Ca-Al Silicate Formation During Low-grade Metamorphism in the Upper Continental Crust

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Zeolite formation is an important process in rocks of the continental crust. It takes place at temperatures below 250°C under hydrothermal conditions. Low-grade mineral assemblages are the key to the appreciation of water-rock interaction in hydrothermal and geothermal systems located in granites and gneisses of the crystalline basement.
A number of zeolite species have been described from Alpine fissures in crystalline rocks of the Swiss Alps. These are rather unusual occurrences compared to “normal” zeolite settings. The zeolites occur together with other low temperature Ca-Al silicates like prehnite and epidote in granites and gneisses, either as overgrowth on earlier mineral of the fissure assemblages, or as single stage fissure deposits in late clefts. The fissures contain usually the assemblage epidote, prehnite, chlorite and various species of zeolites in different modal abundance. Laumontite, stilbite and scolecite are common, whereas heulandite, chabazite and epistilbite occur occasionally. The specific zeolite mineral formed in the fissures depends mainly on the temperature. All zeolites are dominated by Ca as extra-channel cation.
Zeolite formation is tied to the plagioclase alteration reaction in the rock matrix, which releases components for zeolite formation to a CO_2-poor, alkaline aqueous fluid. The altered zeolite-bearing rock, replaces unaltered gneiss along a sharp reaction front. The net reaction plagioclase + 2quartz + $4H_2O$ => laumontite + albite produces the assemblage in the replacement zone. The reaction is associated with a 10% volume increase for the solids. The textural evidence, however, indicates that the oligoclase replacement reaction produces significant porosity in the product albite. We conclude that much of the produced volume is transferred to the central extension fracture by mineral precipitation in the open fracture. Furthermore, the porous product albite suggests that the propagation of the reaction front through the gneiss matrix occurred via a dissolution-precipitation mechanism. Quantitative models for the mass transfer in the system suggest a significant loss of Ca from the entire system.
Ar/Ar dating of apophyllite crystals, that overgrows laumontite as euhedral crystals as the last mineral formed in the fissures indicate, that the formation of the low-grade minerals occurred during late stage of cooling and exhumation of the alpine orogen.

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