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Rare Earth Element Mobilization and Enrichment in Weathered Carbonatite of the Dong Pao Deposit, Vietnam

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The Eocene Dong Pao rare earth element (REE) deposit in Vietnam is one of the world's largest, with reserves of 0.55 Mt REO at an average grade of 3.6 wt %. The REE mineralisation is associated with a carbonatite-syenite complex and the related laterite contains 0.9 Mt REO at an average grade of 4 wt %. An ~100 m thick profile from the laterite to the carbonatite bedrock has been characterised to investigate the REE mobilisation and enrichment processes during weathering.

The carbonatite bedrock is mainly composed of calcite and has an accessory mineral assemblage of tainiolite, apatite, pyrochlore-group minerals, barite, celestine, bastnäsite-(Ce), synchysite-(Ce), fluorite, monazite, strontianite, quartz, and sulphides. In the laterite residual barite and monazite occur, but residual bastnäsite-(Ce) is only observed in the saprolite. Secondary rhabdophane-(La,Ce), florencite-(Ce), cerianite, Fe-Mn oxides, and kaolinite occur throughout the laterite. Acicular rhabdophane-(La,Ce) occurs filling fractures, while fibrous florencite-(Ce) fills cavities. Cerianite rims the edges of corroded monazite and voids in florencite-(Ce) and occurs as veinlets cutting rhabdophane-(La,Ce).

The REE concentration of the bedrock is highly variable, ranging from 170 to 57,000 ppm total REE with (La/Yb)_N ratios from 13 to 3,000, and occasionally with positive Y anomalies and high SiO₂ contents. In the laterite, the REE patterns are consistently highly LREE-enriched and without Y anomaly. Positive Ce anomalies are observed in the uppermost laterite, with negative Ce anomalies lower in the profile. REE concentration shows a depletion-enrichment pattern with depth, from ~5,000 ppm at the top of the profile to ~30,000 ppm in the saprolite and decreasing to ~10,000 ppm in the saprock. Geochemical correlation indicates phosphates are the main REE hosts, with niobates deeper in the saprolite. Substantial REE re-distribution has taken place during weathering to generate an REE-rich ore horizon and homogenise the variable REE compositions of the bedrock.