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POTASSIUM-ARGON DATES AND STRONTIUM ISOTOPIC VALUES FOR ROCKS OF THE TOBACCO ROOT BATHOLITH, SOUTHWESTERN MONTANA

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This report presents new potassium-argon mineral dates and rubidium-strontium whole-rock isotopic data for rocks of the Tobacco Root batholith in Madison and Jefferson Counties, Montana. These studies are part of a continuing investigation of the igneous and metamorphic rocks of the Tobacco Root Mountains by the Department of Geology, Indiana University (Vitaliano and others, 1979). Samples were collected by Robert Methot. Potassium-argon analyses were performed in the Mobil Research and Development Corporation laboratory at Dallas, Tex., and the Department of Geology, Florida State Univ. Samples for rubidium-strontium studies were analyzed at the Department of Geology, Univ. of North Carolina at Chapel Hill.

Argon concentrations were determined by standard isotope dilution techniques. Potassium analyses were performed by atomic absorption (M.R.D.L.) and flame photometry (F.S.U.). Techniques utilized for rubidium-strontium analyses are described in Fullagar and Butler (1979). The uncertainty in reported ages (± 3%) represents only the estimated analytical uncertainty at one standard deviation. Constants used for age calculations are: $\lambda_\epsilon\ ^{40}K = 0.581 \times 10^{-10}\ yr^{-1}$; $\lambda_\beta\ ^{40}K = 4.962 \times 10^{-10}\ yr^{-1}$; $^{40}K/K_{total} = 1.167 \times 10^{-4}$ mole/mole; $\lambda\ ^{87}Rb = 1.42 \times 10^{-11}\ yr^{-1}$.

GEOLOGIC DISCUSSION

The Tobacco Root batholith is a concentrically zoned or composite body containing six distinct units ranging from diorite and tonalite to granite. The batholith is emplaced within a highly metamorphosed series of Archean gneisses which form the core of the Tobacco Root Mountains. Contacts between the intrusion and country rocks are sharp and associated with a relatively narrow zone of pyroxene hornfels contact metamorphism. Other than local shearing and deuteric(?) alteration, rocks of the batholith do not exhibit significant post-intrusive thermal or deformational effects.

Previous investigators have considered the Tobacco Root batholith to be a satellite body of the larger Boulder batholith exposed 25 km to the northwest. Giletti (1966) reported K-Ar biotite dates of 76 and 54 m.y. (values recalculated to present decay constants) for the quartz monzonite unit of the Tobacco Root batholith. The 54 m.y. age was from an analysis with a low radiogenic argon content (29%) and may be erroneous. The 76 m.y. date is approximately the same as those reported for the main phase of the Boulder batholith by Tilling and others (1968).

Results of the present study are somewhat problematical in establishing a temporal relationship between the two batholiths. Biotite K-Ar dates from several different units of the Tobacco Root batholith yield values (77–72 m.y.) similar to those of the Boulder batholith. However, coexisting hornblende from two of these samples (MHD-4, HD-4) yield significantly older dates (125, 118 m.y.). Discordance between the K-Ar dates of coexisting biotite and hornblende suggests two possible interpretations for the age of intrusion:

1. Hornblende dates reflect the actual age of intrusion; biotite, being more sensitive to Ar loss by thermal effects, has been partially or completely reset by a later thermal event. The resetting may have been associated with a later intrusion near the core of the batholith. Several intrusive bodies in this portion of Montana were emplaced in this age range; these include a syenite unit (106 ± 6 m.y., K-Ar biotite) of the Sand Creek sill in the nearby Sappington Canyon (Daugherty and Vitaliano, 1969), a sill (103 m.y., K-Ar hornblende) in Squaw Creek of Madison Valley (R. A. Chadwick, personal communication) and a dike (120 m.y., K-Ar hornblende) near Niehart, Montana (Catanzaro and Kulp, 1962). Evidence of early Cretaceous igneous activity is also suggested by the presence of volcanic cobbles in the Kootenai Formation in the Sun River area (Mudge and Sheppard, 1968).

2. An alternate interpretation would be that hornblende dates are too old due to the presence of excess ^{40}Ar; biotite dates would reflect the true age of intrusion. Due to the limited number of samples it was not possible to test for excess ^{40}Ar by the K-Ar isochron method (Hayatsu and Carmichael, 1970). A simple evaluation of the slope ($\Delta\ {}^{*40}Ar/\Delta$ K%) for the two samples yields a value of 76 m.y. nearly identical to that of biotite dates. Since both samples were collected near the border of the batholith, excess ^{40}Ar may have been incorporated in hornblende by the degassing of near-by country rock.

Attempts to determine the age of the Tobacco Root batholith by Rb-Sr whole-rock dating were unsuccessful due to the limited range of $^{87}Rb/^{86}Sr$ and the scatter of data when evaluated by the isochron method (Fig. 1). Analytical data is presented in Table 1. The observed variations in $^{87}Sr/^{86}Sr$ are too large to be accounted for by radioactive decay. Different portions of the batholith have different $^{87}Sr/^{86}Sr$ initial ratios, either due to different magma sources, or perhaps more likely, varying degrees of contamination by country rock. The relatively low $^{87}Sr/^{86}Sr$ values suggest the batholith was not derived by melting of the surrounding upper crustal Archean crystalline complex, but must have been derived from a more primitive source, perhaps the lower crust.

CONCLUSIONS

K/Ar data on biotite from rocks of the zoned Tobacco Root batholith of southwestern Montana indicate that it cooled at between 77 and 72 million years ago thus suggesting contemporaneity with emplacement of the nearby

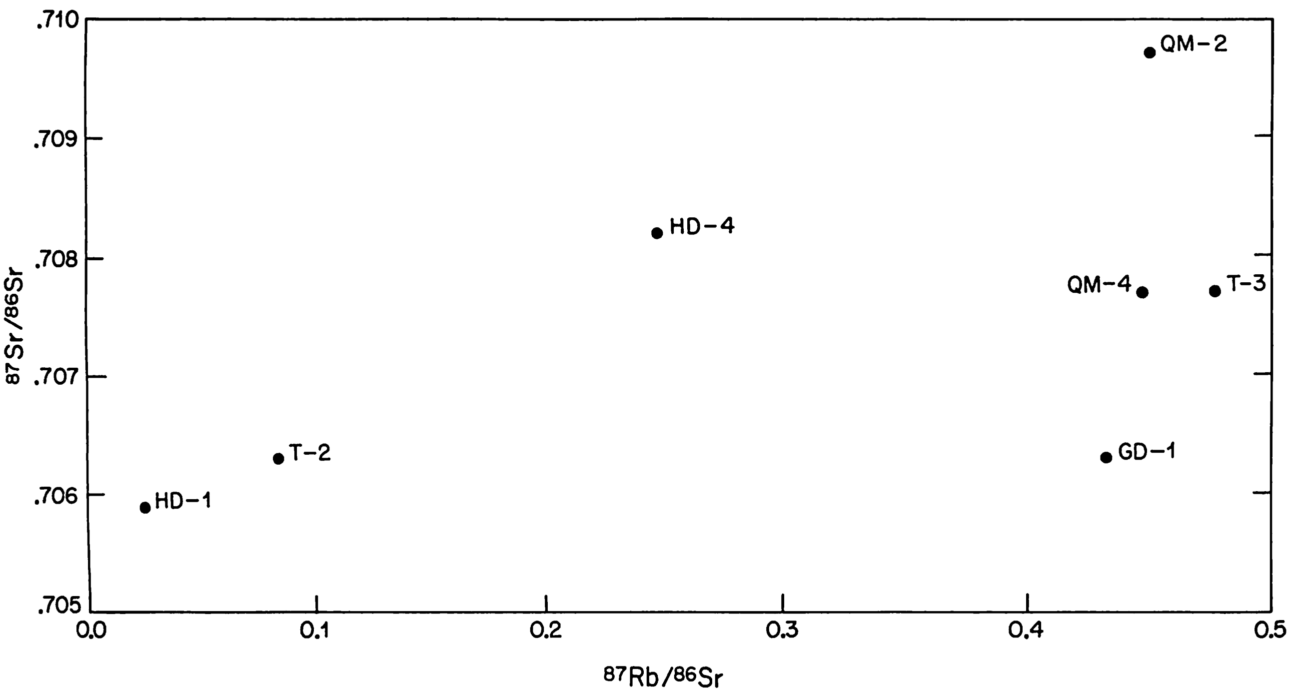

FIGURE 1. Rb and Sr isotopic data for Tobacco Root batholith samples.

Table 1. Rb-Sr isotopic data for rocks of the Tobacco Root batholith.

Sample	Latitude/ Longitude	Rock type	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
HD-1	45°36'04"N 111°47'56"W	Biotite hornblende diorite	16.2	1885.0	.025	0.7059
HD-4	45°38'52"N 111°54'57"W	Biotite hornblende granodiorite	48.5	565.9	.248	0.7082
T-2	45°32'19"N 111°59'53"W	Tonalite	43.4	1478.0	.085	0.7063
T-3	45°33'38"N 112°01'37"W	Tonalite	111.3	676.0	.476	0.7077
GD-1	45°36'06"N 111°53'52"W	Granodiorite	129.1	860.3	.434	0.7063
QM-2	45°31'59"N 111°46'04"W	Quartz monzonite	137.1	881.2	.450	0.7097
QM-4	45°33'46"N 111°46'04"W	Quartz monzonite	113.6	734.6	.447	0.7077

late Cretaceous Boulder batholith. K/Ar determinations on hornblende from some of the same rocks near the batholith's perimeter yield dates of 118 and 125 m.y.,—dates that we feel are the result of entrapment of excess argon by hornblende. The hornblende dates from the rocks in the pluton are much higher than K/Ar data obtained on hornblende from associated hypabyssal intrusives of mafic to intermediate composition within this region, which, on the basis of direct field evidence, are older than the plutonic rocks. The hornblende dates of the hypabyssal rocks (i.e. ca. 100 m.y.) are corroborated by K/Ar determinations on similar rocks as well as field data elsewhere in southwestern Montana and may record the time of igneous activity inception in this petrographic province.

SAMPLE DESCRIPTIONS

1. *MHD-4* K-Ar
Biotite-hornblende granodiorite (S24,T2S,R3W; 45° 38'52"N, 111°54'57"W; MT). A fine to medium-grained granitoid rock, with a hypidiomorphic texture and high color index. Composed of plagioclase, perthite, quartz, hornblende, and biotite with minor amounts of magnetite-ilmenite, sphene, apatite, zircon, and secondary calcite which is usually restricted to plagioclase. The rock is exceptionally fresh with only minor sericitization of plagioclase and chloritization of biotite. Other than undulatory extinction of quartz, the rock exhibits no evidence of later deformation or metamorphism. *Analytical data*: (hornblende), K = 0.639, $^{*40}Ar = 1.444 \times 10^{-10}$, 1.429×10^{-10}, 1.428×10^{-10} moles/gm., $^{*40}Ar/\Sigma^{40}Ar$ = 81.9%, 81.4%, 82.4%; (biotite), %K = 6.30, $^{*40}Ar = 8.488 \times 10^{-10}$, 8.615×10^{-10} moles/gm., $^{*40}Ar/\Sigma^{40}Ar$ = 90.1%, 85.0%. *Dated by*: Mobil Research & Development Corp.
(hornblende) 125 ± 4 m.y.
(biotite) 77 ± 2 m.y.

2. *HD-4* K-Ar
Biotite-hornblende diorite (S24,T2S,R3W; 45°38' 52"N, 111°54'57"W; MT). A medium to coarse-grained rock with a hypidiomorphic texture. Principle minerals are hornblende and plagioclase with lesser amounts of biotite and minor quartz, magnetite-ilmenite, and apatite. *Analytical data*: (hornblende) %K = 0.758, $^{*40}Ar = 1.601 \times 10^{-10}$ moles/gm., $^{*40}Ar/\Sigma^{40}Ar$ = 80.7%; (biotite), %K = 5.40, $^{*40}Ar = 6.908 \times 10^{-10}$ moles/gm., $^{*40}Ar/\Sigma^{40}Ar$ = 89.5%. *Dated by*: Florida State Univ.
(hornblende) 118 ± 4 m.y.
(biotite) 72 ± 2 m.y.

3. *MGD-6* K-Ar
Biotite granodiorite (S23,T2S,R3W; 45°38'37"N, 111° 56'28"W; MT). A gray, medium-grained, equigranular rock composed of plagioclase, quartz, perthitic microcline, and biotite, with minor magnetite-ilmenite, sphene, hornblende, epidote, and apatite. Olivine-green biotite is present in large well-formed books and as paler fine-grained aggregates, possibly formed by replacement of hornblende. Alteration is minor, calcite occurs in veinlets, and quartz-chlorite veinlets fill apparent tension fractures. Quartz is highly strained and locally biotite has kink bands. These features suggest post-crystallization shearing. *Analytical data*: (biotite) %K = 6.67, $^{*40}Ar = 8.842 \times 10^{-10}$, 8.958×10^{-10} moles/gm., $^{*40}Ar/\Sigma^{40}Ar$ = 80.9%, 79.2%. *Dated by*: Mobil Research and Development Corp.
(biotite) 75 ± 2 m.y.

4. *MQM-2* K-Ar
Granodiorite (S31,T3S,R1W; 45°31'59"N, 111°46' 04"W; MT). A light gray, medium-grained, porphyritic rock. Phenocrysts and groundmass both have hypidiomorphic to idiomorphic habit. Quartz, perthite, and plagioclase are major minerals in both phenocrysts and groundmass. The groundmass also contains lesser amounts of biotite, hornblende, magnetite-ilmenite, sphene, epidote, apatite, zircon, and tourmaline. Minor amounts of fine clay-mica are present as an alteration product after plagioclase, and may be due to weathering. Undulose extinction of quartz and bent plagioclase grains suggest some post-crystallization deformation. *Analytical data*: (biotite), %K = 7.10, $^{*40}Ar = 9.083 \times 10^{-10}$, 9.301×10^{-10} moles/gm., $^{*40}Ar/\Sigma^{40}Ar$ = 86.2%, 84.3%. *Dated by*: Mobil Research and Development Corp.
(biotite) 73.2 ± 2 m.y.

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