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Mineral chemistry, geothermobarometry and P-T-X modelling of shear zone in gabbroic rock

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Metamorphism is a dynamic process that involves growth of new minerals and chemical modification of preexisting minerals due to changes in temperature (T), pressure (P) and introduction of chemically active fluid. Equilibrium thermodynamics based classical thermobarometry and computational phase equlibrium algorithms (P-T-X pseudosection) to determine the of Gibbs energy minima is considered as one of the most effective tools to determine the *PT* conditions of a rock. P-T-X pseudosection modelling in conjunction with classical P-T estimates, may be used to determine the effective equilibrium reaction volume of newly formed minerals, amount of fluid required for metamorphic reactions and change in physio-chemical properties of the minerals in response to-changing P,T conditions. In this contribution, we present results of classical thermobarometry and P-T-X pseudo section to model the a) effective reaction volume of amphibole formation, b) the amount of water required for the reaction and c) the change in the physical and chemical compositions of minerals in different PT conditions that promote amphibole growth in shear zone in gabbro from Seiland Igneous Province (SIP), Northern Norway.

The Hasvik Gabbro, Sørøy Island, contains magmatic plagioclase ($X_{An} = 0.64 - 0.66$), clinopyroxene ($X_{Mg} = 0.84 - 0.87$), orthopyroxene ($X_{Mg} = 0.65 - 0.66$) with sub-ordinate biotite ($X_{Mg} = 0.71 - 0.72$) and ilmenite. In the gabbro, millimeter to centimeter wide shear zones with an extremely steep strain gradient are observed.

The shear zone consists of alternate bands of recrystallized pyroxene ($X_{Mg}^{Opx} = 0.65 - 0.68$, $X_{Mg}^{Cpx} = 0.83 - 0.84$) and mixed phase aggregates. Three stages of amphibole growth are observed in the shear zone. The first stage of mphibole (M_1; *(Ferrian) magnesiohornblende* ; $X_{Mg} = 0.80 - 0.81$) growth is observed along the cracks of recrystallized pyroxene bands (D_1) (Opx + Cpx + Pl + H_2O -> Amph). Amphibole-t (matrix) plagioclase (Hb-Pl) geothermobarometry estimates temperatures of 650-700^{O}C and pressures of 0.35-0.50 GPa for the amphibole formation. The viscous shear zone between pyroxene bands is characterized by a random mixture of orthopyroxene ($X_{\overline{M}g}^{=}0.66$), amphibole (*Ferrian-tschermakite*;$X_{Mg} = 0.74 - 0.78$) and biotite together with plagioclase (D_2, M_2: Opx+ Pl+ H_2O -> Amph +Qtz). Hb-Pl estimates equilibrium temperatures of 675-700 ^{O}C at 0.4- 0.6 GPa. The through-going recrystallized pyroxene bands are mantled by compositionally zoned amphibole (M_3; core: *magnesiohornblende*; rim: *ferrian-tschermakite,* $X_{Mg}^{core-rim} = 0.81 - 0.78$,). The compositionally zoned amphibole grows at temperature 700-725 ^{O}C with increasing pressure from 0.40 -0.60 GPa towards the plagioclase. A clockwise (prograde) PT path is therefore suggested for the shear zone in Hasvik gabbro.

P-T-X modelling using PERPLEX (NCFMASH, solut_08.dat, hp04ver.dat) of Amph (M1, DHP) composition confirms lower crustal P-T conditions of 650-700°C at 0.40 to 0.50 GPa for the nucleation of M_1 amphibole. The effective reaction volume of Opx(HP), Cpx(HP), Pl(h), melt(HP)) is determined from the superimposition of PT estimate and isopleth topology. The T-X(H_2O) diagram at 0.4 Gpa (M_1, Hb-Pl barometer) shows a mimimum of 1-2 mole% of water is required for the initiation of nucleation of M_1amphibole. The lack of an appropriate solution model of amphibole (NCKFMASH) and absence of K-feldspar in the reaction domain prevents us to determine the reaction volume of M_2 amphibole. P-X (composition) pseudosection of M_3 amphibole at 725 ^{O}C (M_3, Hb-Pl thermometer) reveals that amphibole grows towards the plagioclase with increase in pressure, confirming a clockwise PT path.

P-T-X modelling of magmatic Opx reveals that adiabatic shear modulus and bulk modulus are inversely proportional with temperature. So, high stress is required to initiate the fracturing in the magmatic Opx. So, the small recrystallized grains near the crack with higher surface area and energy will perticipate in the amphibole forming reaction with avaliability of water. Thus, continued hornblende formation will require fluid infiltration by a continued fracturation process or grain boundary sliding.

D -> Deformation stage, M -> metamorphic stage