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Research paper

Micro-textures in plagioclase from 1994–1995 eruption, Barren Island Volcano: Evidence of dynamic magma plumbing system in the Andaman subduction zone

M.L. Renjith*

Marine and Coastal Survey Division, Geological Survey of India, 4th Floor, C-Block, Kendriya Bhavan, Kakkanadu, Cochin, Kerala 682037, India

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ABSTRACT

A systematic account of micro-textures and a few compositional profiles of plagioclase from high-alumina basaltic aa lava erupted during the year 1994–1995, from Barren Island Volcano, NE India ocean, are presented for the first time. The identified micro-textures can be grouped into two categories: (i) *Growth related textures* in the form of coarse/fine-sieve morphology, fine-scale oscillatory zoning and resorption surfaces resulted when the equilibrium at the crystal-melt interface was fluctuated due to change in temperature or H_2O or pressure or composition of the crystallizing melt; and (ii) *morphological texture*, like glomerocryst, synneusis, swallow-tailed crystal, microlite and broken crystals, formed by the influence of dynamic behavior of the crystallizing magma (convection, turbulence, degassing, etc.). Each micro-texture has developed in a specific magmatic environment, accordingly, a first order magma plumbing model and crystallization dynamics are envisaged for the studied lava unit. Magma generated has undergone extensive fractional crystallization of An-rich plagioclase in stable magmatic environment at a deeper depth. Subsequently they ascend to a shallow chamber where the newly brought crystals and pre-existing crystals have undergone dynamic crystallization via dissolution-regrowth processes in a convective self-mixing environment. Such repeated recharge-recycling processes have produced various populations of plagioclase with different micro-textural stratigraphy in the studied lava unit. Intermittent degassing and eruption related decompression have also played a major role in the final stage of crystallization dynamics.

1. Introduction

In an open-system volcanic process, the erupted magmatic products contain mixed crystal populations of xenocryst, antecryst, phenocryst and microlite (Jerram and Martin, 2008). A mineral phase, in any of such forms, highly sensitive to the modifications in the volcanic system, and able to record the changes in thermodynamic equilibria in their textural and compositional zoning patterns, depending on the process they underwent, will be a power full tool in understanding the magma process. Specifically, several studies have concluded that texture and chemical zoning in plagioclase, in particular, may be an efficient tool for confining the dynamics and kinetics of magmatic process, due to its high sensitivity to changes in physical-chemical conditions (T, P, $P(H_2O)$, $f(O_2)$, melt composition) of the system (Stamatelopoulou-seymour et al., 1990; Blundy and Shimizu, 1991; Stimac and Pearce, 1992; Singer et al., 1995; Tepley et al., 1999, 2000; Ginibre et al., 2002a,b; Humphreys et al., 2006; Ginibre and Wörner, 2007; Smith et al., 2009; Viccaro et al., 2010, 2012).

High-alumina basalt (HAB) erupted in the form of aa lava from the Barren Island Volcano (BIV), NE Indian Ocean, during the year 1994–1995, constituted of various physical mixtures and genetically related phenocrysts and xenocrysts (2–5 mm size) of Ca-rich plagioclase, Mg-rich olivine and clinopyroxene (Luhr and Haldar, 2006). According to them these phenocrysts and xenocryst have been entered the magma through contamination of troctolitic crystal mushes or plutonic xenoliths at depth. This argument is

* Tel.: +91 484 2428937; fax: +91 484 2428940.
E-mail address: renjithml@rediffmail.com.

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supported by the elevated Ca-rich plagioclase phenocryst percentage, high Eu anomaly (>1), Sr (209–227 ppm) and Al_2O_3 (21–23 wt.%) contents when compared to older lavas and imply the vital role of plagioclase in the petrogenesis of HAB. However, the mechanism of plagioclase addition has not been well understood yet and, of course, it is a difficult task in separately identifying the foreign derived xenocrysts from co-genetic phenocrysts of a single lava unit. This paper presents various micro-textures in plagioclase from this lava unit and based on that various plagioclase populations, their growth history and dynamic plumbing system operated during this aa lava eruption are envisaged qualitatively.

2. Background information

Barren Island Volcano, the only active subduction-related volcano in the Andaman Sea, NE Indian Ocean (12.29°N, 93.85°E) is a circular shaped island covering an area of ~10 km^2 with ~3 km diameter, and its cinder cone rises 355 m above the sea level (Fig. 1a,b). BIV falls within the northern extension of Sumatra volcanic chain formed by northeastward oblique subduction of Indo-Australian oceanic plate beneath the Southeast Asian plate (Fig. 1a). This active volcano erupted in three major cyclic stages leaving a small quiescent period in between (Luhr and Haldar, 2006; Sheth et al., 2009; Pal et al., 2010 and the references therein). First cycle: predate the year 1787 (pre-historic lava) and has no age record yet; second cycle: between the year 1787 and 1832; and the third cycle: from 1991 to 2009 consists of four stages of eruption, during the year 1991, 1994–1995, 2005–2006 and 2008–2009. Though, in gist, the erupted products are in the form of aa and blocky aa lava flows along with volcanoclastic deposits including tephra fallout, lahars and surge deposits (Sheth et al., 2009).

3. Analytical technique

A total of 106 samples were randomly collected from aa lava flow unit of 1994–1995 eruption during the field visit to Barren Island, Andaman sea, way back in December 2004 (Fig. 1b). About 146 thin sections were made and petrographic observations with special emphasize on micro-textures in plagioclase were carried under polarizing microscope. The identified micro-textures are presented as microphotographs (Figs. 2–9) as well as schematic diagrams (Table 1) for a better visual understanding. Four plagioclase grains displaying maximum micro-textural diversity were selected for determining the compositional profile by micro-probe analysis and the data obtained are presented in Table 2. Plagioclase phenocryst was analyzed along the core-rim transect with steps of ~5–10 μm. Electron Probe Micro Analysis (EPMA) carried out with a CAMECA SX100 (Central Petrological Laboratory, Geological Survey of India, Kolkata) operated at 15 kV, 12 nA using natural mineral standards and results were corrected with a PAP matrix correction program. The standards were analyzed at regular intervals to check the precision of sample analysis. Fe^{2+} and Fe^{3+} were distributed based on stoichiometry.

4. Present study

Present study is confined to the lava unit erupted during 1994–1995 (Fig. 1b). They are black coloured massive looking blocky aa lava with rugged surface. They erupted in different pulses in strombolian style and have high-alumina basaltic composition (SiO_2: 51–52 wt.%) with unusual An-rich plagioclase, cpx and olivine phenocryst and xenocrysts (Luhr and Haldar, 2006). Morphologically they show remarkable similarities with viscous tooth paste lavas reported from Hawaii, Paricutin and Etna volcanic fields (Sheth et al., 2011). Hand specimen shows salt and pepper appearance due to the presence of whitish-grey plagioclase phenocrysts in a fine-size to glassy black matrix. Under microscope all samples show porphyritic texture developed by the unusually large euhedral plagioclase (>97%), euhedral olivine (2–3%) and cpx (0–4%) set in a background mass consisting of glass and microlites of same phenocryst phases. Plagioclase, the dominant modal phase in all samples, found in three sizes such as small (<1 mm), medium (1–3 mm) and large (3–5 mm) crystals. Proportion of these size-groups varies from sample to sample. Medium and large-size crystals often display various micro-textures. Percentage of plagioclase with micro-textures varies sample to sample, though some sections have hardly any. Detailed descriptions of micro-textures are as follows.

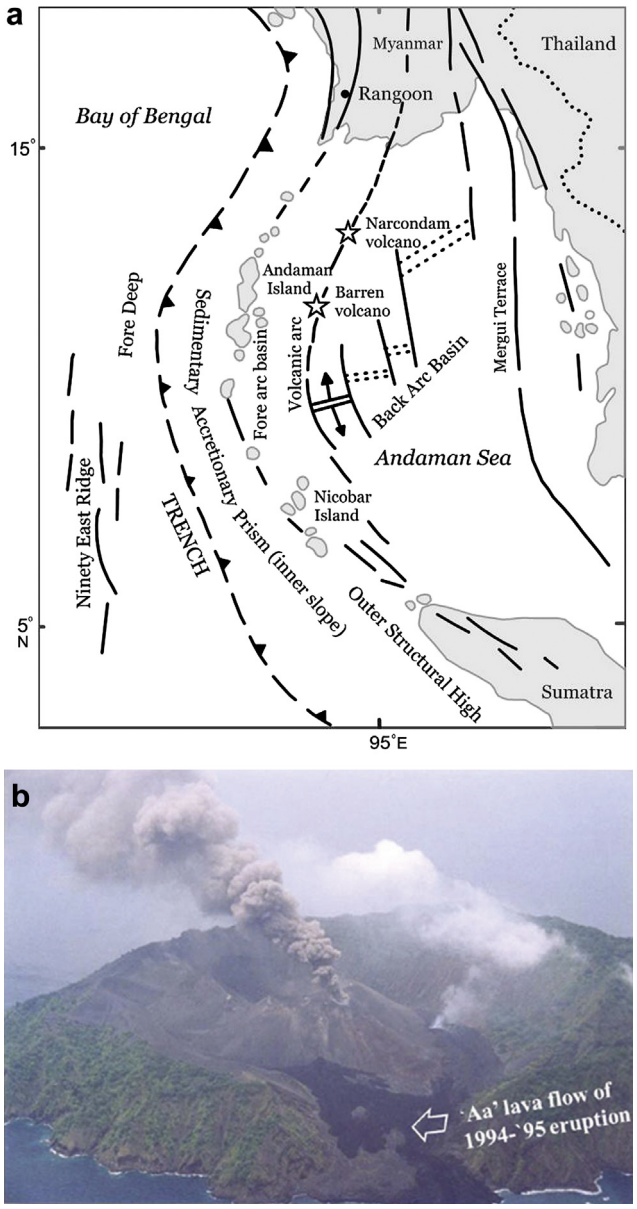

Figure 1. (a) Map showing location of Barren Island Volcano and major tectonic elements in the Andaman Sea, NE Indian Ocean; (b) aerial photo of Barren Island Volcano (panoramic view from west towards east) captured in the year 2002 (photo courtesy: Indian Navy) shows the studied aa lava flow unit of the 1994–1995 eruption (dark patches).