U-Th-Pb age and initial strontium isotopic ratios of the coxcomb granodiorite, and a K-Ar date of ilivone basalt from the Coxcomb mountains, southern California

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U-Th-Pb AGE AND INITIAL STRONTIUM ISOTOPIC RATIOS OF THE COXCOMB GRANODIORITE, AND A K-Ar DATE OF OLIVINE BASALT FROM THE COXCOMB MOUNTAINS, SOUTHERN CALIFORNIA

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The Coxcomb Mountains are located in the southern Mojave Desert approximately 240 km east of Los Angeles, California (fig. 1). Most of the range is underlain by the Coxcomb Granodiorite of Miller (1944). The granodiorite intruded the McCoy Mountains Formation of Harding and Coney (1985) and is overlain by Tertiary fanglomerate deposits that contain olivine basalt flows. This report summarizes previous K-Ar and Rb-Sr data from the granodiorite, and reports new U-Th-Pb and K-Ar dates from the granodiorite and olivine basalt, respectively. The U-Th-Pb data confirm the Late Cretaceous age of the granodiorite as previously determined by the K-Ar data and constrain the minimum age of the McCoy Mountains Formation. The new K-Ar date helps to define the minimum age of faulting in the southern Coxcomb Mountains.

Calzia (1982a) divided the Coxcomb Granodiorite into four cognetic intrusive facies. Three of these intrusive facies are (from oldest to youngest) biotite-hornblende granodiorite, porphyritic biotite granodiorite and monzogranite, and biotite-muscovite monzogranite. The biotite-hornblende granodiorite intruded the McCoy Mountains Formation near the southern end of the range. A gradational contact between the biotite-hornblende granodiorite and the porphyritic biotite granodiorite and monzogranite, and a smooth continuum of major element geochemistry between these two intrusive facies and the biotite-muscovite monzogranite suggest that these three facies are related through continuous magmatic differentiation by fractionation of hornblende and plagioclase (Calzia, 1982a,b).

The biotite-muscovite monzogranite intruded a fourth facies of porphyritic biotite granodiorite. Chemical data suggest that the fourth intrusive facies crystallized from a more primitive magma and may be older than the other intrusive facies. Intrusive relationships that would substantiate this suggestion are absent.

Previously determined K-Ar dates (table 1) from the Coxcomb Mountains suggest that the Coxcomb Granodiorite cooled in Late Cretaceous time. Biotite from the biotite-hornblende granodiorite and muscovite from the biotite-muscovite monzogranite yield K-Ar dates of 70.8 and 68.8 m.y., respectively (Armstrong and Suppe, 1973). Biotite from the monzogranite yields a younger date of 54.9 m.y., but this biotite contained only 6.36% K_2O, a low value compared to other biotite from the Coxcomb Granodiorite (table 1). The biotite may have been chloritized or contaminated by other minerals that contain very little potassium, and hence the date from the biotite may be artificially young. Other biotite from the monzogranite do not have reduced dates, thereby indicating that the cause of the 54.9 m.y. date is related to a relatively local phenomenon or a poor mineral separate, not a thermal event younger than about 65 m.y. as proposed by Miller and Morton (1980) for areas to the west of the Coxcomb Mountains.

Calzia (1982b) reports a Late Jurassic age of 145 m.y. for the Coxcomb Granodiorite based on strontium isotopic data. The strontium isotopic data, listed in table 2 for the first time, are scattered about the 70 m.y. reference isochrons and show little variation in the $^{87}Rb/^{86}Sr$ ratio (fig. 2). New U-Pb data, combined with the above K-Ar dates, suggest that the Late Jurassic age is erroneous.

ANALYTICAL PROCEDURES

U-Th-Pb. Zircon and sphene from the biotite-hornblende granodiorite were concentrated by separatory table, heavy liquid, magnetic, and hand-picking procedures. Dissolution and chemical preparation of the samples was slightly modified from Krogh (1973). Uranium, thorium, and lead concentrations were determined by standard isotope-dilution techniques, using ^{235}U, ^{232}Th, and ^{208}Pb spikes. Lead concentrates were dissolved by phosphoric acid, loaded onto single filaments, and coated with silica gel. Uranium and thorium concentrates were dissolved by nitric acid and loaded onto triple filaments for mass spectrometry. All isotope ratios were determined on a 30.5 cm digitized solid-source mass spectrometer at the U.S. Geological

TABLE 1. K-Ar data for the Coxcomb granodiorite and olivine basalt, Coxcomb Mountains, California.

Sample no.	Location N latitude, W longitude	Rock description	Mineral dated	$\%K_2O$ (ave.)	$^{40}Ar_{rad}$ (10^{-10}moles/gm)	$\%^{40}Ar_{atm}$	Apparent age (m.y.)	Reference
024	34°06′51″ 115°31′31″	biotite-muscovite monzogranite	biotite	8.99	8.59	85	65.1 ± 2.0	Calzia and Morton (1980)
69-68	34°05′33″ 115°24′28″	biotite-muscovite monzogranite	biotite	6.36	5.10	73	54.9 ± 1.5[1]	Armstrong and Suppe (1973)
			muscovite	9.92	10.01	78	68.8 ± 1.0[1]	
69-67	33°55′32″ 115°18′07″	biotite-hornblende granodiorite	biotite	8.10	8.42	79	70.8 ± 1.0[1]	Armstrong and Suppe (1973)
015	33°55′53″ 115°23′55″	olivine basalt	whole rock	1.20	0.08	86	4.5 ± 0.29	This report

[1]Data corrected for decay constants listed in Steiger and Jager (1977).

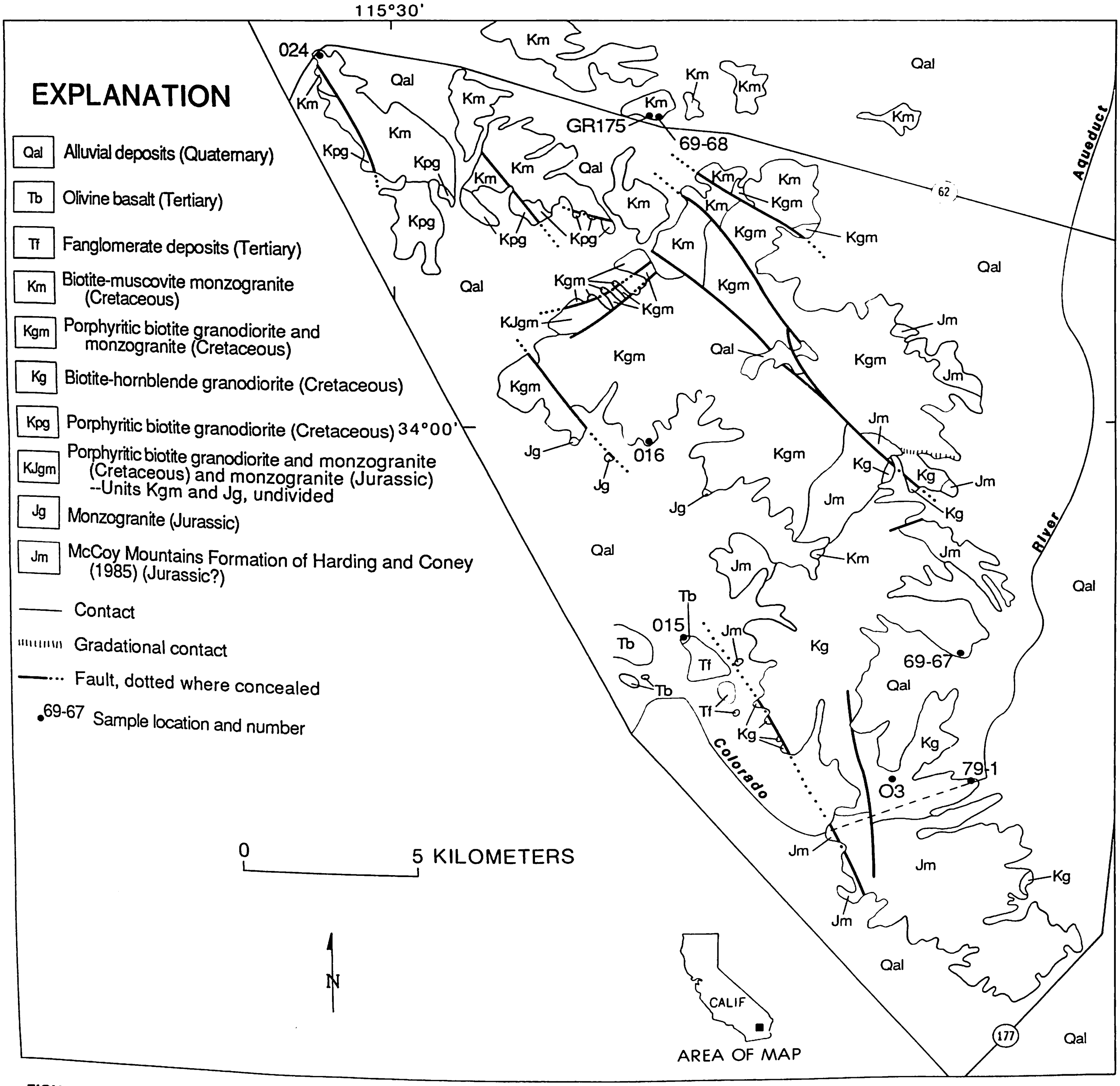

FIGURE 1. Generalized geologic map of the Coxcomb Mountains, California (modified from Calzia and others, 1983).

Survey, Denver, Colorado. Uncertainties of $^{207}Pb/^{206}Pb$ and $^{208}Pb/^{206}Pb$ ratios are 0.05 percent or less. Constants used for the U-Th-Pb dates are: $\lambda(^{238}U) = 1.55125 \times 10^{-10}$ year^{-1}; $\lambda(^{235}U) = 9.8485 \times 10^{-10}$ year^{-1}; $\lambda(^{232}Th) = 4.9475 \times 10^{-11}$ year^{-1}; atomic ratio $^{238}U/^{235}U = 137.88$.

Rb-Sr. The concentration of rubidium and strontium in whole-rock samples of the biotite-hornblende granodiorite, porphyritic biotite granodiorite and monzogranite, and biotite-muscovite monzogranite were determined by energy dispersive x-ray fluorescence. Strontium isotope ratios were determined on a 30.5 cm radius, 90°-sector mass spectrometer in Menlo Park, California, using a triple rhenium filament mode of ionization, automatic peak switching, and digital output. The $^{86}Sr/^{88}Sr$ ratios were normalized to 0.1194, and the $^{87}Sr/^{86}Sr$ ratios were further adjusted to an Eimer and Amend $SrCO_3$ value of 0.7080. Uncertainties in the rubidium and strontium concentrations and the $^{87}Sr/^{86}Sr$ ratios are about ± 1.0 and 0.008%, respectively. $\lambda(^{87}Rb) = 1.42 \times 10^{-11}$ year^{-1}.

K-Ar. A whole rock sample of olivine basalt was sized to less than 32 and greater than 64 mesh in Menlo Park, California. Potassium concentration was determined by flame photometry with a lithium internal standard. Argon concentration was determined by standard isotope dilution and mass spectrometry techniques described by Dalrymple and Lanphere (1969). Constants used are: $\lambda_\epsilon + \lambda'_\epsilon = 0.581 \times 10^{-10}$ year^{-1}, $\lambda_\beta = 4.92 \times 10^{-10}$ year^{-1}, and $^{40}K/K$ (total) $= 1.167 \times 10^{-4}$ mol/mol.

TABLE 2. Rb-Sr data for the Coxcomb granodiorite, Coxcomb Mountains, California (data from R. W. Kistler, 1981, written communication)

Sample no.	Location N latitude, W longitude	Rock description	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
03	33°53'22" 115°19'56"	biotite-hornblende granodiorite	62.9	805	0.226	0.70941
16	33°59'33" 115°24'35"	porphyritic granodiorite and monzogranite	126	515	0.708	0.71050
024	34°06'51" 115°31'31"	biotite-muscovite monzogranite	98.8	352	0.812	0.71171
GR175	34°05'40" 115°24'35"	biotite-muscovite monzogranite	150	323	1.34	0.71167

U-Th-Pb DATA

Four nonmagnetic size fractions of zircon from the biotite-hornblende granodiorite have greatly discordant U-Pb and Th-Pb dates that range from 122 to 744 m.y. (table 3). Pb-Pb dates are much older and range from 1119 to 1485 m.y. The coarsest zircon yields the oldest U-Pb date and acicular-shaped, finest-grained zircon yields the youngest date. Th-Pb dates also decrease with decreasing grain size. The U-Pb data define a very linear discordia that has a lower intercept with the concordia curve of 70 ± 1 m.y. (fig. 3). We interpret the 70 ± 1 m.y. date to be the time of crystallization of Late Cretaceous zircon and the emplacement age of the granodiorite.

The progressively older U-Pb and Th-Pb dates for coarser-grained zircon indicates a component of Proterozoic radiogenic lead and/or inherited zircon within the Late Cretaceous zircon. The amount of this inherited component increases as the size of the zircon increases, indicating that the coarse zircon contains a greater percentage of inherited material (Proterozoic seed crystals?) than the finer zircon, and/or that the seed crystals in the coarser zircon have lost less of their radiogenic lead to the Late Cretaceous magma than have the smaller seed crystals. The actual cause of the discordance and the significance of the upper intercept date are being investigated by the authors.

Sphene from the biotite-hornblende granodiorite has concordant U-Pb and Th-Pb dates of 75 m.y., but a slightly discordant Pb-Pb date of 84 m.y. Common lead corrections applied to the sphene dates (table 3) are the same as those used for the zircon (i.e. model lead isotopic ratios for 70

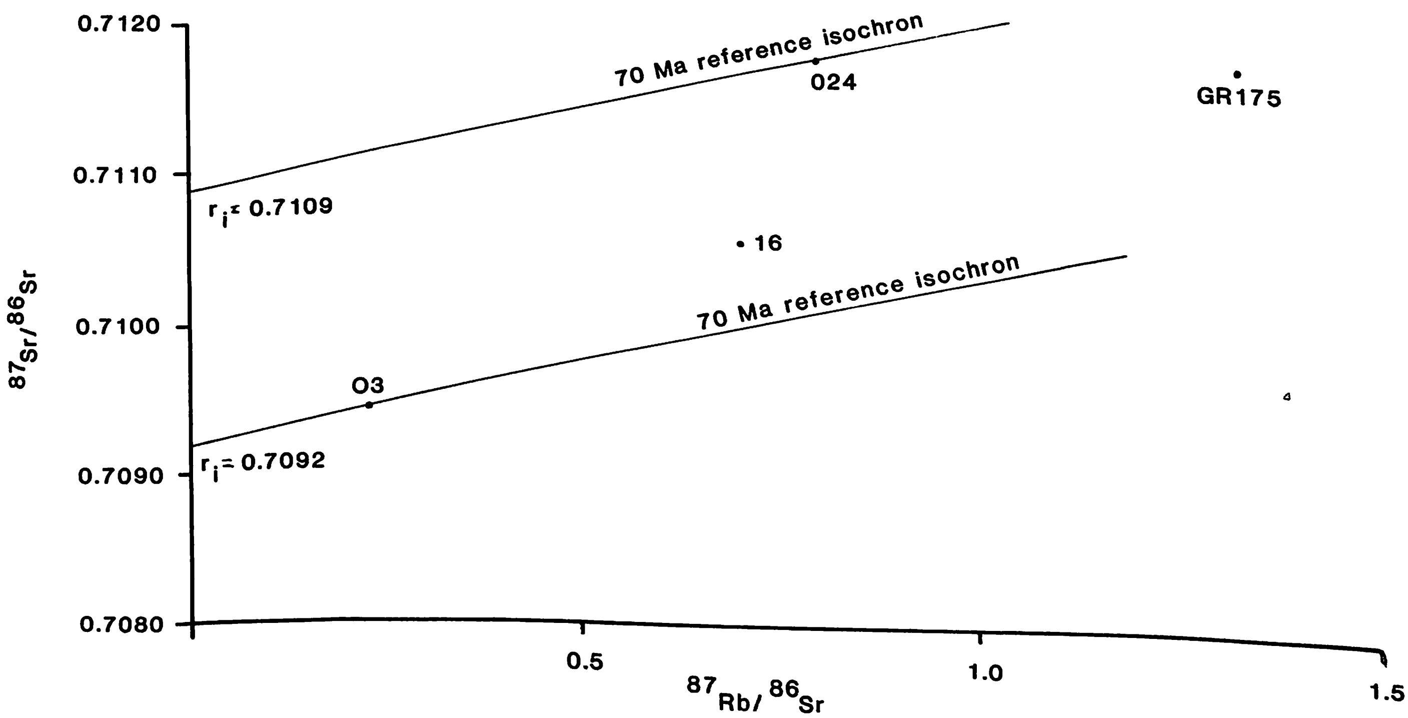

FIGURE 2. Plot of Rb-Sr isotopic data and calculated initial $^{87}Sr/^{86}Sr$ ratios (r_i) for the Coxcomb Granodiorite of Miller (1944).

TABLE 3. U-Th-Pb analytical data and age calculations for zircon and sphene from the biotite-hornblende granodiorite, Coxcomb Mountains, California.

Sample no.	Location N latitude, W longitude	Mineral	(mesh size)	U (ppm)	Th (ppm)	Pb (ppm)	Atomic composition of Pb[1] 204	206	207	208	Age (m.y.) $^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{208}Pb/^{232}Th$
79-1	33°53'13" 115°17'52"	zircon	(+100)	518.5	180.8	44.51	1	3605.46	348.74	287.68	522.4	744.0	1485.1	326.3
											522.8*	744.5*	1485.5*	330.5*
		zircon	(−100+150)	537.4	217.0	30.06	1	3128.11	293.77	299.17	341.2	520.9	1413.9	219.6
											341.5*	521.4*	1414.4*	222.2*
		zircon	(−250+325)	617.1	305.6	21.89	1	1749.75	158.74	222.61	212.4	328.4	1261.4	140.2
											212.7*	329.0*	1262.4*	142.6*
		zircon (acicular crystals)	(−200+250)	430.3	177.9	12.41	1	463.08	49.82	84.59	158.8	238.4	1119.5	122.0
											159.1*	239.3*	1125.3*	129.7*
		sphene		38.3	90.8	2.38	1	35.46	16.43	51.75	74.7	74.9	84.0	75.2

[1]Laboratory blank lead with isotopic composition $^{206}Pb/^{204}Pb$ = 18.7, $^{207}Pb/^{204}Pb$ = 15.6, $^{208}Pb/^{204}Pb$ = 38.2 removed. No common lead correction has been applied to these ratios.

Common lead correction used for zircon and sphene age calculations: $^{206}Pb/^{204}Pb$ = 18.567, $^{207}Pb/^{204}Pb$ = 15.624, $^{208}Pb/^{204}Pb$ = 38.503.

*Dates calculated using 1760 m.y. common lead corrections: $^{206}Pb/^{204}Pb$ = 15.646, $^{207}Pb/^{204}Pb$ = 15.3, $^{208}Pb/^{204}Pb$ = 35.279.

m.y. lower crust and mantle). Ideally, lead isotope ratios from co-existing potassium feldspar should be used for this correction. Also, the uncertainty in the age calculation for young sphene containing only 38 ppm uranium is about ± 3–4 m.y., greater than the uncertainty in the lower intercept for the zircon data. Because the sphene has a slightly discordant Pb-Pb date of 84 m.y., we believe that inheritance of Proterozoic radiogenic lead, as discussed above, is partially responsible for U-Pb and Th-Pb dates which are slightly older than the lower intercept age of 70 ± 1 m.y. defined by zircon.

Rb-Sr DATA

A plot of the strontium isotopic data from the three intrusive facies indicates a substantial variation in initial strontium isotopic ratios. Calculated initial ratios, based on the 70 m.y. age from the U-Pb and K-Ar data, vary from 0.7092 to 0.7109 (fig. 2). This variation may be caused by three different but nearly synchronous magmas with different initial strontium isotopic ratios, or by contamination of a granodiorite magma by Proterozoic material. Field, chemical, and the U-Th-Pb data suggests that the latter is the more likely case.

K-Ar DATA

Olivine basalt interbedded with fanglomerate deposits along the southwest side of the Coxcomb Mountains (fig. 1) yields a whole-rock K-Ar date of 4.5 ± 0.29 m.y. (table 1). The basalt and fanglomerate deposits dip 25°–40° southwest and are adjacent to a northwest-trending fault that cuts the McCoy Mountains Formation and the Coxcomb Granodiorite. Outcrops of the McCoy Mountains Formation are unknown west of this fault. The fault, part of the Sheep Hole fault zone of Hope (1966), is overlain by alluvial deposits that include an isolated outcrop of white, subhorizontal ash that correlates with the Bishop ash bed (A. M. Sarna-Wojoicki, 1982, written commun.; Merriam and Bischoff, 1975). Sanidine from the Bishop ash yields a K-Ar date of 0.75 m.y. (Dalrymple and others, 1965). The field and K-Ar data suggest: (1) the Sheep Hole fault zone is the western limit of known outcrops of the McCoy Mountains Formation; and (2) this fault was active in the last 4.5 m.y. and is older than the Bishop ash.

DISCUSSION

It is apparent from the U-Th-Pb and the Rb-Sr data that the Coxcomb Granodiorite either has been extensively contaminated by Proterozoic lead and strontium, or that the magma which crystallized to form the granodiorite actually was created from isotopically inhomogeneous Proterozoic crust. The U-Pb age calculations assumed that common lead incorporated into the magma during its formation had an isotopic composition of model upper mantle or lower crustal material at 70 m.y. If the magma actually was created from a 1760 m.y. protolith (the approximate age of the nearest dated Proterozoic crystalline rocks) that contained zircon—and that zircon did not lose all of its radiogenic lead to the magma—a much less radiogenic component of common lead could have been incorporated into the magma.

The second set of dates in table 3 indicate that even if 1760 m.y. material had melted to create the parent magma, the U-Pb dates would be at most 0.5% older. The resulting lower intercept of the discordia derived from such U-Pb dates would be 69 ± 1 m.y., indistinguishable from the 70 ± 1 m.y. date calculated above. Even if 1760 m.y.

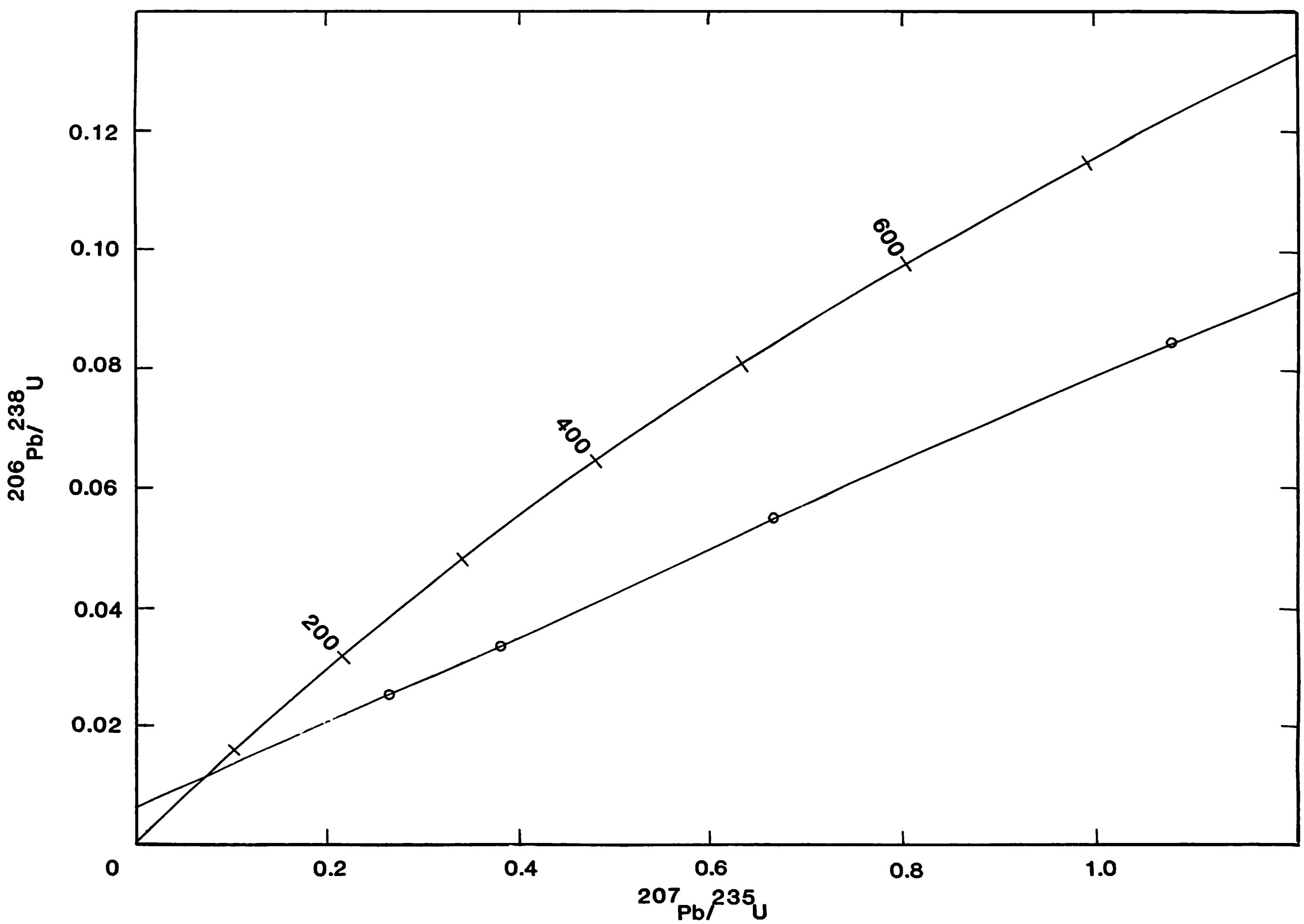

FIGURE 3. Concordia diagram for zircon from the biotite-hornblende granodiorite (spl. no. 79-1). Concordia intercepts at 70 ± 1 and 1580 ± 4 m.y.

zircon from such a lower crustal source had completely melted (which they have not, as witnessed by the pattern of discordancy) and liberated all their radiogenic lead, the lower intercept with concordia would be unaffected, as the discordia defined by the data is essentially a mixing line between 70 m.y. and Proterozoic zircon.

The U-Th-Pb data confirm the 70 m.y. age of the Coxcomb Granodiorite originally suggested by K-Ar dates, and preclude the 145 m.y. date reported by Calzia (1982b) based on Rb-Sr data. The granodiorite apparently was emplaced and cooled very quickly, as K-Ar biotite dates from fresh material (indicative of the time when the pluton cooled below 225°C) are identical to emplacement ages for the body. The undeformed granodiorite discordantly intruded the folded and foliated McCoy Mountains Formation, thereby indicating that this formation must be older than 70 m.y.

SAMPLE DESCRIPTIONS

1. *79-1* U-Pb
   Biotite granodiorite (33°53′13″N,115°17′52″W; Coxcomb Mountains 15′ quad., CA). Light gray, medium to coarse grained, generally massive (although Miller, 1944, describes a local poorly-developed foliation). *Mode* (in volume percent): 20.3% quartz; 18.7% perthitic potassium feldspar with inclusions of quartz and plagioclase; 48.8% andesine (An_{32-43}); 11.7% mafic minerals including biotite; 0.5% accessory minerals including zircon, sphene magnetite, and apatite. *Analytical data:* see table 3. *Collected by:* Ed DeWitt.

2. *03* Rb-Sr
   Biotite-hornblende granodiorite (33°53′22″N, 115°19′56″W; Coxcomb Mountains 15′ quad., CA).

Gray, medium grained. *Mode:* 18.4% quartz, 17.4% perthitic microcline with inclusions of quartz and plagioclase, 50.4% andesine (An_{35-43}), 12.3% mafic minerals including subhedral biotite with inclusions of sphene and an unidentified partially resorbed mineral with amphibole habit, and 1.5% accessory minerals including zircon, resorbed sphene, magnetite, and apatite. *Analytical data:* see table 2. *Collected by:* J. P. Calzia.

3. *16* Rb-Sr
Porphyritic monzogranite (33°59'33"N, 115°24'35"W; Coxcomb Mountains 15' quad., CA). Gray, medium grained; magmatic foliation expressed by alignment of biotite and by compositional layering of biotite, quartz, and microcline. Euhedral microcline phenocrysts include zones of plagioclase inclusions that are parallel to the edge of the phenocryst. *Mode:* 27.7% quartz, 23.6% microcline (in groundmass), 41.2% zoned andesine (An_{30-34}) with more calcic cores, 7.5% biotite, and trace amounts of zircon, magnetite, and apatite. *Analytical data:* see table 2. *Collected by:* J. P. Calzia.

4. *024* Rb-Sr
Biotite-muscovite monzogranite (34°06'51"N, 115°31'31"W; Dale Lake 15' quad., CA). Tan, fine to medium grained, equigranular. *Mode:* 29.6% quartz, 33.4% microcline, 41.3% zoned andesine (An_{34-38}) with cores altered to sericite, 2.5% mafic minerals including biotite and fine-grained euhedral muscovite, and 0.6% zircon. *Analytical data:* see table 2. *Collected by:* J. P. Calzia.

5. *GR 175* Rb-Sr
Biotite-muscovite monzogranite (34°05'40"N, 115°24'35"W; Cadiz Valley 15' quad., CA). *Mode:* not available, see Lee (1984) for major and trace element geochemistry. *Analytical data:* see table 2. *Collected by:* D. E. Lee.

6. *015* K-Ar
Olivine basalt: (33°55'53"N,115°23'55"W; Coxcomb Mountains 15' quad., CA). Gray, aphanitic, vesicular, massive. Sequence of multiple flows separated by sandy siltstone and mudstone interbeds. Sample collected just above lowermost interbed. *Analytical data:* see table 1. *Collected by:* J. P. Calzia.

(whole rock) 4.5 ± 0.29 m.y.

REFERENCES

Armstrong, R. L., and Suppe, John (1973) Potassium-argon geochronometry of Mesozoic igneous rocks in Nevada, Utah, and southern California: Geological Society America Bulletin, v. 84, p. 1375–1392.

Calzia, J. P. (1982a) Geology of granodiorite in the Coxcomb Mountains, southeastern California: Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada, Cordilleran Publishers, San Diego, p. 173–180.

_________ (1982b) Petrology and magmatic history of the Coxcomb granodiorite, Coxcomb Mountains, southeastern California: Geological Society of America Abstracts with Program, v. 14, p. 153.

Calzia, J. P., and Morton, J. L. (1980) Compilation of isotopic ages within the Needles 1° × 2° quadrangle, California and Arizona: U.S. Geological Survey open-file report 80-1303.

Calzia, J. P., Kilburn, J. E., Simpson, R. W., Jr., Allen, C. M., Leszcykowski, A. M., and Causcy, J. D. (1983) Mineral resource potential map of the Coxcomb Mountains Wilderness Study Area (CDCA-328), San Bernardino and Riverside Counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1603-A.

Dalrymple, G. B., Cox, Allan, and Doell, R. R. (1965) Potassium-argon age and paleomagnetism of the Bishop Tuff, California: Geological Society America Bulletin, v. 76, p. 665–674.

Dalrymple, G. B., and Lanphere, M. A. (1969) Potassium-argon dating: San Francisco, W. H. Freeman and Co., 258 p.

Harding, L. E., and Coney, P. J. (1985) The geology of the McCoy Mountains Formation, southeastern California and southwestern Arizona: Geological Society American Bulletin, v. 96, p. 755–769.

Hope, R. A. (1966) Geology and structural setting of the eastern Transverse Ranges, southern California: University of California, Los Angeles, Ph.D. thesis, 158 p.

Krogh, T. E. (1973) A low-contamination method for hydrothermal decomposition of zircon and extraction of U and Pb for isotopic age determinations: Geochimica et Cosmochimica Acta, v. 37, p. 485–494.

Lee, D. E. (1984) Analytical data for a suite of granitoid rocks from the Basin and Range province: U.S. Geological Survey Bulletin 1602, 54 p.

Merriam, Richard, and Bischoff, J. L (1975) Bishop Ash: A widespread volcanic ash extended to southern California: Journal Sedimentary Petrology, v. 45, p. 207–211.

Miller, F. K., and Morton, D. M. (1980) Potassium-argon geochronology of the eastern Transverse Ranges and southern Mojave Desert, southern California: U.S. Geological Survey Professional Paper 1152, 30 p.

Miller, W. J. (1944) Geology of the Palm Springs-Blythe strip, Riverside County, California: California Journal of Mines and Geology, v. 40, p. 11–72.

Steiger, R. H., and Jager, E. (1977) Subcommission on geochronology: convention and use of decay constants in geo- and cosmochronology: Earth and Planetary Science Letters, v. 36, p. 359–362.