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Fluorine-Driven REE Enrichment in Melts: Implications for the Carbonatite-Phoscorite Complex

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The Carbonatite-Phoscorite Complex is a significant LREE deposit, consisting of carbonatite, containing more than 50% carbonate minerals, and phoscorite, predominantly containing Fe-rich minerals. Their formation requires a low degree of partial melting, followed by rapid ascent driven by volatile components. Elements such as F, OH, and Cl enhance the volatility of the melt, promoting rapid ascent and enhancing REE mobility. In major carbonatite-phoscorite deposits such as Maoniuping and Bayan Obo, REE phosphates and REE carbonates precipitate during both the early and late stages of melt crystallization. In contrast, deposits like Araxá and Mount Weld, as well as the Hongcheon Carbonatite-Phoscorite Complex, predominantly show REE phosphate (monazite) precipitation during the late crystallization stage.

In the Hongcheon Carbonatite-Phoscorite Complex, ankerite and magnetite crystallize in the early stage of carbonatite formation, whereas monazite and ankerite precipitate in the late stage. In phoscorite, apatite and magnetite crystallize in the early stage, while monazite, apatite, and ankerite precipitate in the late stage. A notable characteristic of apatite precipitated in both early and late stages is their relatively high fluorine content.

A comparative analysis of these deposits indicates that elevated fluorine content plays a pivotal role in:

1. Facilitating the late-stage precipitation of REE phosphates rather than REE carbonates, and
2. Controlling REE mobility and behavior within the carbonatite-phoscorite complex.

Stage	Early	Late
Hongcheon	Ank, Mag, Ap	Ap, **Mnz**, Ank, Qtz
Araxá	Dol, Ap, Pcl	**Mnz**, Pcl, Rha, Bar, Ap, Mag
Mountain Weld	Ap, Dol, Ank, Phl, Amph	Dol, **Mnz**, Ap, Rha
Bayan Obo	Cal, Dol, Mag, Ap, **Bas**	Dol, Ap, Mag, **Bas, Mnz**, Par
Maoniuping	Cal, Fl, Bar, Qtz, **Bas**	**Bas**, **Mnz**, Bar, Ap, Qtz, Fl, Py

Table 1. Major mineral composition in representative carbonatite deposits. Minerals that contain REEs are highlighted in bold. Mineral abbreviation. Ank = ankerite; Mag = magnetite; Mnz = monazite; Qtz = quartz; Ap = apatite; Bas = bastnasite; Par = parisite; Pcl = pyrochlore; Rha = rhabdophane; Bar = barite; Fl = Fluorite; Py = pyrite.