

10GPaにおけるガーネット、カンラン石/含水メルト間の元素分配実験 Element partitioning between garnet, olivine and hydrous melt at 10GPa

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It is thought that the bottom depth of Earth's magma-ocean would be more than 1000km. In order to understand chemical differentiation of magma-ocean, it is important to estimate pressure dependence of element partition coefficients quantitatively. PC-IR diagram is modeled by strain energy of lattice site in crystal by Blundy and Wood (1994). We aim to expand the model to various conditions pertinent to the Earth's magma ocean (pressure, temperature, amount of water etc.). We determined PC-IR diagram of olivine / dry melt between 1 atm. and 10GPa, and found that the parabolic curve for trivalent cations becomes wider with pressure (Imai et al., Goldschmidt Conference 2009). The widening of parabola means that Young's modulus of crystal site decreases with pressure, but it is unreasonable because lattice site is compressed by pressure (Imai et al., JpGU 2010). The widening parabola can be explained with adopting Young's modulus of 'melt' which was not considered in Blundy and Wood's model. In other words, we propose that melt becomes 'harder' with pressure. In this study, we focus on element partitioning and PC-IR diagram for hydrous magma ocean.

According to two component model, early earth might contain about 2 wt. % H₂O. Ikoma and Genda (2006) suggested that hydrogen atmosphere covered early earth and might coexist with magma-ocean. Thus, we may not ignore the effect of water for chemical differentiation of magma-ocean.

In present study, we investigated partition coefficients between garnet, olivine and melt which contain various amounts of water at 10 GPa using a Kawai-type multi-anvil apparatus and compared with previous studies at dry and hydrous conditions (dry: Suzuki et al., in prep.; Imai et al., in prep, hydrous: Inoue et al., 2000; Mibe et al., 2006). We prepared two mafic starting materials (45 and 39 wt. % SiO₂), doped with 26 trace elements and added 5 to 13 wt. % H₂O. Platinum was used as sample container. Major, minor and trace elements analysis of garnet, olivine and coexisting hydrous melt were performed with EPMA and LA-ICP-MS. After experiment, some amount of iron in samples reacted with capsule, and alkali ions escaped with aqueous fluid when it was quenched.

Partition coefficients (D) between garnet, olivine and hydrous melt were calculated using obtained elements concentrations in each phase, and were compared with previous experimental results at dry conditions. For major elements in garnet, D values for divalent ions (Mg²⁺, Fe²⁺, Ca²⁺) at hydrous conditions are smaller and those of Al³⁺ and Si⁴⁺ are higher than those at dry conditions. For trace elements in garnet, D values of other ions (REE₃₊, Sc³⁺, Y³⁺) are the same between dry and hydrous conditions. D values for divalent cations in olivine at hydrous conditions are slightly smaller, and that for Si⁴⁺ is larger than at dry condition. All D values for trivalent cations in present study are obviously smaller than those at dry condition (Imai et al., in prep.). When PC-IR diagrams at 5 GPa are compared between hydrous and dry condition (Mibe et al., 2006; Imai et al., in prep., respectively), similar features are present.

We fitted our results using lattice strain model (Blundy and Wood, 1994) on PC-IR diagram and obtained three parameters, optimum ionic radius in lattice site (r_0), the partition coefficients of host cation (D_0) whose ionic radius is r_0 , and apparent Young's modulus of lattice site for crystal and melt (E). The change in partition coefficients between dry and hydrous can be explained by the effect of only D_0 and temperature. The r_0 and E remains constant for both dry and hydrous conditions. The change of D_0 is explained by the variation in composition of melt. Although absolute value of partition coefficients decrease dramatically from dry to hydrous conditions, our analysis can predict the changing value with limited information (i.e., temperature and concentration of some key elements in melt, Takahashi and Irvine, 1981).

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