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Review

Glass structure, melt structure, and dynamics: Some concepts for petrology

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Abstract

The thermodynamic and transport properties of the aluminosilicate melts at the heart of most magmatic processes vary in complex ways with composition, temperature, and pressure. Insights into these properties can come from information on the structure of the melts themselves, and more commonly from their glassy, quenched equivalents. Although most such connections remain qualitative or semi-quantitative, they are fundamentally important in interpretation of observations on igneous systems in nature and the laboratory, and in the formulation of physically accurate models. This review presents some of the important concepts of aluminosilicate glass and melt structure and dynamics that are most relevant to furthering our understanding of the igneous processes so central to how our planet has formed and evolved. The relationships among glasses, melts, and crystals are introduced. The structural underpinnings of temperature and pressure effects on melt free energies, densities, and viscosities, constraints on the extent of order/disorder among cations and anions in melts, why silica activity varies so strongly with composition, and how liquid-liquid phase separation can be understood, are discussed. Some simple, but useful, general views are presented on melt disorder and the shapes of liquidus surfaces (key to magmatic phase equilibria), as are links between atomic-scale dynamics and viscous flow and diffusion.

Keywords: Silicate melt, glass structure, phase equilibria, viscosity, igneous process, Invited Centennial article, Review article