XII Congreso Geológico Chileno
Santiago, 22-26 Noviembre, 2009

**S8_002**

# Barren Island (Andaman Sea, NE Indian Ocean) Volcanics: An important reference for the Indonesian Volcanic Arc

Alam, M.A.[1], Chandrasekharam, D.[2], Vaselli, O.[3], Capaccioni, B.[4], Manetti, P.[3], Santo, A.P.[3], Tassi, F.[3]

(1) Departamento de Geología, Universidad de Chile, Plaza Ercilla 803, Santiago, Chile
(2) Department of Earth Sciences, Indian Institute of Technology Bombay, Powai, 400076 Mumbai, India
(3) Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Via La Pira 4, 50121 Firenze, Italy
(4) Dipartimento di Scienze della Terra e Geologico-Ambientali, Università di Bologna, Piazza di Porta San Donato 1, 40126 Bologna, Italy

ayaz@ing.uchile.cl

## Introduction

Barren Island (12.29°N, 93.85°E, 10 sq km) is a small volcanic island located 135 km north-east of Port Blair (administrative capital of the Andaman and Nicobar Islands, a Union Territory of India) in the Andaman Sea, NE Indian Ocean (Fig. 1). Barren Island (hereafter BI) volcano is the only active volcano on the Indian Territory. Along with the dormant volcano of Narcondam and a few volcanic sea mounts (e.g., Alcock, Sewell) in the Andaman Sea, BI is a part of the chain of volcanoes commonly referred as Indonesian Volcanic Arc (hereafter IVA) that extends from the dormant volcanoes of Myanmar to the active volcanoes of Sumatra and Java in Indonesia. Location of BI is quite unique, as it is located in a region where collision (without subduction) and subduction are concurrent, because of oblique convergence of Indian and Burmese plates [1].

BI is almost circular with a diameter of ~3 km and represents the uppermost part (~0.3-0.4% of the total volume) of a submarine volcano rising more than 2 km above the sea floor. Unfortunately, no information is available about the rocks that constitute its submarine mass (~99.5% of the total volume), in the absence of drilling or dredging studies. So, whatever information is available about BI is based on the exposed part that forms the island. The island has an almost circular caldera of ~2 km diameter. All the historical and recent eruptions are confined within and around an active polygenetic cinder cone within the caldera, which is formed by the collapse of the primitive cone probably through subsidence, as there is no evidence of any explosive eruption causing its formation through blowing off of the primitive cone. Detailed geological description and map, along with volcanological history, has been reported elsewhere [2, 3].

Barren Island Volcanics

BI volcanics can be classified in two broader groups: (i) Pre-caldera, comprising the volcanics of unknown age (referred as Prehistoric) that constitute the caldera wall and (ii) Post-caldera, comprising the rocks that are confined within the caldera and are known to have erupted during historic times and recently. However, a third group Syn-caldera has also been reported constituting ~50 m thick monotonous sequence of breccia and tuff representing syn-caldera phreatic and hydromagmatic activities [4].

Narrow compositional range (from low-K basalts to basaltic andesites) and single tholeiitic trend in the $K_2O$ vs. $SiO_2$ diagram and the common petrochemical characteristics of the BI volcanics suggest a comagmatic origin. The general trends in the variation of major oxides and trace elements indicate major role of crystal–liquid fractionation process in determining the petrologic and geochemical characteristics.

Petrogenesis

For the petrogenetic evolution of the BI rocks, the role of heterogeneous magma source is indicated from (a) the presence of large phenocrysts of xenocrystic origin, (b) the variation in the ratios between incompatible trace elements in the basaltic rocks (c) the small but significant variations of the Sr isotopic ratios and (d) the relationships between the $^{87}Sr/^{86}Sr$ ratios and trace elements. The formation of the caldera represents an important episode in the history of BI, and the pre-and post-caldera volcanics reflect a modification of the magmatic plumbing system. Pre-caldera rocks show a generally less evolved composition (high Mg# and Ni and Cr contents), a distinct scattering behavior of major and trace elements and certain variation in terms of Sr and Nd isotopic ratios. On the contrary, post-caldera rocks have a more homogeneous composition with relatively constant $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ isotopic ratios that correspond to the highest and lowest values respectively, measured during this study.

Although most of the BI volcanics are low-K tholeiites, the pre-caldera volcanics display the lowest degree of evolution. In the Sunda Arc (a part of the Indonesian Volcanic Arc), the tholeiitic rocks at Galunggung are considered of near-primitive (MgO= 10.6–12.5%), representing the best estimated composition of unmodified mantle melt entering the crust [5]. The trace element pattern corresponding to the mean Galunggung tholeiitic basalts (Fig. 2) shows higher abundances of the most incompatible trace elements, except Ba, and almost similar or lower abundances of Nd to Yb elements when compared to one sample from BI. Most of BI pre-caldera rocks have low $^{87}Sr/^{86}Sr$ and high $^{143}Nd/^{144}Nd$, low Pb isotope values and low Th/Ce and U/Th ratios, which imply little or no contribution from fluids and/or sediments in the source. The most primitive BI volcanics composition (Mg# = 71, Ni = 218 ppm, Cr = 557 ppm), with the lowest Th (0.39 ppm) content in the arc, is an important reference composition in the IVA study.

The post-caldera rocks display almost constant and relatively high $^{87}Sr/^{86}Sr$ isotopic ratios (clustering around 0.7040), similar to the highest values found in the pre-caldera rocks. Some petrologic and geochemical characteristics observed among the post-caldera rocks suggest that fractional crystallization process was able to modify the magma composition from basaltic to basaltic andesitic. In principle, this evolutionary process can be quantitatively tested for major and trace elements using different starting magma compositions, both pre-caldera and post-caldera basaltic rocks displaying similar Sr isotopic ratio. However, the BI basaltic rocks are characterized by the ubiquitous presence of anorthite-rich (An > 90%) large plagioclase phenocrysts and, less frequently, large phenocrysts of olivine and clinopyroxene. The composition of the Ca-rich plagioclase is in disequilibrium with the whole rock composition. Presence of similar Ca-rich plagioclase in all BI rocks irrespective of the silica content, suggests the xenocrystic origin of the Ca-rich plagioclase. On the contrary, olivine and clinopyroxene crystals, independently by their size, show a composition that could be in equilibrium with the host rock. In order to perform quantitative modeling, the starting magma composition can be calculated subtracting 10–15% of plagioclase to take into account the high content of plagioclase xenocrysts. Variable solid fractionation of about 25–30% can reproduce the observed major element trends, with fractionating mineral assemblage dominated by plagioclase (about 20%), with minor clinopyroxene (about 3–5%), olivine (3–1.5%) and Ti-magnetite as accessory mineral. Another mechanism could be the mixing process between batches of magmas having different evolutionary degree. Mixing between more evolved magmas and basic liquids are also supported by the disequilibrium evidence from mineral chemistry data and return to more basic compositions.

References

[1] Curray, J.R. (2005) Tectonics and history of the Andaman Sea region, *Journal of Asian Earth Sciences*, vol. 25, 187–232.
[2] Alam, M.A. (2008) Geological, Geochemical and Geothermal Studies on the Barren Island Volcano, Andaman Sea, Indian Ocean. Ph.D. Thesis (Unpublished), Indian Institute of Technology Bombay, Mumbai, India, 174 p.
[3] Chandrasekharam, D., Santo, A.P., Capaccioni, B., Vaselli, O., Alam, M.A., Manetti, P., Tassi, F. (2009) Volcanological and petrological evolution of Barren Island (Andaman Sea, Indian Ocean). *Journal of Asian Earth Sciences*, vol. 35, 469–487.
[4] Alam, M.A., Chandrasekharam, D., Vaselli, O., Capaccioni, B., Manetti, P., Santo,

A.P. (2004) Petrology of the prehistoric flows and dyke of Barren Island, Andaman Sea, Indian Ocean. *Journal of Earth System Science*, vol. 113, 715–721.

[5] Turner, S. and Foden, J. (2001) U, Th and Ra disequilibria, Sr, Nd and Pb isotope and trace element variations in Sunda arc lavas: predominance of a subducted sediment component, *Contribution to Mineralogy and Petrology*, vol. 142, 43–57.

[6] Sun, S.S. and McDonough, W.F. (1989) Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. In: Saunders, A.D., Norry, M.J. (Eds.), *Magmatism in Ocean Basins*. Geological Society of London, Special Publications No. 42, 313–334.

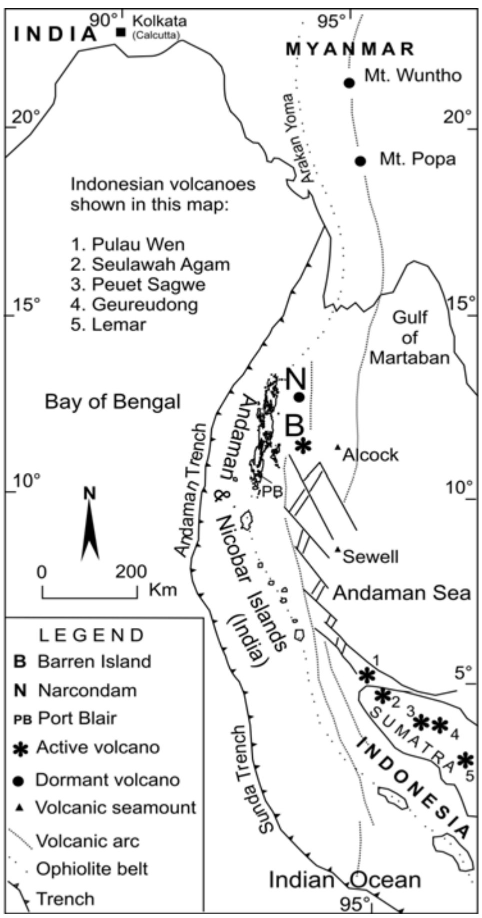


Fig. 1: Location and tectonic setting of the Barren Island Volcano [1]

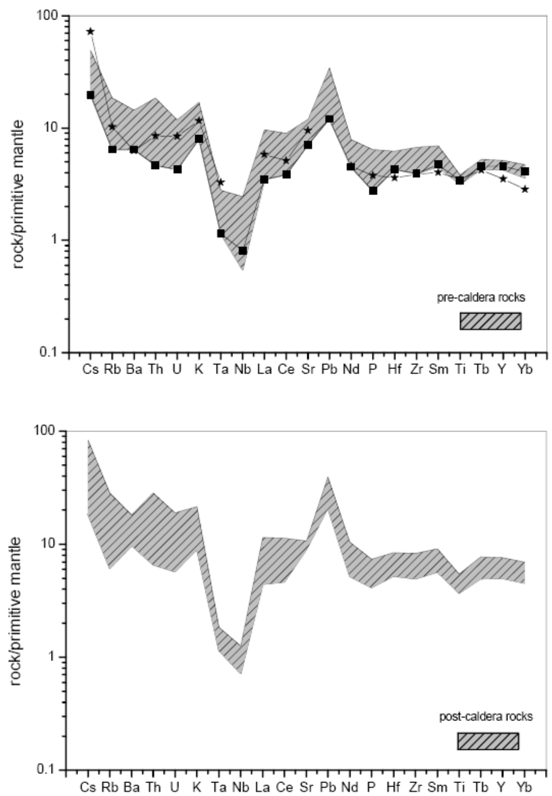


Fig. 2: Primitive mantle normalized [6] incompatible trace element patterns for the Barren Island volcanics. Stars: Galunggung (Sunda Arc) primitive tholeiitic basalt [5]; Squares: BI sample.