

Apatite as an archive of pegmatite-forming processes: An example from the Berry-Havey pegmatite (Maine, U.S.A.)

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ABSTRACT

Apatite is an accessory phase in all the units of the internally zoned Berry-Havey complex pegmatite. This body presents a highly fractionated core zone, enriched in Li, F, B, Be, and P, which hosts three different types of pockets, some of them often containing tens to hundreds of gemmy euhedral Li-rich tourmaline crystals, together with other mineral phases such as lepidolite. Processes involved in the complex internal evolution of pegmatitic melts that give rise to zoned bodies containing pockets are not completely understood. To shed light on these processes, apatite from all the different units of the Berry-Havey pegmatite (wall zone, intermediate zone, core margin, and core zone pods) and from the three pocket types (Li-poor, Li-rich, and apatite seams) has been characterized petrographically and later analyzed for major (electronic microprobe) and trace elements (LA-ICP-MS). Results indicate that apatite chemistry changed significantly during the crystallization of the Berry-Havey pegmatite, reflecting the conditions at each stage and mainly depending on the fractionation degree, f_{O_2} , and paragenetic association.

Fluorapatite is found in all the units except the core margin, the Li-poor pockets, and the seams, where Mn-bearing fluorapatite is present. A gradual increase of the Mn content in apatite from the pegmatite border (wall zone) inward, up to the formation of subrounded masses of Mn-Fe phosphate in the core zone pods, parallels the increasing fractionation of the melt. Phosphate crystallization would deplete the residual melt in Mn, probably causing the significant Mn-decrease observed in apatite from the core zone pods and Li-rich pockets. The late depletion of Mn could also be related to an increase of f_{O_2} in the melt during the later stages of its evolution.

Main trace element variations in apatite at both pegmatite and crystal scales correspond to REE, Y, and Sr. Yttrium and REE behave in a very similar way, decreasing inward, i.e., with fractionation of the pegmatitic melt (Σ REE from 1796 ppm in the apatite from the wall zone to 0 ppm in the core zone; and Y from 1503 ppm in the apatite from the wall zone to 0 ppm in the core zone); which could be due to early crystallization of REE-bearing phosphates such as monazite and xenotime. Strontium shows a more complex trend, with an initial depletion in apatite from the wall zone (52 ppm) to the intermediate zone (3 ppm) and a pronounced increase from the core margin (23–87 ppm) up to the core zone and pockets (up to 2.87 wt%). This increase of Sr at the latest fractionation stages of the pegmatite is interpreted to be associated with a late, incompatible character of this element in highly fractionated melts, related to the composition of feldspars from the core margin (mainly pure albite). The lack of Ca in feldspars would decrease affinity for Sr incorporation into their structure and, consequently, Sr would go preferentially to apatite in the core zone pods and, more markedly, in the pockets.

Apatite also records changes in the redox conditions during crystallization, with the highest f_{O_2} at the end of the crystallization, mainly reflected in the Eu and Ce anomalies. The chemistry of apatite also reflects the evolution of the pegmatitic melt during crystallization regarding the fluids saturation and pockets generation. Accordingly, at least two exsolution events took place during the Berry-Havey crystallization history: (1) at the beginning of the core zone crystallization, giving rise to the Li-poor pockets, and (2) after the crystallization of the Li-rich pods of the core zone, resulting in the Li-rich pockets. The apatite-rich seams may have crystallized between these two exsolution events or later, at a subsolidus stage, after a Na-autometasomatism episode.

This study shows how a detailed petrographic and chemical characterization of apatite associated with different units of a highly fractionated, internally zoned pegmatite may help understand the crystallization history of pegmatitic melts. It is also evidenced that during the internal evolution of pegmatites, apatite chemistry records variations in the f_{O_2} , elemental fractionation, interaction with competing mineral phases, fluids activity and exsolution events. In addition, it is shown how apatite chemistry may be useful as an exploration tool for pegmatites.

Keywords: Berry-Havey pegmatite, Maine, apatite, internal fractionation, pockets formation