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Oxygen Isotope Compositions of Some Basaltic Lavas from the Snake River Plain

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The Snake River Plain (SRP; Pliocene to Holocene) is an elongate structural and topographic depression that arcs nearly 400 miles across southern Idaho from the rhyolitic Yellowstone plateau (Pleistocene) on the northeast to the tholeiitic Columbia River (Miocene) and high-alumina Malheur (Pliocene-Holocene) plateaus on the northwest and west. The Plain includes two or three zones of late Cenozoic crustal extension (Stone, 1969), having been downfaulted in the west (Malde, 1959) and downfolded in the east (Kirkham, 1931). It is characterized, at least in the west, by anomalously thick intermediate crust ($V_P = 6.7$ km/sec) and a deep Mohorovicic discontinuity (40-45 km; Hill and Pakiser, 1967).

The SRP is filled by dacitic to rhyolitic volcanic rocks, fluvial and lacustrine sediments, and basaltic lavas, predominantly olivine tholeiites (nomenclature of Yoder and Tilley, 1962). The latter are distinctive in their comparatively high iron enrichment ($F/(F + M)^* = 0.64$),

$$*F/(F + M) = (0.9\text{Fe}_2\text{O}_3 + \text{FeO}) / (0.9\text{Fe}_2\text{O}_3 + \text{FeO} + \text{MgO}) (\text{wt } \%).$$

high TiO_2 (2.8 wt %), and high P_2O_5 (0.6), low SiO_2 (46.6), and low to moderate total alkalis (3.1) (Powers, 1960a; Stone, 1966, 1967).

① The oxygen isotope compositions of a variety of basaltic lavas and constituent phenocrysts from the SRP range from 5.0 to 6.3‰ (Table). This spread of δO^{18} values is broader than expected for a basaltic suite that presumably originated by partial melting of upper mantle material, and the O^{18} content of McKinney basalt (samples 59P13 and 59P160) is lower than that of any other fresh continental basalt.

① With the notable exception of Iceland (Muehlenbachs, Anderson, and Sigvaldason, 1972), the oxygen-isotope compositions of basalts from oceanic regions fall in the range 5.5 to 6.0‰ (Garlick, 1966; Taylor 1968; Anderson, Clayton, and Mayeda, 1971; Muehlenbachs and Clayton, 1972a). Most rocks of the continental crust are richer in O^{18} (δO^{18} of shales averages 19‰, Savin and Epstein, 1970; that of granites, 8 to 10‰, Taylor, 1968). Basaltic magma contaminated by wall rock during its ascent through continental crust should therefore be enriched in O^{18} . Indicative of this effect are O^{18} -rich quartz xenocrysts in basalts that are themselves relative O^{18} -rich (Taylor, 1968). Basalts of Medicine Lake Highlands and Mono Craters (Taylor, 1968) are slightly enriched in O^{18} relative to oceanic basalt ($\delta O^{18} = 6.8$ and 6.9‰; Table); this amount is consistent with contamination by crustal rocks. However, some continental basalts have oxygen isotope compositions identical with those of oceanic basalts, thereby indicating no significant exchange of oxygen with O^{18} -rich crustal material. For example, two samples of the youngest Columbia River basalts (Upper Yakima basalt at Ice Harbor Dam; Wright, Grolier, and Swanson, 1973) have δO^{18} values of 5.5 and 5.6 ‰ (Table).

① The Snake River olivine tholeiites, like most other continental tholeiites, are characterized by Sr^{87}/Sr^{86} values (0.706 to 0.708; Leeman and Manton, 1971) that are markedly higher than those of most oceanic tholeiites (0.702 to 0.704, Hart, Year Books 70 and 71, pp. 354, 288-290). The possibility that they may have been contaminated by relatively radiogenic continental material must therefore be considered. Moreover, some highly evolved Snake River lavas have bulk chemical and strontium isotope compositions that are difficult to explain by simple schemes of igneous differentiation.

Leeman and Manton (1971) concluded, however, that the uniformly high $\text{Sr}^{87}/\text{Sr}^{86}$ values of Snake River olivine tholeiites, which are widely distributed in space and time (30,000 sq mi; 10 m.y.), are more likely characteristic of their parent magmas than due to homogenized crustal contamination. The oxygen isotope data presented here are consistent with their interpretation; the Snake River olivine tholeiites are not or only slightly contaminated by O^{18} -rich crustal material.

Of the Snake River lava samples analyzed thus far, those having the highest O^{18} contents, $\delta^{18} = 6.3$ and 5.9‰ , are, respectively, the most basic representatives of the highly evolved King Hill ($F/(F + M) = 0.78$ to 0.88) and Cold Springs Creek ($F/(F + M) = 0.74$ to 0.90) series (Powers, 1960b; Stone, 1970). The isotopic data are consistent with the hypothesis that the highly evolved lavas may have been slightly contaminated by crustal rocks. The King Hill rocks were reported by Leeman and Manton (1971) to have unusually high and variable strontium isotope ratios (0.7107 to 0.7180), which define a pseudo-isochron "with an apparent age of 870 million years and an initial $\text{Sr}^{87}/\text{Sr}^{86}$ ratio of 9.709 ." They interpreted the pseudo-isochron as a contamination mixing line.

Although xenoliths of crustal rocks are not common in Snake River lavas, they have been reported in some localities; e.g., in the Mud Lake (Stearns, 1926), Craters of the Moon (Stearns, Crandall, and Steward, 1938), and Bellvue areas (Schmidt, 1961). A granitic gneiss xenolith from Crystal Butte west of the Island Park caldera (72Sl6A; oligoclase + intermediate alkali feldspar + quartz) has a δO^{18} of 9.1‰ , a reasonable value for crustal rocks. It manifests incipient melting on its margins and internally parallel to banding. The host lava, an andesine-augite porphyry of andesitic composition, is enriched in O^{18} . However, its

whole-rock oxygen composition is not in equilibrium with those of its constituent minerals. This nonequilibrium might be due to some very low-temperature, secondary alteration of the groundmass that has not affected the phenocrysts, or the preservation by quenching of differences in the rate of oxygen exchange between xenoliths, melt, and phenocrysts.

The relatively low δO^{18} value of McKinney olivine tholeiite (59P13 and 59P160) is comparable to that of some Icelandic basalts ($\delta O^{18} = 1.8$ to 5.7‰). Other characteristics in common between the Snake River and Icelandic provinces are crustal extension and postulated hot spots or mantle plumes (Morgan, 1971), low- O^{18} meteoric waters, and the presence of high-titanium, iron-enriched basalts in a bimodal basalt-rhyolite assemblage. In both provinces, it remains to be demonstrated whether oxygen isotope compositions reflect mantle characteristics or processes, or as yet ill defined interactions between magma and meteoric water.

TABLE* Oxygen Isotope Compositions of Volcanic Rocks from
the Snake River Plain, Idaho

Sample No.	$\delta O^{18*}, \text{‰}$	Description
62-P-69		Olivine tholeiite, Snake River Group; National Reactor Testing Station, well No. 80, 63' below surface; uppermost flow.
Whole rock	5.4	
Plagioclase	5.6	
Augite	5.1	
55-P-275		Madson olivine tholeiite, Snake River Group: near Malad Springs, Gooding County, Idaho (olivine-plagioclase pillow vitrophyre).
Whole rock	5.6	
59-P-13		McKinney olivine tholeiite, Snake River Group: near mouth of Malad River, Gooding County, Idaho.
Glass	5.0	
59-P-160	4.8	Cognate xenolith in McKinney olivine tholeiite (olivine-plagioclase cumulate), Snake River Group; McKinney Butte, Gooding County, Idaho.
54-P-65		Olivine tholeiite (olivine and plagioclase phenocrysts), Snake River Group: near Devil's Washboard Falls, Gooding County, Idaho.
Plagioclase	5.5	
OB-32		King Hill lava--basic end of series, iron-enriched basalt (olivine + plagioclase + magnetite + ilmenite microphenocrysts); Bruneau Formation, Idaho Group: near King Hill, Elmore County, Idaho.
Whole rock	6.3	

(continued)

59-P-276A

Cold Springs Creek lava--basic end of series, iron-enriched pillow basalt (olivine + plagioclase + magnetite + ilmenite + apatite microphenocrysts), Bruneau Formation, Idaho Group: Ryegrass Creek, Elmore County, Idaho.

Glass 5.9

72-S-16A

Granitic gneiss xenolith (oligoclase + intermediate alkali feldspar + quartz) in lava like 72-S-15A; same location.

Xenolith 9.1
Host lava 8.6
Plagioclase 7.2

72-S-15A

Plagioclase-augite andesitic porphyry, east rim of Crystal Butte, Fremont County, Idaho approximately 10' from xenolith location.

Groundmass 8.9
Plagioclase 7.1
Augite 6.3

Washington

71-104 Z

Upper Yakima, high-titanium basalt, plagioclase phenocrysts, Ice Harbor Dam, near Pasco, Washington.

Whole rock 5.5

71-114 Y

Upper Yakima, high-titanium basalt, plagioclase, pyroxene, olivine phenocryst, Ice Harbor Dam, near Pasco, Washington.

Whole rock 5.6

Oregon

Pl-7-3*

5.9

Basalt, Newberry Crater.

California

ML†

5.9-6.8

Basalts, Medicine Lake Highland.

CA5‡

6.9

Subalkaline basalt, Mono Craters.

*Definitions and experimental techniques as in Muehlenbachs, this report.

†Data from Taylor, 1968.

‡Datum from Anderson, Clayton, and Mayeda, 1971.