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PETROCHEMISTRY OF THE PALISADES SHEET, CIMARRON PLUTON, NORTHERN NEW MEXICO

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Abstract—The middle Tertiary Cimarron pluton is exposed in northern New Mexico at the transition between the Southern Rocky Mountain and Great Plains physiographic provinces. This epizonal pluton is a >180 km^2, stacked laccolithic body, over 1 km thick in the vicinity of Baldy and Touch-Me-Not Mountains. The base of the pluton is in contact with either Precambrian crystalline rocks or sandstones of the late Paleozoic Sangre de Cristo Formation. Overlying intrusive sheets were emplaced into Mesozoic and early Tertiary sedimentary rocks.

A detailed petrographic and geochemical study of the 400-m-thick lowermost intrusive sheet of the pluton exposed in Cimarron Creek Canyon (informally known as the Palisades sill) reveals a uniform composition transitional between trachydacite and rhyolite. The rocks consist of about 40% phenocrysts of partially resorbed quartz, plagioclase, biotite and hornblende in a very fine-grained groundmass of quartz, K-feldspar and plagioclase. The unaltered rock is characterized by high Na_2O content and a distinctive REE pattern—low total REE and a significant depletion in heavy REE; $(Ce/Yb)_n$ = 16 and Yb = 0.6 ppm. The initial $^{87}Sr/^{86}Sr$ of the pluton (~0.7052) is similar to the values of plutons associated with the Questa caldera.

INTRODUCTION

Tertiary igneous rocks in northern New Mexico include thick volcanic sequences in the Rio Grande rift and the Ocate and Raton-Clayton volcanic fields (Fig. 1), which are associated with the northeastern end of the Jemez lineament. These volcanic rocks are dominantly mafic to intermediate in composition and have calcalkaline to subalkaline affinities (Dungan et al., 1989). Late Oligocene to early Miocene volcanic rocks of the Latir volcanic field located along the eastern margin of the Rio Grande rift (Fig. 1) have an intermediate to felsic composition, and are associated with a resurgent caldera located near Questa, New Mexico (Lipman, 1988).

Within the Questa caldera and immediately to the south are major epizonal plutons that were probably emplaced during resurgent activity.

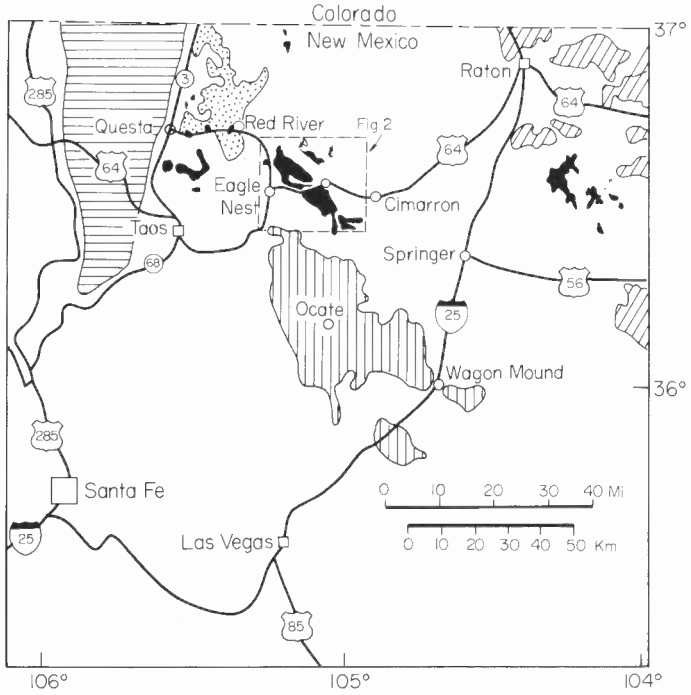


FIGURE 1. Location map of northern New Mexico showing the distribution of Tertiary volcanic and plutonic rocks. Rio Grande volcanic field—horizontal ruled lines; Ocate volcanic field—vertical ruled lines; Raton-Clayton volcanic field—diagonal ruled lines; Latir volcanic field—stippled pattern. Intrusive rocks are shown in black. Intrusive rocks within the inset and on Figure 2 are the Cimarron pluton.

The volcanic and plutonic rocks of the Questa area have received considerable recent attention (Lipman et al., 1986; Lipman, 1988; Johnson et al., 1989, 1990); however, a major pluton in the Cimarron-Baldy Range, immediately east of Questa, has only received limited attention. This pluton, here informally named the "Cimarron pluton," has an areal extent that is actually greater than that of the Questa plutons. Several major skarn- and fissure-type gold deposits are associated with the upper levels of the intrusion (Lindgren et al., 1910). This paper presents a summary of petrographic, geochemical and isotopic studies that are used to interpret the regional significance of this pluton.

GEOLOGIC SETTING

The Cimarron pluton is located in the Cimarron-Baldy Range between Cimarron and Eagle Nest, New Mexico (Figs. 1, 2). Lindgren et al. (1910) and Smith and Ray (1941, 1943) provided initial reports on the geology of this pluton. Robinson et al. (1964) and Clark and Read (1972) produced the first detailed geologic maps that included the pluton. Excellent outcrops of the lower portion of the pluton are present along cliff exposures (the Palisades) within Cimarron Creek Canyon, west of Ute Park, New Mexico.

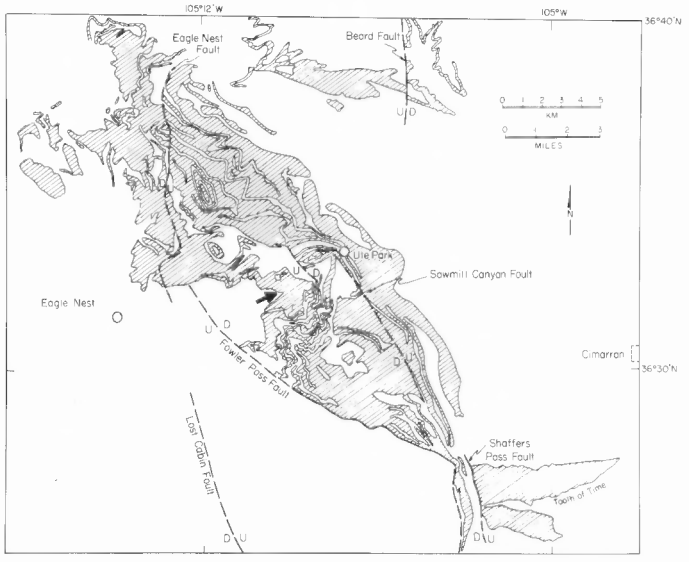


FIGURE 2. Outline map of the Cimarron pluton, Colfax County, New Mexico. Based on geologic maps of Clark and Read (1972) and Robinson et al. (1964). Intrusive units are shown in diagonal pattern. Arrow indicates base of section where sample traverses were taken.

The geometry of the pluton is that of a series of stacked laccolithic bodies. In the vicinity of Baldy and Touch-Me-Not Mountains six individual laccolithic sheets have cumulative thickness exceeding 1 km (Robinson et al., 1964, pl. 5). At the southeastern end of the pluton a composite 500-m-thick sheet extends 7 km out into the High Plains to form the famous Tooth of Time Ridge. Individual intrusive sheets of the pluton range from a few meters to over 500 m in thickness. In Cimarron Creek Canyon, at the Palisades, the base of the pluton rests upon Precambrian gneisses. Elsewhere the base of the pluton is in contact with the Pennsylvanian-Permian Sangre de Cristo Formation. The upper portion of the intrusion is within the lower Tertiary Poison Canyon and Raton Formations. Reconstructions from geologic cross sections by Robinson et al. (1964) indicate that the uppermost portions of the pluton were originally buried to a depth of at least 1 km. In the thicker exposed sheets tall colonnades have formed from cooling fractures.

At least three phases of the pluton have been reported, one of which may be a separate intrusion (Clark and Read, 1972). These phases are: (1) laccolithic bodies that form the crest of the Cimarron-Baldy Range and extend into the High Plains; (2) a quartz-monzonite phase exposed on the upper part of South Ponil Creek on the west side of the Baldy Range; and (3) a rhyolite phase exposed as a plug(?) and laccolithic sheets on McElvoy Hill along the southwestern corner of the pluton. These three phases have not been subdivided in Figure 2.

The feeder system for the sheets of the intrusion is not exposed. On the basis of overall pluton geometry, Robinson et al. (1964) interpreted that the feeder system may in part follow the Laramide-age (?) Fowler Pass fault.

The age of the Cimarron pluton is not well known. The youngest rocks intruded by the pluton are the early Tertiary Poison Canyon and Raton Formations. Armstrong (1969) reported a K-Ar biotite age of 34.7 Ma (corrected to new decay constants) for a sample from the Palisades sheet; however, the analyzed sample contained 25% chloritized biotite plus 20% groundmass. The impure nature of the dated material makes the significance of the age uncertain. More recent radiometric dates on the pluton (summarized in Mutschler et al., 1987) indicate an age as young as 26 Ma; such an age would be similar to the ages of plutonic bodies south of the Questa caldera (Lipman et al., 1986; Lipman, 1988).

The pluton is cut by several normal faults (Fig. 2) in Cimarron Creek Canyon and Moreno Valley. These faults appear to be high-angle, normal faults that are probably associated with the development of the Rio Grande rift system during the early Miocene (Dungan et al., 1989). Basalt flows that may be associated with the Ocate volcanic field cap the mesas just south of the Tooth of Time Ridge. The basalt flows appear to postdate the normal faults; however, this relationship is equivocal (Robinson et al., 1964, p. 112), and some faulting may postdate the basalt flows.

RESULTS

Sampling and analytical techniques

Sixty-five 10 cm-sized samples of the lowermost laccolithic unit of the Cimarron pluton (the Palisades sheet) were collected 4 km southwest of Ute Park, New Mexico; the arrow in Figure 2 points to the bottom of the section from which the samples were taken. The samples were from two profiles that extend from the bottom to the top of the Palisades sheet. One profile ("vertical") was collected from cliff exposures, approximately normal to the intrusive contacts. A second profile ("horizontal") was collected along the floor of Cimarron Creek Canyon; here the steam valley cuts through the Palisades sheet approximately perpendicular to strike. The samples were collected and analyzed by R. P. Cannon (1976) as a part of a major-element geochemical study of this intrusion.

The 65 samples were analyzed for major elements plus Rb and Sr by atomic absorption spectrometry (MgO, Na_2O) and x-ray fluorescence. Precision for all major- and trace-element analyses is given as the coefficient of variation. Precision was less than 1.4% for major elements and 10% for Rb and Sr. Selected samples were analyzed for CO_2, rare-earth elements (REE) and $^{87}Sr/^{86}Sr$ isotopic composition. Loss on ignition (LOI) was determined gravimetrically; analytical precision was approximately 5%. Carbon dioxide was determined by volumetric analysis (5% precision). Rare-earth elements were determined by neutron activation analysis (NAA). Precision for NAA was 10%. Strontium isotopic measurements have a precision of 0.03% (2 standard errors of the mean).

Petrography

The dominant lithology in the Cimarron pluton is a light-gray, porphyritic rock containing phenocrysts of plagioclase, quartz, biotite and hornblende in an aphanitic groundmass. Field descriptions (Robinson et al., 1964; Clark and Read, 1972) indicate that the pluton has a relatively uniform composition. Early workers variously described the composition as monzonite porphyry (Lindgren et al., 1910), quartz-monzonite porphyry (Smith and Ray, 1941), prophyritic monzonite (Smith and Ray, 1943) and dacite porphyry (Robinson et al., 1964). Clark and Read (1972) noted the dominance of quartz and plagioclase in the phenocryst assemblage and called the rock a quartz-diorite porphyry. The silica and total alkali composition of the least altered portions of the Cimarron pluton (Table 1) indicate that these rocks have a trachydacite composition using the classification of Le Bas et al. (1986). On the basis of both texture and chemical composition, the most appropriate name for this rock is porphyritic trachydacite.

Samples collected from the Palisades sheet have a uniform mineralogic composition. An average phenocryst assemblage includes plagioclase (30%), quartz (6%), plus biotite and hornblende (4%). An aphanitic groundmass of subhedral quartz, plagioclase, potassium feldspar and Fe-Ti oxides makes up approximately 60% of the rock.

Euhedral to subhedral plagioclase phenocrysts are medium- to coarse-grained (0.5–7.0 mm in length). Plagioclase grains exhibit several types of twinning, and some phenocrysts are zoned. Glomeroporphs are common (Fig. 3A), and inclusions of biotite and apatite are visible in some plagioclase phenocrysts. Quartz phenocrysts range from 0.2 to 7 mm in diameter and are highly variable in form. Some quartz phenocrysts are subhedral, diamond-shaped grains indicative of beta quartz. Most quartz phenocrysts are highly corroded and embayed (Fig. 3H), an indication of late-stage resorption of quartz by the magma. Biotite and hornblende phenocrysts are euhedral to subhedral, and are medium- to fine-grained (0.2–1.0 mm). The groundmass has an anhedral-granular texture and is composed of very fine-grained (0.1 mm) quartz, plagioclase, potassium feldspar and Fe-Ti oxides.

Almost all samples taken from the Palisades sheet exhibit varying degrees of alteration. Plagioclase phenocrysts and plagioclase in the groundmass tend to be the most commonly altered mineral. Alteration phases included white mica, calcite and minor epidote. Plagioclase alteration appears to occur in progressive stages. Initial alteration is normally restricted to planar zones that follow cleavage or fracture surfaces (Fig. 3B). Subsequent alteration may occur around the outer rim or within the core of the plagioclase grain (Fig. 3C). In some grains, calcite is the alteration mineral in the core, whereas white mica forms the alteration product around the rim (Fig. 3D). Extreme alteration tends to produce ghostlike pseudomorphs (Figs. 3E and 3F). Mafic minerals (biotite and minor hornblende) have been altered to secondary green biotite, chlorite and a brownish-green serpentine mineral. All altered mafic minerals contain small (0.3 mm) secondary grains of Fe-Ti oxide.

Near the upper portion of the Palisades sheet, rocks have been silicified. The groundmass of these rocks has undergone recrystallization and has a granoblastic texture. Quartz phenocrysts are rimmed by overgrowths that are optically continuous with the original grain (Fig. 3G).

Geochemistry

A set of representative chemical analyses from the vertical sampling profile of the Palisades sheet is given in Table 1. In addition, the arithmetic mean and standard deviation for the 28 most unaltered samples of both sampling profiles are given at the bottom of Table 1. Limited

TABLE 1. Representative whole-rock chemical analyses from the "vertical" profile, Palisades sheet of the Cimarron pluton. Major oxides and LOI are in weight percent and trace elements (Rb and Sr) are in ppm.

SAMPLE	DISTANCE# (meters)	SiO_2	Al_2O_3	Fe_2O_3 (Σ Fe)	MgO	CaO	Na_2O	K_2O	TiO_2	LOI	TOTAL	Sr	Rb
P-2	382	69.3	15.3	1.50	0.24	1.83	4.44	3.20	0.29	2.72	98.8	677	57
P-4	366	71.8	14.7	1.04	0.16	0.83	5.68	4.04	0.08	1.61	99.9	549	108
P-6	355	72.0	14.3	1.02	0.16	1.64	4.18	3.98	0.07	2.99	100.3	486	112
P-8	340	66.5	15.5	2.99	0.84	2.67	4.82	3.30	0.36	3.29	100.3	370	63
P-10	325	67.5	16.5	2.81	0.76	1.00	5.46	3.35	0.34	1.60	99.3	655	56
P-12	307	67.4	15.4	2.98	0.90	3.00	4.91	3.32	0.33	2.63	100.9	934	55
P-14	292	68.0	16.2	3.02	0.86	3.00	4.79	3.06	0.32	0.99	100.3	909	58
P-16	280	67.8	16.0	2.75	0.82	2.03	4.91	3.24	0.32	2.08	100.0	700	57
P-18	258	66.4	15.7	2.46	0.66	3.17	4.50	3.30	0.28	3.69	100.2	606	59
P-20	243	67.2	15.5	2.42	0.72	2.48	4.33	3.22	0.28	3.34	99.5	551	58
P-22	229	66.1	15.6	2.44	0.78	3.37	4.44	3.18	0.30	4.12	100.3	617	59
P-24	213	67.4	15.3	2.31	0.64	3.14	4.40	3.12	0.26	3.34	99.9	590	57
P-26	195	68.7	15.8	2.48	0.60	1.73	5.36	3.32	0.27	1.42	99.6	922	60
P-28	178	67.7	15.9	2.46	0.70	2.28	5.00	3.26	0.29	2.58	100.1	799	57
P-30	150	68.2	16.0	2.46	0.70	2.76	4.54	3.24	0.28	1.51	99.7	909	57
P-32	134	68.4	15.8	2.58	0.73	1.78	4.36	3.34	0.32	1.97	99.3	644	56
P-34	118	68.4	15.6	2.48	0.72	2.78	4.48	3.30	0.28	2.08	100.1	780	59
P-36	102	68.7	15.9	2.41	0.56	1.38	5.14	3.14	0.30	3.30	100.7	823	54
P-38	84	68.2	15.8	2.44	0.55	2.63	4.64	3.20	0.26	1.77	99.5	940	56
P-40	71	69.3	15.3	2.46	0.68	2.50	4.42	3.18	0.27	1.52	99.6	882	52
P-42	48	68.9	15.6	2.49	0.68	2.66	4.43	3.28	0.27	1.51	99.8	893	61
P-44	31	68.5	16.0	2.57	0.64	2.66	4.61	3.24	0.25	1.59	100.0	910	57
P-48	21	66.6	15.3	2.40	0.69	3.45	3.80	3.21	0.30	4.38	100.2	464	59
P-46	20	68.4	15.6	2.46	0.74	3.01	4.51	3.36	0.27	2.04	100.4	912	55
P-50	0.3	66.3	15.4	2.38	0.68	3.52	3.95	3.28	0.27	4.50	100.3	562	62
UNALTERED†		68.5	15.9	2.54	0.68	2.12	4.96	3.30	0.28	1.51	99.7	872	58
SAMPLES (σ)		0.4	0.3	0.13	0.08	0.57	0.38	0.09	0.02	0.36	0.4	121	3

Distance from base of the intrusion.

† Arithmetic mean and standard deviation for the 28 most unaltered samples from the Palisades sheet of the Cimarron pluton.

variation exists for several major-element oxides (Al_2O_3, K_2O, Fe_2O_3 as total iron, MgO, TiO_2) and the trace element Rb. However, SiO_2, Na_2O, CaO and Sr exhibit significant variation (Fig. 4). This variation cannot be explained by normal crystal fractionation effects. For example, despite the abundance of plagioclase phenocrysts, Al_2O_3 is constant, thus CaO and Na_2O trends cannot be explained by plagioclase fractionation. Likewise, the negative correlation between CaO and Sr argues against plagioclase fractionation. The lack of variation for Fe_2O_3, MgO and TiO_2 suggests that ferromagnesian minerals were not involved in fractionation.

The strong negative correlation of CaO, Na_2O, SiO_2 and Sr with respect to LOI suggests that variations are due largely to the effects of alteration of the primary minerals due to replacement. In order to remove another possible effect, dilution of concentrations due to introduction of volatiles (as measured by LOI), some oxides were recalculated as atomic ratios with respect to a probable immobile element. The immobile element chosen was Al, and a normalization method described by Pearce (1968) was employed. The analyzed samples were plotted with respect to LOI in Figure 5. The nearby constant value of Si/Al suggests that Si variations are an effect of dilution by volatiles rather than mobility due to alteration. Both Ca/Al and Na/Al show significant variation with LOI; Ca/Al increases, and Na/Al decreases with increasing LOI.

The implicit negative relationship between Na and Ca may be indicative of the replacement of sodic plagioclase by calcite. This is supported by the strong positive correlation between LOI and CO_2 for selected samples of the Palisades sheet (Fig. 5). Above 1.5% LOI, approximately half the LOI can be accounted for by CO_2 (Fig. 5).

The intensity of alteration, as measured by LOI, is not uniform within the Palisades sheet. The most intense alteration is at the upper and lower contacts and in the upper one-third of the sheet (Fig. 6). A narrow zone of silicification is present in the upper 50 m of the sheet.

The REE distribution in the Palisades sheet (Table 2) does not appear to be affected by alteration (Fig. 7). Samples P-14 and P-26 are the least altered, and sample P-65 is highly altered. Systematic differences in REE concentrations between sample P-14 and the remaining samples may be due to different accuracies. Sample P-14 was analyzed by ICP-MS, whereas the remaining samples were analyzed by INAA; we have more confidence in values for sample P-14. Precision for the INAA analyses, however, is sufficiently good to determine whether a difference exists between unaltered and altered samples with respect to their REE concentrations.

The overall REE abundances are similar to plutonic rocks of similar silica content in the Questa area and dacitic rocks of the Raton-Clayton volcanic field (Fig. 7). One distinct feature of the REE patterns for rocks of the Cimarron pluton is the presence of a positive Eu anomaly (Fig. 7). Igneous rocks of similar composition in the Questa area and the Raton-Clayton volcanic field have either no Eu anomalies or slight negative anomalies.

The $^{87}Sr/^{86}Sr$ isotopic compositions for selected samples of the Ci-

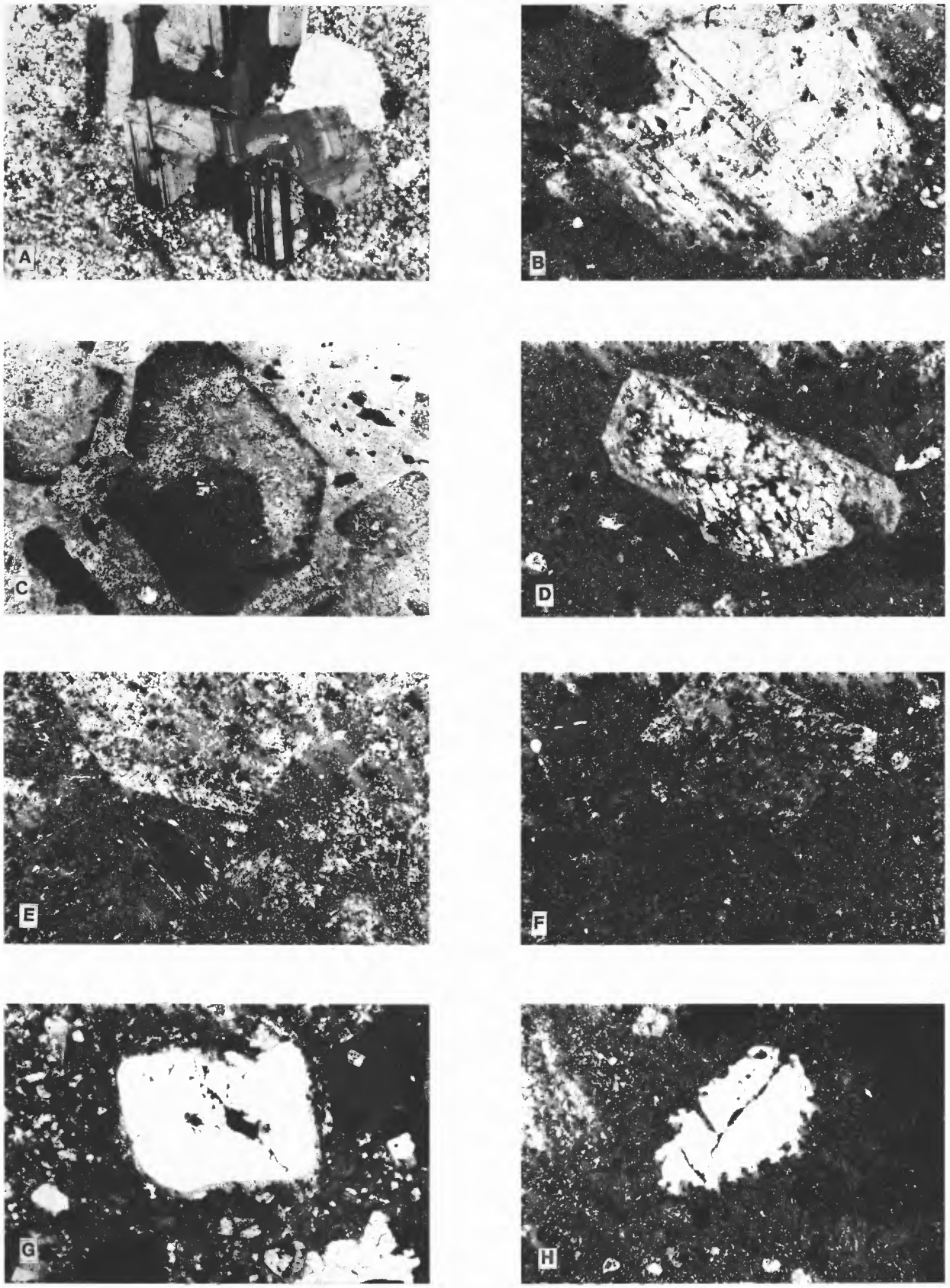


FIGURE 3. Photomicrographs of rocks from the Cimarron pluton. Photographs A–F show progressive stages of plagioclase alteration. Field of view in all photographs is 5.0 mm wide. A, Glomeroporphs of unaltered plagioclase; sample P-14, crossed polars. B, Initial stages of plagioclase alteration along cleavage planes; sample P-29, crossed polars. C, Intermediate stages of plagioclase alteration; the core of the phenocryst is completely altered to white mica, calcite, and epidote; sample P-1, uncrossed polars. D, Intense alteration of plagioclase with calcite in core and white mica in rim; sample P-2, crossed polars. E, F, Intensely altered plagioclase (now a pseudomorph of calcite and white mica) and chlorite-magnetite pseudomorphs of hornblende; sample P-79, crossed polars. G, Silicified sample exhibiting overgrowths on quartz phenocrysts as well as recrystallization and silicification of matrix; sample P-6, crossed polars. H, embayed and scalloped quartz phenocrysts; sample P-38, crossed polars.

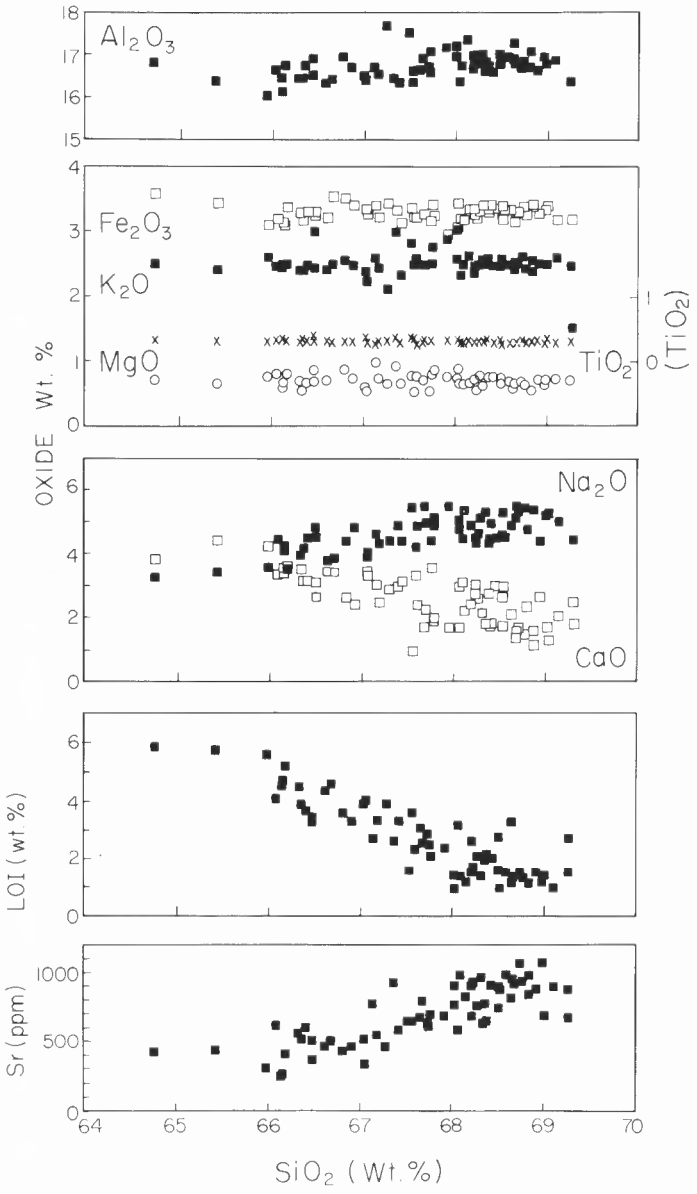


FIGURE 4. Harker diagrams for 63 samples from the Palisades sheet of the Cimarron pluton. Fe_2O_3 represents total Fe as Fe_2O_3. LOI is loss on ignition. Silicified samples have been omitted from this diagram.

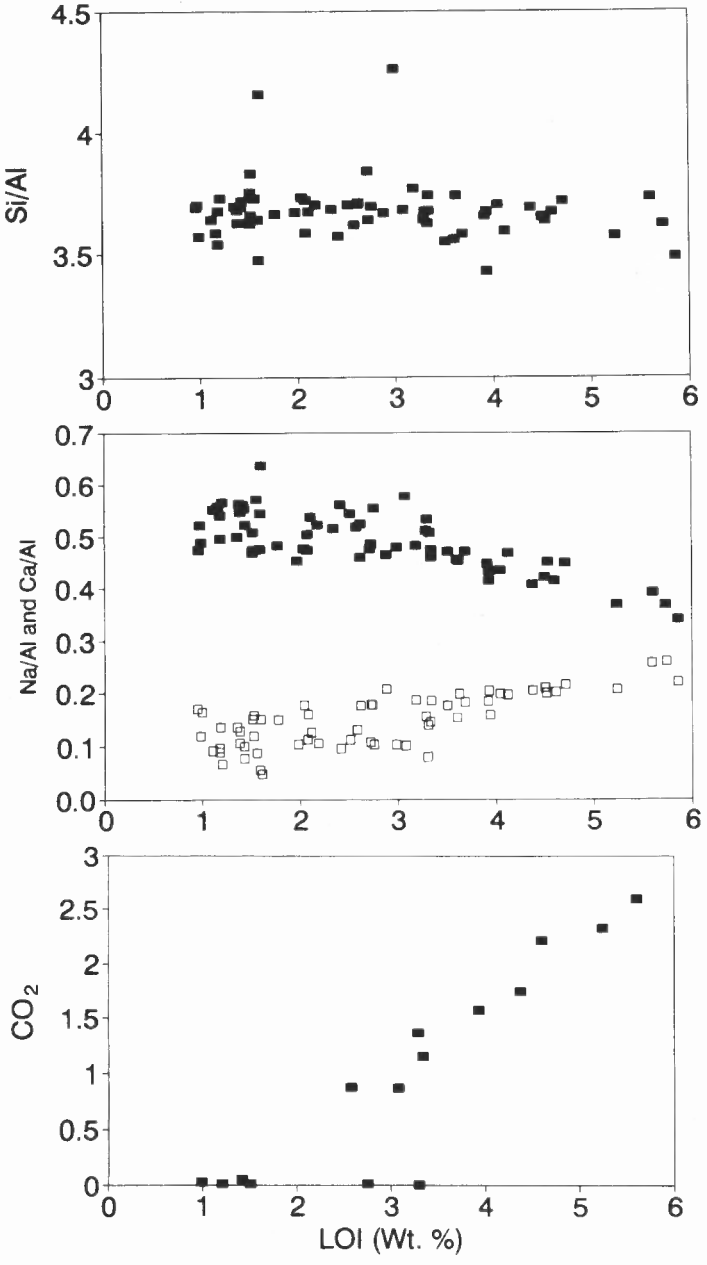


FIGURE 5. Plots of LOI (loss on ignition) versus (A) atomic ratio Si/Al, (B) atomic ratios Na/Al (filled squares) and Ca/Al (open squares) and (C) weight percent CO_2 for selected samples from the Palisades sheet of the Cimarron pluton.

marron pluton are presented in Table 3. Samples that are only slightly altered (P-14 and P-26) yield initial $^{87}Sr/^{86}Sr$ ratios of approximately 0.7052 (assuming an intrusive age of 26 Ma). An acid leach for a highly altered sample (P-51) yields a present day $^{87}Sr/^{86}Sr$ ratio of 0.70617. The correction for *in situ* radiogenic Sr in this sample is negligible. The slightly elevated $^{87}Sr/^{86}Sr$ ratio of this sample may be due to addition of Sr from surrounding sedimentary and metamorphic rocks.

DISCUSSION

Unaltered samples of the Palisades sheet, Cimarron pluton, have a distinctive chemistry and mineralogy relative to other Tertiary igneous rocks in this region. Some of these distinctive characteristics are: (1) high concentrations of Na_2O; (2) low concentrations of MgO; (3) REE patterns that exhibit high HREE depletion and positive Eu anomalies; and (4) lack of potassium-feldspar phenocrysts compared to rocks of similar chemistry in this region. The unique chemical and mineralogical character of the sheet may be due to a number of factors. They include regional variations in source compositions and differences in degrees of partial melting, as well as accumulation of Na-rich plagioclase phenocrysts.

The REE patterns for rocks of intermediate composition in the southern Rocky Mountains are characterized by moderate depletion in HREE (Lipman, 1987), whereas similar rocks in the adjacent Great Plains have greater depletion in HREE (Fig. 7). The Palisades sheet of the Cimarron pluton appears to have the HREE depletion (Yb = 0.6 ppm, $(Ce/Yb)_n$ = 16) similar to igneous rocks of the Great Plains. These relationships suggest regional differences in source compositions between the southern Rocky Mountains and the Great Plains. Major crustal differences between the southern Rocky Mountains and Great Plains are well known, so differences in source compositions and geothermal gradients between the two regions are to be expected. Low MgO contents may be due to relatively small percentages of partial melting.

Robinson et al. (1964, p. 50) noted that plagioclase-phenocryst abundances and sizes progressively increase from the eastern margins westward toward the center of the Cimarron pluton. The feeder system is reportedly near the center of the pluton (Robinson et al., 1964), thus lateral filter pressing could have led to accumulation of Na-rich pla-

TABLE 2. Rare-earth element concentrations for samples of the Palisades sheet of the Cimarron pluton. Concentrations are reported in ppm.

	P-14	P-26	P-20	P-65
La	21.9	17.1	18.1	18.1
Ce	38.5	28.0	32.0	31.0
Pr	4.3	na.	na.	na.
Nd	19.5	15.0	16.0	16.0
Sm	3.4	2.0	2.1	2.3
Eu	1.2	0.8	0.8	0.8
Gd	2.0	na.	na.	na.
Tb	0.4	<0.5	<0.5	<0.5
Dy	1.5	na.	na.	na.
Ho	0.2	na.	na.	na.
Er	0.6	na.	na.	na.
Tm	0.1	na.	na.	na.
Yb	0.6	0.3	0.4	0.3
Lu	0.09	<0.05	<0.05	<0.05

na. - not analyzed.
Sample P-14 analyzed by ICP-MS, all other samples analyzed by INAA.

TABLE 3. Rb and Sr isotopic data for the Palisades sheet of the Cimarron pluton.

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ measured	$^{87}Sr/^{86}Sr$ initial
P-14	58	909	0.185	0.70521	0.70514
P-26	60	922	0.188	0.70537	0.70530
P-51L	<10	2660†	<0.010	0.70617	0.70617

† Concentration probably not correct due to removal of Sr from phases other than calcite

gioclase phenocrysts in the study area. This accumulation could account for both the positive Eu anomaly and the high Na_2O contents. In addition to different source compositions, the high HREE depletion may be explained by significant amounts of hornblende fractionation, as suggested by the presence of hornblende phenocrysts.

Alteration of the Palisades sheet is pervasive and is characterized by minerals associated with propylitic alteration. Compared to other rocks that have undergone propylitic alteration, however, these rocks have an unusually high amount of calcite as an alteration phase. Carbonate-bearing shales and limestones overlie and are intruded by the pluton (Robinson et al., 1964). Hydrothermal fluids, in part generated from meteoric water, may have leached the carbonates and altered the nearby igneous rocks of the pluton.

Several major gold and base-metal-ore deposits are located within the upper portions of the Cimarron pluton and in the surrounding sedimentary rocks (Lindgren et al., 1910; Clark and Read, 1972). These deposits have been classified as either fissure- or skarn-type and are typically associated with limy or carbonaceous shale. The mechanisms responsible for the ore deposits may also be responsible for the alteration

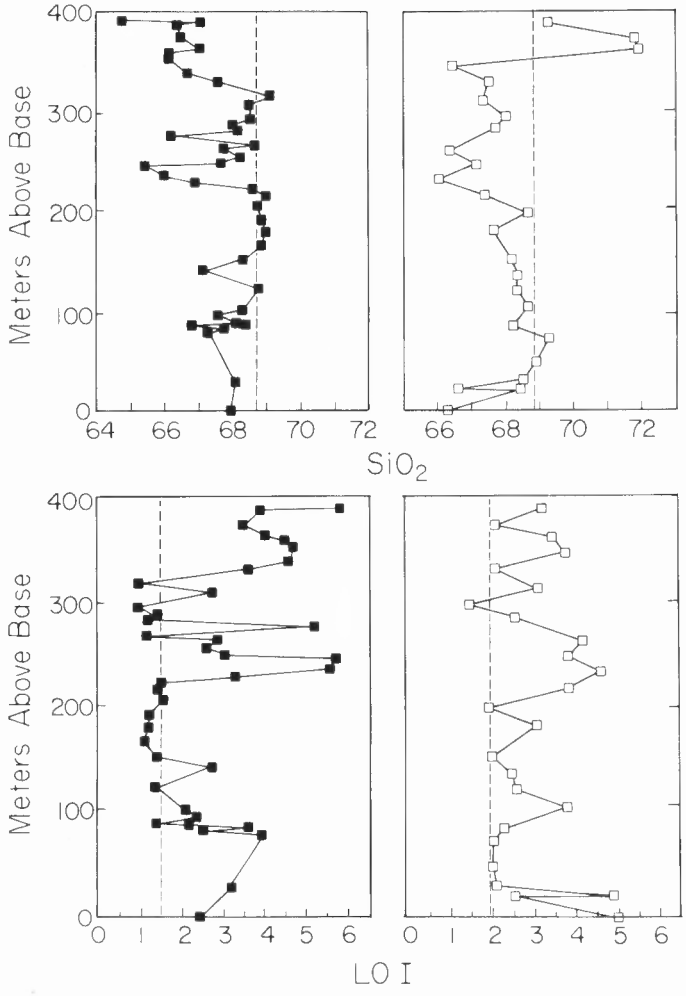


FIGURE 6. Variation of weight percent SiO_2 and LOI ("loss on ignition"—volatile components) with position in the Palisades sheet of the Cimarron pluton. Black symbols represent samples collected along the "horizontal" (canyon) profile, while open symbols are from a "vertical" (cliff) profile that is nearly perpendicular to intrusive contacts. Dashed lines represent the approximate composition of the least altered samples. The thickness of the intrusive sheet in the horizontal profile has been adjusted to be equivalent to the thickness of the vertical profile.

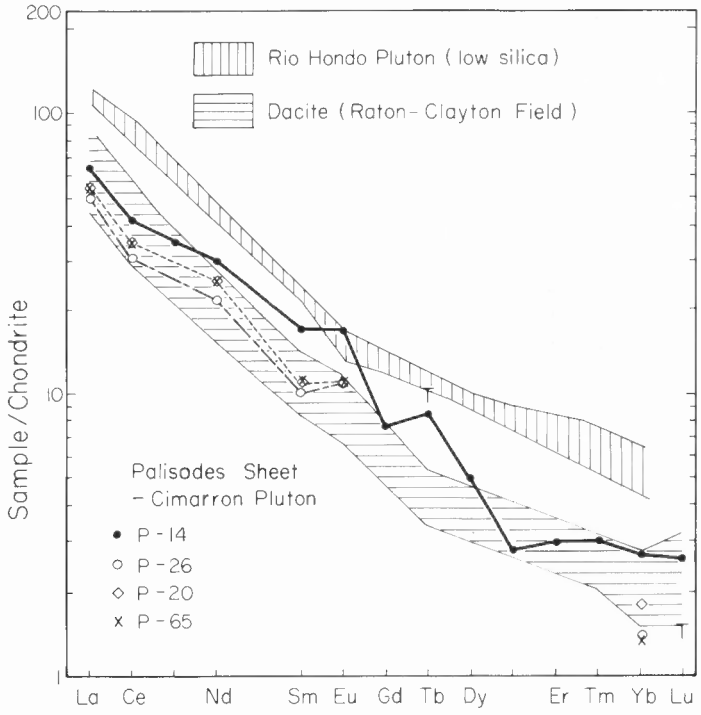


FIGURE 7. Chondrite-normalized REE plot for samples of the Palisades sheet from the Cimarron pluton that exhibit different degrees of alteration. Sample P-26 is least altered, and sample P-65 is most altered. The "T" for Tb and Lu indicates the detection limits, thus concentrations of these elements in the three samples are lower than these values. For comparison, igneous rocks from nearby areas that have similar major-element compositions are also shown. Low silica (~68%) portions of the Rio Hondo pluton (Johnson et al., 1989); dacite from the Raton-Clayton volcanic field (Dungan et al., 1989).

within the pluton. More research is required to investigate the relationships between the alteration and ore deposits.

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West Portal, Baldy Deep Tunnel Mine, 1912. When work began in 1900, the goal was to tunnel completely through Baldy Mountain in search of the mother lode. Little operational history of this monumental project has been preserved—such records as existed were allegedly destroyed by a storm near Houston, Texas, prior to the 1930's. The above view was made about the time the tunnel attained the 3600-ft mark. Note that some of the timbers have been pre-cut for square-set stope support, possibly for use in the heavy ground surrounding the 6-ft vein encountered at 2300 ft. Finally in 1936, after 35 years of work, the 9171-ft tunnel was completed, at a cost of about $2 million, without encountering any significant shows of mineralization. Photo courtesy of Kit Carson Foundation.