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Influences of paleo-weathering and fluid-assisted element redistribution on the critical metal mineralization of the Delitzsch Carbonatite Complex, Eastern Germany

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The sub-surface late Cretaceous Delitzsch-Storkwitz Carbonatite Complex (E Germany) resembles carbonatitic breccias with fragments of plutonic glimmerites (metasomatized Na-fenites), calcite-dolomite carbonatite, dolomite carbonatite and granitic host rocks. These breccias are cross-cut by fine-grained calcite carbonatite dykes and associated with lamprophyres. This study examines the HFSE (including REE) enrichment and redistribution in the carbonatites, focusing on the breccias' mineral potential. The breccias show variable signs of multistage alteration and weathering processes: (1) Red breccias (250-296 m depth) are strongly influenced by supergene processes and the matrix is dominated by clay minerals, Fe-oxyhydroxides, apatite, and secondary monazite. (2) At greater depths (360-427m), the green breccias host REE-F-carbonates in pores, dolomite, apatite, pyrochlore and remnants of feldspar xenocryst. (3) The grey matrix in breccias from 427-549 m depth is characterized by REE-F-carbonates, sulfides, sulfates, dolomite, pyrochlore, apatite, biotite and feldspar xenocrysts. Furthermore, dolomite carbonatites comprise REE-F-carbonates with baryte and pyrite in hexagonal pseudomorphs, interpreted as relics of magmatic alkali-REE carbonates remobilized by hydrothermal fluids. However, no REE-F-carbonates are observed in calcite-dolomite and calcite carbonatite dykes. All breccia matrices show REE enrichment (TREE up to 1.29 wt.%), with steep REE patterns (chondrite-normalized La/Yb up to 730). Negative Ce anomalies in some samples (highest in the breccia matrices; Ce/Ce* = 0.63) indicate fluid-rock interaction and oxidation-related fractionation. Positive correlation between $(La/Yb)_N$ and Ba in most samples indicates hydrothermal co-enrichment of LREE and Ba, although some outliers suggest more complex processes. Primitive-mantle normalized trace element patterns show Sr depletion in all breccia matrices (along with calcite-dolomite carbonatite fragments and most calcite carbonatite dykes) and Sr enrichment in dolomite carbonatite fragments, consistent with primary magmatic Sr-bearing minerals like apatite in such samples. Niobium enrichment is strongest in dolomite carbonatite, consistent with magmatic pyrochlore. An unsystematic Nb depletion in samples of the same unit is attributed to fluid interaction, evidenced by altered pyrochlore textures, followed by the breccia matrices and the calcite carbonatite dykes. Zirconium depletion shows a similar trend: dolomite carbonatite > breccia matrices > calcite carbonatite dykes. This study highlights the complex interplay between magmatic, hydrothermal, and supergene processes resulting in HFSE-REE enrichment within carbonatites.