rocks. Four periods of tectonic activity have rotated and faulted the Precambrian terrain: Mississippian to Permian (ancestral Rocky Mountains uplift), Late Cretaceous to middle Eocene (Laramide orogeny), Oligocene volcanism and caldera formation, and Tertiary volcanism and faulting associated with the Rio Grande rift (Chamberlin 1981, 1982).

GEOLOGY OF THE CARBONATITES

The Lemitar carbonatites are fracture controlled. Many trend N-S parallel to major rift-forming faults (fig. 2), and form sharp intrusive contacts with the Precambrian country rocks. Alteration, shearing, and brecciation of country rocks occur adjacent to some dikes, but other dikes intrude unaltered and undisturbed country rocks. The dikes range in thickness from a few centimeters to over a meter and are discontinuous along strike because of pinchouts, faults, or erosion. A few dikes can be traced intermittently along strike for up to 600 m.

A striking feature of the carbonatites is their variability in geometric form. Some of the larger dikes are planar, but many bifurcate abruptly and send off many small dikelets. Smaller dikes bifurcate locally with thin pods of unaltered country rock separating the two parts. Subparallel pairs of dikes are common. Some dikes appear to pinchout, only to reappear along strike, forming a series of lenticular pods. Abrupt changes in width of the carbonatites are common. Local offsets, occasionally steplike, occur in these dikes. Some dikes, especially small ones, are offset up to 30 or 40 cm along transverse fracture planes.

The structures of the dikes are quite variable. Foliation or banding parallels dike contacts in some carbonatites and is caused by differences in mineralogy, texture, or grain size. Fine-grained chilled margins are locally preserved. A few dikes are zoned, typically by magnetite crystals decreasing in size towards the dike margin; others are homogeneous.

The Lemitar carbonatites can be grouped on the basis of mineralogy and mode of emplacement as silicocarbonatite and rodberg dikes. Silicocarbonatite dikes are more abundant in the central Lemitar Mountains, whereas rodberg dikes become more abundant to the north. Both types, however, occur throughout the area, and rodberg dikes intrude silicocarbonatite dikes. Only a few silicocarbonatite dikes occur in the southern Lemitar Mountains.

PETROLOGY

Silicocarbonatite Dikes.—Silicocarbonatite dikes are light to medium gray and brown and radioactive (2 or more times background radioactivity) due to uranium, thorium, and possibly radiogenic potassium. One of the most outstanding features of these rocks is their heterogeneity in grain size, texture, and mineralogy, even in a single dike. They consist of calcite and dolomite matrix (>50%), magnetite (5–15%), mica (biotite, phlogopite, muscovite, and chlorite; 10–20%), apatite (5–10%), and various amounts of accessory minerals, such as fluorite, feldspar, barite, quartz, bastnaesite, and other minerals (table 1). Carbonate minerals are fine-grained, whereas magnetite, apatite, fluorite, feldspar, and quartz are up to 5 mm across. Mica occurs as irregular aggregates or as single books of crystals. Other accessory minerals are small, rarely exceeding a few millimeters in diameter.

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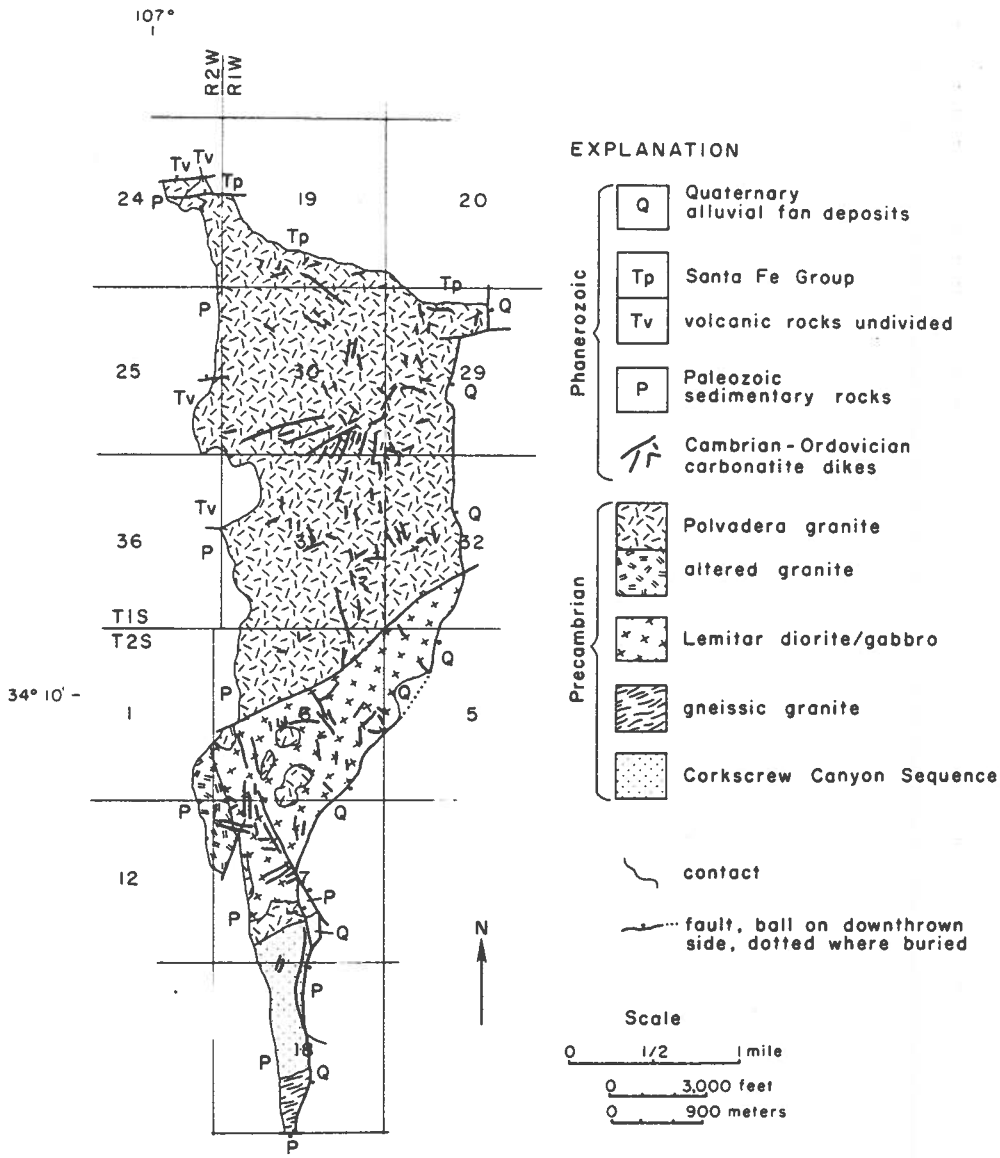

FIG. 2.—Geologic map of Precambrian rocks in the Lemitar Mountains showing distribution and trends of carbonatite dikes (simplified from McLemore 1982).

Some silicocarbonatite dikes contain as much as 40% xenoliths (fig. 3) of various sizes and lithologies, including granite, diorite/gabbro, metasedimentary rocks, and pelitic schists. All xenolith lithologies, except the pelitic schists, occur in the Proterozoic section in the Lemitar Mountains. Pelitic schists are found in the Proterozoic section in the Chupadera Mountains, about 8 km south of the Lemitar Mountains (Kent 1982; Bowring et al. 1983). Some xenoliths are well rounded; others are deformed and fractured. A few are surrounded by microscopic rims of intergrown biotite and magnetite, indicating chemical reactions. Small angular fragments of the adjacent host rock are abundant in many dikes. Other carbonatites are typically fine- to medium-grained without any xenoliths.

The silicocarbonatites can be classified further on the basis of textures observed in thin sections as primary-magmatic and replace-

TABLE 1

MINERALOGY OF THE LEMITAR CARBONATITES

Mineral	Primary-magmatic silicocarbonatites	Replacement silicocarbonatites	Rodbergs	Carbonate veins
calcite	e	e	e	e
dolomite	e	e	e	e
ankerite	vr	c	e	e
bastnaesite	vr	. . .	. . .	. . .
magnetite/ilmenite	e	e	r	r
apatite	e	c	vr	r
muscovite/sericite	r	c	. . .	. . .
biotite/phlogopite	c	c	r	r to c
zircon	vr	. . .	. . .	. . .
chlorite	c	c	r	. . .
sphene/leucoxene	r	vr	. . .	. . .
quartz	c	r	c	vr
pyrrhotite	vr	vr	. . .	. . .
fluorite	r	vr	c	vr
pyrite	r	vr	r	. . .
barite	r	r	c	r
hornblende	r	r	r	. . .
hematite/goethite	r	c	e	r to e
garnet	vr	. . .	. . .	. . .
feldspar	r	r	. . .	vr to c
galena	vr	. . .	r	. . .
sphalerite	vr	vr	r	. . .
chalcopyrite	vr	vr	. . .	. . .
molybdenite	. . .	. . .	vr	. . .
wulfenite	. . .	. . .	vr	. . .

NOTE.—e—essential to all samples examined; c—common to many samples examined; r—rarely found in trace amounts in a few samples examined; vr—found in trace amounts in only one or two samples examined; . . . not found in any samples examined.

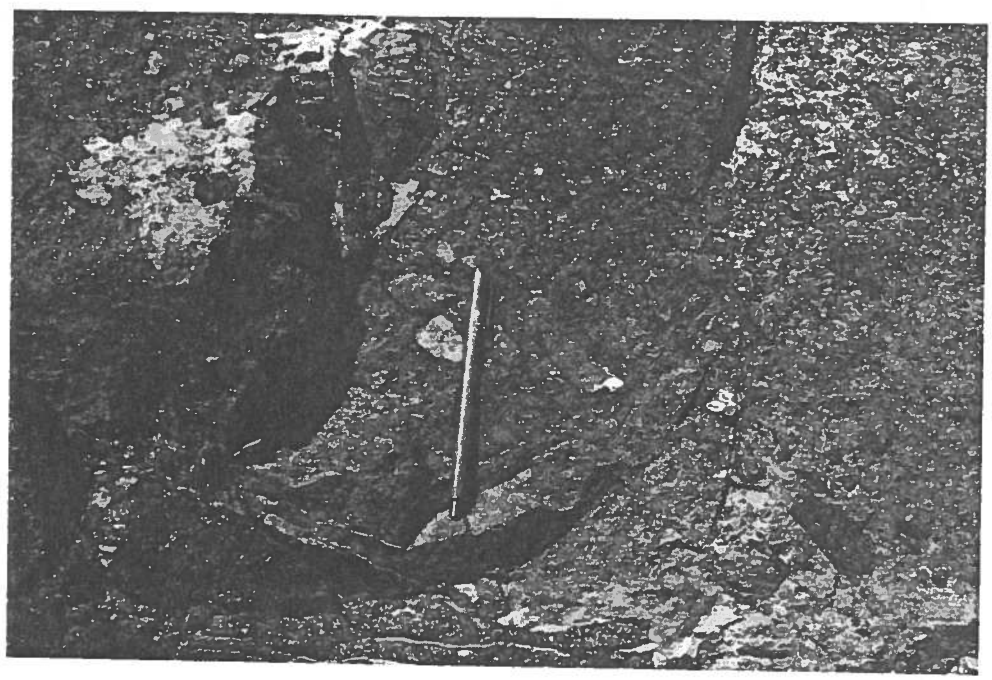

FIG. 3.—Xenolith-bearing carbonatite dike. Xenoliths are Precambrian schists and diorite/gabbro.

Rodbergs	Carbonate veins
e	e
e	e
e	e
...	...
r	r
vr	r
...	...
r	r to c
...	...
r	...
...	...
c	vr
...	...
c	vr
r	...
c	r
r	...
e	r to e
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...	vr to c
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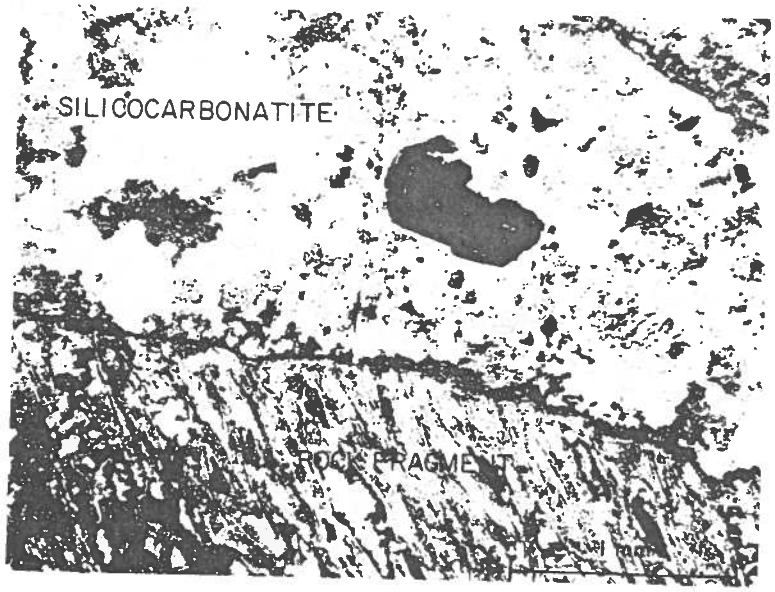

FIG. 4.—Photomicrograph (crossed nicols) of a primary-magmatic silicocarbonatite. Note the reaction rim of mica surrounding the xenolith. The large dark crystal is apatite.

ment silicocarbonatites. Primary-magmatic silicocarbonatites are characterized by porphyritic or hypidiomorphic-granular textures (fig. 4). Phenocrysts are fractured locally, and fractures are filled with carbonate. Corrosion of phenocrysts from partial resorption by the carbonate magma is common. All xenolith-bearing and some fine-grained, homogeneous, silicocarbonatites exhibit primary-magmatic textures.

Replacement silicocarbonatites are fine-grained with relict porphyritic and subophitic to ophitic textures. The preserved textures in replacement silicocarbonatites are identical to textures of unaltered amphibolite dikes or diorite/gabbro. Relict porphyritic textures are preserved by the partial or complete replacement of large feldspar crystals by carbonate minerals (fig. 5). Subophitic to ophitic relict textures are preserved by partial or complete replacement of small hornblende crystals by carbonate minerals (fig. 6).

Apatite is more abundant in primary-magmatic silicocarbonatites, and magnetite is more abundant in replacement silicocarbonatites, although apatite and magnetite occur in both (table 1). Fluorite, sulfides, sphene, and quartz are more abundant in primary-magmatic silicocarbonatites, whereas feldspar, hematite, goethite, ankerite, and hornblende are more abundant in replacement silicocarbonatites. Similar differences in mineralogy are observed in primary-magmatic and replacement carbonatites in the Wet Mountains area, Colorado (Armbrustmacher 1979).

Rodberg Dikes.—In the Lemitar Mountains, rodberg dikes (formerly called ankeritic-dolomite carbonatites by McLemore 1982, 1983) are as much as 1 m wide, dark red to medium reddish brown, and fine- to medium-grained. These dikes consist of varying amounts of calcite, dolomite, ankerite, hematite, goethite, barite, fluorite, quartz, and trace amounts of various minerals including apatite, magnetite, galena, sphalerite, and other minerals (table 1). Rodbergs in the Lemitar Mountains are typically not anomalously radioactive, although adjacent granitic fenites have two to five times the background radioactivity of unaltered granite. Hematite and goethite have obscured original textures and minerals in many thin sections of rodbergs. Rodberg dikes locally grade into silicocarbonatites, and locally rodbergs intrude silicocarbonatites.

HYDROTHERMAL VEINS

Carbonate Veins.—Thin hydrothermal carbonate (greater than 90% calcite or calcite

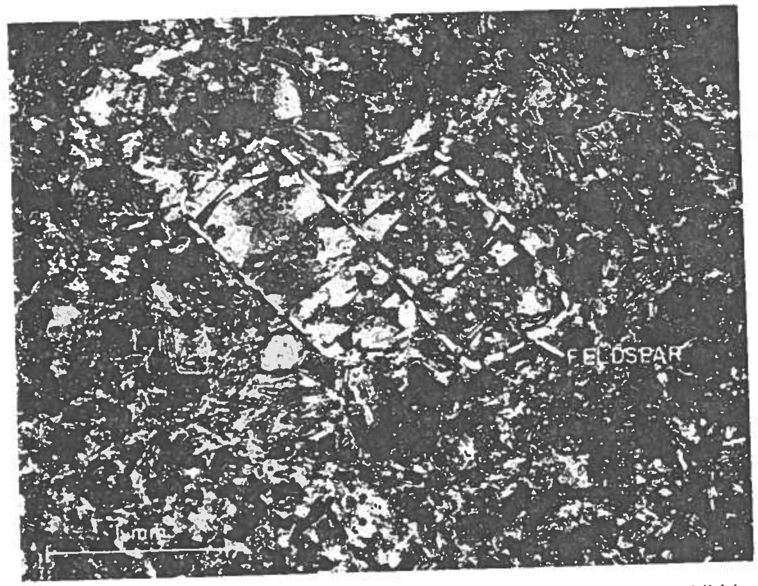

FIG. 5.—Photomicrograph (plane light) of a replacement silicocarbonatite dike exhibiting relict porphyritic texture. Carbonate has replaced the feldspar crystals.

and dolomite) veins intrude many carbonatite dikes and the Precambrian rocks (fig. 7). The veins rarely exceed a few centimeters in width, and most are microscopic. Some veins contain xenoliths of the host rock and may be anomalously radioactive relative to the host rock. Many veins intruding the country rock grade into carbonatite dikes along strike. Stockwork or boxwork patterns are abundant where numerous carbonate veins intrude fractured and brecciated country rock (fig. 8).

The age and origin of these veins are uncertain. Some may represent hydrothermal activity after emplacement of silicocarbonatite and rodberg dikes, and some are probably much younger than the carbonatites.

Barite-Fluorite-Galena Veins.—Veins consisting of barite with varying amounts of

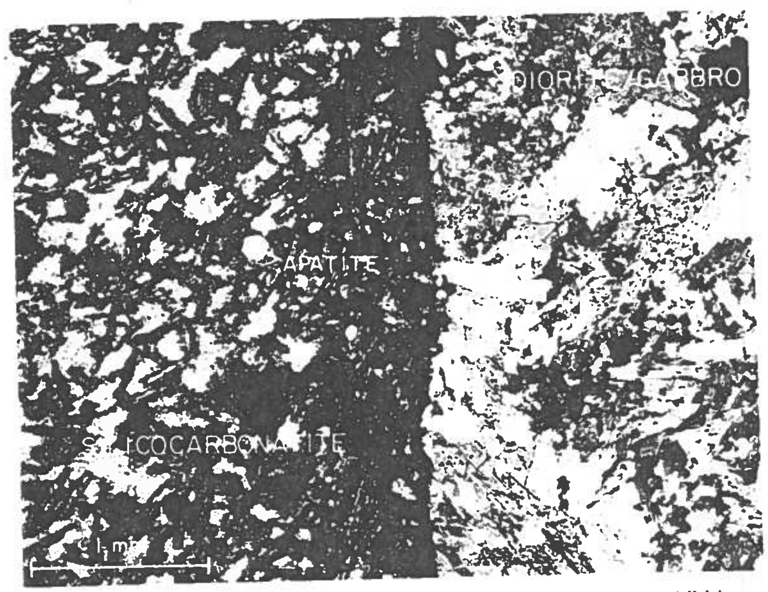

FIG. 6.—Photomicrograph (plane light) of a replacement silicocarbonatite dike exhibiting relict subophitic texture.

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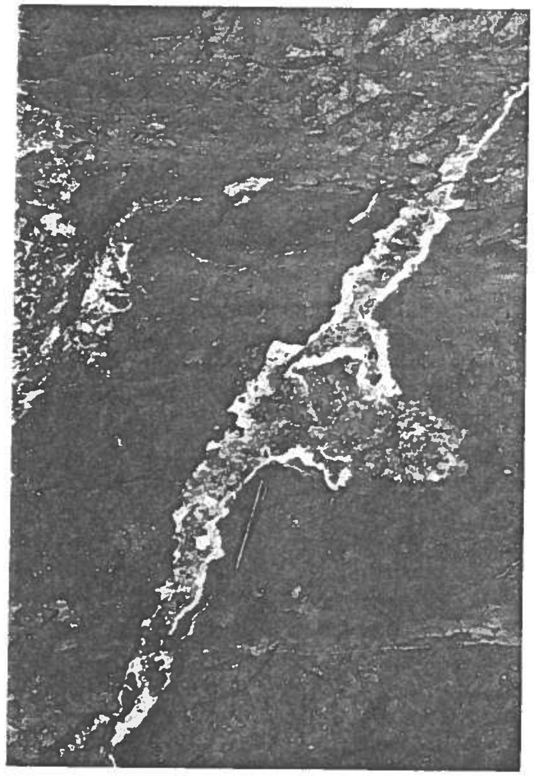

FIG. 7.—A carbonate vein cutting a primary-magmatic silicocarbonatite dike.

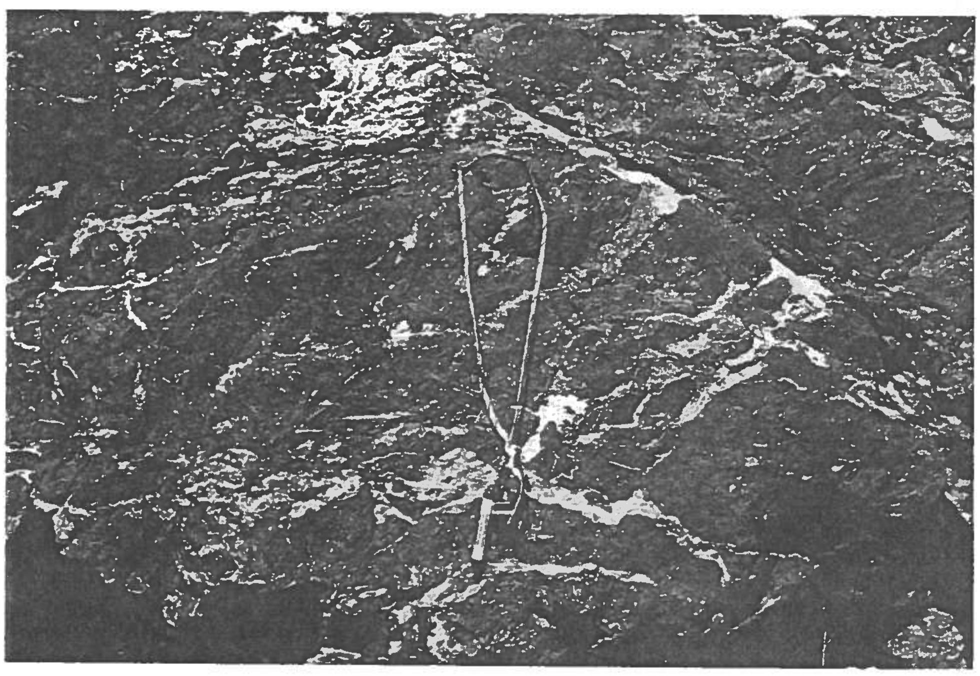

FIG. 8.—Carbonate veins (white) cutting Polvadera granite in a stockwork pattern.

fluorite, galena, calcite, minor quartz, and other minerals are spatially associated with rodberg, silicocarbonatite, and amphibolite dikes. Some of these veins contain as much as 50.7 ppm of silver in selected galena samples (McLemore 1982). Molybdenite, chalcopyrite, wulfenite, vanadinite, pyrite, and sphalerite occur as accessory minerals. Additional veins of barite, fluorite, and galena occur along N-S shear zones in the Polvadera granite and Paleozoic rocks and along the unconformity between the Paleozoic and Proterozoic rocks and are not related to the carbonatites.

The age and origin of these veins are uncertain. The apparent age of many of the veins is probably Tertiary because of the similarity in mineralogy and form to other barite-fluorite-galena veins of sedimentary-hydrothermal origin found within and adjacent to the Rio Grande rift (Van Alstine 1976; North and McLemore 1986; McLemore and Barker 1985). However, some of the veins intimately associated with the rodberg and silicocarbonatite dikes may be related to a late hydrothermal stage of the carbonatites. Worldwide, late-stage barite mineralization is commonly associated with ankeritic or sideritic carbonatites (Heinrich 1966). Preliminary fluid-inclusion studies of fluorite from veins spatially related to the Lemitar rodbergs indicate an unusual abundance of daughter minerals within the inclusions not normally found in veins of sedimentary-hydrothermal origin (North and Tuff 1986). A variety of daughter minerals occur in fluid inclusions within calcite from the Magnet Cove carbonatite complex, Arkansas, and are inferred to represent mixing of carbonatite fluids with local ground water (Nesbitt and Kelly 1977). Such may be the case in the Lemitar Mountains. Additional studies are underway.

GEOCHEMISTRY

Chemical analyses are difficult to obtain from carbonatites because of their compositional heterogeneity and interferences from other elements within the carbonatite. Furthermore, known standards that reflect matrix effects of carbonatites are difficult to obtain. Partial analyses of the Lemitar carbonatites are in table 2. Major and trace elements were determined by atomic absorption spectrometry (total Fe, Mg, Ca, Cr, Ni, Sr, Ba, Li, V, and Cu), titration (FeO, CO_2), colorimetric (P_2O_5, U), gravimetric (SiO_2, loss on ignition or LOI), neutron activation (Cs, Cr, Ba, Hf, U, Th, Ta, Sc, and seven REE), and X-ray fluorescence (Sc, Nb, Sr, Ba, U, and Th). The major elements of some samples were also analyzed by X-ray fluorescence. Analyses from different methods compared well except for Ba. Ba results from neutron activation are reported wherever possible. The relative error for methods used is within $\pm 5\%$. Analytical procedures are discussed in McLemore (1982). The analyses in table 2 are similar to published chemical analyses of carbonatites elsewhere in the world (Heinrich 1966; Gold 1966; Armbrustmacher 1979).

A chemical variation exists between the various types of carbonatites as a result of differences in mineralogy (table 2). Primary-magmatic silicocarbonatites are low in iron and high in P_2O_5, whereas replacement silicocarbonatites and rodbergs are higher in iron and lower in P_2O_5 (fig. 9). Except for #427A, primary-magmatic silicocarbonatites contain more Ta, Th, and total REE than replacement silicocarbonatites. The replacement silicocarbonatites contain more Ni, Sc, Cu, Ba, Cs, and Cr than primary-magmatic silicocarbonatites and more Li, Ni, Sr, Cr, and total REE than rodbergs. Similar differences are observed in the Wet Mountains carbonatites (Armbrustmacher 1979).

The Lemitar silicocarbonatites are enriched in light REE relative to heavy REE and display steep, light REE-enriched chondrite-normalized patterns (fig. 10). Such patterns are found in carbonatites worldwide and are suggestive of a magmatic origin (Mitchell and Brunfelt 1975; Möller et al. 1980; Loubet et al. 1972). The primary-magmatic silicocarbonatites are more enriched in light REE than replacement carbonatites.

The Lemitar rodbergs are significantly depleted in REE relative to other carbonatites and display relatively flat REE patterns (fig. 10). This is unusual, because late-stage carbonatites such as the Lemitar rodbergs are generally more enriched in REE than early-stage carbonatites (Heinrich 1966), although there are several carbonatites worldwide with similar depleted patterns. The Kirumba car-

TABLE 2

CHEMICAL ANALYSES OF CARBONATITES FROM THE LEMITAR MOUNTAINS

	Primary-magmatic silicocarbonatites					Replacement silicocarbonatites		Rodbergs					
	305	427A	427B	500	80-11-1	506	530	531A	531B	811A	803A	805A	806
SiO_2	21.4	11.2	11.6	10.9	7.4	19.1	27.9	3.2	3.6	1.8	18.8	3.5	18.8
Fe_2O_3	2.75	3.50	3.57	3.73	5.13	5.78	9.58	2.23	3.86	7.10	3.97	11.9	11.6
FeO	5.44	4.22	4.28	5.27	3.94	7.38	6.36	12.0	11.5	5.35	5.79	1.51	2.81
MgO	8.92	10.1	9.67	9.53	2.91	9.90	3.70	7.64	6.47	10.2	9.37	3.07	7.01
CaO	24.5	32.5	30.9	31.6	38.0	17.8	17.5	30.2	27.1	33.6	26.4	41.2	24.0
CO_2	23	29	29	26	30	18	17	37	35	..(1)	..(1)	..(1)	..(1)
P_2O_5	3.26	3.72	3.47	3.33	2.00	1.05	1.54	.06	.07	.08	<.05	<.05	1.06
LOI	4	1	1	3	4	1	3	5	4	41	33	36	25
Li	84	18	20	20	<5	61	19	7	7	<5	<5	<5	<5
Sc	11	9	9	14	...	23	24	10	8	...	...	...	...
Ni	51	33	60	31	<15	183	390	48	70	<15	<15	<15	<15
Cu	20	10	10	13	5	100	26	24	2	105	<1	6	5
Sr	492	298	322	540	655	534	2650	136	123	30	30	70	40
Ba	365	272	435	272	...	1250	672	913	285	...	...	...	...
Cs	1	2	...	4	...	14	8	...	.5	...	...	...	...
Cr	20	10	24	10	...	64	398	25	5	...	...	...	...
La	538	661	503	556	...	267	114	22	14	...	...	...	...
Ce	1008	1201	999	1122	...	535	218	55	55	...	...	...	...
Sm	70	62	76	59	...	30	16	12	12	...	...	...	...
Eu	12	11	13	11	...	7	4	3	3	...	...	...	...
Tb	5	4	7	5	...	3	1	3	2	...	...	...	...
Yb	2	5	5	9	...	3	2	9	8	...	...	...	...
Lu	...	2	2	2	...	2	.4	...	1	...	...	...	...
Hf	14	13	16	28	...	22	10	1.2	...	...	...	...	...
Ta	32	16	37	18	...	16	6	5	1	...	...	...	...
Th	40	23	74	108	...	21	14	.9	2	...	...	...	...
U	12.0	2.5	18	31	2.5	3.8	12	1.4	1.1	2.5	2.5	1.7	1.7
V	<100	...	<100	...	...	243	290	...	<100	...	...	...	...
Nb	400	...	405	391	...	308	245	...	...	...	...	...	...
Y	90	...	122	122	...	...	85	...	...	...	...	...	...

NOTE.—Oxides are in percent and trace elements are in parts per million. (1)—CO_2 analyses included in LOI (loss on ignition).

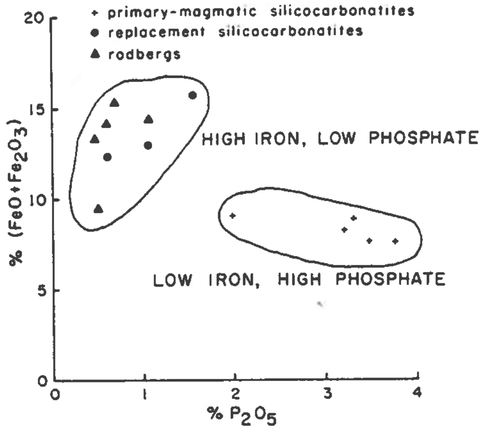

FIG. 9.—Total iron ($FeO + Fe_2O_3$) – P_2O_5 plot of the Lemitar carbonatites showing chemical variation between primary-magmatic and replacement silicocarbonatites and rodbergs.

bonatite in Africa (Loubet et al. 1972), a sövite from Fen, Norway (Mitchell and Brunfelt 1975), and a rauhaugite from Fen, Norway (Möller et al. 1980) display similar depleted REE patterns. This depletion of REE could be a result of hydrothermal alteration related to barite-fluorite-galena veins or may represent a depleted late-stage carbonatite. The REE patterns of such carbonatites have not been studied. Additional REE analyses of rodbergs in the Lemitar Mountains and elsewhere are needed to understand the nature of this REE depletion.

The Lemitar silicocarbonatites are grossly similar in chemical composition to Heinrich's (1966) and Gold's (1966) average carbonatite and to primary-magmatic and replacement carbonatites in the Wet Mountains area, Col-

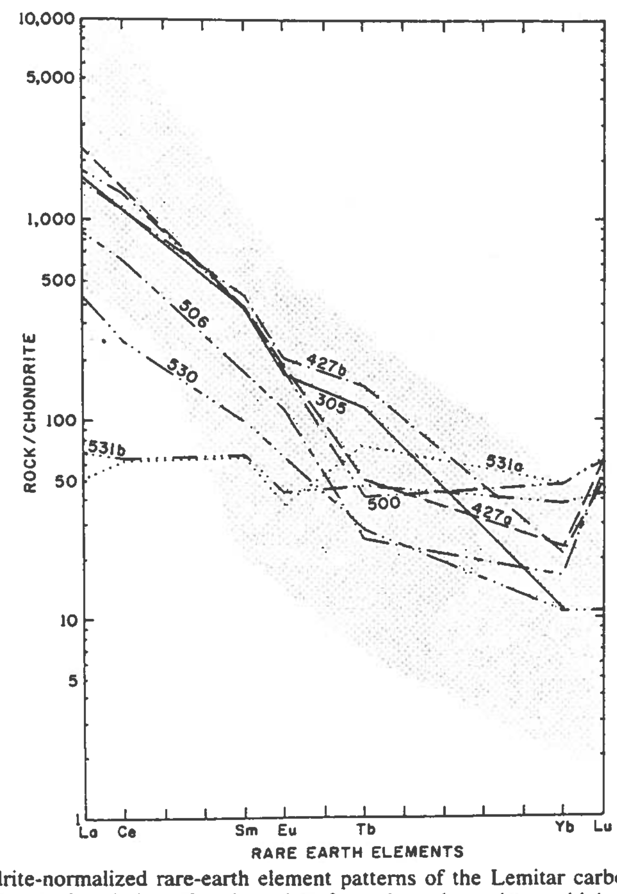

FIG. 10.—Chondrite-normalized rare-earth element patterns of the Lemitar carbonatites. Shaded field represents an envelope of variation of carbonatites from throughout the world (miscellaneous analyses compiled by the author). Chondrite values from Haskin et al. (1968). 305, 427a, 427b, and 500 are primary-magmatic silicocarbonatites. 500 and 506 are replacement silicocarbonatites and 531a and 531b are rodbergs.

orado (Armbrustmacher 1979). The Lemitar rodbergs are similar in composition to rauhaugites from Iron Hill, Colorado (Nash 1972).

ALTERATION

Alteration to Precambrian rocks in the Lemitar Mountains due to intrusion of the carbonatites is minimal, although carbonatization, hematization, and fenitization are locally pervasive. The amphibolite dikes exhibit varying degrees of carbonatization and locally grade into carbonatites. Adjacent to some silicocarbonatite dikes, the amphibolites are extensively altered, and carbonate replaces feldspar and hornblende phenocrysts. Apatite was introduced into the generally apatite-free amphibolite. Farther from the carbonatite, less alteration and replacement of original minerals by carbonate occurs. The occurrence of hematite and carbonate veins in the Precambrian rocks may be a result of intrusion of the carbonatites; however, these veins are common in Precambrian terrains in New Mexico.

Fenitization is absent in the metasedimentary rocks and rare in the granitic and mafic rocks. Red feldspathic fenites, consisting of predominantly albite and/or potassium feldspar, are developed locally in the Polvadera granite adjacent to or in the vicinity of carbonatites. Similar fenites occur at Alnö, Sweden; Mbeya, Tanzania; Chilwa Island, Malawi; and Wet Mountains and Iron Hill, Colorado (Heinrich 1966, p. 576; Heinrich and Moore 1970). An altered facies of the Polvadera granite in the western portion of the area (fig. 2) may, in part, be due to fenitization.

A thin (less than several centimeters wide), discontinuous zone of fenitization of the diorite/gabbro is locally pronounced adjacent to some silicocarbonatite dikes and along fractures and joints within several meters of the silicocarbonatites. The fenite is characterized by large, orange-pink albite crystals, as opposed to the normally white labradorite to andesine plagioclase seen in the unaltered diorite/gabbro. In thin section, small disseminations of hematite "dusts" the feldspars, producing the red color. This reddish color is a common feature of this type of alteration and is thought to be produced by the oxidation and exsolution of iron originally within the feldspar lattice (von Eckermann 1948, p. 29). Verwoerd (1966) describes a similar trend in the beginning stages of fenitization of gabbro adjacent to the Messum carbonatite complex, Southwest Africa. More detailed studies of fenitization and other alteration associated with the Lemitar carbonatites are underway.

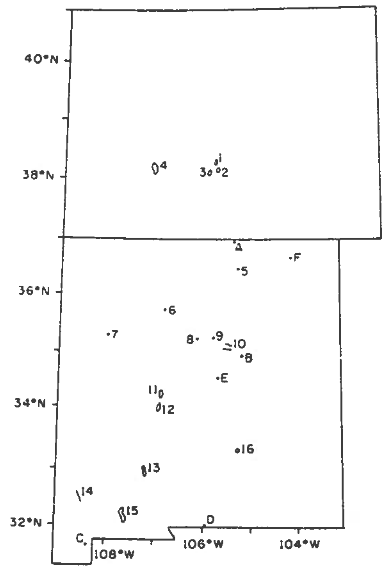

FIG. 11.—Precambrian-Ordovician carbonatites and alkalic rock occurrences in New Mexico and southern Colorado. Locality numbers refer to table 3. Locality letters refer to the text. Not all occurrences have been dated.

REGIONAL CORRELATIONS

Carbonatites similar to those in the Lemitar Mountains are found elsewhere in New Mexico and in southern Colorado (fig. 11, table 3). In New Mexico, carbonatite dikes intrude Precambrian terrains in the Chupadera Mountains and at Lobo Hill and Monte Largo. About a dozen dikes occur in the Chupadera Mountains, approximately 8 km south of the Lemitar Mountains (Kent 1982; McLemore 1983; Van Allen et al. 1986), but only one or two poorly exposed dikes occur in the Lobo Hill and Monte Largo areas. The carbonatite at Lobo Hill is only 15 cm wide and is associated with a red syenite (McLemore 1984). The Monte Largo carbonatite is associated with a melteigite sill or dike (Lambert 1961). These carbonatites are similar in form, texture, mineralogy, and chemistry (unpub. analyses) to the Lemitar

TABLE 3

KNOWN AND POSSIBLE PRECAMBRIAN-ORDOVICIAN CARBONATITE AND ALKALIC ROCK OCCURRENCES IN NEW MEXICO AND SOUTHERN COLORADO

No.[a]	Locality	Age (m.y.)	Method of dating	References
1	McClure Mountains carbonatite-alkalic complex	517–704	K-Ar, Rb-Sr, fission-track	Fenton and Faure (1970), Olson et al. (1977), Armbrustmacher (1984)
2	Syenite of Democrat Creek	520–546	K-Ar, Rb-Sr, fission-track	Olson et al. (1977), Armbrustmacher (1984)
3	Gem Park carbonatite	520–575	K-Ar, Rb-Sr, fission-track	Olson et al. (1977)
4	Iron Hill carbonatite complex	550–579	K-Ar, Rb-Sr, fission-track	Olson et al. (1977), Fenton and Faure (1970)
5	Sangre de Cristo Mountains syenite	?		Reed et al. (1983)
6	Nacimiento Mountains syenite	?		Woodward et al. (1977)
7	Zuni Mountains syenite	?		Lambert (1983), McLemore (unpublished data)
8	Monte Largo Hills carbonatite	?		Lambert (1961), McLemore (1983)
9	Lobo Hill syenite and carbonatite	604 (maximum)	Rb-Sr	Loring and Armstrong (1980), McLemore (1984)
10	Pedernal Hills syenite	496 (maximum)	Rb-Sr	Loring and Armstrong (1980)
11	Lemitar Mountains carbonatite	449 ± 16	K-Ar	This report, McLemore (1982, 1983)
12	Chupadera Mountains carbonatite	?		McLemore (1983), Van Allen et al. (1986)
13	Caballo Mountains syenite	?		Staatz et al. (1965), McLemore (1986)
14	Burro Mountains syenite	?		Gillerman and Whitebread (1956), Hedlund (1978*a*, *b*, *c*)
15	Florida Mountains syenite	503 ± 10	U-Pb	Clemons (in press)
16	Pajarito Mountain	1190 ± 25	K-Ar	Kelley (1968)

[a] Locations shown on figure 11.

carbonatites. The maximum age of the syenite at Lobo Hill is 604 m.y. by Rb-Sr whole-rock methods (Loring and Armstrong 1980); however, the carbonatites have not been dated.

Alkalic complexes in southern Colorado occur in the Wet Mountains area (McClure Mountains, Democrat Creek area, and Gem Park; #1, 2, 3, fig. 11) and the Powderhorn area (Iron Hill complex, #4, fig. 11). Carbonatite dikes, similar to the Lemitar carbonatites, are found in the McClure Mountains and Gem Park complexes (Heinrich 1966; Armbrustmacher 1979, 1984), and a carbonatite stock is found in the Iron Hill complex (Heinrich 1966; Nash 1972). The carbonatites were emplaced about 550–579 m.y., based on K-Ar, Rb-Sr, and fission-track methods (Fenton and Faure 1970; Olson et al. 1977; Armbrustmacher 1984).

Syenites and carbonatites are spatially associated in many areas, but their genetic association is uncertain. In some areas, such as the Haliburton-Bancroft area, Ontario (Heinrich 1966), the syenites are intrusive and older than the carbonatites. Syenitic fenites occur adjacent to other carbonatites, such as at Nemegosenda Lake, Ontario (Heinrich 1966). In many areas, such as Wet Mountains and Iron Hill, Colorado, a second type of metasomatic syenitic rock has been recognized (Heinrich and Moore 1970). These syenites appear to be post-fenite and pre-carbonatite (Heinrich 1966; Heinrich and Moore 1970).

In the southwestern United States, carbonatites and syenites occur together at Lobo Hill and in the Wet Mountains area. Lithologically similar syenites occur sporadically throughout New Mexico, and a few have been dated as Cambrian-Ordovician (fig. 11; table 3). These syenites occur in Precambrian terrains but typically were emplaced after metamorphism. They occur as dikes or irregular bodies, are typically red, and several of them have high concentrations of uranium and thorium. Thorium- and uranium-bearing veins also are associated with carbonatites and syenites in some of these areas. Only four syenites in New Mexico have been dated. The Lobo Hill syenite is 604 m.y. or younger, and the Pedernal Hills syenites are 496 m.y. or younger as determined by Rb-Sr methods (Loring and Armstrong 1980). Rb-Sr whole-rock ages from syenites in the Florida Mountains range from 371 to 1,600 m.y. (Brookins 1974, 1980; Clemons in press); a recent U-Pb concordia age of 503 ± 10 m.y. on zircons from the syenite has been reported (Clemons in press). A syenite pegmatite at Pajarito Mountain was dated by K-Ar on hornblende as 1190 ± 25 m.y. (Kelley 1968), indicating that some syenite in New Mexico is Proterozoic. Additional areas in New Mexico contain lithologically similar syenites; however, these syenites have not been dated (table 3). Many of these syenites may also be Cambrian-Ordovician and may represent a period of alkalic and carbonatite magmatism only recently recognized in New Mexico (Loring and Armstrong 1980).

In New Mexico other lithologies besides carbonatites and syenites have been dated as Cambrian-Ordovician and may be related to this period of magmatism. A diorite dike at Costilla Creek in Taos County (#A, fig. 11) has been dated as about 500 m.y. by Rb-Sr methods (Reed 1984). Various samples of gneiss, quartz-feldspar porphyry, granite, and basalt from several areas in east-central New Mexico (#B, fig. 11) have K-Ar and Rb-Sr age dates from 848 ± 42 to 604 ± 30 m.y. (Setter and Adams 1985). Zircons from granite in the Big Hatchet Mountains in southwestern New Mexico (#C, fig. 11) have age dates (method of dating not specified) of 605 and 640 m.y. (Zeller 1965).

DISCUSSION

The Lemitar carbonatites are similar in age, mode of emplacement, texture, and composition to carbonatites in southern Colorado, which suggests a similar origin. Strontium-, carbon-, and oxygen-isotope studies of Colorado carbonatites indicate an upper mantle source (Fenton and Faure 1970; Olson et al. 1977; Armbrustmacher 1979, 1984). Primary-magmatic textures, mineralogy, chemistry, and strong fractionation of light REE of the Lemitar carbonatites are consistent with an upper mantle source.

Carbonatites, alkalic rocks, and other intrusives of Cambrian-Ordovician age occur throughout southern Colorado and New Mexico (fig. 11) and may represent a period of alkalic and carbonatite magmatism. However, at least three distinct source materials and several geologic processes produced the alkalic rocks in southern Colorado (Armbrustmacher 1984), and it is possible that similar complex processes occurred in New Mexico.

Alkalic rocks and carbonatites are commonly associated with continental rift systems. These rift systems may reactivate periodically throughout time, such as the St. Lawrence Valley system in eastern Canada and the East African rift system (Kumarapeli and Saull 1966). Periodic episodes of alkalic magmatism have occurred in New Mexico. During Proterozoic times, the alkalic complex at Pajarito Mountain (#16, fig. 11) was emplaced (Kelley 1968). Various Precambrian terrains in New Mexico could have been emplaced in a rift system (Condie and Budding 1979). The Rio Grande rift in New Mexico and southern Colorado formed during the Tertiary (Riecker 1979). Also during Tertiary times, alkalic rocks were emplaced in the Cornudas Mountains (#D, fig. 11; Barker 1977; Barker et al. 1977), at Sierra Blanca (#E, fig. 11; Foord et al. 1983), and in the Chico Hills (#F, fig. 11; Collins 1949; Staatz 1982, 1985). A carbonatite dike intrudes the Tertiary phonolites at Chico Hills (Staatz 1985, p. 31). The similarity in petrology and chemistry between the alkalic rocks at Pajarito Mountain and at Sierra Blanca led Foord et al. (1983) to suggest that the Tertiary alkalic rocks at Sierra Blanca were derived from the melting and remobilizing of the Proterozoic syenites and older basement rocks. Such a process may account for distribution of Proterozoic, Cambrian-Ordovician, and Tertiary carbonatites and alkalic rocks in New Mexico. However, melting of a single upper mantle source periodically throughout time could also produce this distribution.

Although theories have been suggested placing rift systems similar to the St. Lawrence system in New Mexico and southern Colorado during Precambrian through Paleozoic times (Larson et al. 1985; Condie and Budding 1979), specific geographic limits of these rift systems are difficult to determine because of complex tectonic events since then (Chapin and Cather 1981; Riecker 1979). A more comprehensive evaluation of the tectonic regime during the Cambrian-Ordovician is required to understand fully the wide distribution of these rocks in the Southwest.

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