Early 2017 activity of the Barren Island volcano: facts versus hype

Barren Island is the northernmost active stratovolcano of the Sunda Volcanic Arc system in the northeastern Indian Ocean. It is the only active volcano in the Indian territory. The arc is a result of subduction of the Indian plate beneath the Burma plate, a sliver of the Eurasian plate. This subduction zone is a southward extension of the Himalayan convergent boundary that takes a turn at the Eastern Syntaxial Bend. Located ~135 km northeast of Port Blair (12°70′N/93°51′E), the Barren Island volcano covers a subaerial area of ~8 km^2. According to historical records, Barren Island has had multiple episodes of eruptions since 1787 (refs 1–3). The recent active phase of the volcano began in 1991; since then, there have been several major lava eruptions[4–6]. At present, the volcano is undergoing strombolian activity with frequent moderate- to low-scale ash eruptions and occasional lava eruptions from the central cinder cone, or from secondary cones located in its flanks. Existing $^{40}Ar–^{39}Ar$ age data on the oldest subaerial lava flows and crustal xenoliths suggest that the volcano sits on a ~106 Ma oceanic crust and possibly became subaerial at ~1.6 Ma (ref. 6). AMS radiocarbon ages on sediment layers bracketing ash layers in a marine sediment core collected ~32 km SE of the island suggest that the volcano had major ash eruptions at ~8, 12, 17, 23, 62 and 71 k yrs ago[7,8].

Responding to media reports of renewed activity of the Barren Island[9–12], we organized a trip to the volcano to validate the report by comparing our field observations with those made in our six previous trips to the island during 2007–2015. We departed Port Blair on-board *ICGS Rajkamal* on 8 March 2017 afternoon and reached near Barren Island several hours before daybreak on the following day (9 March 2017, 03:00 IST). We carefully watched the activity of the volcano until sunrise from a distance, while still on-board the ship. We observed strombolian eruptions of ash plumes every 10–15 min and at times with short spells of fountaining red-hot lava, of limited areal extent, from the central cinder cone of the volcano. Apart from ash, each eruption emitted cinders/lapilli/lava bombs that rolled down the slopes of the cinder cone, which glowed (red) in the night giving a false impression of lava flows/streams. The ash plumes often formed mushroom-shaped clouds rising a few hundreds of metres into the sky and gradually faded away in the direction of the wind.

Upon daybreak, we approached the island by a motorized rubber boat (*Gemini*) and disembarked at our first landing site (LS-1), adjacent to the wide lava delta (Figure 1). We tried to follow the trend of lava delta towards the cinder cone and examined the a′a′ lava flows characterized with typical grooves and ridges (called ‘toothpaste lava’ by Sheth *et al.*[13]), often seen with tilted and overturned large slabs/chunks. These lava flows were possibly from the 1995 activity[6]. Lavas were predominantly porphyritic with abundant plagioclase phenocrysts set into a glassy matrix. We also noticed smokes coming out from the scattered cinders and lava clinkers along the flanks of the cone and on the lava delta, suggesting that there

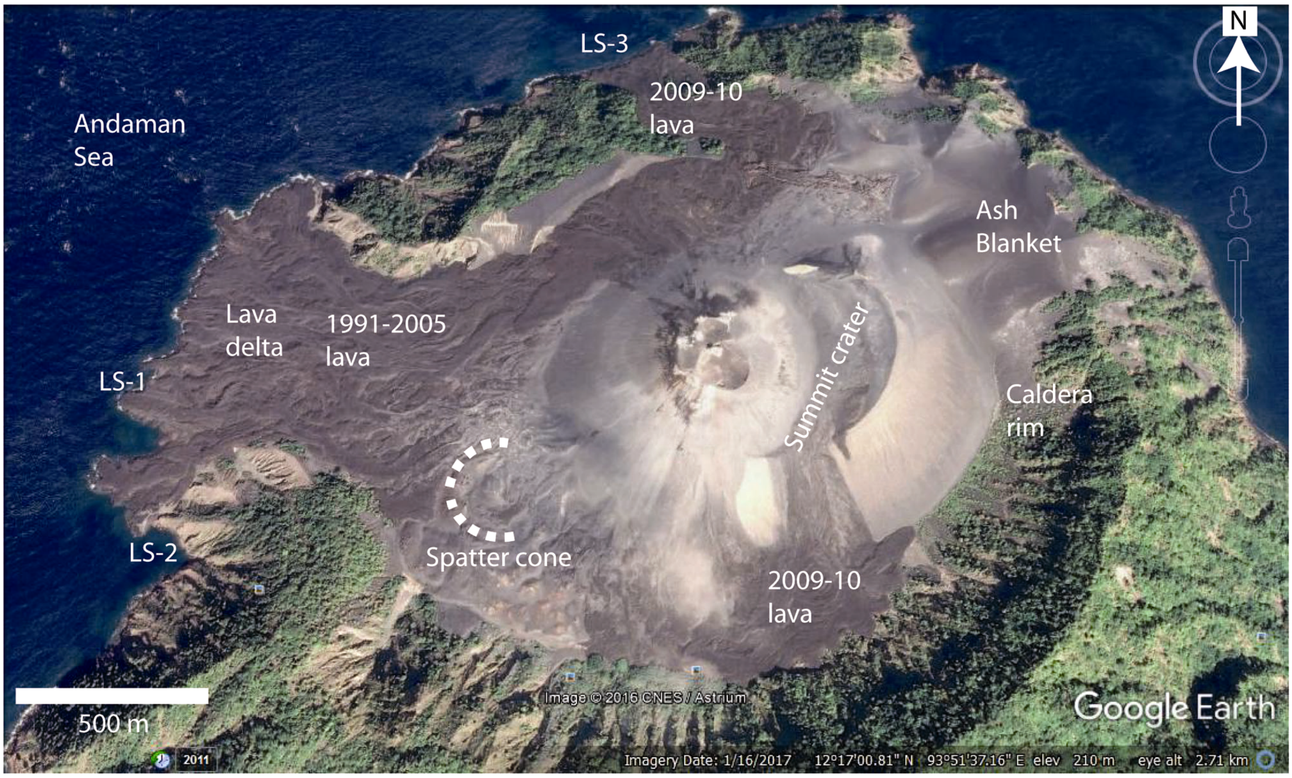

Figure 1. A simplified map of the Barren Island based on Google Earth image. Landing sites are marked as LS-1 to LS-3. Some of the important volcanological features are also marked. Eye elevation is 2.71 km (imagery date 16 January 2017).

may have been some minor lava flows sometime in the recent past. After finishing our work on this site, we moved to our second landing site (LS-2; Figure 1), a small bay area which has been the most convenient spot for landing for most visitors to the island. This site contains many interesting features of the volcano, such as several prehistoric lahars and the oldest sub-aerial lava flows (1.6 Ma)[6] that form the base of the exposed portion of the island. We also came across several rolled-up boulders of a much younger flow that contained large xenocrysts of plagioclase and clinopyroxene (>1 cm), which have been already described in detail and dated to be 106 Ma by Ray *et al.*[6]. These are deemed to have been derived from a mafic lower crust of the volcanic arc[6]. We did not observe any change in the general topography of the landing site or the approach that leads to the edge of the caldera wall, in comparison to our earlier observations[2,4]. After a short traverse, we went back to *Gemini* and revisited the 2009–10 lava flow through the sea (Figure 1). One of us landed on the rocky shore after swimming through the waves (LS-3; Figure 1) and collected a couple of scoria samples from this flow. We returned to the ship and continued observing the activity of the volcano by encircling the island.

Based on the photographs taken during our trips to Barren Island, we have prepared a timeline of activity of the volcano (Figures 2 and 3). As can be seen from the photographs over the last decade (2007–2017), the morphology of the island has changed but not as much as one would expect in a highly active volcanic terrain. The shape and height of the cinder cone are undergoing continuous change. The thickness of the lava delta and extent of the ash blankets appear to have increased (Figures 1 and 2). The volcano had remained in the active phase during the last decade and the eruptions in 2009–10 probably were most intense with lava flows reaching the sea through a route that is different from all the earlier flows since 1991. Contrary to newspaper reports and social media hype generated as a result of erroneous claims by a couple of oceanographers[9–12], we did not observe any fresh lava flow. In fact, we observed that the current activity (2017) is probably the weakest since 1991, with very low frequency of ash eruptions. However, we cannot completely rule out the presence of any

Figure 2 *a–f*. Photographs showing a timeline of eruptions of the Barren Island volcano from 2007 through 2014. Note change in height and shape of the cinder cone. ***c***, Geologists walking on a′a′ lava field/delta. ***d***, The a′a′ lava flowing down the caldera wall into the sea during 2009–10. White fume is evaporated sea water.

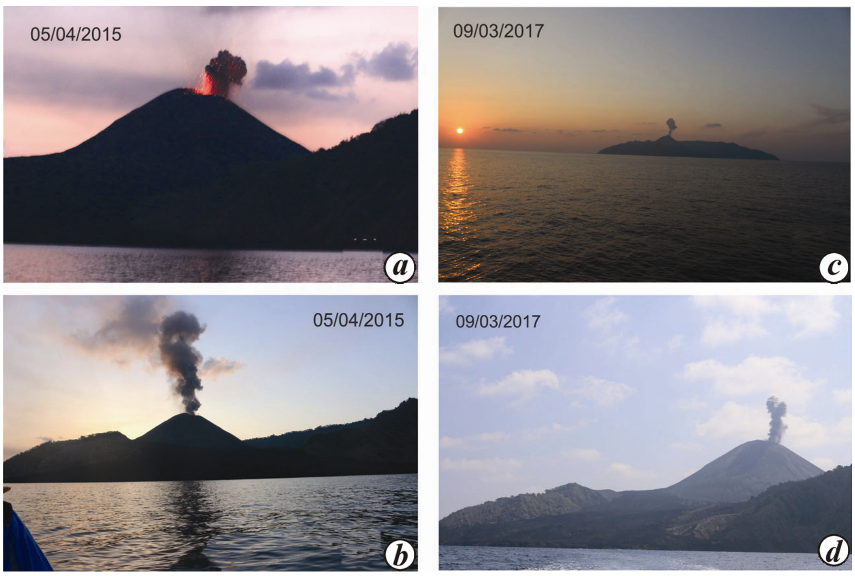

Figure 3 *a–d*. Photographs of activities of the Barren Island volcano during the 2015 and 2017 trips. ***a***, Lava fountain in a strombolian eruption.

discontinuous lava flows that either had erupted from fissures on the flanks of the cinder cone or from the main crater. Current satellite imageries of the volcano, from RISAT-1 and Landsat-8, ISRO (http://www.sac.gov.in/Vyom/index.jsp), show 'hot' zones within the summit crater and around secondary spatter cones that are in tune with the current activity.

The Barren Island volcano is currently in its active phase since 1991, irregularly emitting lava and ash with intermittent quiet periods. The ash eruptions have become a common phenomenon since the 2009–10 lava eruptions; therefore, it should not come as a surprise if sudden eruptions occur during a quiet period. Such eruptions should not be confused with renewed activity of the volcano.

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ACKNOWLEDGEMENTS. We thank the Indian Coast Guard for providing logistic help and the captain and crew of *ICGS Rajkamal* for help during the expedition. This work is funded by the Department of Space, Government of India. We also thank the anonymous reviewer and handling editor for their useful comments and suggestions.

Received 21 April 2017; revised accepted 25 June 2017

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Higher concentration of heavy metals in surface water and fish near a municipal solid waste dump in Guwahati, Assam, India

Solid waste management is one of the biggest environmental challenges in cities and towns across India. Precipitation infiltrating the solid wastes disposed on land mixes with the liquids trapped in the crevices of the waste and leach compounds from solid waste[1]. Discharge of potentially toxic heavy metals from the leachate into aquatic ecosystems poses serious threat because of their toxicity, persistence, bioaccumulation and biomagnification in the food chain.

Fishes are indicators of metal contamination in aquatic systems[2]. Pollutants enter the fish through four main routes: via food or non-food particles, gills, oral consumption of water and through skin[3]. The present study was planned to assess the possible effect of municipal solid waste (MSW) dumping on the concentration of heavy metals in surface water and accumulation in fish tissue collected from the adjoining wetland.

The study area is the Deepor beel wetland, a Ramsar site (Sl. No. 1207), which is contiguous to the MSW dump site of Guwahati city, Assam, India. Five sampling points (S1–S5) were selected from within 3000 m around the MSW dump (Figure 1). Fortnightly collection of water samples in triplicate was continued for a period of 12 months (March 2011–February 2012). Experimental fish samples (*Anabas testudineus*) in triplicate were collected from within 20 m of the dump site during September–October 2011. The control site for sampling of water and fish was situated at a distance of 4928 m from the dump and was not connected with Deepor beel.

For analysis of heavy metals, standard procedures were followed[4]. Water samples were collected in acid-washed 250 ml

Figure 1. Sampling points (S1–S5) of surface water in the wetland.