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Microtextures, microchemistry, and mineralogy of basaltic glass alteration, Jeju Island, Korea, with implications for elemental behavior

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Abstract

The meteoric alteration of basaltic glass in hyaloclastite (0.55 to 0.2 Ma) from Jeju Island, Korea, was examined using high-resolution electron microscopy, in situ sample preparation using focused ion beam, and microchemical analysis. The glass particles showed a sequential development of alteration textures toward the glass interior as follows: oscillatory zoning of smectite and amorphous bands/hemispheres, congruent dissolution of glass with smectite infilling in interparticle pore, and the replacement of nanogranular amorphous aggregate (NAA) for porous leached glass (LG) followed by a partial crystallization of smectite. Chemical compositions of LG widely varied from partial to complete leaching of almost all kinds of cations, to a preferred leaching of Na only. The order of leaching in LG followed $Na^{+}>Mg^{2+}>Ca^{2+}=Fe^{2+}>Al^{3+}>Ti^{4+}$. Leached cations were removed from the hyaloclastite-water system or incorporated into secondary phases. Sodium was all but removed from the system. Magnesium was largely lost with partial incorporation into smectite. Calcium was significantly retained in NAA, partly incorporated into the smectite interlayer, and partly lost. Iron and Al were partitioned between NAA and smectite. Titanium was mostly retained in NAA and Ti-rich silicates. The molar ratio of major cations to Si was reversed from $Ca^{2+}>Mg^{2+}>Na^{+}$ in basaltic glass to $Na^{+}>Mg^{2+}>Ca^{2+}$ in groundwater. The geochemical evolution of pore water was influenced by the microtextural and microchemical evolution of glass particles, and vice versa. Systematic microtextural, microchemical, and mineralogical analyses of natural glass alteration are critical to understanding the long-term behavior of glass alteration.

Keywords: Basalt, hyaloclastite, glass, alteration, TEM, SEM, texture, chemistry, mineralogy