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GEOCHRONOLOGY OF POST-EOCENE RHYOLITIC AND BASALTIC VOLCANISM IN SOUTHWESTERN MONTANA

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Many previous and current studies emphasize the importance of Eocene volcanism in southwestern Montana (Smedes and Thomas, 1965; Chadwick, 1970; Lipman and others, 1972), but post-Eocene volcanism has not been well delineated except for the Plio-Pleistocene activity originating in the Island Park-Yellowstone caldera complex (Christiansen and Blank, 1972). The purpose of this paper is to present new K-Ar radiometric data for post-Eocene volcanics, relate these to previously published age dates, and offer some preliminary suggestions regarding the nature and scope of post-Eocene volcanism in southwestern Montana.

Volcanic deposits interpreted as post-Eocene, or post-40 m.y., on stratigraphic or radiometric evidence are plotted on figure 1, along with locations and ages of radiometrically dated samples. Most such deposits are rhyolitic or basaltic. Dating of andesitic rocks has, on the other hand, thus far yielded principally Eocene or older dates. Spatially extensive, petrographically similar rhyolitic or basaltic deposits are informally grouped into "volcanic fields" where believed deposited during one volcanic episode.

Radiometric analyses reported under this study (see "Sample Descriptions" below) were financed under Grant No. 14-08-0001-G-334 from the U.S. Geological Survey under its Extramural Geothermal Research Program.

RHYOLITIC VOLCANISM

Helena Volcanic Field. In the region around Helena, which encompasses the northern part of the Boulder batholith and areas north and northwest of it, numerous rhyolitic bodies transect or overlie Lowland Creek (Eocene) volcanics (Knopf, 1963; Ruppel, 1963; Smedes, 1966). K-Ar dates (fig. 1) suggest that much, but not all, rhyolite in this region is Early Oligocene. Dates obtained under this study are 36.9 m.y. for a porphyritic quartz-sandine-plagioclase rhyolite at Mullan Pass and 35.8 m.y. on quartz-sandine rhyolite from Lava Mountain east of Alhambra. Earlier work by Ratcliff obtained an age of 37.3 m.y. from rhyolites on Hope Creek north of Mullan Pass (Blackwell and others, 1975). Dates of 40 m.y. on a quartz porphyry stock and 37 m.y. from quartz porphyry dikes and sills were obtained from the nearby Marysville area and may represent correlative intrusive phases (Blackwell and others, 1975). North trending rhyolite dikes at Butte (Meyer and others, 1968) date at 40 m.y., suggesting extension of this igneous province considerably to the south. Tuffaceous sediments of Early Oligocene age are abundant in the Townsend Valley east of the Helena field (Freeman and others, 1958) and may represent volcaniclastic time equivalents.

Beaverhead Field. Plagioclase-bearing red and gray rhyolites crop out along the narrows of the Beaverhead River 20 km southwest of Dillon. Plagioclase phenocrysts from a glassy zone date at 38.9 m.y. (fig. 1). These rhyolites grade into Oligocene tuffs to the north (Lowell, 1965) and probably to the southeast in the Blacktail Range (Cook Ranch volcanics of Scholten and others, 1955).

Crater Mountain Field. A rhyolitic vent complex on Crater Mountain and related ash flows were mapped by Melson (1971). Sanidine from the ash flow unit, which lies on top of an older latitic sequence, yields a K-Ar date of 27.8 m.y. A rhyolitic welded tuff near Drummond 60 km southwest of the Crater Mountain field dates at 29 m.y. by the fission-track method (R. W. Fields, oral commun., 1978). The tuff is overlain by Early Miocene sediments and probably had its source to the northeast (Rasmussen 1969). Evidence thus suggests that rhyolitic volcanism erupted in this region in Late Oligocene time as a phase distinctly younger than that of the nearby Helena field.

Northeastern Pioneer Range. A trachyandesite about 3 km west of the town of Divide and 35 km southwest of Butte yields a whole-rock K-Ar date of 20.5 m.y. (E-an Zen, written commun., 1976). This rock contains 66% SiO_2 and may indicate less silicic volcanism as compared to other districts described in this section.

Avon Field. Gray to pink rhyolitic flows containing clear, fresh sanidine and dark gray quartz phenocrysts crop out in the Little Blackfoot Valley near Avon and Elliston. Sanidine yields a K-Ar date of 19.6 m.y. These rhyolites lie within the valley at a considerably lower elevation than those of the Helena field to the east, which lie largely on the Continental Divide. The Avon rhyolites rest unconformably on undated andesitic rocks.

Upper Madison Field. Rhyolitic welded tuff blankets portions of the Upper Madison Valley and the adjacent southeastern Gravelly Range. The most extensive unit petrographically resembles the 1.9 m.y. old Huckleberry Ridge Tuff of Christiansen and Blank (1972) and yields similar dates of 1.9 and 2.0 m.y. in two places (fig. 1). Petrographically similar welded tuffs crop out in the Gallatin Canyon (Walsh, 1971) and in the eastern Gallatin Range (Todd, 1969). Since the Huckleberry Ridge Tuff originated in the Island Park-Yellowstone caldera complex (Christiansen and Blank, 1972), it must have spread very widely, depositing on surfaces which are now as high as 2900 m above sea level in the Gallatin Range. An alternative hypothesis is that some of the tuff originated from more local Montana sources.

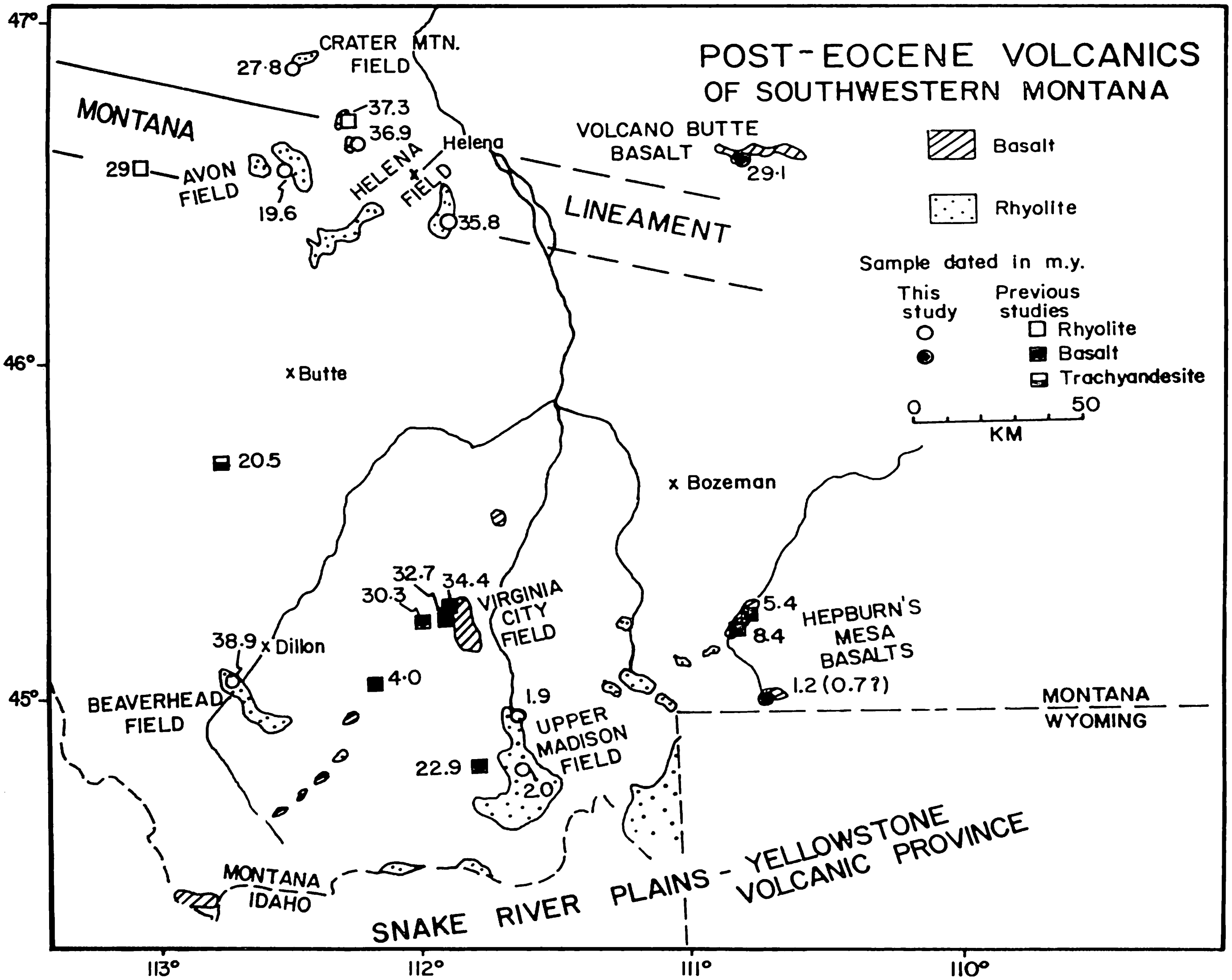

FIGURE 1. Distribution of post-Eocene (post- 40 m.y.) volcanic rocks of southwestern Montana from geologic and radiometric information. Age dates and sample localities are shown.

BASALTIC VOLCANISM

Virginia City Field. Marvin and others (1974) dated 3 basalts in the Virginia City-Alder area as 34.4, 32.7, and 30.3 m.y. The oldest date was estimated as ± 3 m.y., so that all three samples might represent a single volcanic episode about 32–31 m.y. ago.

Volcano Butte. A basalt flow from the Volcano Butte vent complex 13 km northeast of White Sulphur Springs yields a whole rock K-Ar date of 29.1 m.y. The rock is slightly chloritized, and some vesicles are filled, introducing some uncertainty as to the reliability of the date.

Gravelly Range. The Black Butte basaltic plug was emplaced 22.9 m.y. ago (best K-Ar date, Marvin and others, 1974).

Hepburn's Mesa. Two basalt flows in the Upper Yellowstone Valley at Hepburn's Mesa yield whole rock K-Ar dates of 8.4 and 5.4 m.y. and are paleomagnetically normal and reversed, respectively (Chadwick, 1969). Basaltic activity here evidently preceded the main Snake River Plains-Yellowstone volcanism which was migrating northeastward with time and reached the Yellowstone National Park area in the Quaternary (Christiansen and Lipman, 1972).

Sweetwater Canyon. Samples of a basalt flow in Sweetwater Canyon 35 km southeast of Dillon were dated by the whole rock K-Ar method at 4.2 and 3.8 m.y. by Marvin and others (1974). This basalt may correlate in part with basalt flows to the southwest in the Blacktail Creek-Sage Creek area mapped by Scholten and others (1955). Such basalts may represent fringe activity of the Snake River Plains volcanism.

Gardiner area. Basalt from a sequence of flows 1 km northeast of Gardiner has been dated by the whole rock K-Ar method at 1.2 ± 0.6 m.y. Since these flows are paleomagnetically normal, the lower end of this range, 0.6 to 0.7 m.y., seems the most reasonable age. The relationship of these flows to basalts in Yellowstone National Park is uncertain.

SUMMARY

Figure 2 summarizes current radiometric information on volcanic activity in southwestern Montana since 40 m.y. ago. Rhyolitic and basaltic episodes appear common, but present evidence does not support a concept of contemporaneous bimodal volcanism within the individual districts. Thus far no volcanics date in the 19–9 m.y. range, but significance is uncertain. Post-9 m.y. volcanism is concentrated near the Snake River Plains–Yellowstone province.

Rhyolitic volcanism has evidently recurred more than once along the Montana Lineament zone (Helena, Crater Mountain, Drummond, and Avon deposits). The Lineament (fig. 1) represents a major crustal discontinuity (Weidman, 1965) and marks the northern boundary of the Southwestern Montana crystalline province. In addition to the information shown on figure 1, Late Eocene dates were obtained on a rhyolite (44.5 m.y.) and on two basalts (46.7 and 44.9 m.y.) from the Lineament zone 15–25 km northwest of the Drummond sample (Williams, 1975). An eastward extension of the Lineament (dashed lines on fig. 1) passes near the Volcano Butte basalt. Reynolds (1977) postulates that late Cenozoic movement on the Lineament extended the crustal block south of it, allowing development of Basin and Range type fault block valleys such as the Smith River, Townsend, and Helena grabens. The Lineament needs study as a locus of rhyolitic and basaltic activity in post-Eocene (and perhaps late Eocene) time. The relationship of this volcanism to block faulting also needs investigation.

A Late Cenozoic change in the Basin and Range province proper from dominantly andesite to dominantly basalt and basalt-rhyolite volcanism took place due to a shift in tectonism from compressional to extensional (Christiansen and Lipman, 1972). A similar change in nature of volcanism appears to have taken place in southwestern Montana, albeit somewhat earlier, about 40 m.y. ago. Perhaps extensional tectonism was underway there by 40 m.y. ago, resulting in subsidence of sedimentary basins (Kuenzi and Fields, 1971) which evolved into the Basin and Range-type fault block terrain of present-day southwestern Montana (Pardee, 1950). More radiometric studies are needed in the region, including dating of andesitic rocks to see whether they are indeed uncommon in post-Eocene deposits.

SAMPLE DESCRIPTIONS

1. *CC-3 (Geochron No. F-3871)* K-Ar

Black glassy rhyolite porphyry, in brecciated zone above tuff; fresh clear to milky plagioclase crystals; some quartz; glass isotropic; (45°06′58″N, 112°45′08″W; SW/4 SE/4 S19,T8S,R9W; roadcut on old Hwy. 91, W bank Beaverhead River, Beaverhead Co., MT). *Analytical data:* K = 2.274%, $*Ar^{40}$ = 0.006373 ppm, $*Ar^{40}/\Sigma Ar^{40}$ = 38%. *Collected by:* R. A. Chadwick; *dated by:* Geochron Laboratories, Inc.

(plagioclase) 38.9 ± 1.7 m.y.

2. *MP-1 (Geochron No. F-4133)* K-Ar

Light-gray porphyritic rhyolite; dark-gray quartz, iridescent sanidine, and plagioclase phenocrysts (46°39′28″N, 112°19′10″W; SE/4 SW/4 S35,T11N,R6W; top of hill 1.8 km N of Mullan Pass, Lewis and Clark Co., MT). *Analytical data:* K = 4.905%, $*Ar^{40}$ = 0.01305 ppm, $*Ar^{40}/\Sigma Ar^{40}$ = 28%. *Collected by:* R. A. Chadwick; *dated by:* Geochron Laboratories, Inc.

(sanidine) 36.9 ± 1.5 m.y.

3. *LM-1 (Geochron No. F-3643)* K-Ar

Light-gray rhyolite porphyry, clear, iridescent sanidine and dark-gray quartz phenocrysts (46°25′13″N, 111°53′20″W; SW/4 S29,T8N,R2W; SE slope Lava Mountain, 9 km SE of Clancy, Jefferson Co., MT). *Analytical data:* K = 7.785%, $*Ar^{40}$ = 0.02007 ppm, $*Ar^{40}/\Sigma Ar^{40}$ = 42%. *Collected by:* R. A. Chadwick; *dated by:* Geochron Laboratories, Inc.

(sanidine) 35.8 ± 1.4 m.y.

4. *AVCM-1 (Geochron No. F-3870)* K-Ar

Pink rhyolitic ash-flow tuff, fresh sanidine, quartz, and plagioclase crystals, lithic fragments, brown glass shards in matrix (46°55′32″N, 112°30′17″W; E/2 S32,T14N, R7W; summit of Crater Mountain, 0.7 km SE of rhyolitic vent, Lewis and Clark Co., MT). *Analytical data:* K = 5.539%, $*Ar^{40}$ = 0.01069 ppm, $*Ar^{40}/\Sigma Ar^{40}$ = 45%.

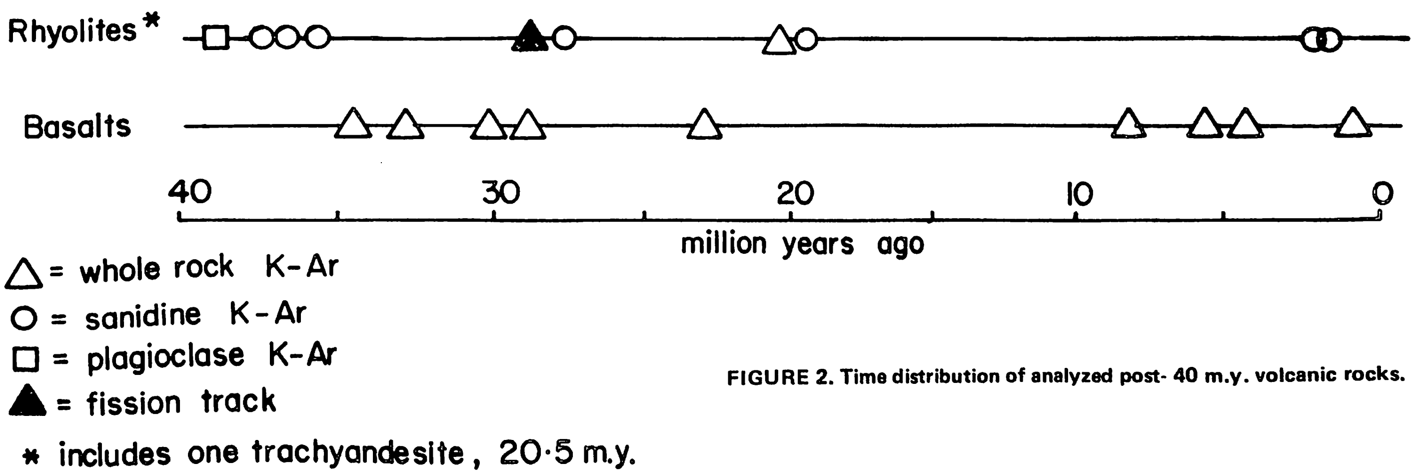

FIGURE 2. Time distribution of analyzed post- 40 m.y. volcanic rocks.

4. (continued)
Collected by: R. A. Chadwick; *dated by:* Geochron Laboratories, Inc.

(sanidine) 27.8 ± 1.1 m.y.

5. *AV-7 (Geochron No. F-3869)* K-Ar
Gray and red rhyolite porphyry with fresh sanidine and dark-gray quartz phenocrysts and minor hematitized biotite (46°35'39"N, 112°34'45"W; NE/4 NE/4 S27, T10N,R8W; roadcut, Hwy. 12, 1.5 km E of Avon, Powell Co., MT). *Analytical data:* K = 7.357%, $*Ar^{40}$ = 0.01033 ppm, $*Ar^{40}/\Sigma Ar^{40}$ = 18%. *Collected by:* R. A. Chadwick; *dated by:* Geochron Laboratories, Inc.

(sanidine) 19.6 ± 0.8 m.y.

6. *FM-1 (Geochron No. F-4052)* K-Ar
Gray rhyolitic ash-flow tuff, lath-shaped sanidine and plagioclase crystals, some quartz (44°50'27"N, 111°38' 45"W; SW/4 SE/4 S30,T11S,R1E; NE slope Flatiron Mountain, Madison Co., MT). *Analytical data:* K = 5.850%, $*Ar^{40}$ = 0.000837 ppm, $*Ar^{40}/\Sigma Ar^{40}$ = 16%. *Collected by:* G. J. Weinheimer; *dated by:* Geochron Laboratories, Inc.

(sanidine) 2.0 ± 0.1 m.y.

7. *WC-2 (Geochron No. F-3644)* K-Ar
Purple streaked rhyolitic ash-flow tuff, clear sanidine and quartz, some plagioclase, flattened lithic fragments (44°59'33"N, 111°39'45"W; SE/4 NE/4 S1,T10S,R1W; cliff face on W bank Madison River 2 km N of mouth Wall Canyon, Madison Co., MT). *Analytical data:* K = 6.888%, $*Ar^{40}$ = 0.000945, $*Ar^{40}/\Sigma Ar^{40}$ = 17%. *Collected by:* R. A. Chadwick; *dated by:* Geochron Laboratories, Inc.

(sanidine) 1.9 ± 0.1 m.y.

8. *VB-1* K-Ar
Black basalt, a few altered olivine phenocrysts, most clinopyroxene fresh but some chloritized, matrix crystalline, fresh-appearing clinopyroxene, lathlike plagioclase, and opaques, some calcite vesicle fillings (46°37'12"N, 110°44'48"W; NE/4 S20,T10N,R8E; roadcut, U.S. Hwy. 12 at W edge Lake Sutherlin, flow from Volcano Butte vent; Meagher Co., MT). *Analytical data:* K = 1.015%, $*Ar^{40} = 1.19 \times 10^{-6}$ cc/gm; $*Ar^{40}/\Sigma Ar^{40}$ = 83%. *Collected by:* R. A. Chadwick; *dated by:* R. L. Armstrong, U.B.C. *Comment:* Matrix appears fresh but due to mild alteration of larger crystals and presence of some calcite vesicle fillings, age may be slightly older than indicated.

(whole-rock) 29.1 ± 1.0 m.y.

9. *G-1* K-Ar
Black nonporphyritic basalt, columnar jointed, olivine, plagioclase, and pyroxene, locally vesicular but vesicles not filled (45°02'27"N, 110°41'51"W; NE/4 NE/4 S23, T9S,R8E; on roadcut on Phelps Creek, 1.0 km NE of Gardiner, Park Co., MT). *Analytical data:* K = 0.326%, $*Ar^{40}$ = 1.52 cc/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 1.2%. *Collected by:* E. M. Struhsacker; *dated by:* R. L. Armstrong, U.B.C. *Comment:* This basalt is paleomagnetically normal and may be about 0.6 to 0.7 m.y. old.

(whole-rock) 1.2 ± 0.6 m.y.

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