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The influence of T, a_{SiO_2}, and f_{O_2} on exsolution textures in Fe-Mg olivine: An example from augite syenites of the Ilimaussaq Intrusion, South Greenland

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ABSTRACT

Two samples from the augite syenite unit of the 1.13 Ga alkaline to peralkaline Ilimaussaq intrusion in South Greenland contain olivine (Fa_{75-85}) with micrometer-sized exsolution lamellae of intergrown augite and magnetite. The exsolved olivine contains only about 0.6 wt% CaO, whereas the reintegrated magmatic composition contained about 1.4% CaO corresponding to about 3 mol% of a larnite (La) component. The exsolved olivine bears no measurable Na, Al, or Ti, but the reintegrated magmatic olivine contained up to 0.4 wt% Na_2O, 0.2 wt% Al_2O_3, and 0.3 wt% TiO_2. Magmatic baddeleyite in the same samples indicates an extremely low silica activity of below 0.4 during the early stages of magmatic crystallization at > 900 °C and 1 kbar. According to the equilibrium Ca_2SiO_4 (La in Ol) + SiO_2 = 2 $CaSiO_3$ (Wo in Cpx), the low silica activity is thought to be responsible for the unusually Ca-rich compositions of the primary olivines, which, in these samples, formed at 875 ± 15 °C and at oxygen fugacities between 1.2 and 2.3 log units below the QFM buffer. The composite exsolution lamellae formed during cooling due to an overstep of the schematic reaction Fa + Kst (Ca-rich component in olivine) + 1/3 O_2 = Hd + 2/3 Mt. Phase equilibria indicate temperatures between 300 and 750 °C and oxygen fugacities close to QFM for this exsolution process. The lamellae only developed in samples where the olivines were both especially high in Ca and presumably rapidly cooled (although not chilled!), as the lamella-bearing samples were collected at the outermost rim of the augite syenite unit and close to the top of the Ilimaussaq intrusion. Schreinemakers analysis shows that Ca-rich olivine of the kirschsteinite-monticellite solid solution series [$Ca(Fe,Mg)SiO_4$] would exsolve from Ca-bearing olivine of the fayalite-forsterite series only at unusually low silica activities, whereas at higher silica activities, the observed exsolutions of clinopyroxene with magnetite are more stable. Hence, both cooling history and evolution of intensive variables during cooling are important for the formation of olivine exsolution textures.