On the enigmatic basalts of the Eastern Snake River Plain, Idaho

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Quaternary, dominantly mafic, volcanism of the Eastern Snake River Plain (ESRP) has persisted across southern Idaho in the wake of time-transgressive Tertiary-Quaternary bimodal magmatism (basalt-rhyolite) associated with the Yellowstone hotspot. Isotopic characteristics of the ESRP basalts suggest a connection to both lithospheric and plume source reservoirs, making it perplexing to define the melting and fractionation conditions for this widespread magmatism.

Sr, Nd, and Pb isotope signatures for the basalts require contributions from enriched crust or mantle sources. Pb isotope signatures in olivine-hosted melt inclusions ($^{208}Pb/^{206}Pb$ = 2.058-2.170) expand the range delimited by their host rocks by a factor of ~2. This heterogeneity is not adequately explained by crustal contamination alone and requires melting of enriched, possibly lithospheric, mantle. In contrast, olivines from magnesian ESRP basalts collected within 200 km of the main locus of activity at Yellowstone caldera have $^{3}He/^{4}He$ ratios >15 R_a. Such elevated ratios are unexpected of enriched mantle and are normally attributed to mantle plumes. Additionally, the ESRP basalts exhibit a range in $^{230}Th/^{232}Th$ that varies from ratios typical of depleted mantle ($^{230}Th/^{232}Th>1.1$) to enriched mantle ($^{230}Th/^{232}Th<0.8$) sources. Activities of ^{230}Th generally exceed those of ^{238}U and the associated Th excesses vary by a factor of >10. Collectively, the range in Th isotope ratios is better explained by extraction of melts from different depths and sources rather than by decay of $^{230}Th/^{232}Th$ during hundreds of k.y of basaltic magma storage.

Possible sources for the ESRP basalts include a deep-seated mantle plume, Proterozoic to Archean-aged lithosphere, and/or depleted upper mantle. Covariations among the isotope ratios, while much more complicated than simple two component mixing, are probably best explained if the basalts are derived from plume-metasomatized subcontinental lithosphere.

Geochemical evidence for multiple, chemically-evolved mafic magma reservoirs beneath the eastern Snake River Plain (ESRP)

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Geochemical and physical volcanological studies of the ESRP imply a system with variably evolved magma batches and possibly several magmatic sources. Chemical variability is extensive (MgO = ~11.2 – 4.6 wt. %; La = ~8 – 60 ppm) in over 500 analyses of samples representing ~40 individual eruptions. Petrologic modeling suggests that early magmas in the sequence form (layered?) sub-volcanic mafic intrusions that fractionate to evolved compositions. Later mafic magmas commingle with these earlier-derived intrusions, partially melt and assimilate late-stage fractionates, and erupt with chemically evolved, but isotopically unevolved compo-sitions. Olivine equilibrium temperatures range ~1210 – 1068 °C, and the most mafic magmas in the system are tightly constrained to temperatures above 1200 °C, suggesting separation of magma from upper mantle regions and little, if any, interaction with pre-Neogene crust. Samples representing lower temperature magmas typically have the highest LIL elements and diktytaxitic textures made up of coarse interlocking plagioclase crystals and large pore spaces. Textures are apparently related to high volatile contents obtained during magma evolution in crustal reservoirs. Temperature and oxygen fugacity (fO_2) measurements indicate a close adherence to the QFM buffer, at least within ~0.5 log units. Geochemical models and fO_2 measurements further suggest concomitant increase in volatiles with increasing incompatible elements and decreasing Mg. Oxide equilibria temperatures ranging ~750 – 1040 °C indicate possible protracted conditions of final cooling and ripening. These results suggest that an extensive system of small mafic intrusions was, and perhaps still is, recently active beneath the ESRP. A vertical series of evolving magmas, in which magmas undergo extensive fractionation and “autoas-similation”, may be similar to the magmatic columns evident in other chemically variable mafic systems.