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Main contents of the Ph.D. thesis

Four different subjects are addressed in my doctoral thesis.

The understanding of textural evolution, melt migration and permeability of analogue systems of MOR areas is crucial for the investigation of MORB basalt generation. We calculated the percolation rate for an analogue system of middle oceanic ridge areas in dynamic conditions (never before attempted), consisting in olivine added with some amounts of basaltic melt (4-14 vol%). The main result was to derive, from experimental evidences, new values for the permeability of the source rock of MORB melt. We computed permeabilities 10 to 100 times larger than previously assumed, thus implying extraction velocities 1-2 orders of magnitude faster then before assessed, with a major influence on the preservation of elemental and isotopic signatures of MORB melt and on the modelling of MORB extraction dynamics.

The behaviours of olivine grains, settling through a basaltic melt, then forming a compact layer (so called ‘cumulus layer’), is another topic discussed in my elaborate. The main aim was to understand the dynamics of the on-set and build-up of ‘cumulus layers’ in magma chambers. The achieved results were the measurement of the minimum residual porosity and the calculation of formation times for pure mechanical settling of olivine in a basalt melt (formation of ‘orthocumulates’). Moreover, we also extrapolated the formation times in the case of subsequent chemical compaction of such layers, leading to the formation of ‘adcumulates’. These results have been achieved for the first time at magmatic conditions (P, T, f_{O2}).

A third part of my project involved the study of a system constituted by olivine plus Fe-S melts and peridotite plus Fe-S melts. Textural maturation features, dihedral angle measurements and interconnectivity threshold evaluation for such a system is a key point for discussing core formation processes in growing planets and smaller bodies. With static piston cylinder experiments and in-situ electrical conductivity measurements, we managed to shed new light on the variation of dihedral angle of metal melts, in contact with olivine, for a broad range of dissolved oxygen concentration in the melt, indicating that at high pressures (i.e. 1 GPa), metal melts are always non-wetting fluids in respect to silicates, even for the largest oxygen content. The most crucial results was, however, to observe that interconnectivity of Fe-S melt pockets in olivine and peridotite could be just temporary, even above the accepted ‘percolation threshold’ (in agreement with the results of Walte et al., 2007), because, with time, the thin bridges of melt, connecting the melt pools, disappears, with the formation of larger, rounded melt pools. We actually measure a threshold at more than 18 vol% of metal melt, but further experiments are needed to clarify this issue.

Finally, using our centrifuging piston cylinder, we have performed, for the first time, successful experiments of metal melt separation from solid or partially molten silicates. The key goal of this fourth series of experiments was to understand whether gravitational percolation of Fe-S melt through peridotites could be the leading mechanism that triggered core formation in terrestrial planets. We observed that the presence of some fractions (5-25 vol%) of silicate melt is critical in order to promote non-negligible segregation of Fe-S. Nevertheless, so large quantities of silicate melt were available only during the early accretion stage (large impact stage). Thus, gravity induced percolation of metal melt could contribute to core formation only in the precocious stage of formation of planets and planetesimals.

Summary of Master thesis

The main attempt of my master thesis was to investigate the phase assemblages of a simplified MORB composition representing the oceanic crust involved in a subduction to the depths of the transition zones of the mantle. Experiments were carried out with a Walker type multianvil apparatus to the pressure of 14-20 GPa and temperatures of 900 -1200 °C. Starting materials were a H_2O-, Ti-free MORB gel and a H_2O-, Ti-bearing MORB glass. The main results are the detection of breakdown of clinopyroxene at 16 and 19 GPa at 900 and 1200 °C in the H_2O, Ti-bearing system to give majoritic garnet and Ca-Ti-perovskite and the breakdown of clinopyroxene at 17.5 GPa and 900 °C in the H_2O, Ti-free system to give majoritic garnet and an unknown Fe-rich phase. In the second system, we observed the appearance of an Al-rich phase at 16 and 18 GPa at 900 and 1200 °C. Moreover, we estimated the density contrast between the oceanic crust and the surrounding mantle. The calculation of MORB densities at the investigated depths was operated via computation of the phase abundances at different pressures. The density contrast increases from 2.0 to 3.8 g/cm^3, in favour of MORB, from 16 to 21 GPa, and, thus, is larger then reported in previous studies (e.g. Okamoto and Maruyama, 2003).