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A machine-learning-based approach using clinopyroxene data to improve accuracy and efficiency in predicting tectonic settings: Implications for Rodinia supercontinent breakup triggered by mantle plume events

Hengxu Li[1], Zhaochong Zhang[1,2,*,†], Ruixuan Zhang[3], Marc K. Reichow[4], Zhiguo Cheng[1,2], Zhenjie Zhang[1], and M. Santosh[1,5]

[1]State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Beijing 100083, China
[2]Frontiers Science Center for Deep-time Digital Earth, China University of Geosciences (Beijing), Beijing 100083, China
[3]School of Civil and Environmental Engineering, Queensland University of Technology, Brisbane, Queensland 4000, Australia
[4]School of Geography, Geology and the Environment, University of Leicester, University Road, Leicester LE1 7RH, U.K.
[5]Yonsei Frontier Lab, Yonsei University, Seoul 03722, Republic of Korea

Abstract

Basalts are ubiquitous mafic rocks found within diverse tectonic settings on Earth. Despite concerted efforts to distinguish tectonic settings through the chemical compositions of basalt, some features of these rocks related to tectonic processes can be obscured by weathering and erosion over geological time, making the discrimination results ambiguous. In this study, we utilized major and trace element data of clinopyroxene in basalts from five distinct tectonic settings: continental within-plate basalts (WPB), island arc basalts (IAB), ocean island basalts (OIB), oceanic floor basalts (OFB), and continental flood basalts (CFB). Employing three machine learning techniques—multi-layer perceptron (MLP), support vector machine (SVM), and random forest (RF)—we aim to discriminate tectonic settings and magma affinities. Sparse multinomial regression (SMR) approach is used to quantitatively discern geochemical signatures that are distinctive of each tectonic setting. The outcomes reveal the efficacy of SVM, which attains an accuracy of 92.1% (major-element-based) and 95.2% (major- and trace-element-based) for tectonic discrimination. Furthermore, SVM achieves an accuracy of 92.9% (major-element-based) and 95.7% (major- and trace-element-based) for magma affinity discrimination. Our study shows that the integration of electron microprobe data from clinopyroxene with machine learning techniques provides an effective approach to distinguishing various tectonic settings and magma affinities. The classifier models have been applied to investigate the Neoproterozoic geodynamics of the Jiangnan Orogen. The models show the two pulses of mantle plume events (~830 and ~785 Ma) triggering the break-up of the Rodinia supercontinent.

Keywords: Machine learning, large database, tectonic setting, magma affinity, major and trace elements, clinopyroxene, Mineral Informatics: Revolutionizing Mineralogy, Petrology, and Geochemistry