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Geochemical Neural Network Classification of Indicator Minerals Based on Associated Diamond Content

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The presence and abundances of diamond indicator minerals, as well as their major and minor element concentrations, are the standard in diamond exploration to determine the location of a diamond-bearing body and if the conditions were conducive to diamond formation. Despite compelling diamond indicator mineral geochemistry, some kimberlites, however, are found to contain few diamonds. This study examines the element concentrations of diamond indicator silicate minerals by creating a neural network classification model to differentiate between minerals associated with highly diamondiferous and poorly diamondiferous kimberlites.

Five types of diamond indicator silicate minerals were analysed using an electron microprobe: harzburgitic garnets, eclogitic garnets, clinopyroxenes, orthopyroxenes, and olivines. The suites of minerals were from kimberlites located in the Slave (NT, Canada) and Kaapvaal Cratons (South Africa): Beartooth (highly diamondiferous with 86.34% total octahedrals), Koala (highly diamondiferous with 43.75% total octahedrals), Panda (highly diamondiferous with 56.21% total octahedrals), Kit (noneconomic), New Elands (orangeite with highly resorbed diamond population), and Zero (conditions unsuitable for diamond formation). The minerals with the chemical compositions known only to diamond inclusion minerals and diamond-bearing kimberlitic xenocrysts, xenoliths, and phenocrysts were chosen for further analysis. Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) was used to determine major, minor, trace, and ultratrace abundances in the chosen minerals. A total of 494 diamond indicator silicate minerals were analysed with LA-ICP-MS resulting in maxima of 20 examples from each of the five minerals for the six different kimberlites pipes.

The LA-ICP-MS results were explored, summarized, treated as compositions using the log-ratio approach, and investigated for their element associations using RQ-mode principal component analysis. Based on the exploratory data analysis, neural network classification models for each type of indicator mineral were created using Keras, an open-source Python library. Each set of minerals were split into training, validation, and test subsets. Due to the small number of grains available, the stratified shuffle split was replicated an additional three times to cross-validate the models' effectiveness to separate minerals associated with highly diamondiferous and poorly diamondiferous kimberlites. As a result, five multielement neural network models were created to classify diamond indicator minerals based on their associated diamond content. Feature importance was calculated for each model, and percent probabilities were captured for each grain. An annotated coding companion was created in Jupyter Notebook. Future research would focus on larger data sets and examining the important features within the neural network as well as their relationships to diamondiferous kimberlites.