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Modeling differentiation in igneous systems: On the importance of considering temperature & composition dependent partition coefficients

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Studying magma reservoir processes is one of the keys to understand the evolution of igneous systems. One of the main processes, magma differentiation, governs the thermal evolution and chemical composition of the melt-crystal assemblage (magma or mush depending on the relative proportions), and therefore exerts a first order control over its physical properties (density, viscosity), and thus on reservoir dynamics. Various approaches have been implemented to model differentiation in an attempt to benchmark all the involved variables like initial and phase compositions, temperature, pressure, and oxygen fugacity (C_0, X, T, P, fO_2). Those approaches are among others mass balance calculations considering partition coefficients (D) values, experimental studies, thermodynamic models or a combination of those. In any of those cases, the evolution of trace elements is governed by the value of the D that is known to be dependent on (P, T, X, fO_2). However, most of the present-day studies still use fixed values of D to provide first order estimates.

Here, we present an approach combining thermodynamic modeling (relying on Rhyolite-MELTS, Gualda et al., 2012), that integrates X-T-P-fO_2-dependent D for Rare Earth Elements (REE). We applied this new approach to a MORB system, with olivine, clinopyroxene and plagioclase as main mineral phases, and compared results to more classical approaches. D are derived from the models of Sun & Liang (2012, 2013, 2014) and Sun et al. (2017). The resulting model highlights that T & X effects on the D values can add or counterbalance each other depending on the mineral considered. In any cases our results emphasize the gain of using thermodynamic models along with both T- & X-dependent D values to properly model the evolution of igneous systems. Relying on our results, and on the corresponding thermodynamics constraints, we were also able to provide D for any mineral composition crystallized from this MORB system. Results bring to light that an error of ~1 order of magnitude of the $D^{mineral\text{-}melt}$ value could be introduced when considering a fixed value of D.

Gualda et al. (2012) *Journal of Petrology*, 53-5, 875-890; Sun & Liang (2012) *Contrib Mineral Petrol* 163-5: 807-823; (2013) *Chem Geol* 358: 23-36; (2014) *Chem Geol* 372: 80-91; Sun et al.

(2017) *Geochim Cosmochim Acta* 206: 273-295.