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A PRELIMINARY GEOCHEMICAL STUDY OF THE REDROCK ANORTHOSITE AND GRANITE, BURRO MOUNTAINS, SOUTHWESTERN NEW MEXICO

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Abstract—Approximately two dozen small anorthosite bodies are scattered throughout a northeast-trending zone in a Proterozoic granitic terrain near Redrock in the Burro Mountains, Grant County, New Mexico. Compositions of these chemically and texturally heterogeneous bodies range from anorthosite and gabbroic anorthosite to fine-grained hybrid anorthosite to quartz anorthosite near the contacts. The anorthosites are tan to white, fine- to coarse-grained, and consist of predominantly untwinned plagioclase with accessory hornblende, chlorite, and minor quartz, K-feldspar, biotite, magnetite-ilmenite, sphene, apatite and zircon. Preliminary geochemical studies of one body indicate that the rock is characterized by high CaO (9–10%), high MgO (1–5%), high Al_2O_3 (13–20%), low SiO_2 (46–51%) and low K_2O (1–2%).

The Precambrian granitic rocks in the Burro Mountains have been named the Redrock granite near Redrock and the Burro Mountain granite elsewhere in the range. The Redrock granite is similar in composition and appearance to the Burro granite. It is orange to pink, fine- to medium-grained and consists of equal amounts of quartz, microcline and twinned plagioclase. Geochemically, the Redrock granite is similar to other high-Si and high-K Proterozoic granites in New Mexico. It is characterized by high K_2O (3–6%), intermediate to high SiO_2 (73–76%), low CaO (0.2–0.7%) and low MgO (0.2–1.5%).

Petrographic textures and geochemical data are consistent with a magmatic origin of the anorthosite bodies. A larger body of anorthosite could be in the subsurface. Although mineral deposits have not yet been found associated with the Redrock anorthosites, anorthosites worldwide are known to contain much of the world's resources of titanium with vanadium and iron as potential by-products. Subsurface drilling is required to properly evaluate the mineral resource potential of the Redrock anorthosites.

INTRODUCTION

Anorthosite is essentially a monomineralic plutonic rock consisting of plagioclase feldspar; gabbroic anorthosite contains 10–22% dark minerals and 78–90% plagioclase (Isachsen, 1969). Although most anorthosite and gabbroic anorthosite complexes are Proterozoic, a few Archean and Phanerozoic anorthosites are known (Morse, 1982). Economically, anorthosites account for much of the world's production of titanium, with by-product vanadium and iron (Gross and Rose, 1984; Force, 1986).

Numerous small bodies of gabbroic anorthosite to anorthosite occur in Proterozoic granite near and on the Redrock wildlife preserve near Redrock in the Burro Mountains (Hewitt, 1959; Hedlund, 1980). No other anorthosite occurrences have been reported from New Mexico. A preliminary investigation of these unusual rocks was undertaken in the summer of 1987 as part of a regional study of Precambrian to Paleozoic syenites and alkali granites in New Mexico. Geologic mapping and additional geochemical studies are underway. Preliminary geochemical data are presented to help evaluate their economic potential and speculate on their origin.

GEOLOGY

Geologic setting

The Burro Mountains lie in the Mexican highlands section of the Basin and Range physiographic province and are characterized by extensive fault blocks of Proterozoic, Paleozoic, Upper Cretaceous and Tertiary rocks (Fig. 1). The block faulting is predominantly Miocene-Pliocene, although some older reactivated faults are Late Permian-Triassic and Laramide (Stacey and Hedlund, 1983). The Redrock area consists of one of these fault blocks in the northwestern Burro Mountains (Figs. 1, 2).

The Burro Mountains consist of a complex middle Proterozoic terrain (Fig. 1) with metamorphic rocks of the Bullard Peak Series and Ash Creek Group (1560 ± 50 my; Stacey and Hedlund, 1983) intruded by granite (1445–1550 my), younger rapakivi granite, tonalite and granodiorite, diabase dikes and Tertiary rhyolite and diabase dikes and granitic plutons (Hewitt, 1959; Stacey and Hedlund, 1983; Drewes et al., 1985). The Bullard Peak Series is a more extensive and probably older group of metamorphic rocks consisting of sillimanitic quartz-biotite-muscovite gneiss or metapelite, hornblende gneiss and schist, quartzofeldspathic gneiss, granite gneiss and amphibolite. A younger series of cordierite, andalusite and biotite hornfelses, phyllite and serpentine-carbonate rocks occurs in the Redrock area and has been designated the Ash Creek Group (Hewitt, 1959).

The Proterozoic granitic rocks are collectively designated the Burro Mountain granite. However, in the Redrock area, the granitic rocks are called the Redrock granite (Hedlund, 1980). Aplite and a few pegmatite dikes intrude the Redrock granite.

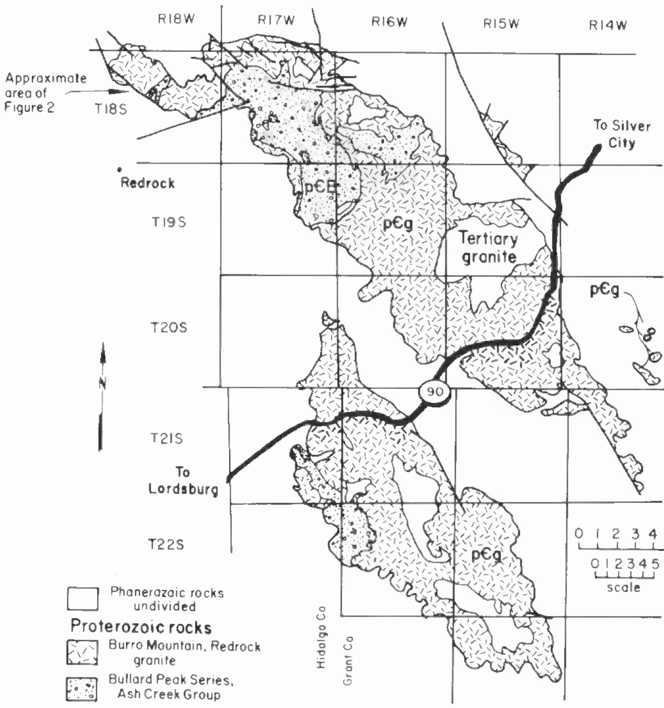

FIGURE 1. Generalized geologic map of the Proterozoic rocks in the Burro Mountains. Geology simplified from Drewes et al. (1985).

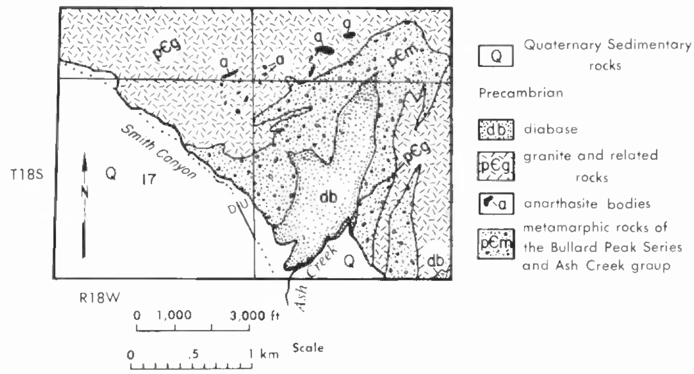

FIGURE 2. Generalized geologic map of the Ash Creek area (secs. 8, 9, 16 and 17, T18S, R18W) near Redrock; from Hewitt (1959), Hedlund (1980) and field reconnaissance by the authors. Aplite dikes are common in the granitic terrain but are not shown.

Numerous small bodies of gabbroic anorthosite to anorthosite occur in the Redrock granite in the area northeast of Redrock (Fig. 2; Hewitt, 1959; Hedlund, 1980). The age relationship of the anorthosites with the granite and nearby metamorphic rocks is uncertain because the contacts are poorly exposed. The anorthosites are probably younger than the nearby metamorphic rocks of the Bullard Peak Series and Ash Creek Group because regional metamorphic textures observed in the metamorphic rocks are absent in the anorthosites (Hewitt, 1959). They are probably older than the enclosing granite.

Metadiabase (Proterozoic) also crops out in the vicinity of the anorthosites within the Redrock granite (Hewitt, 1959; Hedlund, 1980). In Ash Creek Canyon, granite intrudes the metadiabase; however, in most areas the relative ages of the granite and metadiabase are uncertain (Hewitt, 1959). An anorthosite xenolith is enclosed by metadiabase in SE¼ sec. 9, T18S, R18W. The metadiabase may be related to the anorthosites; however, geochemical studies are needed to test this theory.

Anorthosite

Approximately two dozen anorthosite bodies are scattered throughout a northeast-trending zone, about 2 km long (Fig. 2; Hewitt, 1959; Hedlund, 1980). The largest body is approximately 270 m long and up to 30 m wide. The northernmost body was investigated for this report. The contacts with the enclosing granite are poorly exposed. The anorthosite is heterogeneous, ranging from fine-grained hybrid anorthosite, quartz anorthosite, gabbroic anorthosite to anorthosite. The hybrid anorthosite and quartz anorthosite occur near its contact with the enclosing granite and aplite dikes.

The anorthosites are tan to white, fine- to coarse-grained with small patches (up to a meter in diameter) of tan to white and black, hornblende-rich gabbroic anorthosite. In thin section, the anorthosite has a variable texture ranging from hypidiomorphic-granular to diabasic to pegmatic. It consists of predominantly unzoned plagioclase (70–85%) with hornblende and chlorite (5–20%), quartz (0–5%), K-feldspar (0–5%), biotite (0–5%), magnetite-ilmenite (trace–10%), sphene (trace), apatite (trace) and zircon (trace). The euhedral plagioclase crystals vary in size up to several centimeters long and are typically altered to sericite and clay.

The quartz anorthosite consists of 60–80% plagioclase with hornblende and chlorite (5–15%), quartz (5–15%), K-feldspar (5–15%) and trace amounts of biotite, magnetite-ilmenite, sphene, apatite and zircon. It has a hypidiomorphic-granular texture.

The hybrid anorthosite consists of 60–80% plagioclase with hornblende and chlorite (0–5%), quartz (5–15%), K-feldspar (5–15%) and trace amounts of biotite, magnetite-ilmenite, sphene, apatite and zircon. It is fine-grained with an equigranular texture, similar to the aplite dikes.

The distribution of the anorthosite bodies suggests they may be part of a larger continuous anorthosite body at depth. Additional mapping, geochemical studies and subsurface drilling are needed to determine the extent of the anorthosite. A magnetic high (Klein, 1987) and Bouguer gravity high (Wynn, 1981) about 1–3 km long are associated with this area. Anorthosite massifs are associated with magnetic highs; however, most are associated with Bouguer gravity lows. A limonitic area has been defined in the area by Raines (1984) from landsat images.

Redrock granite

The Redrock granite is similar in appearance and composition to the Burro Mountain granite (McLemore and McKee, this guidebook) and is probably part of the same pluton. It is orange to pink, fine- to medium-grained consisting of equal amounts of quartz, microcline and twinned plagioclase (predominantly oligoclase). Accessory minerals include hornblende, biotite, muscovite or sericite, magnetite-ilmenite, apatite and zircon. Graphic intergrowths of quartz and microcline are common. The granite has a hypidiomorphic-granular texture and is slightly foliated locally. Alteration of the granite is minor. Some feldspars are altered to clay and sericite and minor hematization has occurred.

Numerous aplite dikes less than 1–2 m wide intrude the granite. The aplites are orange to pink and consist of equal amounts of quartz, microcline and plagioclase with an equigranular texture. They are probably a late phase of the Redrock granite (Hewitt, 1959).

GEOCHEMISTRY

The northernmost anorthosite body and adjacent Redrock granite and aplite dike (Fig. 2) were sampled and analyzed for major and trace elements. Preliminary chemical analyses are in Table 1 and sample locations and descriptions are in Appendix 1.

Major element oxides were determined by x-ray fluorescent spectrometry (XRF) on fused glass discs following the method of Norrish and Hutton (1969). Some major element oxides were determined by XRF using the fundamental parameters program of Criss Software (Criss, 1980). Trace elements were determined by XRF using pressed powder briquets.

The granite and aplite dikes are metaluminous and similar in chemical composition to the Burro Mountain granite and to Proterozoic high-K and high-Si granites elsewhere in New Mexico (Table 1, Fig. 3; Condie, 1978; McLemore, 1986; McLemore and McKee, this guidebook). They

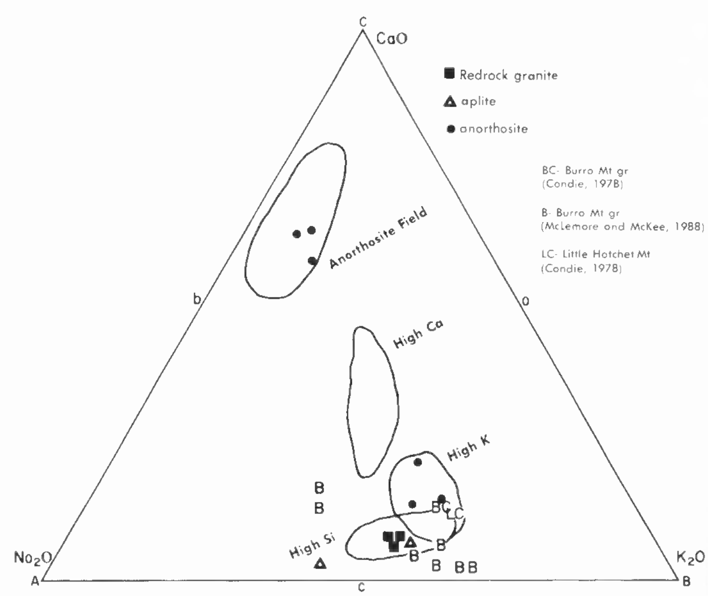

FIGURE 3. CaO-Na$_2$O-K$_2$O diagram of granites, aplites and anorthosites from the Redrock area. Fields shown are high-K, high-Si and high-Ca group granites (Condie, 1978). Each symbol may represent more than one sample. The anorthosite field is defined by miscellaneous chemical analyses of anorthosites and gabbroic anorthosites from throughout the world, compiled from the literature by V. T. McLemore and Shawn Leppert.

TABLE 1. Preliminary chemical analyses of granite, aplite and anorthosites from the Redrock area, Burro Mountains, New Mexico. Major oxides in percent, trace elements in ppm. BD—below detection limit. LOI—loss on ignition.

	B16.1R Granite	B16.2R Aplite	B9.1 Aplite	B9.2 Anortho-site	B9.3 Anortho-site aplite contact	B9.4 Anortho-site	B9.5 Anortho-site	B9.6 Anortho-site near aplite	B9.7 Anortho-site-granite contact	B9.8 Granite	B9.9 Granite
SiO_2	72.1	76.2	76.2	50.9	70.8	51.1	46.5	71.7	74.0	73.8	76.0
TiO_2	0.29	0.06	1.44	1.44	0.28	0.98	3.51	0.29	0.27	0.28	0.09
Al_2O_3	13.5	12.8	12.4	20.3	13.6	22.1	13.9	14.2	8.39	13.3	12.2
Fe_2O_5	1.68	0.82	0.20	1.80	0.68	1.65	2.50	0.85	0.97	1.13	0.84
FeO	0.51	0.13	0.16	4.08	0.68	3.59	11.0	1.76	1.94	0.49	0.67
MgO	1.51	0.48	0.62	2.34	1.03	3.77	4.96	1.98	1.40	0.20	0.37
CaO	0.70	0.27	0.61	9.30	1.70	10.5	9.17	1.51	4.31	0.61	0.62
Na_2O	4.04	4.66	3.48	4.33	3.29	4.01	3.72	3.65	2.70	3.36	3.66
K_2O	4.91	3.61	5.11	2.03	6.02	1.76	1.09	5.45	2.02	5.16	4.74
MnO	0.04	0.02	0.02	0.11	0.03	0.09	0.24	0.04	0.08	0.01	0.03
P_2O_5	0.17	0.02	0.01	0.24	0.16	0.21	0.48	0.15	0.05	0.09	0.03
LOI	1.33	0.69	0.73	2.00	2.59	2.31	1.60	0.96	4.01	2.26	1.11
TOTAL	100.78	99.76	100.98	98.87	100.86	102.07	98.67	102.54	100.14	100.69	100.36
Ga	20	20	20	22	17	22	21	18	13	13	19
Zn	45	43	18	144	22	30	144	23	25	20	27
Cu	7	10	6	53	8	5	6	8	BD	6	12
Ni	8	9	4	16	6	17	13	5	BD	5	5
Ba	1699	144	159	448	662	351	181	682	150	612	188
V	14	BD	3	121	10	68	210	16	16	14	2
Cr	8	BD	6	25	16	29	20	12	15	11	11
Pb	27	49	24	51	28	2	22	35	10	23	30
Th	48	22	26	2	27	1	5	38	7	31	35
Rb	504	221	272	146	261	119	51	245	66	174	383
U	6.9	11	13	4	12	2	3	11	7	7	10
Sr	91	37	42	415	136	439	257	123	41	84	41
Y	62	12	57	24	59	15	39	105	39	79	60
Zr	327	52	69	59	369	52	127	221	250	253	130
Nb	19	13	19	4	22	4	11	28	8	25	16
CIPW Norm											
Q	26.5	34.0	31.8	--	24.4	--	--	22.9	41.8	--	34.3
C	0.7	0.8	--	--	--	--	--	--	--	1.3	--
O	29.0	21.3	29.8	12.8	35.6	10.4	6.7	32.2	11.9	30.4	28.0
AL	34.2	39.4	34.1	30.0	27.8	27.2	26.5	30.9	22.8	31.1	31.0
AN	2.4	1.2	1.9	32.9	4.6	37.1	18.1	6.3	4.8	1.5	2.9
HY	3.8	1.2	2.5	--	1.8	--	--	7.0	--	4.1	1.9
MAG	0.9	0.3	0.5	2.3	1.0	2.4	2.3	1.2	1.4	0.8	1.2
HEM	1.0	0.6	0.1	--	--	--	--	--	--	0.9	--
IL	0.6	0.1	0.1	2.7	0.5	1.9	7.0	0.6	0.5	0.5	0.2
AP	0.4	0.1	0.1	0.8	0.4	0.5	1.4	0.4	0.1	0.5	0.1
DIO	--	--	0.9	9.2	2.2	11.0	19.4	0.2	1.2	--	--
NEP	--	--	--	4.1	--	3.6	4.7	--	--	--	--
OL	--	--	--	5.1	--	5.7	14.4	--	--	--	--
WOL	--	--	--	--	--	--	--	--	0.6	--	--

are characterized by relatively high K_2O (3–6%), intermediate to high SiO_2 (73–76%), low CaO (0.2–0.7%) and low MgO (0.2–1.5%).

The Redrock anorthosites are characterized by high CaO (9–10%), high Mgo (1–5%), high Al_2O_3 (13–20%), low SiO_2 (46–51%) and low K_2O (1–2%) relative to the adjacent Redrock granite (Table 1, Figs. 3, 4). They have a lower differentiation index (Fig. 5) and are lower in Rb and Ba and higher in Sr than the Redrock granites (Figs. 6, 7). The hybrid and quartz anorthosites are higher in SiO_2 and lower in CaO than the gabbroic anorthosites and they plot in the high-K granite field on a Na_2O-Cao-K_2O diagram (Fig. 3), indicating that contamination or alteration by granitic or aplite fluids has occurred. The Redrock anorthosites are grossly similar in chemical composition to other anorthosites worldwide (Fig. 3; Papezik, 1965; Enslie, 1973; Duchesne and Demaiffe, 1978; Simmons and Hanson, 1978; Fountain et al., 1981).

DISCUSSION

Preliminary geochemical studies indicate that the anorthosite samples are part of a geochemically related suite of rocks as shown by major and trace element variation diagrams (Figs. 4, 5, 6, 7). Although geochemical plots of major element oxides and differentiation index (Figs. 4, 5) may at first suggest the anorthosite suite may be genetically associated with the adjacent granite and aplite, trace element distributions, such as Rb, Sr and Ba (Figs. 6, 7), indicate that there is no geochemical or genetic association, other than possible contamination or alteration of the anorthosite body by granitic magmas.

The origin of the Redrock anorthosite is uncertain. Small bodies of anorthosite, such as at Redrock, could form by metamorphism of limestone or shale, but metamorphic textures are absent in the Redrock anorthosites. Petrographic textures and geochemical data are consistent with a magmatic origin of the anorthosite bodies. The anorthosites may be intrusives or xenoliths within the Redrock granite. Geochemical data and field relationships support a xenolith model. A larger anorthosite body could be present in the subsurface. The geophysical data are consistent with this theory.

There are two types of magmatic anorthosites. One type is associated with layered mafic intrusives. Generally, these anorthosites have rhythmic layering and cumulate textures, and are free of megacrysts. The second type of anorthosite occurs in anorthosite massifs. They lack cumulate

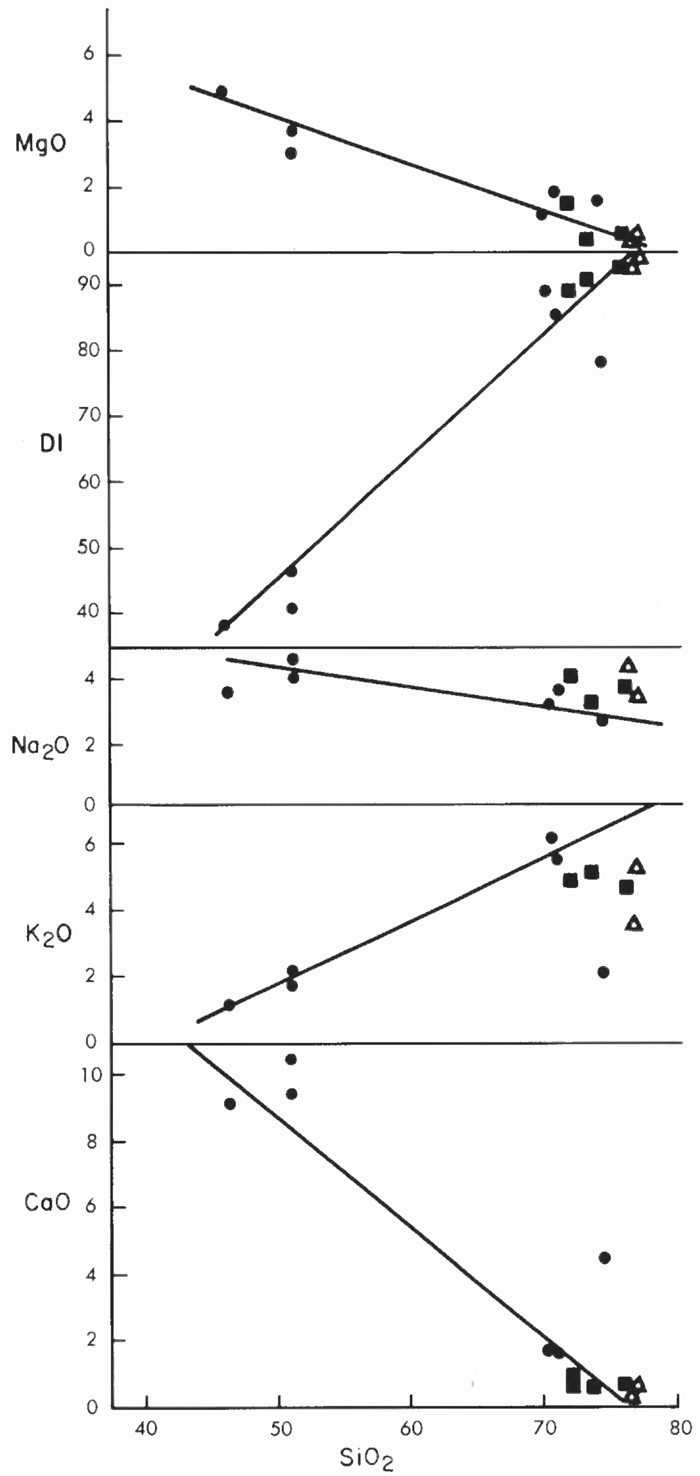

FIGURE 4. Variation diagram of oxides versus SiO_2 (in percent). Symbols are explained in Figure 3.

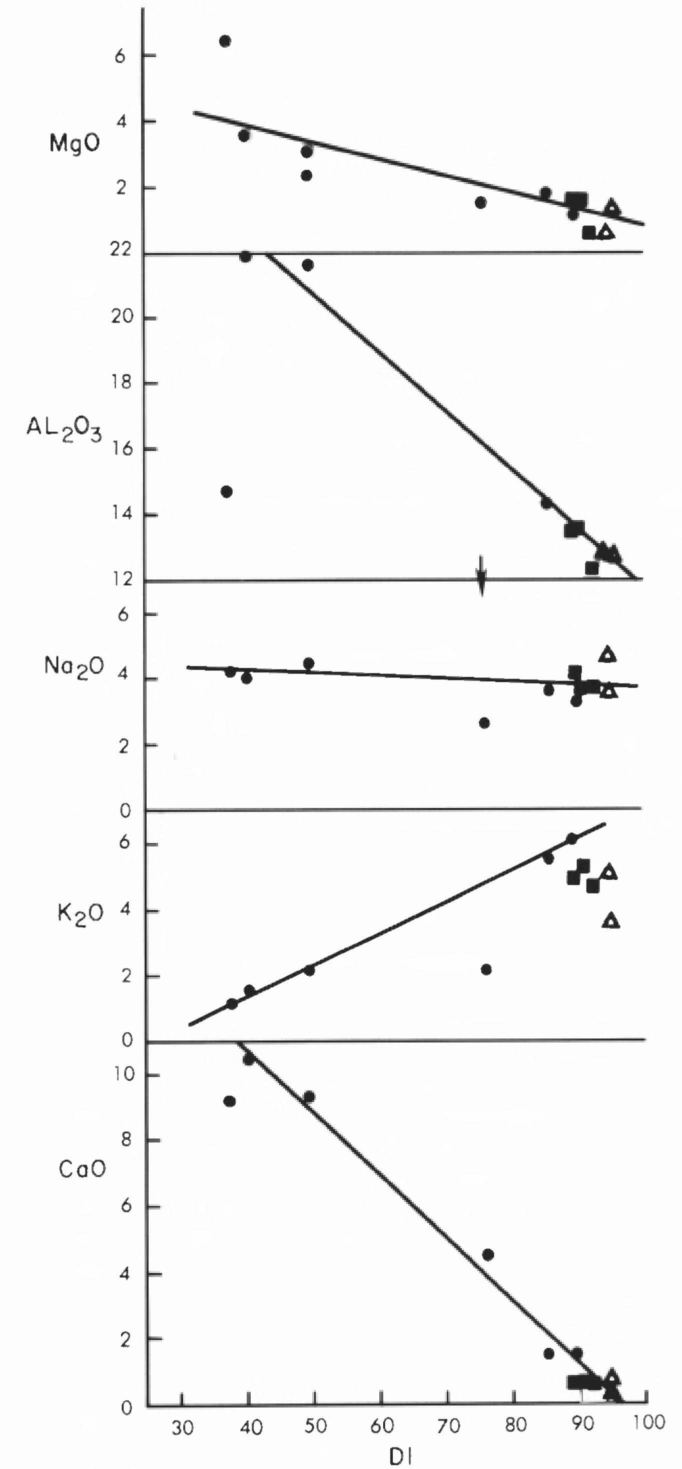

FIGURE 5. Variation diagram of oxides (in percent) versus differentiation index (DI). Symbols are explained in Figure 3.

textures and have large megacrysts. The Redrock anorthosites do not have rhythmic layering or cumulate textures and they do have large megacrysts and therefore appear to be related to anorthosite massif type. The nature of the parent magma of the Redrock anorthosites is unknown; additional geochemical studies are under way.

ECONOMIC POTENTIAL

Ilmenite and rutile concentrations occur in many anorthosite complexes and constitute a major source of titanium with by-product vanadium and iron (Gross and Rose, 1984; Force, 1986). Titanium metal is used as an alloy in jet engines, airframes, missiles and other ordnance applications and in the chemical processing industry. Titanium dioxide is used as a pigment for white paint, varnishes, lacquers, papers, plastics, rubber and ceramics (U.S. Bureau of Mines, 1987).

Ilmenite and rutile deposits occur as disseminations and veinlets along the anorthosite margins in both the anorthosite and country rocks. Concordant layers and veins of ilmenite and rutile may occur in the anorthosite body (Force, 1986). There is little hydrothermal alteration associated with these deposits.

Although large concentrations of ilmenite or rutile have not yet been

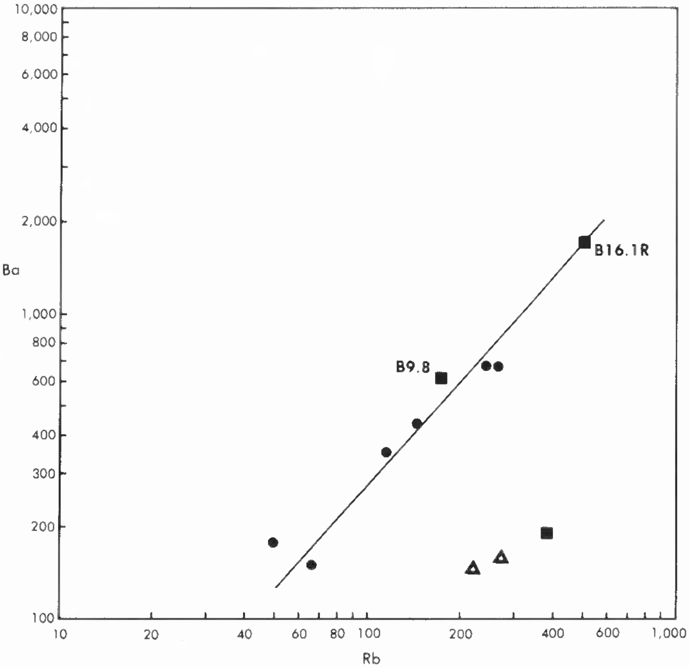

FIGURE 6. Rb-Ba plot of Redrock anorthosites and granites (in parts per million). Symbols are explained in Figure 3.

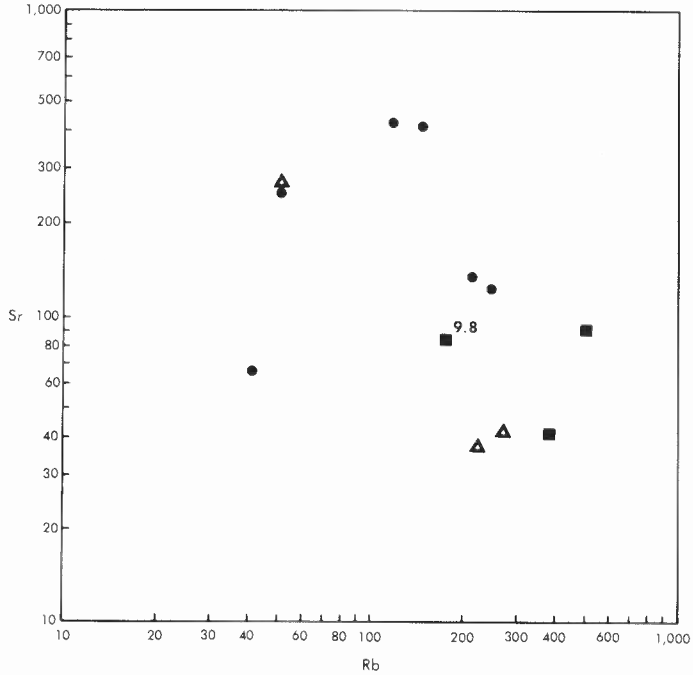

FIGURE 7. Rb-Sr plot of Redrock anorthosites and granites (in parts per million). Symbols are explained in Figure 3.

found associated with the Redrock anorthosites, such deposits could occur in the subsurface. The area of the Redrock anorthosite outcrop occurs as a relative magnetic high (Klein, 1987), which is consistent with, but not conclusive evidence for, ilmenite-rutile mineralization. However, the area is interpreted as an anomalous limonitic area from a landsat color-ratio composite image (Raines, 1984), which is unusual for ilmenite-rutile deposits. Examination of geochemical element-distribution maps compiled from data in a report by Union Carbide Corporation (1981) was inconclusive; stream-sediment samples were high in titanium, vanadium, iron and phosphate, but were within the normal range for Precambrian granitic terrains. These data are part of the HSSR (Hydrogeochemical and Stream Sediment Reconnaissance) survey of the NURE (National Uranium Resource Evaluation) program of the U.S. Department of Energy. The economic potential for the Redrock anorthosites cannot be evaluated properly until subsurface exploratory drilling is performed. However, much of the anorthosite outcrop is on the Redrock wildlife preserve, operated by the New Mexico Game and Fish Department.

ACKNOWLEDGMENTS

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APPENDIX 1
LOCATION AND DESCRIPTION OF SAMPLES

B16.1R NW¼ NE¼ SE¼, sec. 15, T18S, R18W; Redrock granite.
B16.2R NW¼ NE¼ SE¼, sec. 16, T18S, R18W; aplite dike in the Redrock granite.

Granite-anorthosite complex, SE¼ NW¼ SE¼, sec. 9, T18S, R18W:

B9.1 aplite dike in Redrock granite near anorthosite.
B9.2 coarse-grained anorthosite.
B9.3 fine-grained hybrid anorthosite near the aplite dike contact.
B9.4 hornblende-rich anorthosite.
B9.5 fine-grained hornblende anorthosite.
B9.6 fine-grained hybrid anorthosite near aplite dike contact.
B9.7 quartz anorthosite near the contact with the Redrock granite.
B9.8 Redrock granite near anorthosite.
B9.9 Redrock granite, about 500 yds south of anorthosite body.