Geophysical Research Abstracts
Vol. 19, EGU2017-2704, 2017
EGU General Assembly 2017

Earth's first stable continents did not form by subduction

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The geodynamic setting in which Earth's first stable cratonic nuclei formed remains controversial. Most exposed Archaean continental crust comprises rocks of the tonalite–trondhjemite–granodiorite (TTGs) series that were produced from partial melting of low magnesium basaltic source rocks and have 'arc-like' trace element signatures that resemble continental crust produced in modern supra-subduction zone settings. The East Pilbara Terrane, Western Australia, is amongst the oldest fragments of preserved continental crust of Earth. Low magnesium basalts of the Paleoarchaean Coucal Formation, at the base of the Pilbara Supergroup, have trace element compositions consistent with the putative source rocks for TTGs. These basalts may be remnants of the $\geq$35 km-thick pre-3.5 Ga plateau-like basaltic crust that is predicted to have formed if mantle temperatures were much hotter than today.

Using phase equilibria modelling of an average uncontaminated Coucal basalt, we confirm their suitability as TTG source rocks. The results suggest that TTGs formed by $\sim$20–30% melting along high geothermal gradients ($\geq$700 °C/GPa), which accord with apparent geotherms recorded by >95% of Archaean rocks worldwide. Moreover, the trace element composition of the Coucal basalts demonstrates that they were derived from an earlier generation of mafic/ultramafic rocks, and that the arc-like signature in Archaean TTGs was inherited through an ancestral source lineage. The protracted multistage process required for production and stabilisation of Earth's first continents, coupled with the high geothermal gradients, are incompatible with modern-style subduction and favour a stagnant lid regime in the early Archaean.