Lithos 196–197 (2014) 131–149

Contents lists available at ScienceDirect

Lithos

journal homepage: www.elsevier.com/locate/lithos

Contrasting petrogenesis of Mg–K and Fe–K granitoids and implications for post-collisional magmatism: Case study from the Late-Archean Matok pluton (Pietersburg block, South Africa)

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A R T I C L E I N F O

Article history:
Received 30 October 2013
Accepted 3 March 2014
Available online 11 March 2014

Keywords:
Fe–K granitoids
Post-collisional magmatism
Sanukitoids
Lithosphere reworking
Kaapvaal Craton
Matok pluton

A B S T R A C T

This study investigates the origin of the 2.69 Ga-old Matok pluton, emplaced in the Pietersburg block, northern Kaapvaal Craton (South Africa), forthwith after a major tectono-metamorphic event ascribed to continent–continent collision. The Matok pluton consists of diorites, granodiorites and monzogranites. Petrography and whole-rock major- and trace element compositions of the Matok samples are similar to those of post-collisional Fe–K suites, which are very common in Proterozoic terranes. These granitoids are particularly rich in FeO_t, TiO_2, P_2O_5, span a wide range of SiO_2 contents and display elevated concentrations in K_2O, Ba, HFSE and REE, with moderately fractionated REE patterns.

All samples of the Matok pluton have unradionegic Nd isotopic compositions ($\varepsilon_{Nd(2.69\ Ga)} = -2.7$ to -4.6), but only a few monzogranite samples derive from reworking of older crust. Crustal contamination of basaltic melt cannot explain either the observed compositions. Most of the suite rather fractionated from a common mafic parent, either by partial melting or crystallization. Geochemical modeling shows that this parent magma or source rock is basaltic in composition, intermediate between calc-alkaline and tholeiitic groups, and enriched in incompatible trace elements with respect to the primitive mantle. It ultimately derives from the involvement of two distinct mantle sources: (1) enriched, sub-continental lithospheric mantle, which was metasomatized by sedimentary material derived from local crust of the Pietersburg block, <0.3 Ga before the pluton emplacement; and (2) asthenospheric mantle.

This model accounts for the differences between Fe–K suites, such as the Matok pluton, and Mg–K suites, such as sanukitoids, the origin of which only requires metasomatized mantle. We propose that the most appropriate geodynamic setting for the interaction between enriched lithospheric and asthenospheric mantle sources is an episode of "lithospheric reworking" (through slab breakoff, retreat or sub-continental mantle delamination) in response to continental collision. Depending on the relative contribution of the two mantle sources in this environment, the resulting magmas can show a wide range of compositions from Fe–K to Mg–K end-members. From a regional point of view, this conclusion supports that the Kaapvaal Craton and the Central Zone of the Limpopo Belt were amalgamated between 2.80 and 2.75 Ga owing to continent–continent collision.

1. Introduction

Continent–continent collision is soon followed (<0.1 Ga) by the emplacement of large volumes of granitoids, referred to as "post-collisional" (e.g. Bonin, 2004; Liégeois et al., 1998), which possibly represents up to 40% of the global granitoid record (Roberts and Clemens, 1993). Several previous reviews pointed out that these magmas are peraluminous to metaluminous, high-K calc-alkaline granitoids, the petrogenesis of the metaluminous ones involving both mantle and crustal components (Barbarin, 1999; Bonin, 2004; Clemens et al., 2009; Kemp and Hawkesworth, 2003; Liégeois et al., 1998). These magmas are (1) common since late-Archean times, as the 3.0- to 2.5 Ga-old sanukitoid suites belong to this group

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http://dx.doi.org/10.1016/j.lithos.2014.03.006
0024-4937/

(Fowler and Rollinson, 2012; Halla et al., 2009; Martin et al., 2009), and (2) possibly represent a significant juvenile addition to the continental crust (Clemens et al., 2009; Laurent et al., 2013b). Therefore, the study of post-collisional granitoids is of primary importance to unravel the nature and tectonic setting of crustal growth processes for the past 3.0 Ga.

Several studies have highlighted the fact that post-collisional granitoids are compositionally diverse and can be separated into two distinct groups, namely "magnesio-potassic" (Mg–K) and "ferro-potassic" (Fe–K). This is the case for both late-Archean granitoids, such as those of the Karelian part of the Baltic shield where Mg-rich sanukitoid suites coexist with Fe-rich counterparts (Mikkola et al., 2011), and Phanerozoic examples, such as the coexisting Fe- and Mg-rich suites in the crystalline massifs of Western Alps (Bonin, 2004; Debon and Lemmet, 1999). Both Mg- and Fe-rich groups are alkali-calcic to calc-alkaline and metaluminous in composition; they differ on the basis of their FeO_t/MgO ratio, Al_2O_3, K_2O and some trace element contents. The petrogenesis of Mg–K suites is fairly well understood: for example, sanukitoids are believed to be derived from the interaction, at mantle levels, between peridotite and a component rich in incompatible elements, either a fluid or melt derived from metabasalts or metasediments (e.g. Fowler and Rollinson, 2012; Halla, 2005; Halla et al., 2009; Heilimo et al., 2010; Laurent et al., 2011; Lobach-Zhuchenko et al., 2008; Martin et al., 2009; Moyen et al., 2003; Rapp et al., 2010).

In contrast, Fe–K magmatic associations are faintly defined and their petrogenesis is still a matter of debate. Although they have been reported from late-Archean to Phanerozoic domains, they are particularly abundant in Proterozoic terranes, in particular in the Sveconorwegian area (Bogaerts et al., 2003, 2006; Demaiffe et al., 1990; Vander Auwera et al., 2003, 2007, 2011) and Western Africa (Ferré et al., 1998; Kouankap Nono et al., 2010; Tagne-Kamga, 2003) where they were extensively studied. Despite this considerable interest, there is no consensus on their origin, which is ascribed to melting of either juvenile lower crust (e.g. Duchesne et al., 2010; Skridlaite et al., 2003), old felsic crustal lithologies (e.g. Tagne-Kamga, 2003) or metasomatized mantle (e.g. Ferré et al., 1998). In addition, there is no existing model able to simultaneously explain (1) the similar post-collisional nature of both Fe–K and Mg–K suites; (2) their close temporal and spatial association in some terranes; and (3) their petrographic and geochemical differences.

Here we present a study of the Matok pluton, which is a 2.69 Ga-old magmatic complex intrusive in the Pietersburg block at the northern margin of the Kaapvaal Craton in South Africa. Whole-rock geochemistry (major-, trace elements and Sm–Nd isotopes) highlights the affinity of Matok pluton with other Fe–K suites worldwide. The aim of this article is to (1) unravel the petrogenesis of the Matok pluton and (2) compare it to that of sanukitoids, in order to propose a geodynamic model that concurrently accounts for (1) the differences between Mg–K and Fe–K suites and (2) their common post-collisional nature.

2. Geological setting

The Pietersburg block is the northernmost terrane of the Archean Kaapvaal Craton of southern Africa. It lies between the Witwatersrand block to the South and the Central Zone of the Limpopo Belt to the North (Fig. 1), from which it is separated by the Thabazimbi–Murchison Lineament and the Palala–Zoetfontein and Tshiphise Shear Zones, respectively (de Wit et al., 1992; Eglington and Armstrong, 2004; Zeh et al., 2009). Lithologies at the level of exposure can be separated into four different groups (Fig. 2a):

(1) the Goudplaats–Hout River and Groot Letaba–Duiwelskloof gneiss units are made up of trondhjemitic to granodioritic orthogneisses (TTG), as well as subordinate granites, amphibolites and pegmatites (Laurent et al., 2013b; Robb et al., 2006; Zeh et al., 2009). Magmatic precursors of the TTG gneisses emplaced during several discrete episodes at ~3.34, ~3.21, ~3.19, ~2.95 and ~2.84 Ga (e.g. Kröner et al., 2000; Laurent et al., 2013b; Zeh et al., 2009).

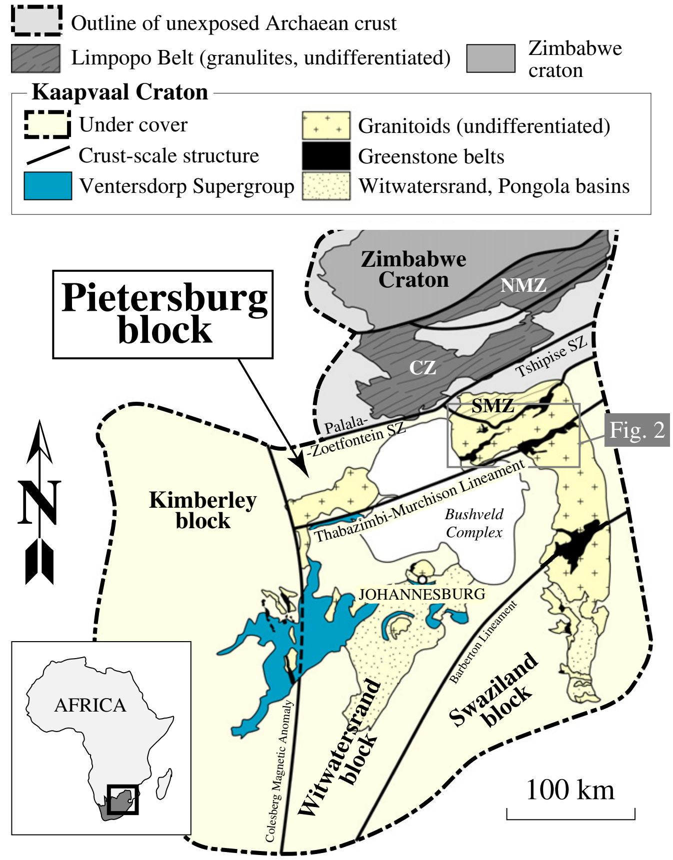

Fig. 1. Sketch of geological map (after Eglington and Armstrong, 2004) detailing the different structural domains of the Kaapvaal craton. The position of the Pietersburg block and the Ventersdorp supergroup are highlighted. The gray rectangle represents the study area. NMZ, CZ and SMZ refer to the three structural domains of the Limpopo Belt, i.e. Northern Marginal Zone, Central Zone and Southern Marginal Zone, respectively.

(2) the Giyani, Murchison, Pietersburg and Rhenosterkoppies greenstone belts consist of greenschist- to lower amphibolite-facies, ultramafic to felsic lavas and metasedimentary rocks (Brandl et al., 2006). U–Pb dating on felsic volcanic rocks provided ages in the range 3.1–2.8 Ga (Brandl et al., 1996; Kröner et al., 2000; Poujol et al., 1996).

(3) granulites of the Southern Marginal Zone (SMZ; Fig. 1, 2a), which crop out to the North of the Hout River Shear Zone, are made up of two lithologies: the Baviaanskloof and Bandelierkop complexes. They are interpreted to represent the high-grade counterparts of the gneiss units and greenstone belts mentioned above, respectively (Kramers et al., 2006; Kreissig et al., 2000; Zeh et al., 2009).

(4) Post-tectonic, high-K calc-alkaline granitoids of the Turfloop, Mashashane, Matlala, Matok and Moletsi plutons intruded all other lithologies (Robb et al., 2006). The age of the Turfloop batholith is ~2.78 Ga (Henderson et al., 2000; Kröner et al., 2000; Laurent et al., 2013b; Zeh et al., 2009) while other plutons, including the Matok one, emplaced at ~2.69 Ga (Laurent et al., 2013b; Zeh et al., 2009).

Age and isotopic constraints point to crust formation in the Pietersburg block between 3.3 and 2.9 Ga (Kreissig et al., 2000; Zeh et al., 2009, 2013). Several authors proposed that the >3.0 Ga-old