Automated mineralogy of complex carbonatite-hosted rare earth element (REE) minerals

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Carbonatite-hosted REE-minerals represent a challenge for microanalytical tools, such as automated mineralogy (AM). The most common REE-minerals at the Fen carbonatite complex, Norway, are parisite, bastnäsite, and monazite, which often show complex intergrowth and associations, commonly at micrometer-scale. A better understanding of these complex mineralogical textures is also necessary to comprehend the changes in flotation properties of the various concentrates and by-products during mineral processing beneficiation studies. We therefore acquired automated mineralogical data of feed material, of the initial and main REE-concentrates, as well as from the by-product at the Norwegian Laboratory for Minerals and Materials Characterisation (MiMaC), Department of Geoscience and Petroleum (IGP), NTNU. Flotation products were collected at the IGP-NTNU Mineral Processing Laboratory. Additionally, drillcore pieces were scanned using micro-computed tomography (µCT) at the NTNU CT scan facilities of the Center of Excellence PoreLab to locate minerals with higher densities (i.e., REE-minerals, thorite). This allows to produce thin-sections (long- and cross-sections) including the high-density target minerals. These thin-sections containing the target minerals were subsequently scanned using automated mineralogy to correlate the high-density minerals in 3D (µCT) and 2D (AM). The MiMaC Laboratory hosts a ZEISS Sigma 300VP field emission SEM and ZEISS Mineralogic software for automated mineralogical analysis. In SEM-based automated mineralogy using Mineralogic, EDS spectra are collected systematically covering a high-resolution grid in the analyzed sample, whereby each individual EDS spectrum identifies a mineral based on the contained element wt% (e.g., Graham 2015). For this study, a step size of 2 µm was used with an acceleration voltage of 20kV. The mineral list for the phase classification is generated prior to the automated run and optimized after the run, allowing to add missing mineral phases. An element wt%-based mineral classification, as used with Mineralogic, enables the distinction of the complex REE-minerals parisite, bastnäsite, and monazite, including the subvarieties that contain varying amounts of Ce, La, Nd, and Y (Silva et al., 2023). The results of this study show that bastnäsite and parisite are the main REE+Y-minerals and commonly are associated and intergrown with carbonates, but also quartz and other mineral phases. Monazite is locally replacing bastnäsite and parisite. Furthermore, using Mineralogic allows to locate elemental Th and U and visualize that elemental Th is mainly present in the Th-mineral thorite, and U in uraninite and coffinite (Lode et al., 2022; Magnushommen, 2022). A correlation of micro-analytical workflows, such as 3D µCT and 2D automated mineralogy when combined with mineral processing beneficiation studies provides an excellent opportunity to optimize sampling/sample preparation and processes that are necessary for an efficient extraction of rare earth elements.

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