Integrating isotopic signatures and geodynamic numerical models to fingerprint geodynamic settings

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Method

In this study, we introduce a new approach to predict the Hf-isotopic evolutionary pattern for rifting and collisional settings based on the integration of numerical models and $^{176}Hf/^{177}Hf$ isotopes. Two critical factors are considered to estimate the Hf isotopic evolution trends for specific tectonic settings: (1) the source components of magmatism; that is the ratios between juvenile melts and recycled continental crust estimated by geodynamic numerical modeling; (2) the source isotopic compositions; that is the $^{176}Hf/^{177}Hf$ ratio of depleted mantle and continental crust through time which is estimated from a global compilation and radiogenic production calculations. The geodynamic numerical models allow us to estimate the proportion of juvenile mantle-derived material added to the crust through time. On the basis of this proportion we calculate changing $^{176}Hf/^{177}Hf$ ratios using mixing models. We use this modeling approach in the case study region of the Halls Creek Orogen, Western Australia to elucidate its tectonic setting through time.

Results

Predicted Hf isotopic patterns generated through this numerical approach imply that juvenile signals are observed during back-arc extension, whereas evolved signatures dominate collisional settings. The links between predicted Hf isotopic evolution, geodynamic numerical models and measured Hf isotopic evolution trend resolve three discrete stages in the tectonomagmatic development of the Halls Creek Orogen: (1) oceanic crust subduction; (2) back-arc basin formation with additions of juvenile mantle input; and (3) docking of the North Australian and Kimberley cratons resulting in the development of mixed-source magmatism formed in a collisional setting and basin closure. This approach can validate geodynamic models by isotopic datasets, which should lead to more rigorous understanding of crustal evolution.