

Experimental temperature cycling as a powerful tool to enlarge melt pools and crystals at magma storage conditions

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ABSTRACT

Experiments in high silica systems at temperatures close to the solidus often produce crystals and melt pools that are too small for in situ analysis. Oscillating the temperature during an experimental run speeds up recrystallization of magma by dissolving small and increasing the size of larger crystals, dramatically changing the crystal size distribution. This principle of periodic heating and cooling, caused for example by repeated injection of hot magma, is also a potential acceleration for the formation of phenocrystic textures in natural rocks.

Here we show that temperature cycling has the potential to significantly enlarge melt pools and crystals in a fluid saturated dacitic system. Using a natural dacite dredged from the Pacific-Antarctic Rise as starting material, we performed crystallization experiments applying temperature cycling systematically for two different temperatures and different water activities at 200 MPa. For experiments at 950 °C (with $a_{\text{H}_2\text{O}} \sim 1$, ~ 0.3 , and < 0.1) an internally heated pressure vessel was used, experiments at 800 °C (with $a_{\text{H}_2\text{O}} \sim 1$, ~ 0.5) were performed in a cold-seal pressure vessel. Comparative experiments at equilibrium conditions with constant temperature were performed for both approaches. For all other experiments temperature was cycled with amplitudes of 20 K for different time intervals but constant total run duration after initial equilibration at constant temperature. Additionally, for one experiment at 800 °C, the temperature was increased several times by 50 K to study the potential of dissolving tiny crystals in the matrix.

As a result of the temperature cycling, tiny crystals in the matrix were preferentially dissolved, leading to large melt pools with only rare mineral inclusions enabling microprobe analysis using a defocused beam. With regard to the area of the 10 largest crystals of each cycling experiment, clinopyroxene crystals were up to 19 times larger, and plagioclase crystals even up to 69 times when comparing to experiments performed at constant temperature. Grain sizes of FeTi-oxide phases are less influenced by this technique. Essential requirements for applying temperature cycling routinely are identical phase relations and compositions in runs with constant and cycled temperature. For all studied temperatures and water activities, the phase assemblage was the same and compositions of all phases are identical within the analytical error. Thus, the temperature cycling technique opens interesting perspectives, especially in facilitating in situ analysis in near solidus systems.

Keywords: Experimental petrology, temperature cycling, crystallization experiments, dacite, crystal growth, phenocrysts