K-Ar ages of basalts from southcentral and southeastern Oregon

W.K. Hart and S.A. Mertzman

Isochron/West, Bulletin of Isotopic Geochronology, v. 33, pp. 23-26

This page is intentionally left blank to maintain order of facing pages.

K-Ar AGES OF BASALTS FROM SOUTHCENTRAL AND SOUTHEASTERN OREGON

WILLIAM K. HART *Department of Geological Sciences, Case Western Reserve University, Cleveland, OH 44106*
STANLEY A. MERTZMAN *Department of Geology, Franklin and Marshall College, Lancaster, PA 17604*

The Columbia Plateau basalts of the Pacific Northwest represents one of the largest outpourings of lava on the surface of the Earth, aggregating a total volume in excess of 10^6 km^3 (Carmichael and others, 1974). Following the stratigraphic usage of Wright and others (1973) and Swanson and others (1979), the Columbia River Basalt Group consists of four formations which, in order of decreasing age, are the Imnaha Basalt, the Grande Ronde Basalt which includes the Picture Gorge Basalt of northcentral Oregon, the Wanapum Basalt and the Saddle Mountains Basalt. Available K-Ar geochronology for the Columbia River Group, summarized by McKee and others (1977) and Swanson and others (1979), indicate the Grande Ronde and Wanapum Basalts were extruded between 16.5 and 13.5 m.y. ago and constitute the vast bulk of the volcanic activity. The age of the Saddle Mountains Basalt extends from 13.5 to 6 m.y. ago, a larger segment of time yet it represents well less than 1 % of the total volume of the Columbia River Basalt Group. It also contains the flows with the greatest chemical diversity including both major and trace elements. The extent of outcrop of the Columbia River Basalt Group is depicted in Figure 1.

The Steens Mountain Basalt of southeastern Oregon (see Figure 1 for its location) has been suggested as correlative with the Grande Ronde Basalt by numerous researchers including Evernden and James (1964) and Bottomley and York (1976). Baksi and others (1967) determined the entire section of basalt exposed on Steens Mountain was erupted 15.1 ± 0.3 m.y. ago and Avent (1970) has summarized the mineralogical, chemical, and age similarities which exist between the Steens Mountain Basalt and the Picture Gorge Basalt.

A third type of flood basalt was encountered in our study, a diktytaxitic, non-porphyritic olivine basalt which would be classified chemically as a low potassium high-alumina olivine tholeiite (HAOT). This basalt is clearly discernible from the lavas of the Columbia River Basalt Group and the Steens Mountain Basalt on the basis of mineralogic, chemical and isotopic characteristics (Mertzman, 1979; Hart and Mertzman, 1980). Previous workers have included lava flows of this flood basalt in various formations of local importance, e.g., Mesa Basalt of Wheeler and Combs (1967) and the Warner Basalt of Powers (1932) and Anderson (1941).

Results

The K-Ar data are reported under the heading of "Sample Descriptions", and the whole rock chemical analyses for the dated samples in Table 1. A general pattern in which the HAOT samples are the youngest in each of the areas investigated is depicted. Even though the older basalts are of quite variable bulk composition, the HAOT are nearly identical even though they are from widely separated locales and spread over 7 million years of geologic time. The older basalts from the eastern Steens area are similar in chemistry and petrography to the Steens Basalt (Gunn and Watkins, 1970; Avent, 1970). However, these basalts have a more highly evolved chemical signature, represented by very high values of Fe, Ti, P, Ba, and Zr. We suggest the following analogy may be appropriate: that these older eastern Steens area basalts are to the Steens Basalt as the Pomona and Elephant Mountain Members of the Saddle Mountains Basalt are to the Picture Gorge–Grande Ronde Basalts of the Columbia River Group; that is, younger in age by 3 to 4 million years, much smaller in terms of volume, and more highly fractionated in terms of chemistry than their basalt predecessors. If this working hypothesis can be further substantiated with additional evidence, it will focus attention on a more striking parallelism than currently exists between the Steens Basalt and the Columbia River Group in terms of chemistry and volume as a function of geologic time.

The older basalt at Polker Jim Rim is similar in petrography, chemistry and age to the Steens Basalt described by Gunn and Watkins (1970). The younger HAOT flow which caps the escarpment permits a maximum age to be assigned to the Basin and Range faulting in the area—the displacement along the fault can be no older than 6.85 ± 0.59 m.y.

The older basalts which form the Abert Rim are time correlative with the Steens Basalt and the Picture Gorge–Grande Ronde Basalts; however, these basalts are somewhat distinctive from both of these groups with respect to their lower Fe and P, higher Ni, and significantly higher K/Rb ratios. Any relationship these basalts may have with the three major categories of Miocene flood basalts in Oregon is presently not clear and awaits further investigation. The younger HAOT basalt flows around the base of the Abert Rim fault scarp and indicates most of the movement along the fault occurred between 6 and 15 million years ago.

Constants used in calculating ages are: $\lambda_\epsilon = 0.581 \times 10^{-10} yr^{-1}$; $\lambda_\beta = 4.962 \times 10^{-10} yr^{-1}$; $^{40}K/K = 1.167 \times 10^{-4}$ mol/mol.

SAMPLE DESCRIPTIONS

1. *H-8-73* K-Ar
Basalt (SE¼ S26,T30N,R38E; 13.5 mi N of Burns Jct. along Ore. Hwy. 78 in roadcut with tumuli extending E and W of road; OR). Gray, diktytaxitic with olivine microphenocrysts; subophitic plagioclase (An_{60-72}) and augite, titanomagnetite and minor glass. Mode: 48.73% plg., 23.48% ol., 20.35% cpx., 7.39% Ti-mt + glass. *Analytical data:* Sample weight = 7.2 gm; K_2O = 0.308 (wt) %; $^*Ar^{40}$ = 0.189 x 10^{-12} moles/gm; $^*Ar^{40}$ = 5.54%.
(whole rock) 0.43 ± 0.09 m.y.

2. *H-8-74* K-Ar
Basalt (S16,T30S,R38E; 17 mi N of Burns Jct. along Ore. Hwy. 78; from high point of older material surrounded by younger material (H-8-73); OR). Dark gray, massive, porphyritic with phenocrysts of red/orange olivine and plagioclase in intergranular matrix of plg., cpx., ol., and opaques;

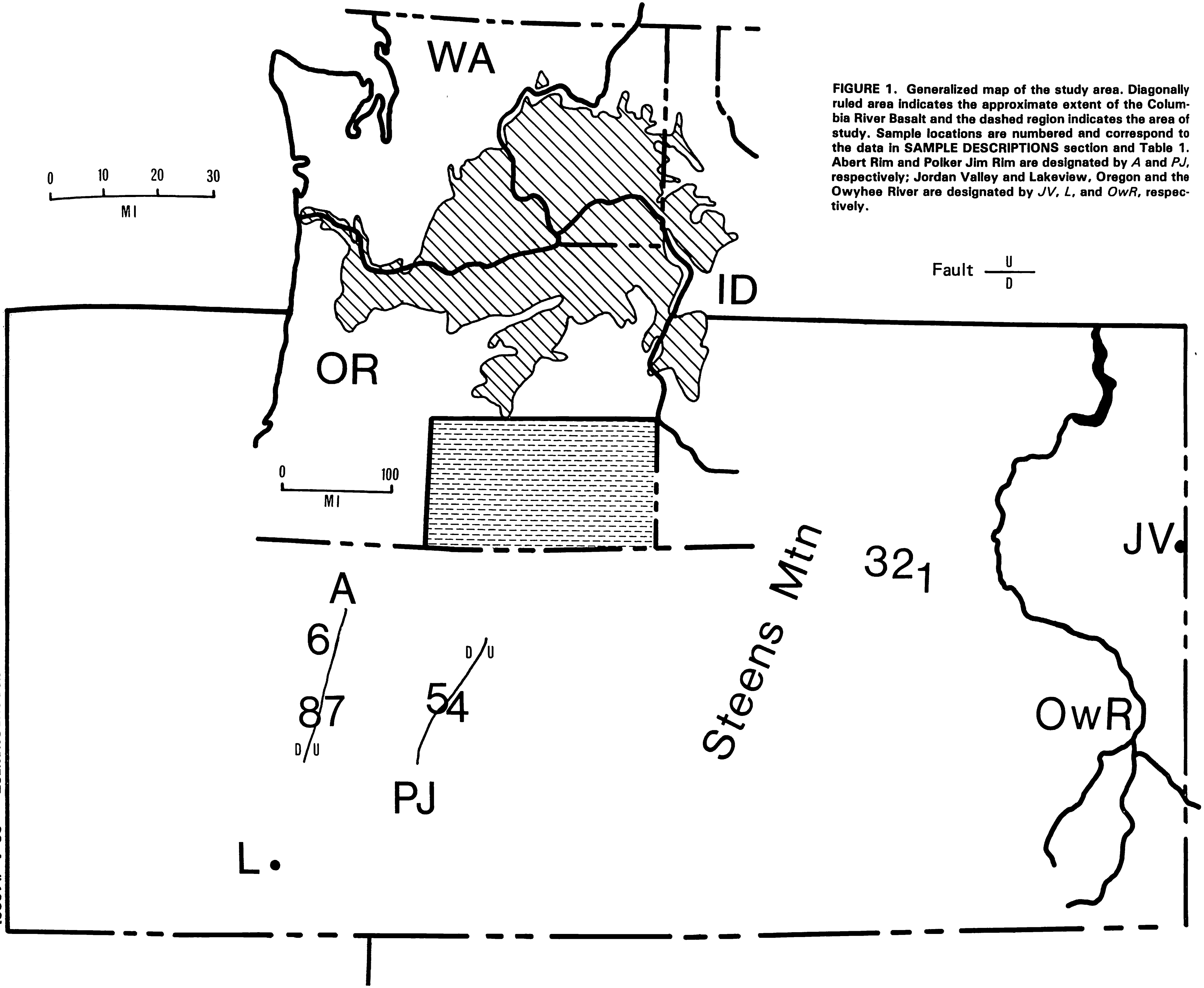

FIGURE 1. Generalized map of the study area. Diagonally ruled area indicates the approximate extent of the Columbia River Basalt and the dashed region indicates the area of study. Sample locations are numbered and correspond to the data in SAMPLE DESCRIPTIONS section and Table 1. Abert Rim and Polker Jim Rim are designated by *A* and *PJ*, respectively; Jordan Valley and Lakeview, Oregon and the Owyhee River are designated by *JV*, *L*, and *OwR*, respectively.

glomeroporphyritic clumps of ol. + plg. Mode: 44.67% plg., 24.74% ol., 18.72% cpx., 9.86% oxides, 2.0% interstitial material.

Analytical data:

Run (#)	K_2O (wt %)	Sample weight (gm)	$*Ar^{40}$ (x 10^{-12} moles/gm)	$*Ar^{40}$ (%)
1	1.02_7	4.1760	17.157	72.17
2	1.02_7	4.0148	17.532	69.56
3	1.02_7	4.0285	17.386	58.28
4	1.02_7	4.0663	17.350	57.50

(whole rock) 11.71 ± 0.65 m.y.

3. *H-9-32* K-Ar
Basalt (SE¼ S34,T30S,R38E; E of Sheepshead Mtns.; from top of high point 1500 m with younger material from the northeast flowing around base [H-8-73]; OR). Dark gray, fine grained holocrystalline intergranular assemblage of plagioclase (An_{44-46}), Ti-rich augite and iddingsitized olivine with porphyritic plg. laths (An_{48-52}) up to 6 mm and interstitial oxide and oxide-rich cryptocrystalline material. *Analytical data:* Sample weight = 4.0684 gm; K_2O = 1.605 (wt) %; $*Ar^{40}$ = 25.878 x 10^{-12} moles/gm; $*Ar^{40}$ = 38.83%.

(whole rock) 11.17 ± 0.65 m.y.

4. *H-8-84* K-Ar
Basalt (SE¼ S36,T34S,R25E; top flow along with Polker Jim Rim; OR) Med. gray, diktytaxitic holocrystalline, iddingsitized 2–3 mm olivine and some smaller pristine grains subophitic plagioclase (An_{62-68}) and augite, microphenocryst to interstitial titanomagnetite. Mode: 46.79% plg., 27.45% ol., 22.87% cpx., 2.89% Ti-mt. *Analytical data:* Sample weight = 7.2076 gm; K_2O = 0.284 (wt) %; $*Ar^{40}$ = 2.806 x 10^{-12} moles/gm; $*Ar^{40}$ = 26.08%.

(whole rock) 6.85 ± 0.59 m.y.

5. *H-9-75A* K-Ar
Basalt (SE¼ S36,T34S,R25E; flow beneath H-8-84 at Polker Jim Rim, OR). Med. gray, med.-fine grained, diktytaxitic iddingsitized/oxidized olivine and abundant oxide plus porphyritic plg. laths (An_{65-72}) up to 24 mm; minor interstitial oxide-rich cryptocrystalline material. *Analytical data:*

TABLE 1. Major and trace element chemistry, weight percent and ppm, respectively.

[The analyses were determined by XRF techniques described in Mertzman (1977). (DL = detection limit; LOI = loss on ignition)]

	Eastern Steens Area				*Polker Jim*		*Abert*	
Sample #	H-8-73	H-8-74	H-9-32	H-8-84	H-9-75A	H-9-72	H-9-71A	H-9-71C
Map #	1	2	3	4	5	6	7	8
SiO_2	48.17	45.88	49.80	48.32	47.83	46.60	46.82	50.00
TiO_2	1.02	3.09	3.00	0.83	2.86	0.92	1.27	1.64
Al_2O_3	16.12	15.51	15.40	16.42	15.86	16.58	15.91	19.54
Fe_2O_3	1.23	6.71	7.59	2.40	8.21	4.76	6.05	3.42
FeO	8.80	7.96	6.40	6.80	5.76	5.60	4.80	5.68
MnO	0.18	0.22	0.23	0.16	0.20	0.18	0.17	0.12
MgO	8.84	4.79	3.51	8.66	4.29	9.19	6.71	4.69
CaO	11.43	8.72	7.24	11.42	8.26	11.44	11.85	10.53
Na_2O	2.47	3.56	3.50	2.31	3.44	2.37	2.79	3.07
K_2O	0.30	1.03	1.61	0.28	1.40	0.25	0.66	0.78
P_2O_5	0.08	0.95	1.37	0.18	0.53	0.11	0.22	0.23
LOI	0.58	1.00	0.73	1.09	0.68	1.98	2.15	0.74
Total	99.18	99.42	100.38	98.87	99.32	99.98	99.40	100.44
FeO_T	9.92	14.06	13.30	8.98	13.22	9.93	10.30	8.79
Rb	<DL	11	18	1.32*	25	1.67*	2	7
Sr	236	424	474	253	512	308	474	489
Ni	117	43	6	163	19	187	111	72
Ba	94	718	1112	152	580	103	537	178
Zr	94	301	430	79	325	98	168	211
V	201	426	221	172	301	198	236	220
Y	11	23	62	16	45	28	22	20
K/Rb	—	777	742	1772	465	1215	2739	925
Rb/Sr	—	0.026	0.038	0 005	0.049	0.005	0.004	0.014
Ba/Sr	0.398	1.693	2.346	0.601	1.132	0.334	1.133	0.364
K/Ba	26.5	11.9	12.0	15.3	20.0	20.2	10.2	36.4
ppm K	2490	8549	13363	2339	11620	2028	5478	6474

*Analysis by isotope dilution.

Sample weight = 3.9747 gm; K_2O = 1.396 (wt) %; $*Ar^{40}$ = 30.363 x 10^{-12} moles/gm; $*Ar^{40}$ = 71.61%.

(whole rock) 15.04 ± 0.79 m.y.

6. *H-9-72* K-Ar
Basalt (SE¼, NW¼ S16,T33S,R22E; flow around base of Abert Rim lying directly on top of reddish-tan tuffaceous material; OR). Med. gray, fine grained, diktytaxitic, holocrystalline-equigranular assemblage of plagioclase (An_{68-72}), augite and highly iddingsitized olivine (some microphenocrysts up to 0.6 mm) in intergranular to subophitic intergrowth; minor intergranular/interstitial oxide plus calcite lining many small vesicles. *Analytical data:* Sample weight = 7.9677 gm; K_2O = 0.256 (wt) %; $*Ar^{40}$ = 2.241 x 10^{-12} moles/gm; $*Ar^{40}$ = 15.04%.

(whole rock) 6.07 ± 0.66 m.y.

7. *H-9-71A* K-Ar
Basalt (SE¼, NW¼ S30,T34S,R22E; top flow along Abert Rim; OR). Med. gray, med.-grained, diktytaxitic, holocrystalline, equigranular assemblage of plagioclase (An_{65-68}), augite and abundant iddingsitized olivine in intergranular to patchy subophitic relationship, abundant interstitial and intergranular oxide and oxide-rich cryptocrystalline material as well as calcite lining in vesicles. *Analytical data:* Sample weight = 6.0495 gm; K_2O = 0.664 (wt) %; $*Ar^{40}$ = 15.057 x 10^{-12} moles/gm; $*Ar^{40}$ = 56.97%.

(whole rock) 15.68 ± 0.83 m.y.

8. *H-9-71C* K-Ar
Basalt (SW¼, NW¼ S30,T24S,R22E; flow approx. 200 m below H-9-71A at Abert Rim; OR). Med. gray, extremely porphyritic with *abundant* large phenocrysts (up to 20 mm) and clumps of plagioclase (An_{55-62}) set in a fine grained, intergranular to subophitic groundmass of plg. laths (An_{60-64}), altered olivine (iddingsite?) grains and microphenocrysts up to 0.9 mm and augite, also abundant interstitial oxide-rich cryptocrystalline material and secondary interstitial oxides. *Analytical data:* Sample weight = 5.9956 gm; K_2O = 0.785 (wt) %; $*Ar^{40}$ = 16.591 moles/gm; $*Ar^{40}$ = 62.16%.

(whole rock) 14.62 ± 0.72 m.y.

REFERENCES

Anderson, C. A. (1941) Volcanoes of the Medicine Lake Highland, California: Univ. Calif. Dept. Geol. Sci. Bull., v. 25, no. 7, p. 347–422.

Avent, J. C. (1970) Correlation of the Steens–Columbia River Basalts: some tectonic and petrogenetic implications: Proc. Second Columbia River Basalt Symposium, p. 133–156.

Baksi, A. K., York, D., and Watkins, N. D. (1967) Age of the Steens Mountain geomagnetic polarity transition: Jour. Geophys. Research, v. 72, p. 6299–6308.

Bottomley, R. J., and York, D. (1976) ^{40}Ar-^{39}Ar age determinations on the Owyhee basalt of the Columbia Plateau: Earth Planet. Sci. Lett., v. 31, p. 75–84.

Carmichael, I. S. E., Turner, F. J., and Verhoogen, J. (1974) Igneous Petrology: New York, McGraw-Hill Book Company.

Evernden, J. F., and James, G. T. (1964) Potassium-argon dates and Tertiary floras of North America: Am. Jour. Sci., v. 262, p. 945–974.

Gunn, B. M., and Watkins, N. D. (1970) Geochemistry of the Steens Mountain Basalts, Oregon: Geol. Soc. Amer. Bull., v. 81, p. 1497–1516.

Hart, W. K., and Mertzman, S. A. (1980) Late Cenozoic volcanic geology of the Jordan Valley area, SE Oregon: Geol. Soc. America Abs. with Programs, v. 12, no. 7, p. 443.

McKee, E. H., Swanson, D. A., and Wright, T. L. (1977) Duration and volume of Columbia River basalt volcanism, Washington, Oregon, and Idaho: Geol. Soc. America Abs. with Programs, v. 9, no. 4, p. 463–464.

Mertzman, S. A. (1979) Strontium isotope geochemistry of a low potassium olivine tholeiite and two basalt-pyroxene andesite magma series from the Medicine Lake Highland, California: Contr. Mineral. Petrol., v. 70, p. 81–88.

Powers, H. A. (1932) The lavas of the Modoc lava-bed quadrangle, California: Am. Mineralogist, v. 17, no. 7, p. 253–294.

Swanson, D. A., Wright, T. L., Hooper, P. R., and Bentley, R. D. (1979) Revisions in stratigraphic nomenclature of the Columbia River Basalt Group: U.S. Geol. Survey Bull. 1457-6, 59 pp.

Wheeler, H. E., and Combs, H. A. (1967) Late Cenozoic Mesa Basalt sheet in the northwestern United States: Bull. Volcanologique, v. 31, p. 21–44.

Wright, T. L., Grolier, M. J., and Swanson, D. A. (1973) Chemical variation related to the stratigraphy of the Columbia River basalt: Geol. Soc. Amer. Bull., v. 84, p. 371–386.