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High-K calc-alkaline magmatism at the Archaean-Proterozoic boundary: implications for mantle metasomatism and continental crust petrogenesis. Example of the Bulai pluton (Central Limpopo Belt, South Africa)

Oscar Laurent (1,2,3), Hervé Martin (1,2,3), Régis Doucelance (1,2,3), Jean-François Moyen (2,3,4), Jean-Louis Paquette (1,2,3)

(1) Clermont Université, Université Blaise Pascal, Laboratoire Magmas et Volcans, BP 10448, F-63000 Clermont-Ferrand, France, (2) CNRS, UMR 6524, LMV, F-63038 Clermont-Ferrand, France, (3) IRD, R 163, LMV, F-63038 Clermont-Ferrand, France , (4) Université Jean Monnet, Laboratoire Magmas et Volcans, Département de Géologie, 23 rue du Docteur Paul Michelon 42023 Saint-Étienne, France

The Neoarchaean Bulai pluton, intrusive within the supracrustal granulites of the Central Limpopo Belt (Limpopo Province, South Africa) is made up of large volumes of porphyritic granodiorites with subordinate enclaves and dykes which have monzodioritic and charno-enderbitic compositions. New U-Pb LA-ICP-MS dating on separated zircons yielded pluton emplacement ages ranging between 2.60 and 2.63 Ga, which are slightly older than previous proposed ages ($\sim$ 2.57–2.61 Ga).
The whole-rock major- and trace-element composition of the Bulai pluton evidences unequivocal affinities with "high-Ti" late-Archaean sanukitoids. It belongs to a high-K calc-alkaline differentiation suite, with metaluminous affinities ($0.7 < A/CNK < 1$) and relatively high Mg# (0.4–0.6). These rocks have "juvenile" affinities, such as eNd ranging between -0.5 and 0.5, and in addition, are very rich in all incompatible trace elements, which is particularly obvious in monzodioritic enclaves and enderbites where primitive mantle-normalized LILE and LREE contents are up to 300. These characteristics point to an enriched mantle source for the Bulai batholith.
Chondrite normalized, REE patterns are strongly fractionated ([La/Yb]N $\sim$ 25–80), mainly due to high LREE contents (LaN $\sim$ 250–630), and chiefly high HFSE contents (Nb $\sim$ 15-45 ppm ; up to 770 ppm Zr) indicate that the metasomatic agent is a silicic melt rather than a hydrous fluid. Moreover, based on high Nb/Ta, Th/Rb, La/Rb and low Sr/Nd and Ba/La, we suggest that the metasomatic agent is a granitic melt generated by melting of terrigenous sediments. Interactions of this melt with mantle peridotites implies that sediments are located under a mantle slice; geometry which is easily achieved in subduction zone settings. This conclusion is supported by the fact that Bulai trace element patterns are very similar to those of sub-actual potassic magmas generated in magmatic arc environments by interactions between mantle and terrigenous sediments (e.g. Sunda arc).
Geochemical modeling indicates that the mafic facies of the Bulai pluton can be achieved by a two-stage process: 1) a liquid produced by melting of subducted terrigenous sediment is entirely consumed by metasomatic reactions with mantle peridotites, producing a metasomatic amphibole- and phlogopite-bearing assemblage ; 2) Low-degree melting of this metasomatized mantle gives rise to magmas with the same trace element signature than the Bulai mafics. Such a petrogenetic model is consistent with previous geochemical and experimental study about sanukitoids, which concluded that these magmas result of interactions between slab melts and the overlying mantle wedge. Subsequently, at crustal levels, the Bulai monzodiorite not only underwent significant fractional crystallization, but also induce melting of the host rocks, and mixed with the resulting felsic crustal magmas. Such that it can be concluded that the whole Bulai suite can be derived through AFC processes.
Our geochemical study failed in demonstrating any significant role played by melting of subducted metabasalts, which contrasts to Archaean times, and would point to lower thermal regimes as the wet solidus of metasediments is $\sim$ 50 to 100°C lower than that of metabasalts at slab pressures. In addition the fact that the whole felsic melts were consumed by reaction with peridotite is indicative of lower degrees of melting of the slab compared with Archaean processes. Both conclusions imply that the geodynamic changes that took place at the Archaean-Proterozoic transition and witnessed by sanukitoid-related rocks are the result of progressive and global cooling of Earth.