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Chemical thermodynamics of orthopyroxene recrystallization in ductile shear zones of the Flakstadøy Basic Complex, Lofoten, Norway

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The driving potential for the compositional change of a material during recrystallization (ΔG_{chem}= $G_{product}$ - $G_{reactant}$) is crucial to understand the progress of any natural reactions at different pressure and temperature conditions. In this contribution, we discuss the effect of chemical changes on G_{chem} of orthopyroxene deformation and recrystallization in ductile shear zones developed in the undeformed gabbro/troctolite at Flakstadøy Basic Complex, Norway.

Several mm to cm wide ductile shear zones are observed within the undeformed troctolite. Igneous plagioclase (Pl_{mag}), olivine (Ol_{mag}) and orthopyroxene (Opx_{mag}) define the cumulus texture. Metamorphic orthopyroxene (Opx_{meta}) and garnet (Grt^{I}_{meta}) corona around magmatic Pl and Ol indicate the onset of subduction (M_1, 700-750 °C, 1 GPa). Alternate aggregates of Opx_{mag}- Omp - Grt^{I}_{meta} layer and Pl_{meta} - Amp_{meta}- $Cpx_{meta}\pm$ Spl_{meta} layer characterize the shear zone. Opx_{mag} porphyroclasts (100-150 μm) are mantled by recrystallized Opx^{rex}_{mag} grains (20-30 μm) and show asymmetrical σ-porphyroclast with sinistral sense of shear (D_1). Static overgrowth of Omp $\pm$ Grt^{II}_{meta} around the Opx is the peak pressure stage (M_{2A}, 650-750 ^{0}C, $>$ 1.8 GPa). Cpx_{meta} - Pl_{meta}symplectite at the outer rim the Omp indicate decompression from the peak pressure stage (M_{2B}, 600-650 °C, 1 GPa). Breakdown of Grt^{II}_{meta} to $Amp_{meta}\pm$ $Pl_{meta}\pm$ Spl during decompression and hydration characterize M_3 metamorphism.

The Opx_{mag} and the Opx^{rex}_{mag} have similar X_{Mg} (0.75-0.79). However, relict Opx_{mag} porphyroclasts have higher Al^{oct} (0.03-0.08 p.f.u) content compared to the Opx^{rex}_{mag} grains (Al^{oct}= 0.00 -0.01). The mineralogical similarity, smaller grain size of the Opx^{rex}_{mag} and the lack of crystallographic orientation of Opx_{mag} and Opx^{rex}_{mag} indicate that Opx_{mag} deformed via cracking before the M_1metamorphic stage.

To document the change in G_{chem} during deformation and recrystallization of Opx_{mag} to Opx^{rex}_{mag}, P-X (composition) and T-X (composition) diagrams are constructed using Perplex _07. In the in the P-X (composition) pseudosection, the values of G_{chem} isopleths decreases with decrease of pressure, opposite to the T-X (composition) pseudosection, where values of G_{chem} isopleths decreases with increase of temperature. Moreover, the negative slope of the G_{chem} isopleths from Opx_{mag} to Opx^{rex}_{mag} in the P-X (composition) pseudosection indicates the deformation and recrystallization of Opx_{mag} should occur along an isothermal decompression path to achieve the stable Gibbs energy configuration ($\Delta G_{chem.} \leq 0$) An alternate path of recrystallization and minimization of $\Delta G_{chem.}$ can be explained in the T-X (composition) pseudosection due to the increase of temperature during recrystallization of Opx_{mag} to Opx^{rex}_{mag}. However, such a situation is unlikely, as no evidence of heating during the recrystallization of Opx is observed in the present study. However, due to lack of a proper solid-solution of Opx that incorporate the effect of Ca and Na, the exact value of ΔG_{chem} during the recrystallization could not be determined.

It is widely believed that the shear zones at Flakstadøy developed due to deformation and fluid infiltration in the eclogite facies condition. However, the present study indicates that the orthopyroxene deformation and the shear zone developed in the sub-magmatic to granulite facies condition due to crystallization and exhumation of the igneous rocks at lower crustal level.