

CO₂, SO₂, and H₂S degassing related to the 2009 Redoubt eruption, Alaska

Cynthia Werner¹, Peter J Kelly², William C Evans³, Micheal P Doukas², Robert McGimsey¹, Christina Neal¹

¹US Geological Survey, Alaska Volcano Observatory, USA, ²US Geological Survey, Cascades Volcano Observatory, USA, ³US Geological Survey, Menlo Park, USA

E-mail: cwerner@usgs.gov

Emissions of CO₂, SO₂, and H₂S from the 2009 eruption of Redoubt Volcano, Alaska were well monitored. Elevated CO₂ emissions were measured 5 months prior to the eruption and varied from 3630 to 9020 tonnes per day (t/d) in the 6 weeks prior to the eruption. In contrast, low S emissions were typical during the pre-eruptive period, resulting in molar C/S ratios of 30–60. However, the high C/S ratio dropped to a value typical for Cook Inlet volcanoes (ave. = 2.4) coincident with the first phreatic explosion on March 15, 2009, and remained low throughout all phases of the eruption. Observations of melt water discharge and water chemistry leading up to the eruption suggested that surface waters represented drainage from surficial lenses of condensed magmatic steam and glacial meltwater, and that only a few hundred tonnes/day of SO₂ were reacting to a dissolved component, not the > 2100 t/d SO₂ expected from degassing of magma in the upper crust (3–6.5 km), where petrologic analysis showed that the final magma equilibration occurred. Thus, the high pre-eruptive C/S ratios could reflect bulk degassing of upper-crustal magma followed by nearly complete loss of SO₂ in a magmatic-hydrothermal system deep in the edifice, though no clear hydrothermal component was detected in the analyses of the effluent, even in post-eruption sampling (Oct. 2012). Alternatively, we prefer that the high C/S ratios are attributed to degassing of low silica andesitic (LSA) magma that intruded the mid-crust in the 5 months prior to eruption; modeling suggests that mixing of this LSA magma with a pre-existing high silica andesite magma or mush in the mid-to-upper crust would have resulted in a C/S ratio consistent with that measured during the eruption. Maximum emission rates measured with airborne techniques were 33,110 t/d CO₂, 16,650 t/d SO₂, and 1230 t/d H₂S. Pre-eruptive open system degassing accounted for 14% of the total CO₂ and 4% of total SO₂, whereas post-eruptive degassing was responsible for 27 and 30% of the total CO₂ and SO₂ with measurements extending over one year following the cessation of dome extrusion. The magma degassed primarily as a closed system with approximately 59 and 66% of the total CO₂ and SO₂, respectively, emitted during the explosive and dome growth periods. SO₂ made up on average 92% of the total S throughout the eruption. Primary volatile contents calculated from pairing degassing estimates with the erupted magma volumes over the same time periods range from 0.9–2.1 wt.% CO₂ and 0.27–0.56 wt.% S, with preferred estimates of 1.25 wt.% CO₂ and 0.35 wt.% S. Assuming these values, up to 30% more magma degassed in the year following final dome emplacement.