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Experimental quantification of P-T conditions of mantle refertilisation at shallow depth under spreading ridges and formation of plagioclase + spinel lherzolite

Françoise Chalot-Prat (1), Trevor J. Falloon (2), and David H. Green (3)

(1) CRPG-CNRS, magmatic and mantle petrology, VANDEOUVRE LES NANCY, France (chalot@crpg.cnrs-nancy.fr), (2) Arc Centre of Excellence in Ore Deposits and School of Earth Sciences, University of Tasmania, Private Bag 79, Hobart, Tasmania 7001, Australia (trevor.falloon@utas.edu.au), (3) Arc Centre of Excellence in Ore Deposits and School of Earth Sciences, University of Tasmania, Private Bag 79, Hobart, Tasmania 7001, Australia (David.H.Green@utas.edu.au)

We studied the first-order melting process of differentiation in the Earth, and the major process of rejuvenation of the upper mantle after melting related to plate spreading (Chalot-Prat et al, 2010; 2013).
We conducted experiments at High Pressure (0.75 and 0.5 GPa) and High Temperature (1260-1100°C) to obtain magma compositions in equilibrium with the mineral assemblages of a plagioclase + spinel lherzolite. These PT conditions prevail at 17-30km below axial oceanic spreading ridges. We used a "trial and error" approach in a system involving nine elements (Cr-Na-Fe-Ca-Mg-Al-Si-Ti-Ni). This approaches as closely as possible a natural mantle composition, Cr being a key element in the system.
Our objectives were :
• to determine experimentally the compositions of melts in equilibrium with plagioclase + spinel lherzolite, with emphasis on the role of plagioclase composition in controlling melt compositions;
• to test the hypothesis that MORB are produced at shallow depth (17-30kms)
• to quantify liquid- and mantle residue compositional paths at decreasing T and low P to understand magma differentiation by "percolation-reaction" at shallow depth in the mantle;
• to compare experimental mantle mineral compositions to those of re-fertilised oceanic mantle lithosphere outcropping at the axis of oceanic spreading ridges, enabling quantification of the pressure (i.e. depth) and temperature of the re-fertilisation process that leads to formation of plagioclase and indicates the minimum thickness of the lithosphere at ridge axes.
In the normative basalt tetrahedron, liquids plot on two parallel cotectic lines from silica-oversaturated (basaltic andesite at 0.75 GPa or andesite at 0.5 GPa) at the calcic end to silica-undersaturated compositions (trachyte) at the sodic end. The lower the pressure, the greater the silica oversaturation. Besides the plagioclase solid solution has a dominant role in determining the solidus temperature of plagioclase + spinel lherzolites, at a given pressure at shallow depth.
The cotectic lines can be interpreted either as defining partial melting compositions or evolution trends for melts invading and metasomatizing refractory peridotite by reactive porous flow, at 17-30 km. The mismatch between the compositions of the most primitive MORB glasses and the experimental liquids from plagioclase+spinel lherzolites confirms that melt equilibration and segregation of parental MORB occurs deeper than 30km.
Mantle mineral compositions are mostly pressure dependent, excluding the co-variance of Na2OCpx and AnPlag, which is pressure independent and enables estimation of AnPlag (if the plagioclase is saussuritised), knowing Na2OCpx of the natural mantle Cpx.
Our experimental data are thus tools for estimating mantle re-fertilisation depth in natural plagioclase+spinel lherzolites. The Lanzo plagioclase ± spinel re-fertilised lherzolites (Piccardo et al., 2007) clearly match our 0.75 GPa data, suggesting that re-fertilisation of the oceanic lithosphere occurred at depths of 25 - 30 km below the mid-ocean ridge axis.
The most exciting result of this HT-HP experimental work, which imparts even more confidence and significance to our data, is the fit of the five phases of an experimental plagioclase + spinel lherzolite with those of natural plagioclase ± spinel lherzolites.

References:
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