The Earth's Transition from Stagnant Lid to Plate Tectonics: Constraints from Titanium Isotopes

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A major unknown in the Earth's history is when plate tectonics became prevalent. Using the Hekla and Agung volcanoes as case studies, we show that Ti has contrasting isotopic behaviors in plume and island arc settings during magma differentiation. As such, Ti isotopes cannot be used as a direct tracer for the presence of a felsic crust in the past as suggested previously [1], and instead, when combined with SiO_2 content it can serve as a proxy for the geodynamic setting at the origin of crustal rocks. By measuring the Ti stable isotopic compositions of shales, cherts, and banded iron formation, we confirm that the δ^{49}Ti value (the per mil deviation of the ^{49}Ti/^{47}Ti ratio relative to OL-Ti standard) of the continental crust has been ≈ 0.2‰ higher than the typical mantle value since ≈ 3.8 Ga [1-2]. This high δ^{49}Ti value for sediments is close to the weighted average δ^{49}Ti values of both plume and island arc settings, corroborating that the continental crust has been produced under these two tectonic settings. The past composition of the continental crust can be then reconstructed by averaging Ti isotopic compositions of sedimentary rocks in age groups, and using the Rb/Sr ratios of crustal rocks [3] and the ratios of insoluble elements in the terrigenous sediments (e.g., Ni/Co, Cr/Zn and Cr/U) [4-5] as likely SiO_2 proxies. This suggests that the continental crust at ≈ 3.8-3.5 Ga was mainly generated under plume settings, and started to be dominated by island arc rocks after 3.0 Ga. Such a change for the surface rocks points to a transition in the Earth's regime from stagnant lid to plate tectonics during the late Archean.

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