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A bird's eye view of "Understanding volcanoes in the Vanuatu arc"☆

The Vanuatu intra-oceanic arc, located between 13 and 22°S in the southwest Pacific Ocean (Fig. 1), is one of the most seismically active regions with almost 39 earthquakes magnitude 7+ in the past 43 years (Baillard et al., 2015). Active deformation in both the Vanuatu subduction zone and the back-arc North-Fiji basin accommodates the variation of convergence rates which are c.a. 90–120 mm/yr along most of the arc (Taylor et al., 1995; Pelletier et al., 1998). The convergence rate is slowed down to 25–43 mm/yr (Baillard et al., 2015) in the central segment where the D'Entrecasteaux ridge - an Eocene-Oligocene island arc complex on the Australian subducting plate – collides and is subducted beneath the fore-arc (Taylor et al., 2005). Hence, the Vanuatu arc is segmented in three blocks which move independently; as the north block rotates counter-clockwise in association with rapid back-arc spreading (~ 80 mm/year), the central block translates eastward and the south block rotates clockwise (Calmant et al., 2003; Bergeot et al., 2009). (See Fig. 1.)

Vanuatu volcanic activity (earliest descriptions by Aubert de la Rüe, 1945 and Taylor, 1956) provides an exceptional diversity of eruptive styles, with caldera-forming eruptions such as the Kuwae eruption in 1452 A.D. (Monzier et al., 1994; Witter and Self, 2007; Németh et al., 2007) and the 1913 effusive eruption along Ambrym axial rifts, which evolved toward highly hazardous phreatomagmatic eruption while the fissure entered the sea (Németh and Cronin, 2011).

Along the arc, magmas display a broad chemical range from high-Mg andesites at the southernmost end to low-K tholeiites and alkaline compositions, which are limited to the central islands (Monzier et al., 1997). They span a wide spectrum of Sr-Nd-Pb isotopic signatures with a marked imprint of the ridge-arc collision, which may have modified the mantle dynamics and caused a possible influx of more fertile Indian-type mantle (Peate et al., 1997). The Vanuatu arc is also known for the uncommon extrusion of ankaramitic magmas (Green et al., 2004; Sorbadere et al., 2013).

The first survey of He isotopic geochemistry through the arc combined measurements of the isotopic compositions of hot springs, fumaroles and olivine crystals and produced a range of $^3He/^4He$ ratios from 6.4 ± 0.5 Ra in the southern segment and 7.23 ± 0.09 Ra in the North to typical MORB values in the central islands (7.68 ± 0.06 - 8.0 ± 0.1 Ra), except hot-spot-like values of waters (9.8 ± 0.2 Ra) and bubbling gases (10.21 ± 0.08 Ra) from northwest Ambrym (Jean-Baptiste et al., this Issue).

This Special Issue highlights the diversity of the volcanic processes that make the Vanuatu arc an exceptional laboratory for studying the melt and gas geochemistry, and the dynamics of magma degassing in a tectonically-active convergent setting. This Issue contributes to a better understanding of the volcanic activity in this region and its environmental impacts through a multidisciplinary approach.

Presently, five volcanoes are active (Fig. 1). From north to south there are Mt Garet within the summit caldera of Gaua composite volcano, Aoba (or Ambae) shield volcano whose summit caldera hosts two crater lakes (Voui and Lakua), Lopevi conical-shape volcano, Ambrym volcanic complex with two active intra-caldera cones (Benbow and Marum), and Yasur cone in Siwi resurgent caldera in the south of Tanna island.

The near-real-time monitoring of the thermal activity of these active volcanoes over the last 15 years provides, by using a new volcanic hot spot detection system (MIROVA), a perfect illustration of the diversity of their eruptive dynamics in both the long- and short-term (Coppola et al., this Issue).

Airborne-based measurements of SO_2 emission rates reveal that the Vanuatu arc is one of the prominent sources of volcanic degassing on Earth with a prevalent contribution of Ambrym volcanic system (Bani et al., 2012). Ambrym volcano is a large system with magma stalling and crystallization at the crust-mantle interface, mid-crustal (Shehaan and Barclay, this Issue), and shallow crustal (Allard et al., this Issue) levels. The active craters of Benbow and Marum cones presently host high-temperature lava lakes (Németh and Cronin, 2008; Radebaugh et al., this Issue), and their persistent volcanic activity has a long-term impact on the human health, water supply, and vegetation (Cronin and Sharp, 2002; Allibone et al., 2012). Indeed, the persistent degassing of Ambrym volcano sustains SO_2 flux as high as ~8 ktons per day, and substantial emissions of gas (H2O, CO2, SO2, H2S, HCl, HF, HBr, HI), trace metals (Au, Tl, Hg, Cd…), and radioactive species (^{10}Po, ^{210} Bi, ^{210}Pb) that rank among the largest on Earth. These high emissions imply a high supply rate (25 m^3 s^{-1}) of basaltic magma and an efficient convective system (Allard et al., 2016; this issue).

Satellite observations, combined with a refined atmospheric circulation model that includes sulfur chemistry and aerosol processes (Fig. 2), fully confirm the key role of Ambrym's degassing on the regional aerosol composition of the pristine tropical troposphere (Lefèvre et al., this Issue). In terms of sulfur footprint, these authors show that Vanuatu volcanism is almost equivalent to all anthropogenic and oceanic sources in the southwest Pacific but also point to severe limitations of satellite observations, limiting their value in tracking tropospheric volcanic plumes and in retrieving SO_2 fluxes.

Mt Garet activity is more sporadic but the 2009-2010 eruptive crisis produced high gas fluxes (SO_2, HCl, HF), ash plumes and climatic phases of Strombolian activity and lake Letas discoloration because of hydrothermal fluid discharge and concomitant increase of the water Fe concentrations (Bani et al., this Issue). The volume of the basaltic magma required to produce the total amount of SO_2 released over 10 months

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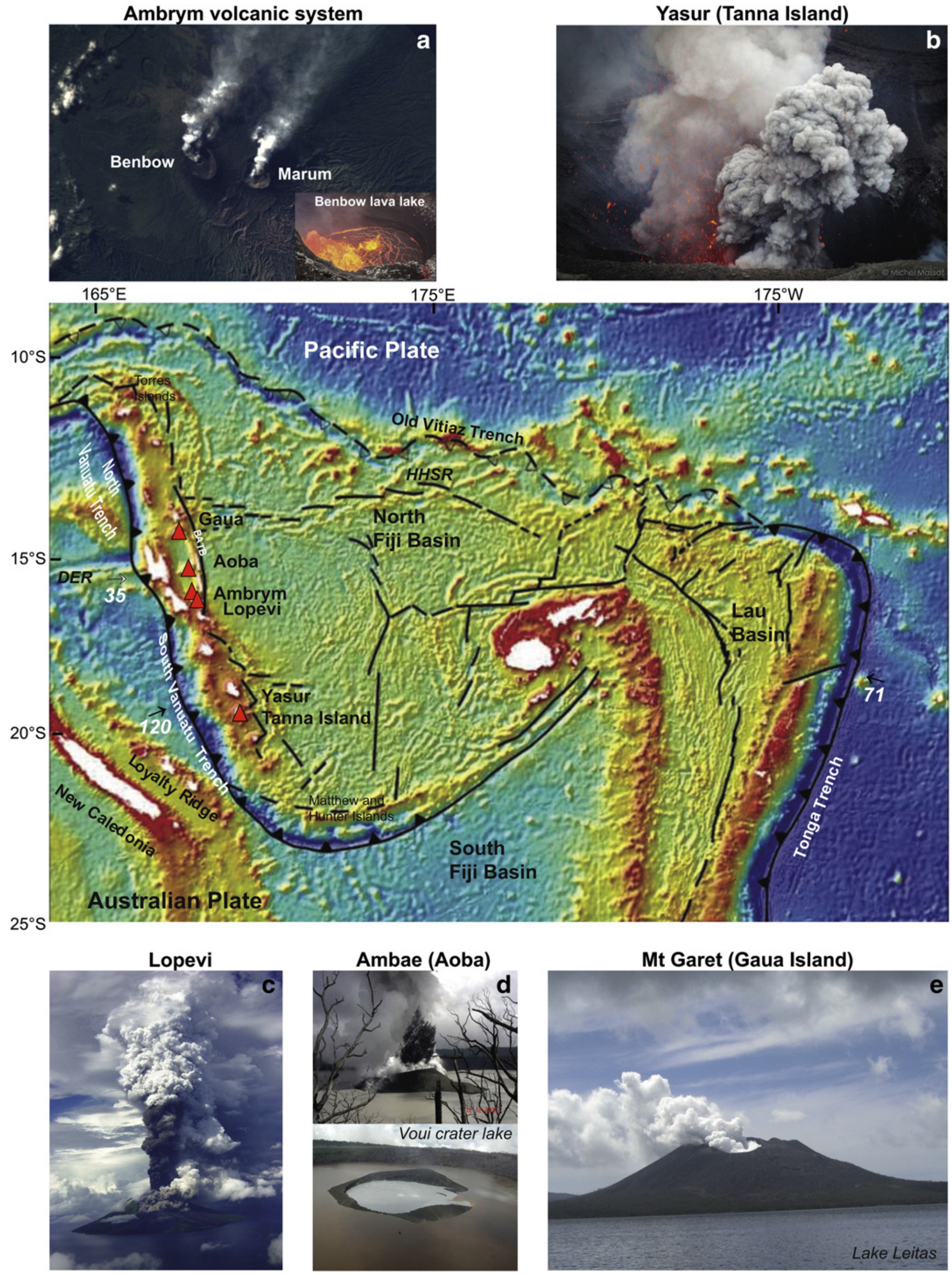

Fig. 1. Geodynamic context of the Vanuatu volcanic arc showing and location of the main active volcanoes showing the bathymetry (map from IFREMER, modified from Jean-Baptiste, this Issue), and the convergence rates (in mm/yr) of the Australian plate (Pelletier et al., 1998; Baillard et al., 2015) and Pacific plate (Richards et al., 2011). DER refers to the D'Entrecasteaux Ridge, HHSR to Hazel-Holme Spreading Ridge; BATB to Back-Arc Thrust Belt. Photos are: ISS view of Ambrym volcanoes from Mike Hopkins (NASA), Benbow lava lake and Yasur crater activity from Michel Massat, Lopevi eruption from Philippe Leloup (Air Vanutatu), Aoba Voui crater lake from Michel Lardy (IRD), and Mt Garet on Gaua from Esline Garaebiti (Geohazards).

of Mt Garet activity was estimated to be ~0.027 km^3, and a model of convection with upward migration of thermal plumes was proposed to account for the eruptive sequence (Métrich et al., this Issue). Mt Garet basalts significantly differ from the pre-caldera stage magmas (Robin et al., 1994), in their alkali (K, Rb) concentrations and La/Sm ratios, features which are interpreted as the results of distinct degrees of melting of their Indian MORB-type mantle sources (Beaumais et al., this Issue).

Close to the southernmost part of the volcanic arc, Yasur is a small scoria cone (360 m above sea level), built up on the western edge of the Yenkahe resurgent dome within the Siwi caldera (Carney and MacFarlane, 1979; Nairn et al., 1988). Yasur magmas are water-poor basaltic-trachyandesite (1-0.4 wt% of H_2O), and more importantly they share similar major and trace element compositions with magma erupted during the Siwi caldera forming eruption (Métrich et al., 2011).

Yasur is characterised by sustained degassing with a continuous Strombolian to Vulcanian type activity (Bani and Lardy, 2007). Lava flow effusions are rare (Carney and MacFarlane, 1979), as are Subplinian phases (Nairn et al., 1988). Typical activity consists of frequent and short Strombolian explosions (each a few minutes) driven by