Long-lived interaction between hydrothermal and magmatic fluids in the Soultz-sous-Forets granitic system (Rhine Graben, France)

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The 5 km deep drilling at Soultz-sous-Forets samples a granitic intrusion allowing study of the evolving conditions of fluid-rock interaction, from the syntectonic emplacement of Hercynian granites at depth until post-cooling history and alteration close to the surface. Isotope compositions of CO_2 and H_2O have been measured in fluid inclusions (FIs) trapped in magmatic Qtz. Early FIs contains aqueous carbonic fluids whereas the latest FIs are H_2O-rich. In the early FIs, $\delta^{13}C$ value reveals 2 distinct sources of carbon, one from sedimentary carbonates (δ^{13} C= -2% V-PDB) and another from the continental crust ($\delta^{13}C$ = -9%. V-PDB). The carbon isotope composition of bulk granites indicates a third carbon source of organic derivation ($\delta^{13}C$= -20%. V-PDB). Using a δD - $\delta^{18}O$ plot, we argue that the water trapped in Qtz is mainly of meteoric origin mixed with magmatic water. The emplacement of the granite pluton occurred in a wrench zone. After consolidation of the granite mush at 600 °C, sinistral shear (γ similar to 1) concentrated the final leucocratic melt in vertical planes oriented along ($\sigma1$, $\sigma2$). At a temperature of 550 °C, crystallization ended with the formation of vertical Qtz veins spaced about 5 mm a width of several cm. The veins form a connected network of a few kilometers in height, generated during hydrothermal contraction of the intrusion. Qtz crystallization led to the exsolution of 30% by volume of the aqueous fluid. As quartz grains were the latest solid phase still plastic, shearing localized inside the connected quartz network. Aqueous fluid was thus concentrated in these vertical channels. Eventually, when the channels intersected the top of the crack network, water boiling caused the formation of primary inclusions. At the same temperature, the saline magmatic waters, which were denser than the meteoric waters, initiated thermohaline convection with the buoyant "cold" hydrothermal water layer. This mechanism can explain the mixing of surface and deep-seated fluids in the same primary inclusions trapped during the crystallization of magmatic minerals. This study, which separately considers fluid-rock interactions at the level of successive mineral facies, brings new insights into how fluids may be different, their origin and composition, and depending on tectono-thermal conditions, bears implications for eventual ore forming processes.