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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).

Ranges of sample 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 Olduval 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.

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

**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:

   \[ \lambda_e = 0.580 \times 10^{-10} \text{yr}^{-1}, \lambda_R = 4.962 \times 10^{-10} \text{yr}^{-1}, \text{and} \frac{40K}{K_{total}} = 1.167 \times 10^{-4} \text{ mol/mol.} \]

2. This sample location is not on map (fig. 1).
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, diktystaxitic 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

This work was supported by a fellowship from the Japanese Agency for Industrial Science and Technology (AIST). We thank the members of the AIST office in Tsukuba, the International Office of the Geological Survey of Japan (GSJ), and the Isotope Geoscience Section of the GSJ for assistance. RMC thanks Laureen C. Wagoner for help in preparing samples at the GSJ. Dave Sherrod at the Cascades Volcano Observatory (U.S. Geological Survey) made many useful comments on the manuscript, and was responsible for the design of figure 2.

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. 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.

   0.51 ± 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 glass; 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 (2%) and plagioclase (1-2%) phenocrysts in a seriate-intergranular groundmass of plagioclase, pyroxene, opaque minerals, 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

7. **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 (1-2%) and plagioclase (1-2%) phenocrysts in a subophitic-intergranular groundmass of plagioclase, and augite, opaque minerals, and glass; traces of oxidation or alteration.

Weighted mean age 1.43 ± 0.05 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 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.

1.43 ± 0.05 Ma

9. **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 (2%) phenocrysts in a subophitic-intergranular groundmass of plagioclase, augite, opaque minerals, and glass; traces of oxidation or alteration.

Weighted mean age 1.53 ± 0.39 Ma

10. **92TB-13** 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 (2%) phenocrysts in a subophitic-intergranular groundmass of plagioclase, augite, opaque minerals, and glass; traces of oxidation or alteration.

Weighted mean age 1.53 ± 0.39 Ma

11. **CLR-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 (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

REFERENCES


[ISOCHRON/WEST, no. 63, November 1996]