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Experimental solidification of an andesitic melt by cooling

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The transition from a silicate melt to a fully solidified magmatic rock is an important phase transformation occurring on the Earth. The melt to rock transition involves vitrification and/or crystallization, two processes related to the melt composition and to temperature/pressure variation. The aim of this study is to investigate the crystallization behaviour of an andesitic melt under dynamic cooling conditions. Solidification experiments at (a) five different cooling rates (25, 12.5, 3, 0.5 and 0.125 ˚C/min) between 1300 and 800 ˚C, and (b) variable quenching temperatures (1100, 1000, 900 and 800 ˚C) at a fixed cooling rate of 0.5 ˚C/min were performed on an andesitic melt (SiO_2= 58.52 wt.% and Na_2O + K_2O = 4.43 wt.%) at air conditions from high superheating temperature. Results show that simultaneous and duplicated experiments with Pt-wire or Pt-capsule produce identical run-products. Preferential nucleation on Pt-containers or bubbles is lacking. Plagioclase and Fe-Ti oxide crystals nucleate firstly from the melt. Clinopyroxene crystals form only at lower cooling rates (0.5 and 0.125 ˚C/min) and quenching temperatures (900 and 800 ˚C). At higher cooling rates (25, 12.5 and 3 ˚C/min) and quenching temperature (1100 ˚C), plagioclase and Fe-Ti oxide crystals are embedded in a glassy matrix; by contrast, at lower cooling rates (0.5 and 0.125 ˚C/min) and below 1100 ˚C they form an intergrowth texture. The crystallization of plagioclase and Fe-Ti oxide starts homogeneously and then proceeds by heterogeneous nucleation. The crystal size distribution (CSD) analysis of plagioclase shows that crystal coarsening increases with decreasing cooling rate and quenching temperature. At the same time, the average growth rate of plagioclases decrease from 2.1×10^{-6} cm/s (25 ˚C/min) to 5.7×10^{-8} cm/s (0.125 ˚C/min) and crystals tend to be more equant in habit. Plagioclases and Fe-Ti oxides depart from their equilibrium compositions under the effect of dynamic crystallization conditions. The anorthite (An) content of plagioclases increases as the cooling rate and quenching temperature increase; consequently, plagioclases shift from labradorite-andesine to anorthite-bytownite. Fe-Ti oxides are mainly close to the magnetite and/or Ti-magnetite end-members. However, at higher cooling rates and quenching temperature some crystals are solid solutions with the spinel s.s. end-member. The progressive decrease of the crystal content with increasing cooling rate and quenching temperature produces glasses characterized by higher CaO and Al_2O_3 and lower SiO_2 and K_2O amounts. Therefore, kinetic effects due to cooling significantly change phase compositions with remarkable petrological implications for the solidification of andesitic lavas and dikes. The glass-forming ability (GFA) of the andesitic melt has been also quantified in a critical cooling rate (Rc) of ∼37 ˚C/min. This value is higher than those measured for latitic (Rc ∼1 ˚C/min) and trachytic (Rc <0.125 ˚C/min) liquids demonstrating that little changes of melt composition are able to significantly shift the initial nucleation behaviour of magmas and the following solidification paths.