Geomorphology 136 (2012) 15–30

Contents lists available at ScienceDirect

Geomorphology

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

Non-explosive, dome-forming eruptions at Mt. Taranaki, New Zealand

Thomas Platz [a,b,*], Shane J. Cronin [b], Jonathan N. Procter [b], Vincent E. Neall [b], Stephen F. Foley [c]

[a] Freie Universität Berlin, Institute of Geological Sciences, Malteserstr. 74-100, Building D, 12249 Berlin, Germany
[b] Volcanic Risk Solutions, Institute of Natural Resources, Massey University, Private Bag 11222, Palmerston North, New Zealand
[c] Earth System Science Research Centre, Institute of Geosciences, University of Mainz, Becherweg 21, 55099 Mainz, Germany

ARTICLE INFO

Article history:
Received 14 March 2010
Received in revised form 16 February 2011
Accepted 16 June 2011
Available online 1 July 2011

Keywords:
Lava dome
Collapse
Block-and-ash flow
Andesite
Rock avalanche
Mt Taranaki

ABSTRACT

Volcanic domes may be emplaced rapidly and with few hazardous consequences, even at the summit of large stratovolcanoes. In this study the most recent activity of Mt. Taranaki in New Zealand is shown to have been a passive effusion of a c. 5.9 million m^3 lava dome with minor associated explosions and little syn-eruptive hazard. This event, the Sisters eruption, appears to have been unrecorded by local indigenous populations but likely occurred between A.D. 1785 and 1820. The magma erupted is chemically distinct from the preceding A.D. 1755 Tahurangi eruption. Based on breakdown of hornblende crystal rims, the Sisters magma was probably only four days outside the hornblende stability field before cooling, and the magma ascended its last four km along a conduit at rates of 0.012 ms^{-1}. Based on dome surface morphology, a relatively low-viscosity magma is inferred. The dome remained in a metastable state for up to 70 years following the eruption; eventually generating a large, cool (<350 °C) collapse of at least 2 million m^3 of rock, forming a highly hazardous mass flow that travelled over 5 km. Factors contributing to the post-eruption dome instability include: its emplacement onto a steep flank of unconsolidated breccia or talus, possible oversteepening, fracturing due to spreading and subsidence, rapid cooling during heavy rain, and a hydrothermally altered inner core. The likely trigger for the collapse was a heavy rainstorm or an earthquake. Volcanic domes in the summit regions of volcanoes must be considered metastable and a potential source for hazardous, non-eruption related mass flows for many decades following their emplacement.

1. Introduction

Lava dome-forming eruptions can last from a few days up to several decades. In most cases, the impacts of these typically small volcanic eruptions are also forgotten within years or decades of the event. While most people anticipate renewed volcanism at long-dormant volcanoes to be large with major environmental impacts, most eruptions at andesite volcanoes are predominantly small and many are brief. Volcano dormancy and cessation of small dome-forming eruptions may lead to complacency within the surrounding population and a consequent underestimation of ongoing volcanic hazard. A lava dome located at high altitudes within a summit crater and partly emplaced onto the outer steep flanks is in a metastable state. When the dome is growing, parts of it may collapse, forming devastating block-and-ash flows (BAFs). Causes of such syn-eruptive lava dome failure include: slope oversteepening (Sparks et al., 2000), dome interior gas-pressurisation (Sparks, 1997; Voight and Elsworth, 2000; Elsworth and Voight, 2001), and fracture propagation due to intense rainfall (Yamasato et al., 1998; Matthews et al., 2002; Simmons et al., 2004; Taron et al., 2007). This hazard has been known for centuries and is focussed upon as a major life-threatening process at many stratovolcanoes (e.g., Sheridan and Malin, 1983; Macias et al., 2008; Procter et al., 2010). By contrast, the hazard potential of a cooled lava dome is often ignored even though the above-listed processes may still occur, because the volcano is considered dormant or extinct. We show here that a cool metastable lava dome may collapse decades to centuries after its emplacement.

Our study was carried out at Mt. Taranaki (2518 m) located on the Taranaki peninsula, western North Island of New Zealand (Fig. 1). It is the youngest edifice along the Taranaki Volcanic Lineament which also comprises the Sugar Loaf Islands, Kaitake, and Pouakai. The latest eruptive period at Mt. Taranaki comprised ten distinct eruptions within the last c. 500 years (e.g., Druce, 1966; Neall, 1973; Cronin et al., 2003; Platz, 2008). Deposits from these eruptions include ash fall and pyroclastic-flow (block-and-ash flows, pumice flows, and surges) deposits and lava flows, and are collectively mapped as the Maero Formation. The lava dome forming the current summit of Mt. Taranaki is thus the latest of the Maero eruptive units. Studies were

* Corresponding author at: Freie Universität Berlin, Institute of Geological Sciences, Malteserstr. 74-100, Building D, 12249 Berlin, Germany. Tel.: +49 3083870822; fax: +49 3083870723.
E-mail addresses: thomas.platz@fu-berlin.de (T. Platz), s.j.cronin@massey.ac.nz (S.J. Cronin), j.n.procter@massey.ac.nz (J.N. Procter), v.e.neall@massey.ac.nz (V.E. Neall), foley@uni-mainz.de (S.F. Foley).

0169-555X/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.geomorph.2011.06.016

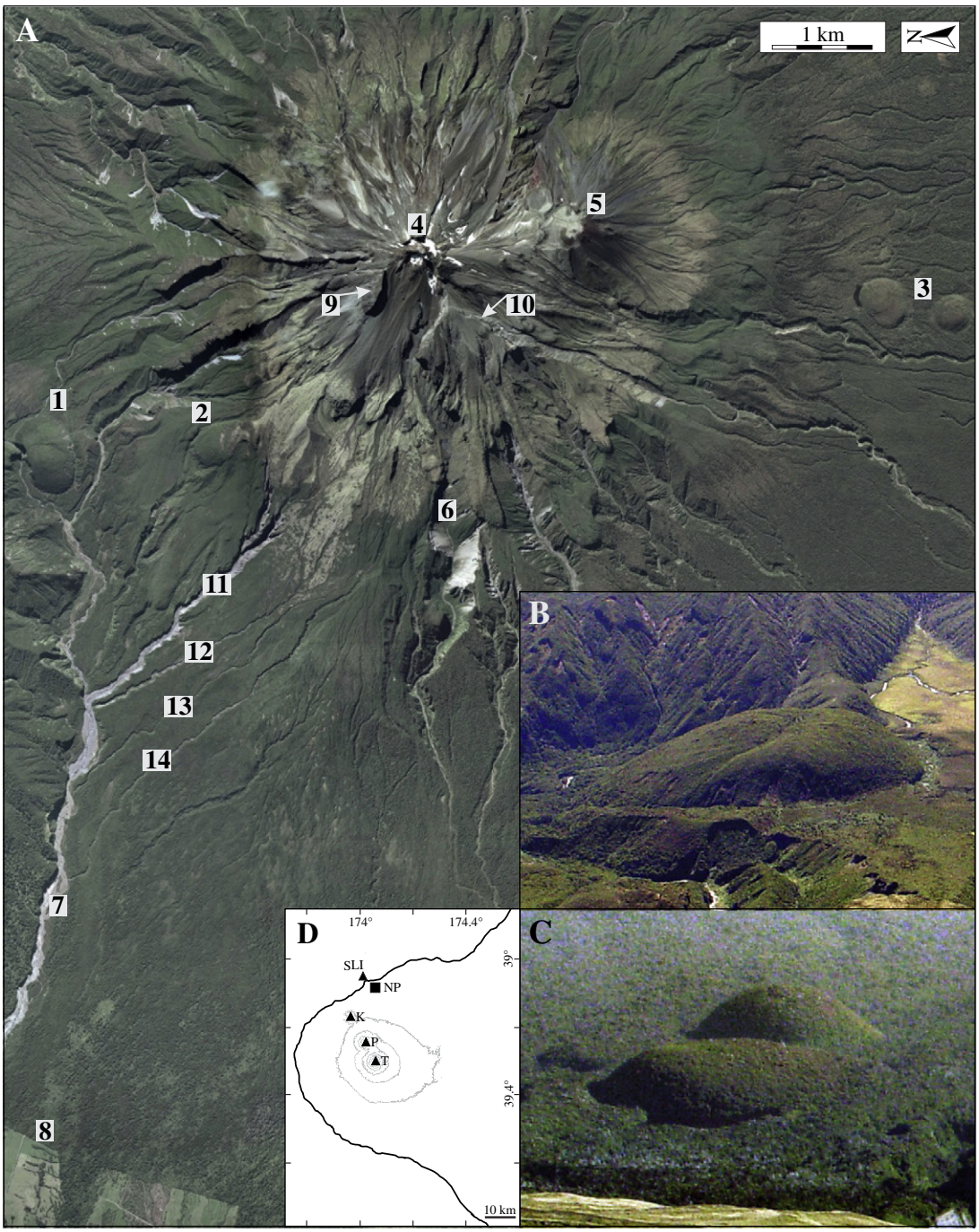

Fig. 1. A) Orthophotograph of Mt. Taranaki including the lower northwestern flanks. Inset shows upper cone area including Fanthams Peak. Major morphological features are indicated by numbers: 1—The Dome, 2—Skinner Hill, 3—the Beehives, 4—summit crater of Mt. Taranaki, 5—satellite vent Fanthams Peak, 6—Okahu Gorge, 7—Stony River, 8—National Park boundary, 9—Turtle, 10—Bobs Ridge, 11—Pyramid Stream, 12—Unnamed Stream, 13—Turehu Stream, 14—Maero Stream. B) Photograph of The Dome. C) Photograph of the Beehives. D) Location of Mt. Taranaki (T) on the Taranaki peninsula, North Island. It is the youngest edifice of the volcanic lineament consisting of Sugar Loaf Islands (SLI), Kaitake (K), and Pouakai (P). The largest town on the peninsula is New Plymouth (NP). Contours are in 300 m intervals (modified after Platz et al., 2007b).

carried out to reconstruct its original geometry, growth dynamics and also zones of weakness within the dome. This allows the description of very common, but non-dramatic, dome effusion events possible at andesitic stratovolcanoes. Factors contributing to both syn- and post-eruptive dome failure are identified. We show that the remnant summit dome at Mt. Taranaki represents an individual eruptive event (termed the Sisters event), postdating the Tahurangi eruption of A.D. 1755. Aspects of magma ascent rates and eruption duration are also constrained through combined morphological and petrological studies.

2. Lava domes

Lava domes are hemispherical to irregularly shaped mounds of volcanic rock representing one or more lava flows extruded above a vent and too viscous to flow far (Fink and Anderson, 2000). The extrusion of lava domes can occur above the central vent of a volcano (e.g. Mt. Taranaki, New Zealand; Gunung Merapi, Indonesia; Mt. St. Helens, USA), on the lower slopes of volcanoes either in isolation or in groups (e.g. Mt. Taranaki, New Zealand; South Sister, Oregon, USA), and along fault lines or caldera ring faults (Mono Lake–Inyo Craters,