Andalusite + diaspore nodule in the quartz core from barren pegmatite at Dolní Bory, Czech Republic: an example of primary crystallization from a sol-gel medium

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The disequilibrium mineral assemblage andalusite + diaspore with pyrophyllite and kaolinite-group minerals was found in the massive quartz core of a barren pegmatite, which is part of the Dolní Bory pegmatite district (335.8±2, 337.2±2 Ma ^{235}U-^{207}Pb monazite ages, Novák *et al.*, 1998), Moldanubicum, Czech Republic. This assemblage corresponds to the system Al_2O_3-SiO_2-H_2O (ASH) and enables an estimation of *PT* conditions during crystallization. Thus it may provide insight into the formation of granitic pegmatites and other Al-rich systems.

The steeply dipping and zoned pegmatite dike is 5 m thick and several tens of m long cutting granulites. The internal structure from contacts inward is comprised of 1) border zone of fine- to medium-grained granitic zone (microcline + quartz + oligoclase + biotite ± muscovite); 2) subordinate graphic zone (microcline + quartz ± muscovite); and 3) a core of blocky microcline and massive quartz. Rare intermediate albite unit containing schorl, muscovite, sekaninaite, biotite and apatite is commonly located between the graphic zone or blocky microcline and massive quartz. No intensive hydrothermal alteration is found in or around the pegmatite except pinitization of sekaninaite.

The andalusite + diaspore nodule, about 1 m^3 in size, was found in massive quartz of the core close to the albite unit. It consists of the following minerals: (i) minor tabular crystals (lamellae) of greyish diaspore, about 1 mm thick and up to 2 cm long, with very rare small inclusions of foitite and pretulite; (ii) volumetrically dominant aggregates and euhedral to subhedral columnar, conic crystals of andalusite, up to 5 cm long, locally zoned with rare pink cores and growing outward from the nodule into massive quartz; (iii) rare fine- to medium-grained aggregates of pyrophyllite; and (iv) rare fine-grained aggregates of a kaolinite-group mineral. Both phyllosilicates also locally replace andalusite whereas diaspore is unaffected. Rare late illite replaces predominantly kaolinite where it is in contact with massive quartz. Along with Al-rich phases and quartz, the nodule contains very rare accessory minerals: foitite, schorl, zoned Nb-poor ferberite to *wolframoixiolite* (replaced by fine-grained mixture of secondary phases), monazite-(Ce), xenotime-(Y), zircon (38.0-38.5 Zr/Hf ratio), ilmenite, rutile, augelite and pyrite. The majority of minerals that make up the nodule are close to their ideal chemical compositions.

The paragenetic sequence of the aluminous minerals diaspore → andalusite → pyrophyllite → kaolinite developed during a time when the activities of B, F and P were low. This mineral assemblage with early diaspore suggests crystallization temperatures below 400 °C at 2 kbar. Mineral equilibria in the Al_2O_3-SiO_2-H_2O system have been extensively studied as both melt and aqueous solution. ASH melt solidus temperatures are far above those inferred for pegmatites in general, but experiments involving crystallization from colloidal solutions (*e.g.*, Hemley *et al.*, 1980) best fit the late-stage evolution of the pegmatite's core. The crystallization of primary phases can be described as the following condensation reactions among the most basic sol-gel building blocks:

1) $Al(OH)_{3(aq)} \rightarrow$ diaspore + H_2O

2) $2Al(OH)_{3(aq)} + H_4SiO_{4(aq)} \rightarrow$ andalusite + $5H_2O$

3) $2Al(OH)_{3(aq)} + 4H_4SiO_{4(aq)} \rightarrow$ pyrophyllite + $10H_2O$

4) $2Al(OH)_{3(aq)} + 2H_4SiO_{4(aq)} \rightarrow$ kaolinite + $5H_2O$

5) $H_4SiO_{4(aq)} \rightarrow$ quartz + $2H_2O$

Replacement phenomena can be characterized as condensation or hydration reactions as follows:

6) andalusite + $3H_4SiO_{4(aq)}$ → pyrophyllite + $5H_2O$

7) andalusite + $H_4SiO_{4(aq)}$ → kaolinite

8) pyrophyllite + $5H_2O$ → kaolinite + $2H_4SiO_{4(aq)}$

9) 3 kaolinite + $2K^+$ + → 2 illite + $3H_2O$ + $2H^+$

The latter K-metasomatic reaction may be the result of local albitization of K-feldspar that is typical in other pegmatite dikes at Dolní Bory.

Crystal growth in all zones was visibly extremely efficient at removing alkali and ferromagnesian components from the parent medium so that highly aluminous phases began to crystallize within the core. During this time, no fluxing components were present to any remarkable degree, nor anions or anionic complexes to aid in the transport of HFSEs except water. After nearly all Al was exhausted, this medium underwent self-organization into massive quartz.

Inferred crystallization temperatures of the disequilibrium mineral assemblage are far below those of ASH melt solidi but in the range of colloidal (sol-gel) systems. Moreover, sol-gel processes eloquently characterize the last part of the pegmatite's "magmatic" stage and all replacement phenomena. This example illustrates that we must first describe the internal evolution of simple pegmatites before contemplating complex ones (*e.g.*, Tanco).

References

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