Geochemical Fingerprinting of Spinel from Tanzania for the Purpose of Gem Exploration and Heat Treatment

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Spinel [commonly $MgAl_2O_4$] is mined globally and is used in abrasives, high-performance ceramics, and as gemstones. The color and clarity of gemstones are influenced, among other things, by trace elements (i.e., chromophores), and/or by mineral inclusions. The trace element chemistry in spinel, which includes Zn, Fe, V, Si, Cr, Ca, Ti, Mn, and Ni, has been used previously to determine the provenance (i.e., metamorphic versus igneous) and regional origin of spinel samples (Giuliani *et al*., 2017). Among the many challenges that the gemstone industry faces, two of the most critical are: [1] the identification of the exact locality and the environments from which they are mined; e.g., typically only the regional scale information is known; and [2] devising viable heat-treatment methods to increase the overall value (i.e., color and clarity) of natural gemstones. In this study, we test the hypotheses that the chemical composition of gemstone-quality spinel can be used to: [1] geochemically fingerprint the locality and provenance of spinel from the Tunduru and Mahenge (Tanzania), and Ocua (Mozambique) regions; and [2] elucidate the mechanisms responsible for color and clarity improvement during heat treatment processes (e.g., dissolution/precipitation reactions of inclusions and/or solid-state diffusion of trace elements). Here, we combine laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), and electron probe microanalysis to quantify major and trace element concentrations of natural spinel derived from mining districts within Tanzania (Tunduru and Mahenge), and Mozambique (Ocua). Additionally, optical microscopy, backscattered electron (BSE) imaging, and energy dispersive spectroscopy (EDS) analyses were used to identify spinel-hosted mineral inclusions (e.g., apatite, zircon, anhydrite, and rutile). These results will be compared to literature data (e.g., Fe vs. Zn, and FeO-Cr_2O_3 vs. $2ZnO$-V_2O_3 discrimination diagrams; Fe-Cr-Zn ternary plots) in order to develop a dataset that fingerprints and characterizes the geochemical signatures of these spinel samples that are indicative of their source locality (Giuliani et al., 2017). Furthermore, elucidating the chemical compositions of gemstone-quality spinel is imperative in order to understand the mechanisms responsible for color and clarity improvement during heat treatment processes. Previous studies have investigated the heat-treating mechanisms of gemstones such as sapphire and ruby (Emmett et al., 2006); however, there is a dearth of information regarding the heat treatment of spinel, especially using unconventional heat-treating techniques (Swain et al., 2016). We will report the first results from heat-treating experiments of spinel using novel, unconventional methods.