Fluid-rock interaction in successive veining events from the Fibbia meta-granite of the Gotthard Massif, Switzerland.

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The physicochemical characteristics of Alpine vein formation and associated fluids in the Fibbia granite (Gotthard massif) were investigated using an analytical and thermodynamic approach in order to identify the evolution of fluid chemistry quantify the amounts of alteration of the surrounding rocks and identify mass transfer and fluid flow mechanisms during vein formation.

Five veining events are associated with prograde and different retrograde stages of Alpine metamorphism. V_{1a} and V_{1b} veins are massive quartz veins without any alteration zones, which formed during pre-Alpine and prograde Alpine metamorphic conditions respectively. V_2 to V_5 formed during middle to late-Alpine retrograde metamorphism. V_3 to V_5 are related to later stages of exhumation, where σ_3 is horizontal SE-NW directed. V_5 veins are formed as a consequence of several phases of cataclastic deformation and during ongoing SE-NW extension and further uplift in the middle to late Miocene times. PT-conditions during vein formation for V_{1b} to V_5 were: V_{1b}: T = 440°C, P= 4 kbar, V_2: T= ~420°C, P= 3.0 kbar, V_3: T ~350°C, P = 1.9 kbar, V_4 :T ~300 °C, P=1.5 kbar, V_5: T ~300-180°C, P= 1.5-0.9 kbar.

Chemical analyses of the different fluid inclusion populations using LA-ICPMS and crush-leach techniques indicate that the electrolyte composition of the vein forming fluids is mainly Na-K-Ca-Li-Cl with smaller amounts of Mg, Fe, Mn, Sr, Ba, Cu, Zn, Pb, As, and minor anions Br and SO_4. Changes in fluid compositions during mineralization are: a general decrease in CO_2 content from V_2 to V_3, with increase in salinity and from V_4 to V_5 a marked decrease in salinity in a CO_2 free fluid.

V_{1b} veins probably formed from dehydration reactions in underlying rocks either from deep-seated fluid migration or multiple hydro fracturing events. The lack of wall-rock alteration around these veins precludes a local origin of the mineralized quartz. V_2 veins have opened as extensional fractures after the gneissic foliation developed during early exhumation of the Gotthard massif. The wall rock around V_2 veins shows typical epi-syenitization features. Biotite and quartz were dissolved in the alteration zones by CO_2-enriched aqueous saline fluids, from which Alpine fissure minerals precipitated. Prediction of the bulk fluid compositions in equilibrium with the bulk rock suggests that it is likely that mineralization of the V_2 veins was mainly related to local dissolution, mass transport and precipitation. With decreasing temperature and pressure adularia tends to form while albite in the host rock tends to dissolve, during continuous quartz precipitation.

Nearly no alteration is observed around small V_3 and V_4 veins, where phengite and hematite (V_3) and chlorite (V_4) precipitated from volatile-free aqueous salt-enriched fluids. Fe^{3+} necessary to form hematite is probably derived from small amounts of dissolution of host rock biotite, as are the other components that are related to phengite and chlorite precipitation. Massive V_5 quartz veins are found in chemically unaltered host-rocks. SiO_2 was transported by and precipitated from heated, NaCl-depleted fluids of meteoric origin.