Constraints on quartz formation processes in the Icelandic crust: a coupled $\delta^{18}O$ and $\delta^{30}Si$ approach

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To investigate quartz formation processes occurring within the Icelandic crust, we study quartz and amorphous silica sampled over a wide range of temperature and pressure conditions. The sample set contains (1) igneous quartz associated with crustal xenoliths and micro-granites (>550°C), (2) high-temperature hydrothermal quartz (~200-400°C) and (3) low-temperature hydrothermal quartz and amorphous silica (<150°C). We analysed the silicon and oxygen isotope composition of quartz grains *in-situ* using SIMS and trace elements of the same grains using EMPA.

$\delta^{18}O_{V\text{-}SMOW}$ and $\delta^{30}Si_{NBS28}$ values are strongly correlated with quartz formation conditions and the source of Si and O to the system. $\delta^{30}Si$ and $\delta^{18}O$ values in quartz range from (1) -0.2‰ to -0.7‰ (Si) and -5.6‰ to +6.6‰ (O) when formed under magmatic conditions, (2) -0.9‰ to +0.7‰ (Si) and -9.3‰ to -12.1‰ (O) when formed under hydrothermal high T conditions and (3) -4.6‰ to +0.5‰ (Si) and -0.9‰ to +30.1‰ (O) when formed under hydrothermal low T conditions.

Quantitative isotope modeling was performed to investigate processes responsible for the formation of secondary quartz. The simulated processes included water-rock interaction, boiling and cooling. Comparison of model results with our new dataset, reveals that the observed $\delta^{30}Si$ values are consistent with isotope fractionation between fluids and quartz upon progressive fluid-rock interaction and boiling for high-temperature hydrothermal quartz. At low T (<100°C), boiling followed by cooling may result in ^{30}Si-depleted quartz and amorphous silica. Kinetic isotope fractionation may also play a role at such low temperatures. The $\delta^{18}O$ values of the same grains were found to be dependent on the source of the water and fractionation between liquid, vapor and secondary minerals.

The results of this study may be used to further constrain and assess formation conditons of quartz and amorphous silica in various geological settings, both past and present.