What do microlites tell us about obsidian pyroclasts?

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Abstract

One model for formation of obsidian pyroclasts suggests that they form through sintering of ash particles on volcanic conduit walls, which are subsequently torn out and entrained in the gas-particle dispersion out of the erupting vent. Here, we investigate microlite abundances and textures in obsidian pyroclasts in order to determine the time required to produce adequate numbers of microlites, and hence the pyroclasts themselves. We measured microlite number densities (MNDs) and microlite and vesicle orientations in obsidian pyroclasts in tephra deposits from the 1340 A.D. North Mono eruption. MNDs increase with decreasing dissolved H₂O concentrations. Also, microlite spatial orientations become less aligned and differ more from vesicle orientations with decreasing dissolved H₂O concentrations. MNDs increase from the second layer (P2) through the final layer (P10). To investigate timescales required to replicate MNDs in the North Mono obsidian, we performed time, temperature and pressure-controlled experiments with rhyolitic glass from the same eruption. MNDs in our experiments initially increase with decreasing pressure (50-35 MPa), then decrease as pressure decreases further (35-10 MPa). MNDs in obsidian from layers P2-P10 were replicated in ~7 hours or less. Based on these observations we propose a model where during the initial phase of the North Mono eruption most obsidian formed close to the magmatic fragmentation depth, equilibrated for short time periods (< 7 hours) and were then erupted out of the volcanic vent. These obsidian clasts have lower MNDs than subsequent phases, and microlites are well aligned with each other and with vesicles, reflecting their short residence time in the conduit, higher dissolved H₂O contents, and lower viscosities. During later phases of the North Mono eruption obsidian formed at various depths in the conduit, equilibrating for longer periods of time (7 hours) before being erupted out of the vent or sintering together with other clasts and equilibrating at shallower depths before being erupted. These obsidian clasts have higher MNDs than earlier phases of the eruption, and microlites are not well aligned with each other or with vesicles, reflecting their variable residence times in the volcanic vent, lower dissolved H₂O contents, and higher viscosities.
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Introduction
Understanding magmatic degassing is critical to understanding volcanic eruptions. Obsidian pyroclasts record degassing, but how the clasts form must be understood in order to correctly interpret the information they contain. To be able to understand what is recorded in obsidian, we constrain timescales for the formation of obsidian pyroclasts from the ~1340 A.D. North Mono eruption, and we investigated their physical evolutions.

Microlite Experiments
We investigated ranges of microlite number densities (MND) in obsidian pyroclasts from the North Mono eruption, and then conducted pressure, temperature and time-controlled microlite growth experiments in order to calibrate microlite growth and constrain obsidian sintering timescales. Pressure was hydrostatic (equal in all directions). Microlites in the experiments are randomly oriented. Contour lines with numbers on top are isochrons that show experimental MND as a function of durations (in hours) of experiments at different pressures.

Stratigraphic trends in obsidian clasts
- MND increase with stratigraphic height. Therefore sintering times of obsidian pyroclasts are progressively longer from P2, through P4 and P6, to P10.
- Percentage of obsidian pyroclasts with distorted-type vesicles (D, StrD) increases markedly with stratigraphic height.
- Every layer contains obsidian pyroclasts with multiple variations of microlite and vesicle textures and alignments. Therefore there is no easily definable stratigraphic trend in microlite (or vesicle) alignments.

Most obsidian pyroclasts in the North Mono eruptive sequence were produced in 7 hours or less.

Eruptive Model
Early in the eruptive sequence, obsidian pyroclasts sintered quicker and were mostly produced at greater depths. Higher dissolved H2O contents / lower viscosities allowed relaxation and efficient alignment of microlites and vesicles. In later phases of the eruptive sequence, obsidian pyroclasts took longer to sinter and were produced mostly at shallower depths. Particles were more viscous and they retained distorted vesicle shapes. Higher viscosities prevented microlites from aligning as efficiently. Most obsidian pyroclasts in the North Mono eruption were produced in 7 hours or less.