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Distinguishing Carbonate and Silicate Melt Metasomatism in Peridotites of the North China Craton Using the Major Element Compositions of Clinopyroxene: A New Discriminant Method Based on Machine Learning

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Mantle metasomatism is a key process in shaping the deep material composition and dynamics of the Earth. Due to the significantly different mineralogical and geochemical characteristics of carbonate melts and silicate melts, their metasomatism has remarkably different impacts on the modification of lithospheric mantle peridotites. However, traditional methods based on trace element ratios of clinopyroxene (such as $(La/Yb)_N$ and Ti/Eu) have problems such as scarce data and limited applicability when identifying and distinguishing the types of mantle metasomatism. In order to overcome these limitations, this paper proposes a method of major element analysis of clinopyroxene based on machine learning, using the major element data of clinopyroxene in mantle peridotites (such as TiO_2, Al_2O_3, Ca/Al ratio, etc.) to distinguish between carbonate melt and silicate melt metasomatism. Based on the analysis of the major element compositions of clinopyroxene in the mantle peridotites from the North China Craton, a new classification method based on the Support Vector Machine (SVM) algorithm is constructed. In this study, the major element compositions of 483 groups of clinopyroxenes from peridotite xenoliths in the North China Craton were used for model training and testing. By combining eigenvalue weight assignment, hyperparameter optimization, and multiple iterative trainings, an improved support vector machine model was constructed. The classification accuracy of this model reached 99.2%, and it showed excellent classification ability when predicting unlabeled samples. By applying this model to the analysis of peridotite xenoliths from the lithospheric mantle of the North China Craton in different geological periods, the evolutionary trend of the lithospheric mantle metasomatism in the North China Craton was revealed: carbonate melt metasomatism dominated the mantle modification in the early stage (before about 125 Ma), while silicate melt metasomatism gradually became dominant after the Early Cretaceous. This discriminant method based on machine learning provides an efficient and reliable new tool for the study of mantle metasomatism, and can provide more accurate support for the study of the temporal and spatial evolution of mantle composition.