Plume-orogenic lithosphere-asthenospheric mantle interaction revealed by machine learning

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The Central Asian Orogenic Belt (CAOB) is the largest accretionary orogen in the world, situated adjacent to the Tarim large igneous Province (TLIP) to the southwest, both of which have large-scale Permian magmatism. However, whether the Permian magmatism in CAOB is related to the Tarim mantle plume still remains controversial, mainly because traditional geochemical proxies or tectonomagmatic discrimination diagrams often yield ambiguous or conflicting results.

Considering the potential influence of the mantle metasomatized by subduction-derived fluids, the upwelling asthenospheric mantle, and mantle plume on the Permian magmatic rocks of CAOB, this study utilized an machine learning classification model to predict the affinity of late Carboniferous to early Permian basalts widespread in the CAOB. The model was built based on training with global data on Cenozoic Island Arc Basalts (IAB), Mid-Ocean Ridge Basalts (MORB), and Ocean Island Basalts (OIB) as the three end-members, which represent the role of the mantle metasomatized by subduction-derived fluids, the upwelling asthenospheric mantle, and mantle plume, respectively. The results revealed spatial variations of OIB-affinity from TLIP to CAOB, wherein the TLIP exhibits a higher OIB-affinity (0.80), which decreases abruptly (0.25) at the southern boundary of the CAOB. However, the basalts in some localities within the CAOB have higher OIB-affinity (0.5), potentially attributed to a small portion of mantle plume materials entered the interior of CAOB, resulted from the obstruction of the Tarim plume head by the CAOB boundary and they ascend along some open channel locations. Additionally, the predictive results also identified that the basalts in the southeastern Tianshan region (i.e., the southeastern margin of the CAOB) have the affinities with all three types. This scenario can be ascribed to the interaction between the Tarim plume, the upwelling asthenospheric mantle resultant from slab window and the mantle metasomatized by subduction-derived fluids.

In conclusion, the machine learning method successfully reveals the influence of the Tarim mantle plume on the CAOB, providing a typical case for elucidating the interaction between mantle plumes and orogenic belts.