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A machine learning approach to discrimination of igneous rocks and ore deposits by zircon trace elements

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Abstract

The mineral zircon has a robust crystal structure, preserving a wealth of geological information through deep time. Traditionally, trace elements in magmatic and hydrothermal zircon have been employed to distinguish between different primary igneous or metallogenic growth fluids. However, classical approaches based on mineral geochemistry are not only time consuming but often ambiguous due to apparent compositional overlap for different growth environments. Here, we report a compilation of 11 004 zircon trace element measurements from 280 published articles, 7173 from crystals in igneous rocks, and 3831 from ore deposits. Geochemical variables include Hf, Th, U, Y, Ti, Nb, Ta, and the REEs. Igneous rock types include kimberlite, carbonatite, gabbro, basalt, andesite, diorite, granodiorite, dacite, granite, rhyolite, and pegmatite. Ore types include porphyry Cu-Au-Mo, skarn-type polymetallic, intrusion-related Au, skarn-type Fe-Cu, and Nb-Ta deposits. We develop Decision Tree, XGBoost, and Random Forest algorithms with this zircon geochemical information to predict lithology or deposit type. The F1-score indicates that the Random Forest algorithm has the best predictive performance for the classification of both lithology and deposit type. The eight most important zircon elements from the igneous rock (Hf, Nb, Ta, Th, U, Eu, Ti, Lu) and ore deposit (Y, Eu, Hf, U, Ce, Ti, Th, Lu) classification models, yielded reliable F1-scores of 0.919 and 0.891, respectively. We present a web page portal (http://60.205.170.161:8001/) for the classifier and employ it to a case study of Archean igneous rocks in Western Australia and ore deposits in Southwest China. The machine learning classifier successfully determines the known primary lithology of the samples, demonstrating significant promise as a classification tool where host rock and ore deposit types are unknown.

Keywords: Zircon, trace elements, igneous rocks classification, ore deposits classification, machine learning, Random Forests