Cumulate thermobarometry

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Igneous cumulates are the expressions par excellence of crystal segregation from magmas and as such they help to reveal how and where magmatic differentiation takes place in the crust. Estimating their pressure and temperature of formation is therefore a fundamental task, which can constrain the physical conditions of magma crystallization, the depth of magma storage zones and the lithological structure of the crust. The Lesser Antilles volcanic arc is an optimum case study to tackle these issues, as it is characterized by a large amount of diverse cumulate xenoliths and numerous (> 400) phase equilibria experiments on the magmatic products of this arc. This allows us to develop a fully integrated approach, including petrological, experimental and thermodynamic constraints, to retrieve the conditions of formation of cumulate rocks.

Application of existing single-reaction thermobarometers to Lesser Antilles cumulate xenoliths is in many instances not possible, either because the given xenolith does not contain the appropriate phase assemblage or because the given method is affected by unacceptably high uncertainties. For some well-equilibrated samples, temperature can be estimated with acceptable uncertainties ($1\sigma = 40 - 50$ °C). On the other hand, existing geobarometers show high uncertainties ($1\sigma > 0.3 - 0.4$ GPa) or show systematic deviations up to 1.0 GPa where compared with phase equilibria experiments. In some cases, the discrepancies are of the same order of magnitude of the whole pressure range under investigation (i.e. 0.0 – 1.0 GPa).

Multiple-reaction thermobarometry is in principle more reliable. An independent set of reactions is considered using internally consistent thermodynamic models, taking account of correlated uncertainties in the activities of mineral end-members. However, this method requires well calibrated activity–composition (*a*–*x*) relations for numerous phases, including complex solid solution in hornblende. Thanks to the vast collection of natural and experimental data, we can use the Lesser Antilles magmatic suite to refine a set of suitable *a*–*x* relations specifically for this purpose. We hope to achieve uncertainties in *relative* pressures of <0.1 GPa, sufficient to discriminate the main magma storage zones in the crust.