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The diversity of granitoids in the northern Kaapvaal craton records late-Archæan geodynamic changes

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The late evolution of most archæan cratons, roughly between 3.0 and 2.5 Ga, is marked by the intrusion of voluminous syn- to post-tectonic potassic granitoids that sharply contrast with the typical archæan magmatism dominated by sodic TTGs. To investigate the nature and origin of these changes, we studied the petrogenesis of archæan granitoids in the northernmost Kaapvaal Craton and the Limpopo Belt in South Africa, based on whole-rock geochemistry (majors, traces, Nd isotopes) and LA-ICP-MS dating of zircon grains. Four granitoid types were recognized. They show a very distinctive spatio-temporal evolution:

(1) The first granitoid group emplaced between 3.20 and 2.95 Ga, throughout the northern Kaapvaal Craton. They appear as variously deformed and migmatized trondhjemites and granodiorites with geochemical features typical of the Archaean TTG series (low K2O/Na2O, high Sr/Y and La/Yb).
(2) The TTGs are always associated with small bodies of undeformed biotite-bearing monzogranites, that occasionally form large batholiths (Turfloop) and intruded between 2.84 and 2.78 Ga. On the basis of their chemical signature and regarding their spatial relationship with the TTGs, they likely derive by partial melting of the latter, and possibly metasediments as well.
(3) Subsequently, several granitoid plutons (Mashashane, Moletsi, Matlala, Matok) intruded in the suture zone between the Limpopo Belt and the Kaapvaal Craton, at 2.70–2.67 Ga. They belong to a metaluminous, high-K, calc-alkaline (HKCA) suite. The geochemical features of these granitoids points to a hybrid origin between local Archaean crust and a juvenile end-member derived from an enriched mantle source. The latter is represented by coeval intermediate to mafic rocks, namely diorites sharing compositional similarities with modern arc andesites.
(4) The youngest magmatic event is the emplacement of the Bulai pluton (2.61–2.58 Ga) in the Central Zone of the Limpopo Mobile Belt. It belongs to sanukitoids and consists in a differentiation suite of high-K monzodiorites to granodiorites with relatively high Mg#, Ni–Cr as well as incompatible element contents. The source of these rocks is an enriched, amphibole- and phlogopite-bearing pyroxenite, i.e. mantle peridotite previously hybridized with a hydrous, felsic melt.

In summary, this evolution of granitoid rocks in the northern Kaapvaal Craton shows that relatively simple, TTG juvenile petrogenetic mechanisms during the Archæan gave way to generalized recycling, both as intracrustal differentiation and involvement of a hybrid mantle source, previously enriched by recycled continental material. This spatial association of magmatic products derived from both crust anatexis and enriched mantle melting are typical of modern, late- and post-orogenic settings, and are the hallmark of subduction-collision cycles.
In addition, a comparison of the late-Archæan granitoid evolution in South Africa with the magmatic record from the French Massif Central (Carboniferous to Permian granitoids of the late-Variscan orogenesis) reveals that the time relationships are closely similar: subduction and enrichment of the overlying mantle occur (genesis of TTG during the Archæan), followed by collision and intracrustal melting (biotite-monzogranites) and eventually by thermal relaxation and extension leading to the involvement of the recently enriched mantle (HKCA granitoids and sanukitoids). As a result, the wide variety of sources and petrogenetic process for late-Archæan granitoid associations probably reflects the initiation of subduction-collision geodynamic cycles typical of "modern-style" plate tectonics.
Two different processes may be responsible for these changes: (1) the increase of the continental volume during the Archæan, that reached a threshold after 3.0 Ga so that crust recycling became significant, through both anatexis and erosion-deposition cycles; and (2) the progressive cooling of Earth, leading to the stabilization of larger and stiffer plates compared with archæan tectonics and so that subduction became possible from a thermo-mechanical point of view and allowed recycling of continental material within the mantle.