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Anoxic chemical alteration of basalt and its implications for petrogenetic investigations: Insights from lavas of the Columbia River flood basalt province, northwestern U.S.A.

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Investigators sampling lavas for the purpose of evaluating petrogenetic processes generally avoid surficially weathered rock, which is readily identified by the reddish color imparted by the oxidation of Fe and its incorporation into hydroxides and oxyhydroxides. It is thereby assumed that avoidance of oxic-altered lava in sampling ensures that analyzed sample compositions correspond to eruptive compositions, and that variations in the chemical characteristics of such samples represent chemical diversity deriving from petrogenetic processes.

The interpretation of analyses of samples obtained from such sampling implicitly incorporates the assumption that chemical alteration of lavas occurs only under oxic conditions of surficial weathering. Upon immersion of lavas in groundwater, however, dissolved oxygen is readily depleted due to abundant reductants in mafic lava, and the redox state commensurately decreases to low positive or negative Eh values. Lava altered under reducing conditions therefore lacks the characteristic visible color changes associated with oxic surficial weathering, such that gray anoxic-altered lava may be misinterpreted as unaltered. The common occurrence of secondary pyrite in subsurface lava samples obtained from boreholes indicates a low-Eh, circum-neutral to moderately alkaline, low-temperature water-rock environment.

In terms of the normalized abundances (to 100 wt% volatile-free) routinely used to interpret magmatic processes, anoxic chemical alteration generates strong Fe depletion and lesser Mg depletion, yielding higher mg#. Normalized abundances of all immobile elements, as well as SiO_2, are higher in anoxic-altered lava than in unaltered lava. The actual changes to lava compositions are not described by normalized abundances. However, they do correspond to mass-normalized abundances corrected for mass loss from mineral dissolution [1, 2].

Basalt-hosted, oxygen-depleted groundwaters undoubtedly have occurred throughout much of Earth's history. The recognition of and correction for anoxic chemical alteration is essential to the correct interpretation of petrogenetic processes for all but those geologically young lavas that have not undergone burial and prolonged immersion in groundwater.

[1] Sawlan (2018), *Geosphere*, 14, 286–303; https://doi.org/10.1130/GES01188.1

[2] Sawlan (2019), *Geosphere*, 15, 1448–1458; https://doi.org/10.1130/GES02137.1