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Machine Learning-Based Classification of Zircons for Provenance Analysis: Unveiling Precambrian Geologic Events through Detrital Zircon Characterization

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The lack of petrological records has led to significant debates regarding major geological events during the Precambrian era, such as the initiation time of plate tectonics [1] and the appearance of water on Earth. Abundant detrital zircons present an effective proxy for investigating the early Earth. Due to their stable physicochemical properties, zircons can retain the information about the composition of the parent magma despite potential multiple sedimentary or metamorphic events [2]. However, in most cases, the petrological background of detrital zircons has been lost, making the identification of their source rocks a primary concern.

Granitoids are the basic components of the continental crust and the most common source rocks for detrital zircon of magmatic origin. Specifically, the occurrence of M-type granitoids, typically formed in mid-ocean ridge settings, implies that plate tectonics initiation during this period, while the occurrence of S-type granitoids, derived from sedimentary rocks, indicates the presence of water on Earth during this period. Hence, it is critical to identify the source rocks of detrital zircons for our understanding major geological events during the Precambrian era. In this study, we employed machine learning techniques to investigate the source rocks for zircon based on magmatic zircon dataset compiled from 5816 analyses. Two supervised algorithms, Random Forest and Support Vector Machine, were applied in the model training with 18 features. The model achieved an accuracy of 86.3%, outperforming previous classification schemes. Employing the classifier for predictive analysis of detrital zircons revealed that the initiation of plate tectonics on Earth likely occurred before 3.5 Ga, with the appearance of water around 4 Ga.

References

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