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Quantification of silicate mineral stability fields in calc-alkaline basaltic systems: an experimental approach

FELIX MARXER, LENNART KOCH, RENAT ALMEEV AND FRANÇOIS HOLTZ

Leibniz University Hannover

Despite recent scientific progresses, there is still a crucial need to improve our knowledge of the influence of physical and chemical parameters on magmatic phase equilibria and, therefore, our general understanding of crystallising igneous systems. For example, currently existing petrological tools to reconstruct magmatic processes, such as thermobarometry or thermodynamic models (e.g. rhyolite-MELTS), are frequently of only limited validity due to significant uncertainties, model interdependence, or deficient calibrations complicating the reliable application of these tools to natural rock samples.

The prediction of phase equilibria is particularly complex for calc-alkaline magmatic systems, because water contents and oxygen fugacity can vary significantly. This contribution is an attempt to fill this gap by providing new experimental data exploring systematically the effects of temperature, pressure, magma composition, H_2O, and fO_2 on phase equilibria in calc-alkaline basaltic systems. Our experimental program was designed to extend existing high-pressure experimental datasets (400-900 MPa) on a high-Mg basalt from the Adamello Batholith (Italy) and a magnesian basalt from the Cascades (U.S.) to upper crustal pressures. Experiments were run in internally heated pressure vessels (IHPV) at 200 and 400 MPa and varying bulk H_2O contents (0-9 wt.%) with fO_2 conditions buffered between NNO+1 and NNO+2.3. Water contents of experimental glasses were measured via Raman spectroscopy to directly quantify the effect of H_2O on mineral stability fields.

Combining our new experimental data with high-quality experimental datasets from literature, we established systematic changes in phase assemblages (i.e. mineral stability fields) and the impact of crystallisation parameters on silicate mineral chemistry (e.g. for olivine, clinopyroxene, orthopyroxene, and plagioclase). Employing our dataset, we formulated empirical mineral saturation models for plagioclase and clinopyroxene predicting the saturation of these phases as a function of bulk system composition, pressure, temperature, H_2O, and fO_2. Furthermore, we used our new dataset to recalibrate pre-existing silicate mineral-melt equilibrium models (e.g. plagioclase-melt) and extend them to hydrous calc-alkaline systems. Moreover, we tested some of the most commonly used mineral-based thermobarometers (e.g. clinopyroxene-melt) to provide some general insight on the limitations of these petrological tools and present some recommendation on their application to natural rocks.