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Generation of felsic crust in the Archean: a geodynamic modeling perspective

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The relevance of contemporary tectonics to the formation of the Archean terrains is a matter of vigorous debate. Higher mantle temperatures and higher radiogenic heat production in the past would have impacted on the thickness and composition of the oceanic and continental crust. As a consequence of secular cooling, there is generally no modern analog to assist in understanding the tectonic style that may have operated in the Archean. For this reason, well-constrained numerical modeling, based on the fragmentary evidence preserved in the geological record, is the most appropriate tool to evaluate hypotheses of Archean crust formation.

The main lithology of Archean terrains is the sodic tonalite–trondhjemite–granodiorite (TTG) suite. Melting of hydrated basalt at garnet-amphibolite to eclogite facies conditions is considered to be the dominant process for the generation of the Archean TTG crust. Taking into account geochemical signatures of possible mantle contributions to some TTGs, models proposed for the formation of Archean crust include subduction, melting at the bottom of thickened continental crust and fractional crystallization of mantle-derived melts under water-saturated conditions. We evaluated these hypotheses using a 2D coupled petrological–thermomechanical numerical model with initial conditions appropriate to the Eoarchean–Mesoarchean. As a result, we identified three tectonic settings in which intermediate to felsic melts are generated by melting of hydrated primitive basaltic crust: 1) delamination and dripping of the lower primitive basaltic crust into the mantle; 2) local thickening of the primitive basaltic crust; and, 3) small-scale crustal overturns. In addition, we consider remelting of the fractionated products derived from underplated dry basalts as an alternative mechanism for the formation of some Archean granitoids. In the context of a stagnant lid tectonic regime which is intermittently terminated by short-lived subduction, we identified two distinct types of continent crust. The first type is a pristine granite–greenstone-like crust with dome-and-keel geometry formed over delaminating–upwelling mantle which is mostly subjected to vertical tectonics processes. By contrast, the second type is a reworked (accreted) crust comprising strongly deformed granite–greenstone and subduction-related sequences and subjected to both strong horizontal compression and vertical tectonics processes. Thus, our study has identified a possible spatial and temporal transition from the lower-grade granite–greenstone terrains to higher-grade gneiss terrains in the Archean as each tectonic cycle is terminated by short-lived subduction. We suggest that the contemporaneity of the proposed mechanisms for the generation of TTGs explains the variety and complexity of the Archean geological record.