

THE COQUEIROS CARBONATITE-RELATED PHOSPHATE DEPOSIT: A KEY EXAMPLE OF ORTHOMAGMATIC MINERALIZATION PROCESSES

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Phosphate is essential in the agriculture sector for the production of fertilizers and animal feed supplements. The most common phosphate sources are sedimentary deposits formed by biochemical rocks (*e.g.* phosphorites). However, in contrast to the worldwide production, most Brazilian phosphate comes from magmatic apatite (*e.g.* carbonatite-related). Significant challenges to the economic viability of igneous phosphate deposits are their mineralogical and lithological complexity. In that sense, a better understanding of the geology and the petrogenetic processes responsible for apatite concentration is critical to support the development of potential targets and in the search for new areas. The Catalão II alkaline-carbonatite complex in the Alto Paranaíba Igneous Province hosts important phosphate resources known as the Coqueiros deposit (45 Mt at 11.0% P₂O₅ for residual apatite in the weathering profile, and 410 Mt at 9.0% P₂O₅ for fresh rock apatite). The Catalão II complex is composed of bebedourites, phoscorites, and carbonatites, with subordinate alkali-feldspar syenites and ultramafic lamprophyres. Apatite-rich lithologies are mostly bebedourites - ultramafic cumulate rocks composed of variable modal proportions of clinopyroxene (*i.e.* diopside and aegirine-augite), olivine, mica (*i.e.* phlogopite and tetraferriphlogopite), apatite, magnetite, and Ca-Ti phases (*i.e.* perovskite, Ti-garnet, and titanite). Three bebedourite intrusive stages can be recognized based on drill-core descriptions, petrography, whole-rock geochemistry, and mineral compositions, two of those intimately associated with clinopyroxene-bearing calcite carbonatites. The Coqueiros bebedourites are titanite-bearing and lack key phases such as olivine, perovskite and Ti-garnet. The first intrusive stage is registered as an outer ring of tetraferriphlogopite bebedourite with abundant K-rich fenite xenoliths. These textural features along with the enrichment in HREE relative to LREE, high Rb/Sr (0.06-0.31), and low Gd/Lu (22.2-51.7) strongly suggest crustal contamination processes. Tetraferriphlogopite bebedourite has minor amounts of modal apatite and does not contain significant phosphate grades in fresh rock. However, residual concentrations may occur in the weathering profile. The second intrusive stage is composed of apatite bebedourite, with local apatite layers, and diopside calcite carbonatite. The third stage is composed of titanite bebedourite and aegirine-augite calcite carbonatite. Gradational modal variations together with compositional trends in apatite (*i.e.* SiO₂ and REE increase, CaO e P₂O₅ depletion), clinopyroxene (*i.e.* Na₂O increase, MgO depletion), mica (*i.e.* FeO and Fe₂O₃ increase, MgO and Al₂O₃ depletion), and calcite (*i.e.* SrO increase), and similar trace-element patterns with enrichment in LREE relative

to HREE, are evidence of fractional crystallization acting within each intrusive stage. Hence, the orthomagmatic phosphate mineralization in the Catalão II complex (the Coqueiros deposit) results from an early stage of extensive removal of silicate phases from the magma and a consequent enrichment in phosphate and carbonate that generated early bebedourites, intermediate apatite-rich rocks, and residual calcite carbonatites. This conclusion highlights the potential for apatite mineralization in fresh rock and brings new insights to improve exploration vectors in alkaline-carbonatite complexes.