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Tourmaline chemistry as a potential discriminator of hydrothermal ore deposit type-a machine learning-based approach

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The mineral tourmaline has been extensively used to fingerprint the nature and the source of mineralizing fluids in many ore genetic systems [1, 2]. In this study, we apply machine learning to discriminate tourmaline from different hydrothermal ore deposits using its major-trace element and B-isotope chemistry.

Our dataset comprises 12 major elements, 44 trace elements and B-isotope composition of tourmaline from 11 different ore deposit types, namely Iron Oxide Cu-Au (IOCG), Iron Oxide-Apatite (IOA), Sn &/W, Unconformity-related U, Porphyry Au, Porphyry Cu-Mo-Sn, Sedimentary Exhalative (SEDEX), Volcanogenic Massive Sulfide (VMS), Orogenic Au, Intrusion-related Gold Systems (IRGS), and Epithermal/Tertiary Au. The eXtreemly Greedy tree Boosting (XGBoost) machine learning classifier is successfully able to discriminate tourmaline from the aforementioned deposit types with an average classification accuracy of 94.9%. The Shapley Additive exPlanations algorithm indicates that $\delta^{11}B$ value, and F, Cl concentrations of tourmaline contribute most in discriminating the different ore deposit types. Amongst them, $\delta^{11}B$ has the maximum control on discrimination of IOA, IOCG, Sn &/W, and SEDEX type deposits. High $\delta^{11}B$ values of tourmaline helps to discriminate IOA and IOCG type deposits from the others, while high Na content of tourmaline from IOCG type deposits helps to differentiate it from the IOA type and other deposits. The high Na concentrations and elevated Cl contents suggest that saline fluids play a key role in IOCG-type deposits. Tourmaline from orogenic and epithermal Au deposits are mostly of dravitic composition with low to intermediate $\delta^{11}B$ values, while those from porphyry-Au deposits have schorlitic composition and intermediate to high $\delta^{11}B$-values. The positive contribution of Cl, Ca, K, and lower $\delta^{11}B$-values of tourmaline from SEDEX deposits is suggestive of continental evaporitic source for the ore-forming hydrothermal fluids.

The origin of uranium mineralization along the Singhbhum Shear Zone (SSZ) in eastern India is controversial. To address this problem we applied our machine learning classifier on a dataset comprising the major-trace element, and B-isotope composition of tourmaline from rocks in the SSZ. The results indicate that the uranium mineralization along the SSZ is mostly of IOCG type.

[1] Slack and Trumbull, 2011; [2] Trumbull et al., 2020