Geoscience Frontiers 5 (2014) 801–820

Contents lists available at ScienceDirect

China University of Geosciences (Beijing)

Geoscience Frontiers

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

Research paper

Grain to outcrop-scale frozen moments of dynamic magma mixing in the syenite magma chamber, Yelagiri Alkaline Complex, South India

M.L. Renjith [a,b,*], S.N. Charan [b], D.V. Subbarao [b], E.V.S.S.K. Babu [b], V.B. Rajashekhar [c]

[a] Marine and Coastal Survey Division, Geological Survey of India, Cochin 682037, India
[b] Geochemistry Division, CSIR-National Geophysical Research Institute, Hyderabad 500007, India
[c] New Zealand Petroleum and Minerals, Wellington 6037, New Zealand

ARTICLE INFO

Article history:
Received 13 March 2013
Received in revised form
17 July 2013
Accepted 16 August 2013
Available online 17 September 2013

Keywords:
Magma mixing
Disequilibrium textures
Petrology
Synplutonic dykes
Geodynamics

ABSTRACT

Magma mixing process is unusual in the petrogenesis of felsic rocks associated with alkaline complex worldwide. Here we present a rare example of magma mixing in syenite from the Yelagiri Alkaline Complex, South India. Yelagiri syenite is a reversely zoned massif with shoshonitic ($Na_2O + K_2O$=5–10 wt.%, $Na_2O/K_2O = 0.5–2$, $TiO_2 <0.7$ wt.%) and metaluminous character. Systematic modal variation of plagioclase (An_{11-16} Ab_{82-88}), K-feldspar (Or_{27-95} Ab_{5-61}), diopside ($En_{34-40}Fs_{11-18}Wo_{46-49}$), biotite, and Ca-amphibole (edenite) build up three syenite facies within it and imply the role of *in-situ* fractional crystallization (FC). Evidences such as (1) disequilibrium micro-textures in feldspars, (2) microgranular mafic enclaves (MME) and (3) synplutonic dykes signify mixing of shoshonitic mafic magma (MgO = 4–5 wt.%, SiO_2 = 54–59 wt.%, K_2O/Na_2O = 0.4–0.9) with syenite. Molecular-scale mixing of mafic magma resulted disequilibrium growth of feldspars in syenite. Physical entity of mafic magma preserved as MME due to high thermal-rheological contrast with syenite magma show various hybridization through chemical exchange, mechanical dilution enhanced by chaotic advection and phenocryst migration. In synplutonic dykes, disaggregation and mixing of mafic magma was confined within the conduit of injection. Major-oxides mass balance test quantified that approximately 0.6 portions of mafic magma had interacted with most evolved syenite magma and generated most hybridized MME and dyke samples. It is unique that all the rock types (syenite, MME and synplutonic dykes) share similar shoshonitic and metaluminous character; mineral chemistry, REE content, coherent geochemical variation in Harker diagram suggest that mixing of magma between similar composition. Outcrop-scale features of crystal accumulation and flow fabrics also significant along with MME and synplutonic dykes in syenite suggesting that Yelagiri syenite magma chamber had evolved through multiple physical processes like convection, shear flow, crystal accumulation and magma mixing.

1. Introduction

Magma mixing can happen at any stage in the life span of a magmatic system (Perugini and Poli, 2012). However, in space and time the efficiency of mixing between two magmas is controlled by physical parameters (temperature, viscosity, rheology etc.) (Sparks and Marshall, 1986; Fernandez and Barbarin, 1991; Poli et al., 1996), composition and the chaotic dynamics involved (Perugini et al., 2002, 2003a,c, 2006, 2008, 2012; De Campos et al., 2004, 2011; Perugini and Poli, 2004, 2012). Depending on these factors degree of homogenization between the interacting magmas varies; particularly in plutonic rocks, such evidences are well preserved in the form of micro-textures (Grogan and Reavy, 2002; Perugini et al., 2003c; Slaby et al., 2008), hybrid magma (Poli et al., 1996), micro-granular mafic enclaves (MME) (Vernon, 1984; Perugini et al.,

* Corresponding author. Present address: Marine and Coastal Survey Division, Geological Survey of India, Cochin 682037, India. Tel.: +91 (0) 484 2428937; fax: +91 (0) 484 2428940.
E-mail address: renjithml@rediffmail.com (M.L. Renjith).

Peer-review under responsibility of China University of Geosciences (Beijing)

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http://dx.doi.org/10.1016/j.gsf.2013.08.006

2003b; Perugini and Poli, 2012), flow structures (Perugini and Poli, 2012) and synplutonic dykes (Collins et al., 2000).

Magma mixing is very common in calc-alkaline granitoids (e.g., Kumar and Rino, 2006) whereas such process is very unusual in the petrogenesis of syenite or other Si-saturated to undersaturated felsic rocks associated with alkaline complexes from various tectonic settings. The unusual process of magma mixing-mingling in the petrogenesis of syenite analogous to mafic-felsic magma interactions in granitoids is reported here and various physical process involved in the syenite magma chamber during magma mixing is discussed.

2. Geological setting

Southern Indian shield (Fig. 1a) constituted of an Archaean granite-greenstone terrain (Dharwar Craton) in the north and a Paleoproterozoic granulite facies terrain in the south (Southern Granulite Terrain, SGT) (Santosh et al., 2003, 2009 and the references therein). The SGT is dissected by numerous crustal scale shear/fault zones (Fig. 1a) which host a number of A-type granite, syenite, ultramafic and carbonatite complexes dated between 850 and 450 Ma (see review by Veevers, 2007). The studied Yelagiri Alkaline Complex (757 ± 32 Ma; Miyazaki et al., 2000) is a one among them occurring in the northeastern part of the SGT. This circular intrusive body, crops out over an area of 20 × 12 km^2 (Fig. 1b) and emplaced into the 2.55–2.53 Ga old late Archaean epidote-hornblende basement gneisses (Peucat et al., 1993), along the NE–SW trending fault system and high strain zone (Grady, 1971; Braun and Kriegsman, 2003). It composed of syenite, pyroxenite and dunite rock units as ordered by their decreasing areal extent (Fig. 1b). The pyroxenite body engulfs the dunite body show sharp intrusive contact with syenite suggest that latter is youngest intrusive phase (Fig. 1b) (Renjith, 2010). The present study is focused on the syenite units, the pyroxenite-dunite units are not considered in the following discussion.

3. Syenite massif

3.1. Syenite facies

Pegmatoidal to medium grained syenites form a dome shaped massive hilly outcrop of ~828 m height from ground level and found in grey, pink and leucocratic varieties distributed concentrically as demarcated in map pattern (Fig. 1b). Each syenite variety has distinct simple mineral assemblages and modal proportions; accordingly, three litho facies are recognized: inner facies grey syenite contain orthoclase (62–86%), cpx (6–15%), biotite (0.5–7%), plagioclase (0–5%) and opaque (1–4%) wherein middle facies pink syenite composed of orthoclase (61–76%), plagioclase (3–31%), cpx (1–16%) and amphibole (3–11%) and finally in outer facies leucocratic syenite, amphibole (7–11%) is the dominant mafic phase along with orthoclase (43–57%) and plagioclase (18–32%). Biotite is absent. Cpx is accessory amount (0–1%). Quartz (10–12%) bearing syenite occurring at the NE margin implying that syenite is a reversely zoned massif (Fig. 1b) (Renjith, 2010). From inner to outer facies certain petrographic characters are recognized: (i) K-feldspar/plagioclase ratio decreases; (ii) biotite and amphibole contents decrease and increase respectively; (iii) quartz is present only at the NE margin of the syenite body; (iv) titanite is always

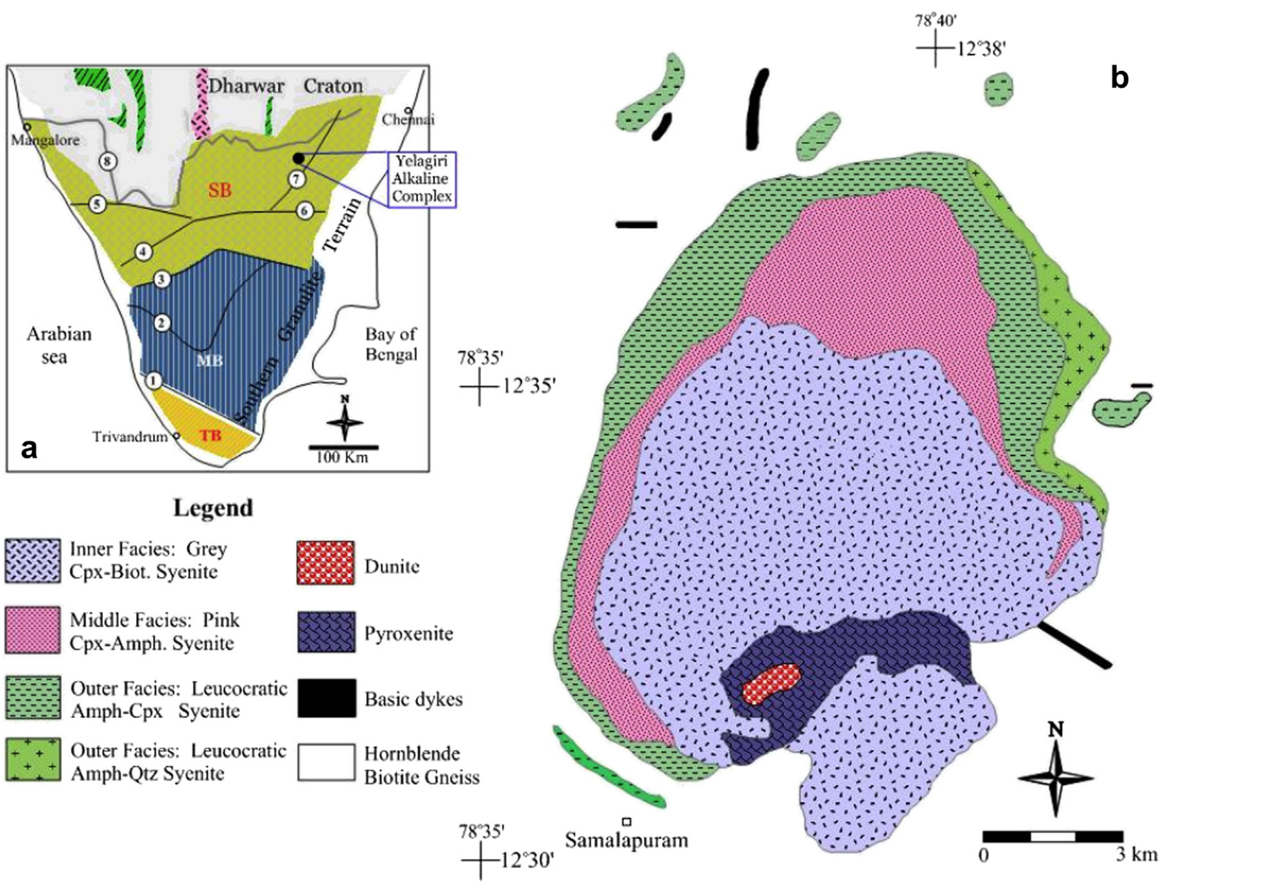

Figure 1. (a) Map of South India showing major tectonic blocks and shear zones (from Braun and Kriegsman, 2003). SB: Salem block; MB: Madurai block; TB: Trivandrum block. Major shear zones are numbered as '1' to '7' and a transition zone as '8'. (b) Geological map of the Yelagiri Alkaline Complex (Mapped by S. Signanenjam, Geological Survey of India, During Field Session: 1988–1990). Syenite litho facies are demarcated based on the present study.