Archaean cratonic mobilism and growth on a subductionless, stagnant lid Earth

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Igneous rocks with geochemical signatures similar to those of Phanerozoic continental or oceanic arcs are rare in the Archaean and proposed Archaean ophiolites, Atlantic-style passive margins, overprinting thrust and fold belts, blueschists, ultra high-pressure rocks, paired metamorphic belts, orogenic andesites, and subduction-zone mélanges that typify Phanerozoic orogens are rare to absent. The archetypal Archaean granite-greenstone dome-and-keel architecture has no modern analogue. Most Archaean lavas have geochemical signatures that imply evolution by assimilation-fractional crystallization, rather than the source-metasomatic signatures of Phanerozoic arcs; and trace element models imply that the felsic contaminants were generated by anatexis of typical Archaean tholeiites. Mass balance calculations imply that melting of subducted crust or fractionation of basalt cannot generate requisite volumes of TTG in the available time, and a basal/delaminated oceanic plateau melting model is preferred.

Despite the absence of evidence for Archaean subduction, many Archaean cratons have shortening fabrics and cratons contain terranes with contrasting histories that were somehow assembled. What could be a plausible driving force for compression and terrane accretion on a subductionless Earth? Cratonic mobilism in response to mantle convection currents offers a possible solution to this paradox. Once a proto-craton develops a stiff mantle keel, it would become subject to pressure from mantle currents and would drift. Immature cratons or oceanic plateaux lack deep keels and so would be static. So, contrary to conventional wisdom, we consider that Archaean cratons are not immobile nucleii along whose margins 'mobile belts' form by subduction-zone accretion. Instead, we propose that Archaean cratons were active tectonic agents, accreting basaltic plateaux, other proto-cratons, and heterogeneous mantle domains as they migrated. Overridden oceanic plateau lithosphere would form subcretion complexes where the underthrust basalt would melt to generate syntectonic pulses of tonalite-trondhjemite-granodiorite (TTG), so contributing to craton growth and stabilisation. Garnet pyroxenite restites from anatexis would founder into the mantle and trigger new pulses of tholeiitic magmatism. The non-cratonic Earth would have been covered by a mosaic of shield volcanoes, with eruption and basal attrition being in a quasi steady-state in a stagnant lid régime, suggesting that mantle convection may have been layered in the Archaean.

The Neoproterozoic Franklin Large Igneous Province, geochemical and isotopic evidence for changing sources, and linkages between intrusive and extrusive components

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The Neoproterozoic (ca.716 Ma) Franklin Large Igneous Province formed during the breakup of Rodinia. The Natkusiak continental flood basalts (≤1 km thick, preserved as 2 lobes in a syncline) are the extrusive phase of the Franklin event, and erupted onto a shallow-water continental platform. An underlying fluvial sandstone, the Kuujjua Fm., pinches out towards the NE, suggesting pre-eruptive thermal doming, possibly associated with arrival of a mantle plume. The lowermost extrusive unit (ca 50-100 m thick) is a primitive basalt (7-11 wt% MgO), and is tentatively interpreted as agglutinate (welded fire fountain deposits) erupted from multiple vents. The unit is characterized by LREE-LILE-enrichment, high L/HREE, high$^{87/86}$Sr$_i$ (up to 0.70791), intermediate εNd (4.0-8.1) and εHf (0.03-6.7), high $^{208/204}$Pb (up to 39.136), high $^{207/204}$Pb (up to 15.686), and high $^{206/204}$Pb (up to18.978) ratios; indicating either an enriched source, extensive crustal contamination, or influx of enriched fluids from the footwall. A hiatus in eruptive activity is marked by deposition of red-weathering volcaniclastic rocks that contain matrix-supported conglomerates (lahars or damburst deposits?) that fill palaeovalleys. Two differentiation cycles of laterally extensive basaltic (10-6% MgO) sheet flows were then deposited above the basal lavas and volcaniclastics. Both cycles show upward shifts in phenocryst populations, decreases in Mg#, Cr and Ni, and increases in incompatible element concentrations, consistent with up-section fractional crystallization. Only cycle 1 sheet flow basalts are exposed in the SW. These have higher εNd (7.7-9.6), lower $^{87/86}$Sr$_i$ (0.70251-0.70605), higher εHf (4.1-9.7), lower $^{208/204}$Pb (36.196-37.623), lower $^{206/204}$Pb (16.147-17. 787), and lower $^{207/204}$Pb (15.383-15.605) than basal basalts. The cycle 1 sheet flow basalts in the NE have trace element and isotopic trends that differ from those in the SW (c.150km separation), indicating regional-scale isotopic heterogeneity in the source and/or contaminants of these lavas. Alternatively, isotopic heterogeneities may have been enhanced during ascent through the crust in a compartmentalized feeder system.

The plumbing system that fed the lavas is dominated by sills, with localized fault-guided dykes. Two magma populations have been identified: Younger diabasic sills with trace element signatures matching the sheet flow lavas, and older sills (based on cross-cutting relationships), commonly with olivine-enriched bases, that match the basal basalts. Field, geochemical and isotopic evidence imply that steep, dyke-like feeders were sites of preferential wall rock assimilation and allowed melt to ascend between sills. On the scale of the entire magmatic system, the secular decrease in incompatible trace element concentrations, L/HREE ratios, and radiogenic isotope signatures could be interpreted as a decrease in the degree of host contamination with time. Changing magma composition could also reflect a shift from a fertile mantle source to a less enriched source, possibly associated with upwelling of asthenospheric mantle during the separation of Siberia from Laurentia.