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Insights into crustal weathering and the formation of (upper) continental crust from tungsten stable isotopes

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Tungsten (W) stable isotopes (expressed as $\delta^{186}W$ values relative to NIST 3163 W standard) have the potential to trace the differentiation of continental crust, as in modern subduction zones W isotopes are on average heavier than bulk silicate earth [1, 2, 3]. To explore the application of W stable isotopes to processes associated with crustal evolution, we report $\delta^{186}W$ values for 24 glacial diamictite composites, deposited between ~2.9 Ga to 0.3 Ga to refine the W stable isotope composition of the upper continental crust (UCC).

The $\delta^{186}W$ values of the diamictites range from 0.016 ± 0.014‰ to 0.182 ± 0.012‰, encompassing the range of previously published values for igneous rocks. We find that $\delta^{186}W$ correlates positively with the diamictite's chemical index of alteration (CIA), suggesting that the continental regolith is characterized by a heavy W isotopic composition. This isotopically heavy W is likely stored in clays, as opposed to the Fe-Mn oxides that dominate heavy W in aqueous environments. Using samples with low CIA (< 60, n = 9), we calculate an average $\delta^{186}W$ of 0.046 ± 0.036‰ for the UCC, from 2.3 to 0.3 Ga [4].

The $\delta^{186}W$ value of the average UCC is much lower than the weighted average $\delta^{186}W$ of intra-oceanic arcs ($\delta^{186}W$ = 0.104 ± 0.052), though the spread in the arc rocks is large. The significant difference in $\delta^{186}W$ between average intra-oceanic island arc lavas and UCC is intriguing given that continental crust is thought to form primarily via arc magmatism. This difference suggests that not all modern intra-oceanic arcs are representative of those that formed the continental crust. Rather, only arcs that are enriched in incompatible trace elements, which also tend to have lighter W isotope compositions, may have been involved in making new continental crust. Alternatively, there may have been a secular change in the W isotope composition of arc magmas that is not reflected in bulk UCC values.

[1] Kurzweil et al. (2019) *GCA* [2] Mazza et al. (2020) *EPSL* [3] Stubbs et al. (2022) *GCA* [4] Mazza et al. (2024) *GCA*