Experimental constraints on partitioning of hydrogen between plagioclase and basaltic melt

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Introduction: The hydrogen in nominally anhydrous minerals (NAMs) can be an indicator of H₂O activity in silicate melts if the partitioning behavior of hydrogen between NAMs and melts is known. Plagioclase is one of the NAMs and one of the most common minerals in arc basaltic rocks. Therefore, hydrogen in volcanic plagioclase (OH) can be a useful proxy of H₂O in arc basaltic magmas. Here, we report experimental results on the partitioning of hydrogen between Ca-rich plagioclase and basaltic melt. We also apply the OH concentration of plagioclase as hygrometer of melt based on experiments.

Experimental: Hydrous melting experiments of arc basaltic magma were carried out at 350 MPa using an inter-nally-heated pressure vessel installed at Magma Factory, Tokyo Institute of Technology. Starting material was hydrous glass (0.8 wt.% < H₂O < 5.5 wt.%) of an undifferentiated rock from Miyakejima volcano, a frontal-arc volcano in Izu-arc (MTL rock: 50.5% SiO₂, 18.1% Al₂O₃, 4.9% MgO). A grain of Ca-rich plagioclase (about 1 mg, An₉₅, FeOₜ = 0.4 wt.%) and 10 mg of powdered glasses were sealed in Au₈₀Pd₂₀ alloy capsule, and then kept at around liquidus temperature. Liquidus phase of MTL rock at 350 MPa is always plagioclase with 0 to 5.5 wt.% H₂O in melt (Ushioda, unpublished data), and therefore, a grain of plagioclase and hydrous melt are nearly in equilibrium. Oxygen fugacity (fO₂) during the melting experiments was not controlled, and the intrinsic fO₂ of the pressure vessel was estimated to be 3 log unit above Ni-NiO buffer. Experiments were quenched after 24-48 hours, long enough to attain equilibrium partitioning of hydrogen between plagioclase and melt. Concentration of H₂O in melt (both molecular H₂O and OH) and concentration of OH in plagioclase was analyzed by infrared spectroscopy.

Results: Experimental results are summarized in Fig. 1. Correlation between total H₂O (molecular H₂O and OH) concentration in melt and OH concentration in plagioclase is non-linear: partition coefficient in molar basis is about 0.01 with low H₂O in melt (< 1 wt.%), while it decreases with increasing H₂O in melt (Fig. 1a). The OH concentration of plagioclase reaches 200-250 ppm H₂O with > 4 wt.% H₂O in melt and saturates. OH in plagioclase linearly correlates with OH in melt (Fig. 1b), which confirms that hydrous species in plagioclase is OH ion as suggested by previous studies.

Application: The OH concentration of Ca-rich plagioclase (about An₉₀) from the 1986 summit eruption of Izu-Oshima volcano, also a frontal-arc volcano in Izu-arc, shows variation ranging from <50 wt. ppm H₂O through 300 wt. ppm H₂O as a result of polybaric degassing (Hamada et al., 2011, EPSL). Hamada et al. (2011) claims that pre-eruptive melt dissolves H₂O up to 6 wt.% and that melt undergoes polybaric degassing during ascent and eruption, based on (i) variation of OH in plagioclase, (ii) hydrous melting experiments to crystallize An₉₀ plagioclase, and (iii) geophysical observation of the 1986 summit eruption of Izu-Oshima volcano. In consistent with previous studies, this experimental studies demonstrates that plagioclase with >250 wt. ppm H₂O can be in equilibrium with melt dissolving >4 wt.% H₂O (Fig. 1a). Such high H₂O concentration corresponds to saturated H₂O concentration in melt at 8 to 10-km-deep magma chambers beneath Izu-Oshima volcano (Mikada et al., 1997, PEPI). Plagioclase from the 1986 summit eruption of Izu-Oshima volcano is expected to record polybaric degassing history of H₂O-saturated magma during eruption.

Keywords: Water in nominally anhydrous minerals, plagioclase, arc basaltic magma, hydrous melting experiment
Fig. 1