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Redoubt 2009 revisited: A melt inclusion volatile perspective on staging and degassing of early erupted andesite

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Redoubt Volcano is a frequently active, very high threat[1] stratovolcano located in the Cook Inlet near Anchorage, Alaska. Here, we present pre-eruptive volatile concentrations measured within melt inclusions (MIs) for two early explosions (events 5 and 6) from the 2009 eruption. These measurements are the first for any Alaska-Aleutian volcano to incorporate both glass and vapor bubble volatiles in plagioclase- and pyroxene-hosted MIs, and thus enable us to present direct petrologic storage pressure estimates and context for surface gas emissions. Volatile contents (H_2O, CO_2, S, Cl, F) in MI glass were measured by secondary ion mass spectrometry, with vapor bubbles analyzed by Raman spectroscopy to constrain total CO_2. Electron probe microanalysis was conducted on groundmass glasses and a subset of MIs. MI glasses are highly evolved (70.0–77.5 wt.% SiO_2) and contain 0.42–3.56 wt.% H_2O, 9–548 ppm CO_2, 9–400 ppm S, 586–6851 ppm Cl, and 121–1157 ppm F. Co-erupted groundmass glass exhibits S up to 260 ppm and Cl concentrations from 670–2300 ppm. Raman spectroscopic measurements of MI vapor bubbles reveal additional CO_2 contributions of 100–950 ppm, doubling melt CO_2 estimates and yielding maximum reconstructed MI CO_2 concentrations of 1030 ppm (Figure 1). Solubility model-derived MI entrapment pressures, factoring in vapor bubble CO_2 concentrations when available, range from ~50–235 MPa, in general agreement with seismic[2] and geodetic[3] constraints, and extending current petrologic estimates (90–160 MPa)[4] by up to 75 MPa. Mass balance calculations suggest that melt CO_2 and S account for <15% of cumulative gas emissions from the erupted 2009 magma, while observed gases were much richer in CO_2 and S. This requires an alternative volatile source for gas emissions, such as an excess fluid phase or gas sparging from a deeper, unerupted mafic magma. Further integration of MI and gas data will facilitate the development of a robust degassing model for the 2009 eruption of Redoubt.

[1] Ewert et al. (2018), *USGS Scientific Investigations Report* 2018-5140, 1-40.
[2] Power et al. (2013), *JVGR* 259, 31-44.
[3] Grapenthin et al. (2013), *JVGR* 259, 115-132.
[4] Coombs et al. (2013), *JVGR* 259, 349-372.

Figure 1.