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Distinguish detrital zircon provenances based on a machine learning technology

SHIHUA ZHONG[1], SANZHONG LI[2] AND REIMAR SELTMANN[3]

[1]Ocean University of China

[2]Frontiers Science Center for Deep Ocean Multispheres and Earth System, Key Lab of Submarine Geosciences and Prospecting Techniques, MOE and College of Marine Geosciences, Ocean University of China, Qingdao, 266100, China

[3]Natural History Museum

Presenting Author: zhongshihua@ouc.edu.cn

Detrital zircons are widely used as a robust tool in many geological fields. This is due to their ability to incorporate a large number of geochemically important trace elements, as well as the physical-chemical durability and resistance to alteration. Based on the types of their source rocks, detrital zircons can be divided into I-, S- and A-type provenances. To identify detrital zircon types continues to be a hot topic. For example, economic geologists pay attention to detrital zircon types because they can carry important clues of potential mineralization types in a region, considering that I-type rocks are normally related to porphyry Cu deposits, whereas S- and A-type rocks are generally related to W-Sn deposits.

Both aluminum and phosphorus contents in zircon have been suggested as evidence for S- and I-type melts, with I-type melts characterized by low Al (< 4 ppm) and low P (< 750 ppm). However, both zircon Al and P contents are susceptible to mineral inclusions (e.g., muscovite and apatite), which are common in zircon grains. Moreover, to use P as the sole metric for I- and S-type zircons may be problematic since many zircons with lower P contents could also derive from sediment-rich sources (i.e., S-type magmas). Thus, there is need for a complementary approach to better identify zircons from these different source rocks. In this work, we use the machine learning technology to distinguish zircon types based on a compiled trace element database of zircons of which the source rocks are well constrained. It is shown that this machine learning method can give a classification accuracy of > 80%, which to our knowledge provides the most accurate method for classifying zircons from different zircon populations. The zircon classifier based on this machine learning method will not only provide a robust tool for mineral exploration, but also can be used, e.g., to distinguish diversity of juvenile versus fertile crustal blocks and microplates, and for study of the composition and origin of Earth's earliest crust (that is implied by detrital zircons in Jack Hills, western Australia).