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Growth of continental crust and its episodic reworking over >800 Ma: evidence from Hf–Nd isotope data on the Pietersburg block (South Africa)

Oscar Laurent (1), Armin Zeh (1), Jean-François Moyen (2), Régis Doucelance (3), and Hervé Martin (3)

(1) J.W. Goethe University, Frankfurt a.M., Institut für Geowissenschaften, Dept. Mineralogy, Frankfurt am Main, Germany (laurent@em.uni-frankfurt.de), (2) Université Jean Monnet, Département de Géologie, Saint-Etienne, France, (3) Clermont Université, Université Blaise Pascal, Laboratoire Magmas et Volcans, Clermont-Ferrand, France

The formation and evolution of the continental crust during the Precambrian, and in particular during the Archaean eon (4.0–2.5 Ga), is still a matter of debate. In particular, it is not yet clear in which tectonic environment the genesis of crust took place and how the large volume of granitoid rocks that form ~70% of the Archaean crust were extracted from the mantle. Many studies highlighted that radiogenic isotope systems, especially Lu–Hf and Sm–Nd, are powerful tools to unravel the respective extent of crustal growth and recycling in Archaean terranes. This work presents coupled Hf and Nd isotope data (analyzed both in situ in accessory minerals and in whole rock samples) of Meso- to Neoarchaean granitoids, applied to unravel the processes of crust formation and evolution of the Pietersburg crustal block in South Africa. This crustal segment, the northermost one of the Archaean Kaapvaal Craton, is separated from older crust (3.65–3.10 Ga) by a large-scale suture zone, and the processes related to amalgamation of both blocks and their subsequent evolution are still unclear.

The Pietersburg block is made up of a wide range of Archaean granitoid rocks, including tonalite–trondhjemite–granodiorite (TTG) series, high-K monzogranites as well as (grano)diorites belonging to the so-called "sanukitoid" group [1], all intruded by late Paleoproterozoic alkaline complexes. Age determinations highlighted two stages of granitoid formation: (1) TTG magmatism took place episodically over >400 Ma between 3.34 and 2.89 Ga, with a major pulse at 2.97–2.90 Ga; while (2) all the other (high-K) granitoid types emplaced subsequently between 2.84 and 2.69 Ga before a long magmatic shutdown until the intrusion of alkaline complexes at ~2.00 Ga [2–3].

Isotope systematics reveal that these two stages are related to juvenile crust formation and crust reworking, respectively. Indeed, all Hf–Nd isotope data from TTG gneisses are suprachondritic, pointing to a juvenile origin and precluding any incorporation of older crust from the core of the Kaapvaal craton. In contrast, all data from the younger granitoids, including ~2 Ga-old alkaline complexes, plot along a single, well-defined trend of decreasing εHf–Nd towards youngest ages. This trend points to model ages around 2.95–3.05 Ga, which is that of the youngest TTGs, indicating that all ≤2.84 Ga-old granitoids formed by episodic reworking, over >800 Ma, of a single crustal reservoir represented by these TTGs. Interestingly enough, this reworking took place "in situ" by both (1) classical intracrustal differentiation (formation of high-K monzogranites) and (2) erosion, sedimentation and recycling of the resulting detrital material in the mantle, producing a hybrid mantle source from which derived the "sanukitoid" magmas and, much later, the alkaline complexes.

All these observations are consistent if the Pietersburg block is regarded as an accretionary, Cordilleran-type orogen, formed along the northern margin of the Kaapvaal block by successive amalgamation of small TTG terranes between 3.34 and 2.90 Ga, as a result of episodic subduction dynamics. This gave rise to (1) a juvenile, accretionary crustal terrane and (2) a (isotopically similar) lithospheric mantle source, hybridized with crustal components derived from it. All the younger granitoids thus reult from significant reworking of these two reservoirs, first during ongoing convergence and continental collision between 2.84 and 2.69 Ga; and second, in response to lithosphere heating (intrusion of the Bushveld Complex?) in a within-plate environment at 2.00 Ga.

[1] Laurent O. et al., submitted to Lithos
[2] Zeh A. et al., 2009. Journal of Petrology 50(5), 933–966
[3] Laurent O. et al., 2013. Precambrian Research 230, 209–226