Crystal archives of the Havre 2012 submarine rhyolite eruption: Understanding the origin of crystal-poor rhyolites

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The Havre 2012 submarine eruption is the largest submarine eruption of rhyolite recorded in historical times. Eruptive products included a ~1.4 km^3 pumice raft and an additional ~0.1 km^3 of magma was emplaced as 12 distinct fissure-fed lava flows/domes across the summit with an associated field of giant seafloor pumice. In addition to the challenges in resolving the dominant eruptive mechanism that produced the pumice raft from such a deepwater setting, the Havre eruption also poses challenges in understanding how large volumes of rhyolite magma are generated in island arc settings. This is because the past eruptive history and previous eruption products that can be used to provide insights into the operation of the Havre magmatic plumbing system are poorly known due to its remote and deep-water (900 mbsl) location. General models for rhyolite magmatism have distinguished two end-member types: 1) crystal-rich rhyolites and dacites as the product of mush remobilisation, and 2) crystal-poor rhyolites that can reflect very efficient melt segregation from crystal mush. The 2012 Havre eruption evacuated a crystal-poor rhyolite (3-5%) to produce the volumetrically dominant pumice raft, while subtly higher phenocryst contents are observed in the seafloor Giant Pumice (5-8%) and lavas (8-12%). For crystal-poor rhyolites like the Havre pumice, it can often remain ambiguous as to whether the few phenocrysts present (in the case of Havre: plagioclase, orthopyroxene, clinopyroxene, titanomagnetite, ±accessory phases of ilmenite, pyrrhotite and quartz) truly represent autocrysts crystallising from the surrounding melt or are antecrysts due to mush remobilization, or possibly a combination of both. The few crystals present are then strongly relied upon to constrain magma timescales and pre-eruptive conditions such as magmatic temperatures, pressures, water content and fO_2 assuming all crystals are autocrystic. Here, we present the first detailed petrographic and chemical study of the crystal cargo of the Havre pumice raft (~93% of the eruptive material) and in comparison, the giant seafloor pumice. This coupled with thermobarometry calculations and MELTS models will constrain the origins of phenocrysts in this crystal-poor rhyolite. Consequently, identifying the proportions of autocrysts versus antecrysts in the Havre pumice is a first step in understanding petrogenetic processes in the Havre volcano. Each crystal population can provide valuable insight into the Havre magmatic system including: 1) the pre-eruptive conditions; 2) the conditions of a parental melt; and 3) mush zone(s). The combined information from each crystal population allows for a more complete understanding of the magmatic processes (i.e., crystal fractionation, magma recharge, mush remobilization) and the timescales needed to generate significant volumes of crystal-poor rhyolitic eruptions in island arc settings.