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Interpreting mineral deposit genesis classification with decision maps: A case study using pyrite trace elements

Yu Wang[1,2], Kun-Feng Qiu[1,*], Alexandru C. Telea[2], Zhao-Liang Hou[1,3,*], Tong Zhou[1], Yi-Wei Cai[1], Zheng-Jiang Ding[4], Hao-Cheng Yu[1], and Jun Deng[1,5]

[1]Frontiers Science Center for Deep-time Digital Earth, State Key Laboratory of Geological Processes and Mineral Resources, School of Earth Sciences and Resources, China University of Geosciences, Beijing 100083, China
[2]Department of Information and Computing Sciences, Utrecht University, 3584 CC Utrecht, The Netherlands
[3]Department of Geology, University of Vienna, Althanstraße 14, Vienna 1090, Austria
[4]Ministry of Natural Resources Technology Innovation Center for Deep Gold Resources Exploration and Mining, No. 6 Geological Team of Shandong Provincial Bureau of Geology and Mineral Resources, Weihai, Shandong 264209, China
[5]Geological Research Institute of Shandong Gold Group Co., Ltd., Jinan 250013, China

Abstract

Machine learning improves geochemistry discriminant diagrams in classifying mineral deposit genetic types. However, the increasingly recognized "black box" property of machine learning has been hampering the transparency of complex data analysis, leading to challenges in deep geochemical interpretation. To address the issue, we revisited pyrite trace elements and proposed the use of the "Decision Map," a cutting-edge visualization technique for machine learning. This technique reveals mineral deposit classifications by visualizing the "decision boundaries" of high-dimensional data, a concept crucial for model interpretation, active learning, and domain adaptation. In the context of geochemical data classification, it enables geologists to understand the relationship between geo-data and decision boundaries, assess prediction certainty, and observe data distribution trends. This bridges the gap between the insightful properties of traditional discriminant diagrams and the high-dimensional efficiency of modern machine learning. Using pyrite trace element data, we construct a decision map for mineral deposit type classification, which maintains the accuracy of machine learning while adding valuable visualization insight. Additionally, we demonstrate two applications of decision maps. First, we show how decision maps can help resolve a dispute concerning the genetic type of a deposit whose data were not used in training the models. Second, we demonstrate how the decision maps can help understand the model, which further helps find indicator elements of pyrite. The recommended indicator elements by decision maps are consistent with geologists' knowledge. This study confirms the decision map's effectiveness in interpreting mineral genetic type classification problems. In geochemical classification, decision maps mark a shift from conventional machine learning to a visually insightful approach, thereby enhancing the geological understanding derived from the model. Furthermore, our work implies that decision maps could be applicable to diverse classification challenges in geosciences.

Keywords: Decision map, mineral deposit genesis, machine learning classification, pyrite trace element, discriminant diagrams