## Morphological and chemical evolution of corundum (ruby and sapphire): Crystal ontogeny reconstructed by EMPA, LA-ICP-MS, and Cr<sup>3+</sup> Raman mapping

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## ABSTRACT

The term "ontogeny," which is commonly used in biology, was introduced into the Earth sciences in 1961 to include the genesis and evolution of single crystals and crystal aggregates. The term encompasses nucleation, growth, alteration, and destruction. We present results of studies concerning the ontogeny of natural corundum (rubies and sapphires), and the chemical and morphological evolution of corundum crystals from deposits in Africa (Kenya, Tanzania, Madagascar) and Southeast Asia (Vietnam). Trace-element compositions indicative for different corundum habits were determined by rim-to-rim LA-ICP-MS and electron microprobe analyses. Raman spectroscopy was applied for Cr<sup>3+</sup> photoluminescence mapping. Results traced the development of corundum crystals and the evolution of their chemistry and morphology, and helped to clarify the geological processes within particular deposits. These variations of corundum morphology are directly correlated with Cr and Fe contents and varying P-T conditions that prevailed during crystal growth. Dipyramidal habits combined with white color in corundum from two deposits in the Mangari area in Kenya have Cr concentrations of  $\sim$ 200–700 µg/g in crystals that grew under high *P*-*T* conditions. Prismatic habit of bright red ruby crystals was linked to Cr concentrations of ≥1500 µg/g in samples from Luc Yen (Vietnam) and Mangari (Kenya), formed under lower P-T. Concentrations of Cr between 700-1500 µg/g are associated with pink color and combinations of different habits (dipyramidal, prismatic, or dipyramidal-prismatic) in these samples. Contents of Fe  $\sim$ 700 µg/g and Cr  $\sim$ 1200 µg/g in sapphire crystals from the Morogoro area of Tanzania caused pink color that correlated with dipyramidal habit and elongation along the c axis. Rhombohedral habit and blue-violet color were observed at Cr ~600  $\mu$ g/g and Fe  $\geq$ 2000  $\mu$ g/g in sapphires from Andranondambo in Madagascar, formed during the final stage of contact metamorphism.

**Keywords:** Corundum, ruby, sapphire, ontogeny, evolution, genesis, geochemistry, crystal morphology, Kenya, Tanzania, Madagascar, Vietnam