Heterogeneity in Columbia River Basalt Group dikes and the flows they feed: Implications for significance and time scale of magma processes

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Heterogeneity in flood-basalt flows and their feeder dikes can provide insight into magma processes, and the time scales of those processes. Columbia River Basalt Group dikes that can be physically correlated to flows they feed appear to fall into three categories: 1) dikes and flows with homogeneous compositions, 2) dikes with heterogeneous compositions that feed homogeneous flows and, 3) dikes and flows with heterogeneous compositions. Dikes-flows with homogeneous compositions typically occur when there are significant time gaps between eruptions (e.g. Saddle Mountains Basalt). Heterogeneous dikes that feed homogeneous flows typically are zoned. The central portion of the dike correlates to the flow but the selvage and margins are much more evolved than the main dike. No surface eruption counterpart to the evolved compositions are found which suggests that the evolved compositions were of minor volume and represent the initial eruption of a slightly zoned magma chamber. These dikes occur both when there are significant time gaps between eruptions, and when many eruptions are occurring close in time. Dikes that have heterogeneous compositions and feed heterogeneous flows tend to be very complex. As an example, one Grande Ronde Basalt dike is zoned from an evolved composition at the margins to a significantly less evolved central portion. The dike fed three lava flows that have a combined volume of nearly 4,000 km^3. The volume of each eruption increases with time and corresponds to a zone in the dike. The first two eruptions were nearly simultaneous and eventually mixed together over 100 km from the vent to form a complex single flow; the third and largest erupted a short time later. This implies that the magma chamber underwent very rapid (months?) changes in composition with each change resulting in the eruption of large volume of a relatively homogeneous magma.

The calc-alkaline paradox of the inland Pacific Northwest

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The main phase of Columbia River flood-basalt volcanism (~16.6-15.0 Ma) was followed by bimodal volcanism along two age-progressive trends: eastward along the Snake River Plain (SRP) and westward along the Oregon High Lava Plains (HLP). Both trends contain tholeiitic basalt but lack intermediate rock types. Superimposed midway between the SRP and HLP, however, is a north-south belt composed largely of partly contemporaneous, intermediate, calc-alkaline to mildly alkaline rocks, which are associated with graben formation extending from the Northern Nevada Rift (NNR) in the south, broadening northward to include the Oregon-Idaho graben, and terminating at the La Grande graben in northeastern Oregon.

Most of these rocks show the lack of Fe-enrichement that defines the calc-alkaline trend. Traditionally, such trends are attributed to the high water content of subduction-related magmas, which depresses plagioclase as a liquidus phase and promotes the crystallization of hornblende and magnetite. However, such a scenario cannot be applied to the eastern Oregon calc-alkaline belt, which lies well east of the Cascade volcanic chain. Others have suggested instead that these rocks are the product of back-arc extension, consistent with both their geographic position and their association with extensional structures. However, there is a lack of empirical evidence for the genesis of calc-alkaline rocks in back-arc environments, which are more typically dominated by mafic rocks with tholeiitic or alkalic compositions.

This apparent paradox in the genesis of these calc-alkaline lavas suggests that there is something unique about the back-arc environment east of the Cascades. We present chemical and petrographic data demonstrating that the calc-alkaline lavas are the product of crustal contamination and/or magma mixing of high-temperature mafic magmas with high-silica, low-Fe granitic sources. This north-south zone of mixing and contamination coincides with the apparent north-south crest of the Yellowstone mantle plume head in Miocene times. Elevated temperatures provided by the plume, in an environment of back-arc extension, generated a unique environment conducive to such mixing.