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Morphological and chemical evolution of corundum (ruby and sapphire): Crystal ontogeny reconstructed by EMPA, LA-ICP-MS, and Cr^{3+} Raman mapping

Elena S. Sorokina[1,2,*], Wolfgang Hofmeister[3], Tobias Häger[3], Regina Mertz-Kraus[3], Stephan Buhre[3], and John M. Saul[4]

[1]Gemological Institute of America, 5355 Armada Drive, Carlsbad, California 92008, U.S.A.
[2]Fersman Mineralogical Museum of the Russian Academy of Sciences (RAS), Leninskiy prosp., 18 b. 2, Moscow 119071, Russia
[3]Institute for Geosciences of the Johannes Gutenberg-University Mainz (JGU), J.-J.-Becher-Weg 21, D-55128 Mainz, Germany
[4]Swala Gem Traders, Box 11063, Arusha, Tanzania

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^{3+} 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 ~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 ~700 μg/g and Cr ~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 μg/g and Fe ≥2000 μg/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