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Dissolved, Exsolved and Re-dissolved H₂O in Volcanology: Rheology, Glass Transition, and Thermodynamics

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All natural magmas originate with dissolved H₂O. All such magmas degas during transport and eruption. The presence, abundance, and state of H₂O in magmas control phase relations and the transport properties of melts and magmas. For example, dissolved H₂O lowers viscosity, lowers glass transition temperatures (T_g), and controls the temperature and nature of crystallization. The effects of exsolved water are also substantial in terms of modifying the bulk transport properties of the magma, facilitating egress of volatiles and, thus, promoting crystallization. Of great interest is the coupling this component (H₂O) creates between the thermodynamic processes (i.e. cooling, crystallization, vesiculation) and the properties (i.e. density, viscosity) controlling the mechanical behaviour (i.e. flow and fracture) of magma during transport and eruption. The coupling allows for strong feedbacks between system variables. The component H₂O also has a retrograde solubility in silicate melts wherein H₂O solubility in the melt increases with decreasing T. Here, we explore some of the consequences of retrograde solubility of H₂O for volcanic systems using a new preliminary

experimental dataset. These data establish the 1-atmosphere solubility limits of H₂O in silicic melt at volcanic temperatures and are complementary to the growing literature on the low pressure (<50 MPa) solubility of volatiles in silicate melts (e.g., Behrens et al. 2009; DiMatteo et al. 2004; Liu et al. 2005; Zhang 1999). We specifically look at the implications of these data, especially the retrograde solubility limits, for welding of pyroclastic deposits (e.g. ignimbrites, conduit fill, fall out). The cessation of welding and compaction processes in pyroclastic deposits is reached when deposits cool below T_g. However, the fact that H₂O has a retrograde solubility means that inter- and intracrust water will be resorbed by vitric pyroclasts as the deposit cools (regardless of load). This has the immediate consequence of reducing the viscosity of the pyroclasts and, more importantly, reducing T_g. The reduction in pyroclast viscosity facilitates sintering, welding and compaction processes. The reduced T_g, due to resorbed H₂O, extends the T-time window for porosity reduction via viscous flow. Variations in welding intensity can, therefore, be an expression of the competition between cooling of the deposit and the re-hydration of vitric pyroclasts during cooling driven by retrograde solubility of H₂O. In essence, the temperature of the cooling deposit chases a descending T_g; once the deposit temperature catches and drops below T_g, viscous deformation processes are quenched. This allows for the H₂O contents of vitric pyroclasts to preserve higher water contents that they had at the time they erupted. The analysis of the relationships between eruptive, emplacement and glass transition temperatures are discussed further. References Cited: Behrens H. et al. 2009: Am Min 94, 105-120. Di Matteo V. et al. 2004: Chemical Geology 213, 187-196. Liu Y et al. 2005: J Volc Geotherm Res 143, 219-235. Zhang Y 1999: Rev Geophys 37, 493-516.

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