Solubility of CO$_2$ in mafic melts up to 8.5 GPa, measured by Raman spectroscopy

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Solubility of CO$_2$ in mafic melts is poorly known at pressures higher than 2 GPa. We present high pressure-high temperature experiments on CO$_2$-enriched mafic and intermediate melts, from 1.5 to 8.5 GPa and 1800-2100 K, in oxidizing conditions. These experiments were realized with a Belt press at Institut Lumière Matière of Lyon, and with a multi-anvil press at Laboratoire Magmas et Volcans of Clermont-Ferrand. Samples were quenched after HP-HT experiments.

Large quantities of CO$_2$ are dissolved, and the concentrations were measured by micro-Raman spectroscopy, where the n1 stretching vibration of the carbonate group was measured. By coupling this measurement with H$_2$O measurement, also by Raman [1], we established a calibration line that is virtually identical to the one published by other authors [2].

CO$_2$ saturation is indicated by the presence of a bubble. The Raman technique allows generating a CO$_2$ map of the samples, showing heterogeneities influenced by proximity of the bubble and that must be averaged. Above 5 GPa, samples are partially crystallized, and their CO$_2$ concentration recovered by image analysis and by micro-Raman mapping.

Our data show that CO$_2$ solubility in mafic melts increases with increasing pressure much more rapidly than expected from Henry’s law (e.g., at 5 GPa, CO$_2$=7–8 wt% as compared to 2.5–3 wt% from Henry’s law), confirming previous molecular dynamics simulations [3]. At 8.5 GPa, our sample is undersaturated at 13.6 wt% and the simulation yields 25 wt%. Possible consequences bear on various processes, including mantle melting, Earth degassing, the generation of kimberlites and carbonatites and core-mantle interactions.

Our work confirms known difficulties to obtain glass on quenching from a HP-HT mixture of silicates and carbonates. We stress that measurements performed in situ during HP-HT experiments are certainly better than traditional quenching.