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POTASSIUM-ARGON AGES OF BORING LAVA, NORTHWEST OREGON AND SOUTHWEST WASHINGTON

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INTRODUCTION

We report here on potassium-argon (K-Ar) ages of chiefly basalt and basaltic andesite lava flows from the Portland basin and the Columbia River Gorge (fig. 1). Mafic lavas that overlie the Columbia River Basalt Group in this part of Oregon and Washington have been referred to as the Boring Lava (Treasher, 1942; Trimble, 1963; Allen, 1975; Beeson and others, 1989, 1991; Madin, 1994). Until our work, few K-Ar ages were reported from the Boring Lava, and thus few constraints were available to date the late Neogene structural evolution of the Portland basin and Columbia River Gorge. Our interest is also directed toward the petrologic evolution of the Boring Lava and its relationship to the tectonic evolution of the Portland basin.

PROCEDURES

K-Ar sample preparation and analyses were conducted at the Geological Survey of Japan (GSJ) in Tsukuba, Japan. Whole-rock samples were crushed to between 10- and 16-mesh and then bathed in an ultrasonic distilled water bath to remove adhering dust. Approximately ten grams of sample were fused; ^{38}Ar spikes were introduced from a spike reservoir. The reservoir was calibrated during the course of the experiments by repeated analyses of standard biotite JG-1 (Uto and others, 1995).

Potassium analyses on powdered splits were performed with flame photometry using internal Li standards to improve precision (Matsumoto, 1989). The pooled one sigma error in K_2O determinations at GSJ is 0.5 percent. Argon analyses were made by standard isotope dilution procedures as described by Dalrymple and Lanphere (1969). Automation and control of the mass spectrometer at the GSJ with a personal computer, combined with digital data collection, significantly reduced analytical errors (Uto and others, 1995).

Potential sources of total analytical error were thoroughly evaluated. The reported one sigma error in age includes contributions from errors in determining spike volumes, atmospheric air ratios, and potassium concentrations, least squares fitting of the $^{38}Ar/^{36}Ar$ and $^{40}Ar/^{36}Ar$ ratios, and errors due to poor radiogenic yields.

We established the magnetic polarity of most sampled lavas with a fluxgate magnetometer. Because of the relative youth and unaltered nature of the Boring Lava, the measured magnetic polarity is likely the thermal remnant magnetization (TRM) acquired during cooling.

RESULTS

The new ages and analytical data are presented in table 1. Approximate locations are shown in figure 1; map numbers are keyed to table 1. Duplicate experiments were performed on two samples (map Nos. 5 and 6); weighted mean ages for those samples are reported below (see Sample Descriptions). Samples 6 and 7 appear to be correlative (based on unpublished chemical data of the authors), and both are stratigraphically beneath sample 5.

Sample 8 from drill core is similar stratigraphically, chemically, and petrographically to sample 12 from roadcut. The ages of these two samples overlap within analytical error because of the large error associated with sample 8. The weighted mean age for this stratigraphic horizon is 1.54 ± 0.16 Ma.

CORRELATION WITH MAGNETIC TIME SCALE

Overall, good agreement was found between the new ages and the magnetic time scale (fig. 2). The reversed polarity of sample 6 and average age of correlative samples 6 and 7 are consistent with their eruption

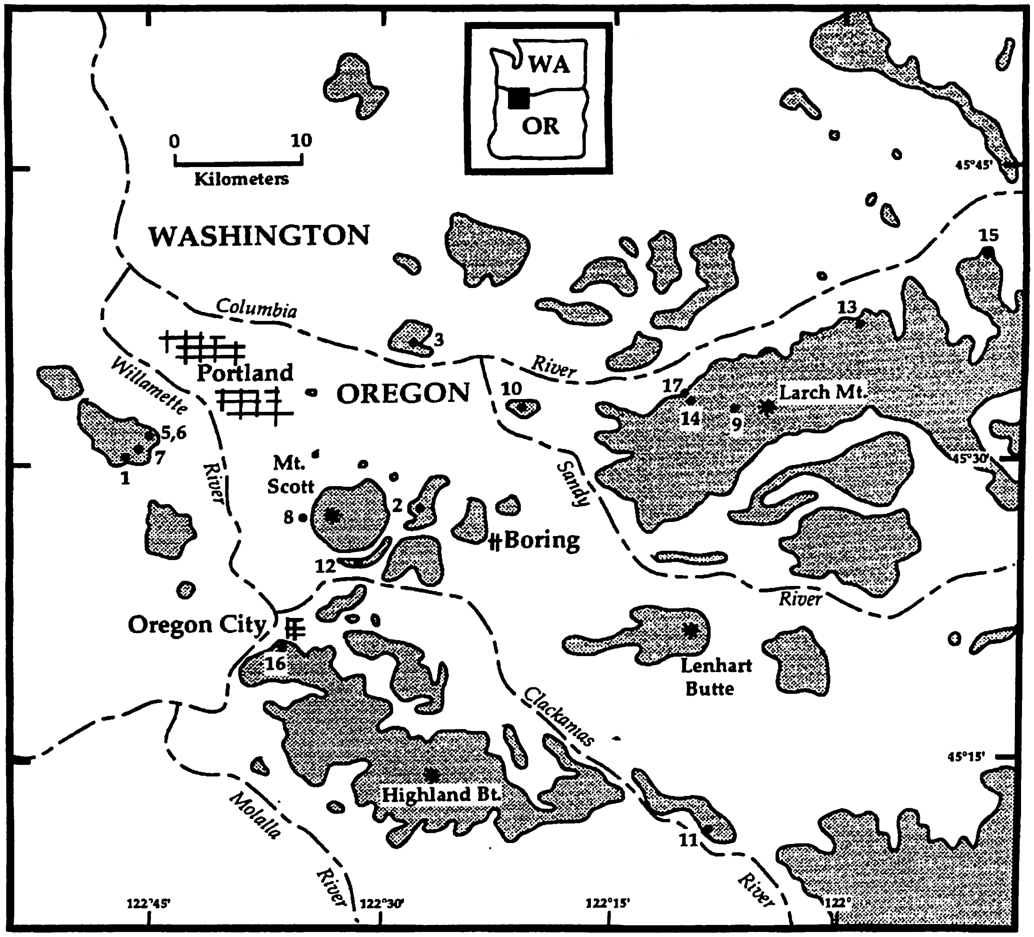

Figure 1. Location map of K-Ar samples (keyed to table 1) from Boring Lava, northwest Oregon and southwest Washington. Outcrop area of late Pliocene and Quaternary mafic lavas (filled pattern) from Sherrod and Smith (1989) and Smith (1993) is shown. Inset map shows portion of Oregon and Washington covered by figure 1. Sample 4 not shown on map; it is located approximately 62 km north of the NE corner of the map (Swanson, 1991).

during the lattermost Matuyama Reversed-Polarity Chron, either shortly before or after the Jaramillo Normal-Polarity subchron. The normal polarity and weighted mean age of sample 5 are inconsistent. Either the age is slightly too old and the sample was erupted during the Brunhes Normal-Polarity Chron, or the age is slightly too young and the sample was erupted during the Jaramillo Normal-Polarity subchron. In the latter case, the eruption ages of sample 6 and 7 are probably pre-Jaramillo; in the former case, they may be post-Jaramillo. More sophisticated age-dating is necessary to resolve these possibilities. In any case, the present evidence suggests samples 5, 6, and 7 were all erupted approximately 0.8-1.0 Ma.

Sample 14, if truly normally polarized, was likely erupted during either the Olduvai or Reunion Normal-Polarity subchrons. Sample 15 was most likely erupted during the Reunion Normal-Polarity subchron. Sample 17 was most probably erupted during one of the reversed-polarity subchrons of the Gauss Normal-Polarity Chron, but the large error in the age determination also allows an early Matuyama age.

AGE AND EVOLUTION OF MAFIC VOLCANISM

Our results suggest a pulse of basaltic volcanism occurred in this part of Oregon and Washington between approximately 0.8 and 3.0 Ma. Most post-1.0 Ma eruptions have been basaltic andesite in composition, and of small individual volumes (Madin, 1994; table 1 and unpublished data of the authors). A temporal progression (oldest to youngest) of magma types from low-K, invariably diktytaxitic, basalt to medium-K basalt to basaltic andesite or rare andesite is especially notable in the Columbia River Gorge, where

TABLE 1. New K-Ar ages from Boring Lava, northwest Oregon and southwest Washington.

Map number	Sample number	Location Lat. (N)	Location Long. (W)	Rock type	Material dated	K_2O (wt %)	$^{40}Ar_{rad}$ (10^{-7} ml/g)	Percent $^{40}Ar_{rad}$	Calculated age (Ma)[1]
1.	92TB-14	45°30.38′	122°45.17′	Basaltic andesite	Whole rock	0.990	0.0819	3.8	0.26±0.11
2.	DA9090-92	45°27.26′	122°27.71′	Basaltic andesite	Whole rock	0.779	0.1282	11.3	0.51±0.08
3.	92TB-4	45°34.88′	122°27.33′	Basaltic andesite	Whole rock	1.080	0.2051	20.9	0.59±0.05
4.	DS92-95[2]	46°25.60′	121°48.25′	Basalt	Whole rock	0.716	0.1925	28.6	0.83±0.05
5.	92TB-16	45°30.57′	122°44.20′	Basalt	Whole rock	1.259	0.3733 0.3250	24.1 22.9	0.92±0.06 0.80±0.06
6.	92TB-15	45°30.57′	122°44.20′	Basalt	Whole rock	0.726	0.1763 0.2260	11.3 16.4	0.75±0.12 0.97±0.03
7.	92TB-13	45°30.48′	122°44.64′	Basalt	Whole rock	0.813	0.2551	13.3	0.97±0.14
8.	92TB-12	45°25.75′	122°33.83′	Basalt	Whole rock	0.603	0.2451	6.7	1.26±0.39
9.	RMC92-4	45°32.25′	122°06.82′	Andesite	Whole rock	1.099	0.5073	49.1	1.43±0.05
10.	92TB-8	45°32.47′	122°22.37′	Basaltic andesite	Whole rock	0.802	0.3954	6.1	1.53±0.39
11.	CLRV-1	45°10.72′	122°09.07′	Basalt	Whole rock	0.405	0.2059	22.0	1.58±0.14
12.	GS9001-92	45°24.75′	122°31.42′	Basalt	Whole rock	0.511	0.2626	17.6	1.59±0.17
13.	RC92-21	45°35.82′	121°59.76′	Basalt	Whole rock	1.130	0.6974	52.4	1.91±0.07
14.	92TB-10	45°32.58′	122°09.68′	Basalt	Whole rock	1.157	0.7711	49.1	2.06±0.05
15.	92TB-7	45°38.48′	121°50.76′	Basalt	Whole rock	0.795	0.5667	35.0	2.21±0.10
16.	ORCT	45°20.94′	122°36.53′	Basalt	Whole rock	0.449	0.3532	41.0	2.44±0.18
17.	BVCK-1	45°32.66′	122°10.09′	Basalt	Whole rock	0.171	0.1655	12.5	3.00±0.44

Notes:

[1]K-Ar ages were calculated using the constants for the radioactive decay and abundance of ^{40}K recommended by the International Union of Geological Sciences Subcommission on Geochronology (Steiger and Jäger, 1977).
These constants are:
$\lambda_\varepsilon = 0.580 \times 10^{-10} yr^{-1}$, $\lambda_\beta = 4.962 \times 10^{-10} yr^{-1}$, and $^{40}K/K_{total} = 1.167 \times 10^{-4}$ mol/mol.

[2]This sample location is not on map (fig. 1).

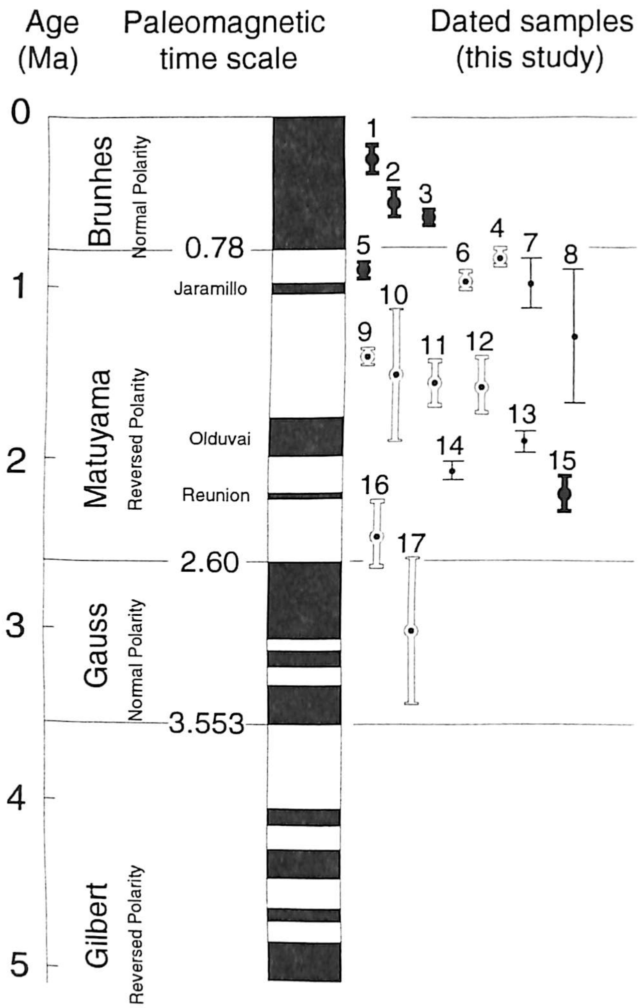

FIGURE 2. Correlation of dated samples with paleomagnetic time scale. Dark fill, normal polarity; white fill, reversed polarity. Bars showing age and standard deviation are similarly patterned. Thin unpatterned bars show samples of unknown or uncertain magnetic polarity. Remnant magnetization determined using fluxgate magnetometer. Time scale from Cande and Kent (1992).

stratigraphic relations are well established. Elsewhere in the Portland basin, where vents are scattered and exact stratigraphic relations cannot be established, the oldest and largest flows are invariably low-K, diktytaxitic basalt, all of which are older than approximately 1.0 Ma.

In comparison with newly determined ages from mafic lavas in the Mount Hood area (Conrey and others, in review), the Boring Lava appears to be younger overall by about one million years. A substantial field of mafic lavas was erupted in the Mount Hood area from 2 to 4 Ma; post-2 Ma basalts are rare and are not the low-K magmatic type. In contrast, the oldest age from the Boring Lava is roughly 3 Ma, and several low-K basalts with ages between 1 and 2 Ma are known (table 1). Eruption of mafic lavas in the Mount Hood area was associated with or closely followed by extension; it is possible that a similar relationship holds in the Portland basin, but the details of structural and volcanic interactions are still unresolved.

ACKNOWLEDGMENTS

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SAMPLE DESCRIPTIONS

1. *92TB-14* K-Ar

   Drill core of lava flow from 37.5 ft (11.4 m) depth of Tri-Met drillhole B14 (S62,T1S,R1W; drill collar at 637 ft elevation, Linnton 7.5′ quad., Washington Co., OR). Normal-polarity. Olivine (2-3%) and plagioclase (<1%) phenocrysts in an intergranular to intersertal groundmass of plagioclase, pyroxene, opaque minerals, and glass; most olivine phenocrysts have thin iddingsite coats; groundmass has sparse but pervasive hematite and other alteration.

   0.26 ± 0.11 Ma

2. *DA9090-92* K-Ar

   Roadcut in lava flow (Center S29,T1S,R3E; Wooded Hills Rd., 750 ft elevation, Damascus 7.5′ quad., Clackamas Co., OR). Normal-polarity. Sample is from Basalt of Borges Road unit of Madin (1994); the 2-sigma error and source of data are misreported therein. Olivine (2-3%), plagioclase (<1%), and augite (<1%) phenocrysts in an intersertal to intergranular groundmass of plagioclase, pyroxene, glass, and opaque minerals; most olivine phenocrysts are mildly altered to iddingsite; traces of groundmass alteration.

   0.51 ± 0.08 Ma

3. *92TB-4* K-Ar
Roadcut in lava flow from Prune Hill (S39,T1N, R3E; Hwy 14, 120 ft elevation, Camas 7.5′ quad., Clark Co., WA). Normal-polarity. Olivine (3-4%) and rare plagioclase and augite phenocrysts in an intergranular to intersertal groundmass of plagioclase, pyroxene, glass, and opaque minerals; traces of alteration and oxidation are present in both olivine phenocrysts and groundmass.
0.59 ± 0.05 Ma

4. *DS92-95* K-Ar
Outcrop of lowest exposed Quaternary lava NW of Tongue Mountain (Unsurveyed [S22,T11N, R8E]; 2,450 ft elevation, Tower Rock 7.5′ quad., Lewis Co., WA; see Swanson, 1991). Reversed-polarity. Olivine (3%) phenocrysts in an intergranular-subophitic groundmass of plagioclase, augite, olivine, opaque minerals, and glass; rare xenocrysts of large kink-banded olivine with rounded opaque spinel inclusions; traces of alteration.
0.83 ± 0.05 Ma

5. *92TB-16* K-Ar
Drill core of lava flow from 94 ft (28.6 m) depth of Tri-Met drillhole B12 (SW1/4 S6,T1S,R1E; drill collar at 763 ft elevation, Portland 7.5′ quad., Multnomah Co., OR). Normal-polarity. Olivine (3%) and rare plagioclase and augite phenocrysts in an intergranular groundmass of plagioclase, augite, olivine, opaque minerals, and phlogopite(?); all olivine grains have moderately thick rinds of iddingsite; groundmass is variably oxidized or altered.
Weighted mean age 0.86 ± 0.04 Ma

6. *92TB-15* K-Ar
Drill core of lava flow from 119 ft (36.3 m) depth of Tri-Met drillhole B12 (SW1/4 S6,T1S,R1E; drill collar at 763 ft elevation, Portland 7.5′ quad., Multnomah Co., OR). Reversed-polarity. Olivine (3-4%) phenocrysts in a seriate-intergranular groundmass of plagioclase, pyroxene, opaque minerals, and glass; olivine phenocrysts have iddingsite rinds; traces of groundmass alteration; chemically similar to sample No. 7 (92TB-13).
Weighted mean age 0.96 ± 0.03 Ma

7. *92TB-13* K-Ar
Drill core of lava flow from 155 ft (47.2 m) depth of Tri-Met drillhole B537 (S62,T1S,R1W; drill collar at 653 ft elevation, Portland 7.5′ quad., Washington Co., OR). Magnetic polarity unknown. Olivine (2%) phenocrysts in a seriate-intergranular groundmass of plagioclase, augite, olivine, and opaque minerals; all olivine grains have rinds of iddingsite; traces of groundmass oxidation or alteration; chemically similar to sample No. 6 (92TB-15).
0.97 ± 0.14 Ma

8. *92TB-12* K-Ar
Drill core of lava flow from 40 ft (12.2 m) depth of Oregon Department of Transportation drillhole B505 (NE corner S37,T2S,R2E; drill collar at 180 ft elevation, Gladstone 7.5′ quad., Clackamas Co., OR). Reversed-polarity (?). Olivine (1-2%) phenocrysts in a seriate, subophitic-diktytaxitic groundmass of plagioclase, augite, olivine, opaque minerals, and rare glass; most olivine grains have rinds of iddingsite; traces of groundmass alteration. Chemically similar to sample No. 12 (GS9001-92), which occurs at similar stratigraphic level.
1.26 ± 0.39 Ma

9. *RMC92-4* K-Ar
Roadcut in lava flow from Larch Mountain (near center S1/2, S30,T1N,R6E; Larch Mountain Road, 2,550 ft elevation, Multnomah Falls 7.5′ quad., Multnomah Co., OR). Reversed-polarity. Larch Mountain is an eroded remnant of a small glaciated andesite shield volcano centered at Sherrard Point. Abundant seriate plagioclase, two pyroxene and sparse olivine phenocrysts in an intergranular to intersertal groundmass of plagioclase, two pyroxenes, opaque minerals, and glass; traces of iddingsite and groundmass alteration.
1.43 ± 0.05 Ma

10. *92TB-8* K-Ar
Outcrop of lava flow at Broughton Bluff (Near E edge S25,T1N,R3E; 360 ft elevation, Washougal 7.5′ quad., Multnomah Co., OR). Reversed-polarity. Olivine (2%) phenocrysts in a subophitic-intersertal groundmass of plagioclase, augite, opaque minerals, and glass; most olivine phenocrysts have thin rinds of iddingsite; traces of groundmass alteration.
1.53 ± 0.39 Ma

11. CLRV-1 K-Ar
Outcrop of lava flow forming intracanyon bench in Clackamas River valley (SE1/4 S35,T4S,R5E; 2,440 ft elevation, Bedford Point 7.5′ quad., Clackamas Co., OR). Reversed-polarity. Olivine (1-2%) and plagioclase (1-2%) phenocrysts in an ophitic groundmass of plagioclase, augite,

opaque minerals, and olivine; most olivine phenocrysts contain thin wisps of iddingsite.

1.58 ± 0.14 Ma

12. *GS9001-92* K-Ar

Roadcut in lava flow (NE1/4 S11,T2S,R2E; SE 135th street, 210 ft elevation, Gladstone 7.5′ quad., Clackamas Co., OR). Reversed-polarity. Sample is from Basalt of Mount Talbert unit of Madin (1994). Olivine (2-3%) and plagioclase (<1%) phenocrysts in an ophitic-diktytaxitic groundmass of plagioclase, augite, olivine, opaque minerals, and glass; most olivines rather heavily iddingsitized. Chemically similar to sample No. 8 (92TB-12), which occurs at similar stratigraphic level.

1.59 ± 0.17 Ma

13. *RC92-21* K-Ar

Outcrop of lava flow (Unsurveyed; switchback on crest of small ridge, Nesmith Point trail, 2,760 ft elevation, Tanner Butte 7.5′ quad., Multnomah Co., OR). Magnetic polarity unknown. Olivine (3-4%), plagioclase (2%), and augite (2%) phenocrysts in an intergranular groundmass of plagioclase, augite, and opaque minerals; traces of alteration.

1.91 ± 0.07 Ma

14. 92TB-10 K-Ar

Outcrop of lava flow (NW1/4 S26,T1N,R5E, 1,360 ft elevation, Bridal Veil 7.5′ quad., Multnomah Co., OR). Normal-polarity (?). Olivine (1%) and seriate augite and plagioclase phenocrysts in an intergranular groundmass of plagioclase, augite, opaque minerals, and traces of phlogopite(?); rare groundmass alteration.

2.06 ± 0.05 Ma

15. 92TB-7 K-Ar

Outcrop of lava flow at top of Benson Plateau (SE1/4 S20,T2N,R8E, 3,960 ft elevation on Pacific Crest trail, Hood River Co., OR). Normal-polarity. Olivine (1-2%) and plagioclase (1-2%) in a seriate-intergranular groundmass of plagioclase, augite, and opaque minerals; traces of iddingsite and groundmass alteration.

2.21 ± 0.10 Ma

16. *ORCT* K-Ar

Block from lava flow exposed at Waterboard Park quarry (S60,T2S,R2E; 380 ft elevation, Oregon City 7.5′ quad., Clackamas Co., OR). Reversed-polarity. Float was inadvertently collected west across street from McLoughlin House; chemical analyses prove identity with lava flow composing bench above Waterboard Park. Age is identical to earlier unpublished age determination of 2.44 ± 0.11 Ma by R. A. Duncan and E. P. Verplanck from sample collected by D. R. Sherrod and N. MacLeod at Waterboard Park quarry (David R. Sherrod, pers. comm., 1994). Sparse (total 2-3%) olivine and plagioclase phenocrysts in a subophitic-diktytaxitic groundmass of plagioclase, augite, olivine, opaque minerals, and rare glass; most olivine grains rather pervasively altered to iddingsite; remainder of sample is fresh.

2.44 ± 0.18 Ma

17. *BVCK-1* K-Ar

Roadcut in lava interbed in conglomerate of Troutdale Formation (NE1/4 S27,T1N,R5E; Palmer Mill Road, 1,120 ft elevation, Bridal Veil 7.5′ quad., Multnomah Co., OR). Reversed-polarity. Sparse plagioclase and olivine phenocrysts in a subophitic-diktytaxitic groundmass of plagioclase, augite, olivine, opaque minerals, and rare glass; most olivines have small patches of iddingsite.

3.00 ± 0.44 Ma

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