PLIOCENE INTRUSIVE ROCKS AND MINERALIZATION NEAR RICO, COLORADO

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ABSTRACT

Fission-track and potassium-argon studies of intrusive rocks in the vicinity of Rico, Colorado, have shown that at least two periods of igneous activity occurred and that significant ore mineralization is associated with alaskites and latites that are 3 to 5 million years old. Discordant fission-track ages of apatite and zircon in the older rocks reveal a major heat source, centered under the mineralized rocks near the townsite of Rico, that cooled in late Miocene or early Pliocene time. This heat source may indicate the presence of a buried stock that is related to the mineralization.

INTRODUCTION AND GEOLOGIC SETTING

Rico, Colorado, is a precious- and base-metal mining camp situated on the Dolores River in the western San Juan Mountains. Previous reports on the geology and mineralization include Farish, 1892; Rickard, 1897; Cross and Spencer, 1900; Ransome, 1901; Cross and Ransome, 1905; Pratt, 1968; Pratt and others, 1969; and McKnight, 1974.

Rico is near the center of the Rico dome, which is a major east-west-trending, breached, elliptical dome with a long axis of about 5 km. The dome consists of uplifted Misssissippian to Cretaceous sedimentary rocks around a core containing a horst of Precambrian rocks that have been uplilfted more than 2 km. Detailed stratigraphic sections are given in McKnight (1974).

GEOCHRONOLOGIC METHODS

Twelve intrusive rocks and one sericite from a vein were dated as part of this study. Table 1 shows 21 fission-track ages on apatite, zircon, and sphene concentrates. Table 2 lists two K-Ar ages, one biotite age, and one sericite age. The map (fig. 1) shows the location and ages of all samples dated in this study.

The fission-track ages were determined using the procedures outlined in Naeser (1976). The zircon and sphene were dated using the external-detector method, and the population method was used for dating the apatite. The standard error of the zircon and sphene ages was calculated using the procedure outlined by Naeser and others (1978). The errors on the apatite ages were calculated by combining the Poisson errors on the fossil and induced counts (Lindsey and others, 1975). The neutron doses were determined by using National Bureau of Standards glass SRM962. The neutron doses were calibrated against the NBS copper neutron dose.

INTRUSIVE ROCKS AND AGE RELATIONSHIPS

Igneous rocks have been emplaced during at least two episodes. Cretaceous?-Paleocene hornblende-latite rocks intrude the sedimentary rocks. The hornblende latites are generally present as sills, but at least one large discordant body cuts sedimentary rocks several kilometers east of Rico, near Hermosa Peak (Pratt, 1976). This body has a minimum age of 57.2±6.9 m.y. (fission track, zircon) and older ages of 80.1±2.4 m.y. (K-Ar, hornblende) and 78±16 m.y. (fission track, sphene) (Marvin and others, 1974, No. 137). Armstrong (1969) reported an age on hornblende latite collected several kilometers south of Rico as 179 m.y.

for a pyroxene concentrate and 61.3 m.y. for the whole rock with the heavy minerals removed. Preliminary studies of the rocks in the Colorado Mineral Belt (Cunningham and others, 1977) provided ages on the hornblende latite of 65 m.y. (fission track, zircon) and 20.2 m.y. (fission track, apatite) indicating that the rock had been partly thermally reset. Ages of zircons from three samples collected for this study range from 59.9± 2.7 m.y. to 64.9±3.7 m.y., indicating that the rock formed close in time to the Mesozoic-Tertiary boundary.

A second major Cretaceous?-Paleocene rock type is augite-monzonite. It forms a composite stock west of Rico. Pratt and others (1969) indicated that the augite monzonite intrudes the hornblende latite; McKnight (1974, p. 42) believed they were nearly contemporaneous; and our studies show sphene from the augite-monzonite as 78 m.y. old, indicating that it may be the oldest rock, although definitive field relationships are lacking. The augite monzonite has been thermally reset, and discordant ages ranging from 82 m.y. (K-Ar, hornblende) (Marvin and others, 1974, No. 132) to 6.6±2.3 m.y. (fission track, apatite) have been determined. The hornblende latite and augite monzonite compose most of the igneous rock exposed at the surface.

The older rocks of the Rico dome are intruded by dikes that include augite lamprophyre, hornblende lamprophyre, basalt, alaskite porphyry, and porphyritic augite latite. We have dated the alaskite porphyry as Pliocene, but the absolute ages of the other dikes are unknown. Pratt and others (1969) reported that augite lamprophyre and basalt dikes cut the hornblende latite.

A stock and several dikes, collectively called the Calico Peak Porphyry (Pratt and others, 1969), were intruded 4.6±0.5 m.y. ago (average of three zircon fission-track ages). The largest intrusive is a stock that cuts sedimentary rocks at Calico Peak. The rock is a biotite-hornblende latite that is pervasively altered. A similar rock type that is much less altered forms a sill several kilometers south of Calico Peak near Priest Gulch. It has a K-Ar age of 4.5±0.2 m.y. (biotite).

A distinctive alaskite porphyry forms several dikes near the town of Rico and is associated with significant mineralization. Zircons from two samples of this dike were dated. Sample 12 from Aztec Gulch, west of Rico, has an age of 3.4±0.3 m.y.; and sample 13 from along Silver Creek, east of town, has an age of 3.9±0.4 m.y. This is the youngest rock we have dated in the area. It may also be the youngest rhyolite in the San Juan volcanic field; the youngest one that Lipman and others (1978) reported is dated at 4.8 m.y. The basalt dikes and alaskite dikes are probably essentially contemporaneous and part of the bimodal suite recognized by Lipman and others (1970).

THERMAL OVERPRINT

A thermal event reset the ages of apatits in all of the older rocks. The one sample we dated of the augite monzonite (1)* has a zircon age of 61.4±2.9 m.y. and an apatite age of 6.6±2.3 m.y. The apatite ages on the hornblende-latite porphyry are all much younger than the intrusive ages of the porphyry. They range from 20.2±7.4 m.y. (2)

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*Refers to sample locality on plate 1.

in the southern part of the district to 4.6±2.9 m.y. (4) near the center of the district. Three samples of the hornblende-latite from within the mining district were dated. The zircon ages from these samples have all been lowered, They range from 38.6±1.5 m.y. (9) to 6.8±0.6 m.y. (5). The hornblende and sphene are systematically older than the biotite and zircon, suggesting that the biotite and zircon are partly reset.

The annealing of fission-track in minerals is known to take place at temperatures as low as 100°C (Naeser, 1979). Apatite will suffer track loss at temperatures between 90° and 150° over periods of time lasting 10^5 years or longer (Naeser and Faul, 1969). The track annealing in zircon is less well known; Naeser has estimated that it occurs at temperatures between 175° and 225°C. Track loss is a gradational process, and partial track loss is possible. This is seen by the apatite ages from samples 2 and 3, and the zircons from samples 1, 4, and 9. Total annealing of apatite was observed in samples 1, 4, 5, 8, and 9. These fine apatites have an average age of 6.3±0.6 m.y., and therefore must have cooled from a temperature in excess of 130°C about 6 m.y. ago. One sample (5) was heated in excess of 200°C The zircon from that sample has an age of 6.8±0.6 m.y., which is concordant with the age of the apatite.

The pattern of reduced fission-track ages on apatite and zircon delineated in this report points to a major thermal disturbance in the Rico area. This disturbance is probably centered near the location of sample 5. We postulate that a stock probably related to the Calico Peak Porphyry or the alaskite porphyry is present at depth just east of Rico.

MINERALIZATION

The Rico mining district has produced gold, silver, copper, lead, and zinc intermittently since 1879. The known deposits consist of sulfide replacement deposits and contact-metamorphic deposits in limestones and veins in clastic rocks (McKnight, 1974).

The ages of all of the mineralization and the relationships to rock units are poorly known. Rickard (1897) observed that the ore veins penetrated the porphyry (apparently the hornblende latite porphyry) in the ore deposits on Newman Hill, immediately southeast of Rico. The literature does not contain any reference to genetic relationships between the alaskite porphyry and sulfide ore. Both samples of alaskite porphyry collected for this study are altered, and sample 12 contains disseminated sulfides and is cut by small sulfide-bearing veins. This suggests that the alaskite porphyry may be genetically related to some, if not all, of the ore. This is further supported by the single sample of sericite from the ore vein along the Black Hawk fault, which has a K-Ar age of about 5.5 m.y. The coincidence in time and space between the young mineralization, young intrusive rocks, and hidden thermal center east of Rico suggests that this may be the site for a young, unexposed stock with the potential for porphyry-type mineralization.

The axis of the Rico dome is the loci of the augite-monzonite stock and possibly governs the location of a hidden stock. The horst of Precambrian rock may be related to the intrusion of this hidden pluton. The relationship between superimposed centers of intrusion and mineralization has been well documented at Climax and Henderson (Wallace and others, 1968, 1978).

Another potential source of economic mineralization is the Calico Peak Porphyry stock at Calico Peak. The alteration assemblage includes significant quantities of alunite. Experimental evidence (Hemley and others, 1969) has shown that to form alunite in this environment, sulfur and a hydrothermal system are needed--two ingredients conducive to ore formation. Alteration features at Calico Peak are similar to the alteration features at Marysvale, Utah, where Cunningham and others (1978) have shown a time-space genetic relationship between alunite alteration and the precious- to base-metal mineralization, and have predicted the presence of a hidden porphyry deposit. Sulfides, tentatively identified as molybdenite, have been reported from the Calico Peak Porphyry (W. P. Pratt, oral commun., 1979).

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DESCRIPTION OF MAP UNITS

Qs SURFICIAL DEPOSITS (QUATERNARY)--Includes alluvium, fan deposits, talus, slopewash, landslide deposits, and calcareous tufa

Tap ALASKITE PORPHYRY DIKES (PLIOCENE)--Light-gray to white rhyolite containing partly resorbed quartz phenocrysts in an aphanitic groundmass of K-feldspar and quartz

CALICO PEAK PORPHYRY (PLIOCENE)

Tcl Porphyritic biotite-hornblende latite--Brownish-gray rock containing phenocrysts of sanidine, plagioclase, hornblende, and biotite in an aphanitic groundmass of quartz and feldspar. Contains minor Fe-Ti oxides, apatite, sphene and zircon

Tca Altered porphyritic biotite-hornblende latite--Light-gray to light-brown porphyrritic rock containing phenocrysts of plagioclase and K-feldspar in an altered aphanitic groundmass. Alteration minerals include alunite and sericite

Td DIKES (PLIOCENE?)--Dikes of varying lithologies, including augite lamprophyre, hornblende, lamprophyre, basalt, and porphyritic augite latite

TKhl HORNBLENDE LATITE PORPHYRY (PALEOCENE TO CRETACEOUS?)--Light- to dark-gray, porphyritic latite containing phenocrysts of andesine and hornblende in an aphanitic groundmass of plagioclase, orthoclase, minor quartz, Fe-Ti oxides, apatite, and zircon. Rock is pervasively propylitized and locally sericitized

TKm AUGITE MONZONITE (PLIOCENE TO CRETACEOUS?)--Gray, hypidiomorphic granular monzonite containing andesine, interstitial orthoclase, green augite ± hornblende ± biotite, conspicuous sphene, minor quartz, zircon, and apatite

KMs SEDIMENTARY ROCKS (CRETACEOUS TO MISSISSIPPIAN)--Includes Dakota Sandstone, Morrison Formation, Wanakah Formation, Entrada Sandstone, Dolores Formation, Cutler Formation, Rico Formation, Hermosa Formation, quartzite of Larsen tunnel area, and Leadville Limestone

p€ UNCOMPAHGRE QUARTZITE, METADIORITE, AND GREENSTONE (PRECAMBRIAN)

CONTACT--degree of certainty not indicated

FAULT--dashed where inferred, dotted where concealed. Bar and ball on downthrown side

APPROXIMATE CRESTLINE OF ELONGATED DOME

1. Sample number tables 1 and 2

A = Apatite Fission-track age

Z = Zircon Fission-track age

S = Sphene Fission-track age

B = Biotite K-Ar age

CORRELATION OF MAP UNITS

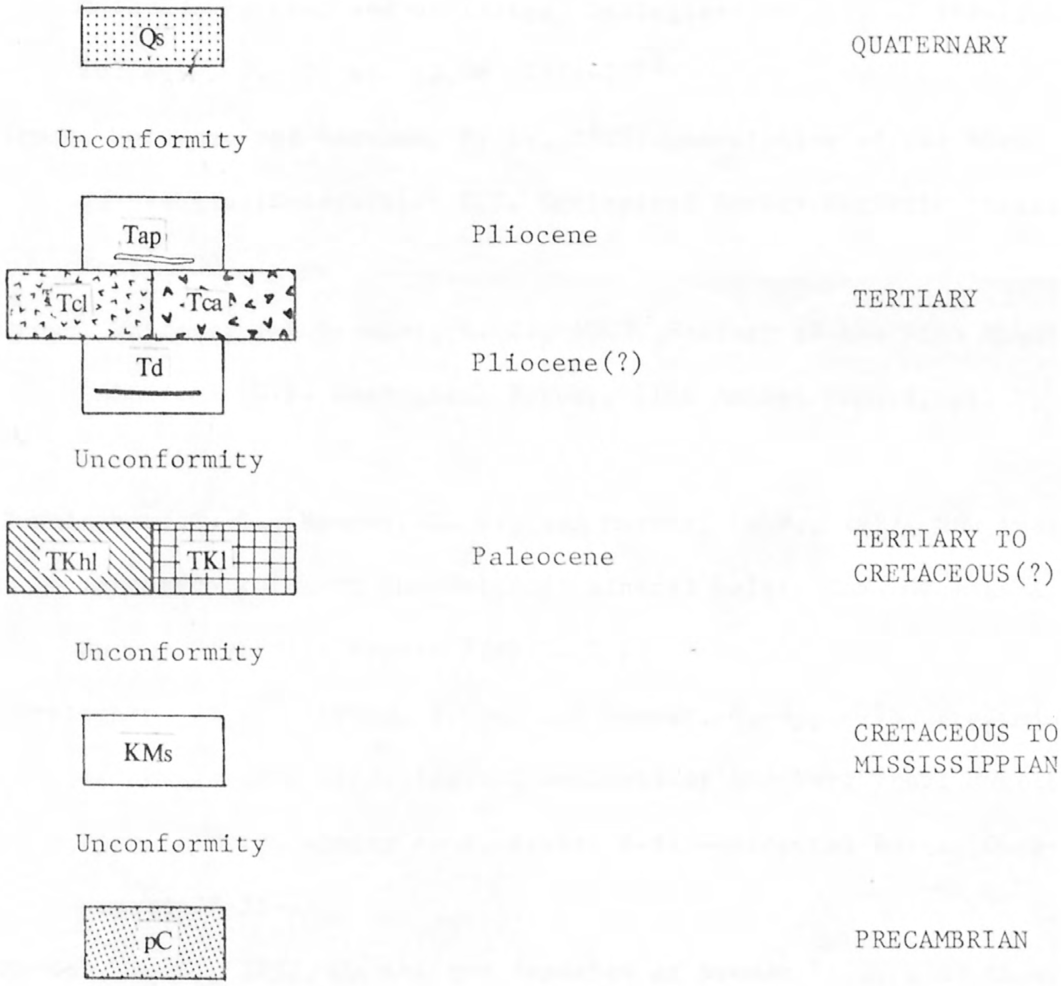

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Table 1.--Fission-track ages, Rico, Colorado

Sample	Mineral	Number of Grains	$r^{1/}$, $\bar{s}_1^{2/}$	ρs $10^6 t/cm^2$	ρi $10^6 t/cm^2$	φ $10^{15} m/cm^2$	U ppm	Age ± 2σ $10^6 yr$
Augite monzonite								
Rico 1	Sphene	6	0.99(r)	8.46 (1645)[3/]	12.15 (1181)[3/]	1.89	210	78.4±3.3
	Zircon	6	0.98(r)	4.78 (1174)	4.86 (596)	1.04	150	61.4±2.9
	Apatite	50	0.068($\bar{s}_1$)	0.016 (34)	0.169 (353)	1.14	4.8	6.6±2.3
Hornblende-latite porphyry								
Rico 2	Zircon	6	0.99(r)	9.89 (2151)	9.72 (1058)	1.07	290	64.9±2.9
	Apatite	50	0.115($\bar{s}_1$)	0.017 (36)	0.038 (121)	1.14	1.6	20.2±7.4
Rico 3	Zircon	6	0.78(r)	11.77 (1835)	10.75 (838)	0.996	310	64.9±3.7
	Apatite	50	0.099($\bar{s}_1$)	0.010 (29)	0.058 (162)	0.961	1.7	10.3±4.1
Rico 4	Zircon	6	0.94(r)	6.12 (850)	10.58 (735)	0.994	310	34.3±1.5
	Apatite	50	0.125($\bar{s}_1$)	0.004 (11)	0.049 (137)	0.961	1.5	4.6±2.9
Rico 5	Zircon	6	0.84(r)	1.29 (219)	11.29 (957)	0.991	330	6.8±0.6
	Apatite	50	0.159($\bar{s}_1$)	0.007 (20)	0.059 (165)	0.961	1.8	7.0±3.3
Rico 6	Zircon	6	0.96(r)	10.74 (1856)	10.56 (913)	0.989	310	59.9±2.7
	Apatite	50	0.10($\bar{s}_1$)	0.007 (20)	0.053 (148)	0.961	1.6	7.8±3.7
Rico 9	Zircon	6	0.98(r)	9.74 (1650)	14.82 (1256)	0.986	430	38.6±1.5
	Apatite	50	0.10($\bar{s}_1$)	0.005 (14)	0.051 (143)	0.961	1.5	5.6±3.2
Calico Peak Porphyry								
Rico 10 (stock)	Zircon	6	0.86(r)	1.45 (271)	21.04 (1961)	0.984	620	4.1±0.4
Rico 11 (dike)	Zircon	6	0.99(r)	0.865 (170)	9.00 (885)	0.982	260	5.6±0.5
Rico 14 (sill)	Zircon	6	0.92(r)	0.931 (221)	13.42 (1592)	0.975	400	4.0±0.4
	Apatite	50	0.05($\bar{s}_1$)	0.027 (77)	0.258 (725)	0.961	7.7	6.1±1.5
Alaskite porphyry								
Rico 12	Zircon	6	0.93(r)	1.12 (209)	19.60 (1827)	0.979	580	3.4±0.3
Rico 13	Zircon	6	0.99(r)	1.08 (147)	16.21 (1099)	0.977	480	3.9±0.4

1/ Correlation coefficient

2/ Standard error of mean induced tracks

3/ ( ) Number of tracks counted

$\lambda F = 7.03 \times 10^{-17}\ yr^{-1}$

Table 2.--K-Ar ages, Rico, Colorado

Sample	Mineral	K_2O (percent)	Radiogenic Ar^{40} (10^{-10} mol/gm)	Radiogenic Ar^{40} (percent)	Age (m.y.) ± 2.6
Calico Peak Porphyry					
Rico 14	Biotite[1]	8.50	0.5479	43	4.5 ± 0.2
(sill)		8.53			
Vein along Black Hawk fault[3]					
57-49I	Sericite[2]	8.44	0.799	64.3	5.45 ± 0.2
57-49II	Sericite[2]	8.34	0.780	56.8	5.39 ± 0.2

1 Analysts: R. F. Marvin, H. H. Mehnert, and V. M. Merritt

2 Analyst: J. D. Obradovich

3 Sericite from near intersection of Argentine tunnel and Black Hawk fault (McKnight, 1974)

Constants: K^{40} $\lambda_{\varepsilon} = 0.581 \times 10^{-10}/yr$ $\lambda_{\beta} = 4.962 \times 10^{-10}/yr$

$K^{40}/K = 1.67 \times 10^{-4}$ atomic ratio

Base map U.S. Geological Survey, 1960

Geology modified from Pratt, McKnight, and De Mon, 1969

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER 25, COLORADO OR WASHINGTON 25, D.C.

RICO, COLO.

1960

PLATE 1.-SIMPLIFIED GEOLOGIC MAP OF THE RICO QUADRANGLE, COLORADO