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SPECIAL COLLECTION: GLASSES, MELTS, AND FLUIDS, AS TOOLS FOR UNDERSTANDING VOLCANIC PROCESSES AND HAZARDS

Aluminosilicate melts and glasses at 1 to 3 GPa: Temperature and pressure effects on recovered structural and density changes†

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Abstract

In the pressure range in the Earth's mantle where many basaltic magmas are generated (1 to 3 GPa) (Stolper et al. 1981), increases in the coordination numbers of the network-forming cations in aluminosilicate melts have generally been considered to be minor, although effects on silicon and particularly on aluminum coordination in non-bridging oxygen-rich glasses from the higher, 5 to 12 GPa range, are now well known. Most high-precision measurements of network cation coordination in such samples have been made by spectroscopy (notably ^{27}Al and ^{29}Si NMR) on glasses quenched from high-temperature, high-pressure melts synthesized in solid-media apparatuses and decompressed to room temperature and 1 bar pressure. There are several effects that could lead to the underestimation of the extent of actual structural (and density) changes in high-pressure/temperature melts from such data. For non-bridging oxygen-rich sodium and calcium aluminosilicate compositions in the 1 to 3 GPa range, we show here that glasses annealed near to their glass transition temperatures systematically record higher recovered increases in aluminum coordination and in density than samples quenched from high-temperature melts. In the piston-cylinder apparatus used, rates of cooling through the glass transition are measured as very similar for both higher and lower initial temperatures, indicating that fictive temperature effects are not the likely explanation of these differences. Instead, transient decreases in melt pressure during thermal quenching, which may be especially large for high initial run temperatures, of as much as 0.5 to 1 GPa, may be responsible. As a result, the equilibrium proportion of high-coordinated Al in this pressure range may be 50 to 90% greater than previously estimated, reaching mean coordination numbers (e.g., 4.5) that are probably high enough to significantly affect melt properties. New data on jadeite ($NaAlSi_2O_6$) glass confirm that aluminum coordination increase with pressure is inhibited in compositions low in non-bridging O atoms.

Keywords: NMR, aluminosilicates, high pressure, aluminum coordination, densification, glass, pressure drop, piston-cylinder apparatus