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Chemical Characterization of Cordierite Breakdown Products in Gneisses and Migmatites of the Schwarzwald and the Bayerische Wald

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Cordierite $(Mg,Fe)_2[Si_5Al_4\ O_{18}]:nH_2O$ is a common framework silicate in medium- to high-grade metamorphic rocks and migmatites. Parallel to its crystallographic c-axis six-membered rings of $(Si,Al)O_4$ tetrahedrons form channel-like cavities which can accommodate volatile species such as H_2O (up to 2.8 wt%), CO_2 and smaller amounts of alkali ions like Na^+, K^+ and Ca_2^+.

In contrast to other cogenetic (Fe,Mg)-silicates cordierite is commonly altered penetratively during retrogression. It seems that cordierite is extremely reactive along the retrograde path of metamorphism. Hence, the retrograde breakdown of cordierite is a potential monitor of the retrograde history of metamorphic rocks, including the composition of retrograde fluids and their influence on the host rock. Unfortunately, the retrograde decomposition products of cordierite are in most cases extremely fine-grained, hampering recognition by optical methods and single phase analysis using the electron microprobe.

The process of retrograde cordierite decomposition is called pinitization. For natural cordierite pinitization is assumed as (Schreyer and Seifert, 1970): 1. The alteration of cordierite by a K_+-bearing fluid to chlorite, muscovite and quartz/Al-silicate. 2. The breakdown of cordierite to Al-silicate/pyrophyllite, chlorite and quartz and subsequent sericitization by a K^+-bearing fluid. Additionally, minor other phases such as septechlorite, paragonite and iron hydroxides may be formed (Layman, 1963). The diversity and composition of cordierite breakdown products and their enrichment in water and alkalis suggests that the decomposition of cordierite is often externally controlled by retrograde fluids.

Preliminary electron microprobe (EM) and scanning electron microprobe (SEM) studies on Variscan migmatites of the Schwarzwald and the Bayerische Wald reveal new details on the retrograde decomposition of metapelitic cordierite. Energy-dispersive (ED) and wavelength-dispersive (WD) element mappings and corresponding EM point analyses of partly decomposed cordierite indicate at least two different pinitization processes that often act simultaneously within the same grain. By optical and compositional means four different kinds of breakdown products can be distinguished:

(a) D-type (diffuse type) pinite: very fine-grained diffuse decomposition products may replace large parts of cordierite or whole cordierite grains. They seem to grow from cordierite rims to cores. D-type pinite has much higher K, Na and water contents and lower Mg contents than cordierite. The Si and Al contents are approximately the same as in cordierite. The EM data suggests that the d-type is in first order an intimately intergrown mixture of chlorite and muscovite or less often of paragonite, muscovite and chlorite. Therefore, d-type pinite obviously represents the above described decomposition reactions.

(b) F-type (fissure type) pinite: along fissures, extremely fine-grained decomposition products are developed. They are characterized by higher Ca, K, Al and water contents and by lower Si, Mg and Fe contents compared to cordierite. The f-type breakdown products show compositional gradients (Ca, K) from the fissure centres to the cordierite contacts. Compared to d-type pinite a higher Ca activity must have prevailed during their formation.

(c) Phyllosilicate clusters: along grain boundaries and fissures of intact and especially in the outer parts of decomposed cordierite, microscopically observable intergrowths of phyllosilicates are developed. Chlorite, muscovite and less often biotite and paragonite have been identified. The compositions of the phyllosilicates are variable and seem to depend on the compositions of the retrograde fluids.

(d) Initial pinite: some EM point analyses show only a slight to moderate decrease of their totals compared to intact cordierite. In contrast to 'mature' pinite the alkali increase is very low. It seems possible that these EM data represent the initial stage of pinitization.

The f-type pinites occur in intact cordierite as well as in decomposed cordierite that is already replaced by d-type pinite. The ED and WD mappings sharply distinguish between d- and f-type pinite, transitional stages between d- and f-type pinite do not seem to exist. This makes clear that the d- and the f-type pinititization are two separate decompositional processes. The phyllosilicate clusters represent an earlier stage of cordierite breakdown.

In order to model retrograde reactions and the composition of retrograde fluids it is necessary to completely understand and quantify pinitization. For this purpose, complete single phase analysis of cordierite breakdown products is required. A suitable method to achieve this is transmission electron microscopy, including chemical analysis. These investigations are on their way.

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