Non-stoichiometric nano-crystallization in magmas: the impact of compositional change on viscosity

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Abstract

Magmas are composed of a silicate melt suspending crystals and/or bubbles. Viscosity exerts a fundamental control on magma behaviour and determines the style of a volcanic eruption. Nanolites – crystals smaller than a micrometer – are thought to affect magma viscosity, but the underlying mechanism for this remains unclear. Here, we measure the viscosity of andesite melts with different amounts of iron as a function of temperature, and of time as nanolites can form and grow. We find that melt viscosity decreases as we heat up melts until a critical temperature where a time-dependent large increase in viscosity occurs with time. The magnitude of this increase is controlled by the melt iron content. At constant temperature, these changes are substantial and can reach up to three orders of magnitude. Using transmission electron microscopy and viscosity modelling, we conclude that this viscosity increase is caused by the formation of nanolite. By testing aggregation and suspension effects, we discount that the solid crystal phase – the nanolites – are themselves the cause of the viscosity change. Instead, we show that the resultant change in the melt composition can explain the increase observed. Our finding suggests that iron-rich melts may become far more viscous once iron is removed from the melt phase to form nanolites. Coupled with previous findings that nanolites can cause bubble nucleation at substantially reduced volatile supersaturation, we conclude that they may play a key role in magma explosivity. Our work demonstrates an underlying mechanism for the role played by nanolites in viscosity changes of magmas from source-to-surface.

Keywords: melt, crystallization, nanocrystals, rheology, volcanology

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