

Melt–Fluid and Fluid–Fluid Immiscibility in $\text{Na}_2\text{SO}_4\text{--SiO}_2\text{--H}_2\text{O}$ System and Its Implications for the Formation of Rare Earth Deposits

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Liquid–liquid immiscibility has crucial influences in geological processes, such as magma degassing and formation of ore deposits. Sulfate, as an important component, associates with many kinds of deposits. Two types of immiscibility, including (i) fluid–melt immiscibility between an aqueous solution and a sulfate melt, and (ii) fluid–fluid immiscibility between two aqueous fluids with different sulfate concentrations, have been identified for sulfate–water systems. In this study, we investigate the immiscibility behaviors of a sulfate- and quartz-saturated $\text{Na}_2\text{SO}_4\text{--SiO}_2\text{--H}_2\text{O}$ system at elevated temperatures, to explore the phase relationships involving both types of immiscibility. The fluid–melt immiscibility appeared first when the $\text{Na}_2\text{SO}_4\text{--SiO}_2\text{--H}_2\text{O}$ sample was heated to ~ 270 °C, and then fluid–fluid immiscibility emerged while the sample was further heated to ~ 450 °C. At this stage, coexistence of one water-saturated sulfate melt and two aqueous fluids with distinct sulfate concentrations was observed. The three immiscible phases remain stable over a wide pressure–temperature range, and the appearance temperature of the fluid–fluid immiscibility increases with increasing pressures. Considering sulfate components occur extensively in carbonatite-related deposits, the fluid–fluid immiscibility can result in significant sulfate fractionation and provides implications in understanding the formation of carbonatite-related rare earth deposits.