Impact of volatiles on the processes of formation and evolution of the Earth's interior

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Characterization of the processes that govern the behavior, budget, and recycling of volatiles in the Earth's interior is fundamental to our understanding of the formation and evolution of the solid Earth, its oceans, and atmosphere. In the proposed session, we will focus on theoretical, experimental, and observational characterization of solubility and solution mechanisms of C-O-H-N-S volatiles in molten and crystalline materials and of oxide components in C-O-H-N-S fluid in the pressure, temperature, composition and redox range of Earth's past and current interior. The major session foci will be:

?Characterization of structure and properties in silicate- C-O-H-N-S melt, mineral, and fluid systems via theoretical modeling and high-temperature/-pressure experimental studies.
?Experimental characterization, at high temperature and pressure, of fractionation of components, compounds and isotopes in the C-O-H-N-S system between minerals, melts, and fluids.
?Element complexing in individual phases, interaction between silicate and trace and minor elements in fluids and melts at high temperature and pressure.
?Examine the principles on which to quantify property behavior and its application to natural processes that include fluids and melts.

Microanalysis of H2O and CO2 in silicate melt using laser Raman spectroscopy

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Water and carbon dioxide are the major volatile components in the crust and mantle. Development of microanalytical techniques of these volatiles has made it possible to investigate mechanisms of igneous and volcanic processes. FTIR has been used as a fundamental tool for this purpose, but its spatial resolution is too large (~30 μm) to analyse small melt inclusions and micro-scale volatile distribution within a high-pressure experimental sample. In this study, we developed a new technique for volatile analysis in silicate glasses with ~1 μm spatial resolution using laser Raman spectroscopy. Standard glasses were synthesized by using a piston-cylinder apparatus in M. Nakamura's laboratory. Basaltic glass power was loaded into a platinum-sleeved nickel capsule together with oxalic acid and run at 1473 K and 0.5-1.2 GPa. After quench, the H2O and CO2 (dissolved as CO32-) contents of the glasses were measured by using FTIR. The same glasses were then analysed with a Thermofisher DXR laser-Raman spectrometer. We normalized the Raman spectra by the intensity of a peak at 500 cm⁻¹ (T-O-T bond) and subtracted the spectrum of the volatile-free glass. The intensities of peaks at 3550 cm⁻¹ (H2O) and 1080 cm⁻¹ (CO32-) in the resulting spectra were compared with the H2O and CO2 contents determined by FTIR spectroscopy.
The H$_2$O and CO$_2$ contents were determined to be 0.7-2.1 wt% and 0.05-0.82 wt%, respectively. Raman spectroscopy showed that the intensities of peaks at 3550 and 1080 cm$^{-1}$ increased with increasing H$_2$O and CO$_2$ contents, respectively. We fitted a linear equation to the data and obtained H$_2$O (wt%) = (3.58±0.14)×I$_{3550}$ and CO$_2$(wt%) = (4.61±0.21)×I$_{1080}$. We applied this technique to volatile analysis of an experimentally-produced bubble-bearing basaltic glass. In the experiment, basaltic melt was first equilibrated with H$_2$O-CO$_2$ mixture fluid at 1473 K and 1 GPa, and then decompressed to 0.5 GPa and kept for 10 minutes. After quench, the H$_2$O and CO$_2$ contents around bubbles were measured along the radial direction at 2-μ m intervals for a total of 50 μ m. The CO$_2$ contents decreased on moving towards the bubble, indicating that CO$_2$ was diffusing into the bubble. Fitting the diffusion equation to this profile, we estimated the diffusivity of CO$_2$ to be 1.2×10$^{-12}$ m$^2$/s. This value is consistent with that reported by Zhang et al. (2007). In contrast to CO$_2$, H$_2$O showed a flat profile, suggesting that H$_2$O was already equilibrated with the fluid in the bubble. This is because the diffusivity of H$_2$O is one order of magnitude greater than that of CO$_2$. Such a diffusive fractionation was observed also in rhyolitic melt (Yoshimura and Nakamura, 2010).