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A model of tephra dispersal from an early Palaeogene shallow submarine Surtseyan-style eruption(s), the Red Bluff Tuff Formation, Chatham Island, New Zealand

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ABSTRACT

The Red Bluff Tuff Formation, an early Palaeogene volcano-sedimentary shallow marine succession from the Chatham Islands (New Zealand), provides a unique framework, in eastern 'Zealandia', to explore tephra dispersal processes associated with ancient small phreatomagmatic explosions (i.e. Surtseyan-style eruptions). Detailed sedimentological mapping, logging and sampling integrated with the results of extensive laboratory analyses (i.e. grain-size, componentry and applied palaeontological methods) elucidated the complex mechanisms of transport and deposition of nine identified resedimented fossiliferous volcaniclastic facies. These facies record the subaqueous reworking and deposition of tephra from the erosion and degradation of a proximal, entirely submerged ancient Surtseyan volcanic edifice (Cone II). South of this volcanic cone, the lowermost distal facies provides significant evidence of deposition as water-supported volcanic- or storm-driven mass flows (e.g. turbidity currents and mud/debris flows) of volcaniclastic and bioclastic debris, whereas the uppermost distal facies exhibit features of tractional sedimentary processes caused by shallow subaqueous currents. Further north, within the proximity of the volcanic edifice, the uppermost facies are represented by an abundant, diverse, large, and well preserved in situ fauna of shallow marine sessile invertebrates (e.g. corals and sponges) that reflect the protracted biotic stabiliszation and rebound following pulsed volcanic events. Over a period of time, these stable and wave-eroded volcanic platforms were inhabited by a flourishing and diversifying marine community of benthic and sessile pioneers (corals, bryozoans, molluscs, brachiopods, barnacles, sponges, foraminifera, etc.). This succession exhibits a vertical progression of sedimentary structures (i.e. density, cohesive and mass flows, and cross-bedding) and our interpretations indicate a shallowing upwards succession. This study reports for the first time mechanisms of degradation of a Surtseyan volcano on Chatham Islands and contributes to a better understanding of complex ancient volcano-sedimentary subaqueous terrains. This model of deposition (i.e. onlapping/overlapping features onto the remains of volcanic edifice(s), a vertical transition of structures from deeper- to shallower-marine environments, disaster faunas and subsequent preferential colonisation of diverse biota, including large in situ sessile invertebrates, on the summit), characterises an extraordinary example to be applied to other ancient subaqueous volcanic environments.

1. Introduction

Discriminating primary volcanic deposits from resedimented facies is a challenging problem faced by researchers of submarine volcano-sedimentary sequences (Bennett, 1972; McPhie et al., 1993), such as the Red Bluff Tuff Formation (herein RBT), Chatham Islands, New Zealand. Moreover, facies of ancient volcanic successions exemplify the spectrum of processes that occur during volcanic events, such as clast formation, transport and deposition, as well as post-volcanic sedimentary processes (Brown et al., 1994; Carey et al., 1996; Cantelli et al., 2008).

In general, volcaniclastic submarine aprons are often the only remaining evidence of submarine volcanic activity (Soh et al., 1989), especially when the volcanic edifice has been eroded following the cessation of volcanism. Therefore, enhanced understanding of these volcaniclastic and resedimented epiclastic facies is important in terms of reconstructing marine palaeoenvironments that were affected by volcanic activity (e.g. Allen et al., 2007).

In view of the above mentioned relevance to improving our comprehension of marine volcanic palaeoenvironments, ample studies have been undertaken in the last 25 years on volcaniclastic sedimentation of arc-related basins in México (White and Busby-Spera, 1987), USA (Busby-Spera, 1988), and New Zealand (Houghton and Landis, 1989); welded Ordovician tuffs in the United Kingdom (Fritz and Howells, 1991); and volcaniclastic aprons in New Zealand (Allen et al., 2007) and Montserrat (Trofimovs et al., 2006, 2008), amongst others.

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However, assessing the complexity of volcaniclastic deposition, due to variations in eruption styles, bathymetry of marine basins and changing volcanic slope angles, is a major challenge as we expand our knowledge in depositional environments and processes that could have formed these deposits. Good preservation and access of coastal exposures, and the lateral and vertical variations of facies of the RBT succession, provide a unique and exciting opportunity to reconstruct the two-dimensional architecture, structure, transport, and deposition processes during shallow marine clastic sedimentation. The results of this investigation allow to a better understanding of complex ancient volcano-sedimentary subaqueous terrains. In this paper, we describe in detail the syn- and post-volcanic facies from the submarine RBT (upper Palaeocene–lower Eocene) relating to pulsed volcanic events along the southwest coast of Chatham Island, and this model of deposition represents a complete, interesting and novel example to be applied to other ancient subaqueous volcanic environments. More importantly, it reports for first time bioclastic and volcaniclastic sedimentation associated with monogenetic Surtseyan volcanism from the Chatham Islands, New Zealand.

2. Geological setting

The Chatham Islands are the only emergent part of the Chatham Rise, a continental submarine plateau extending east from South Island, New Zealand (Fig. 1). The Chatham Rise, along with the rest of the New Zealand subcontinent (New Zealand, Campbell Plateau, Challenger Plateau, Lord Howe Rise, Norfolk Ridge, and New Caledonia) was separated from the continental margin of Gondwana by rifting and extension in the mid-to Late Cretaceous (Larter et al., 2002; Eagles et al., 2004; Laird and Bradshaw, 2004; Stilwell and Consoli, 2012; Mays and Stilwell, 2013). Specifically, Sutherland (1999) and Eagles et al. (2004) place the opening of the Tasman Sea and separation of New Zealand subcontinent from West Antarctica (Marie Byrd Land) at 85–80 Ma; however, recent and more refined studies estimate this timing to 83 Ma (Campbell and Hutching, 2007; Tulloch et al., 2009). The Chatham Rise region (including the Chatham Islands) drifted northward from ~70 to 80°S in the Early Cretaceous to 54°S at the K–Pg boundary (Sutherland, 1995; Stilwell et al., 2006; Timm et al., 2010; Stilwell and Consoli, 2012). The lower Cenozoic units are thin marine successions associated with sporadic volcanism, deposited during regional subsidence of the Chatham Rise and contemporaneous fragmentation of Gondwana (Grindley et al., 1977; Campbell et al., 1993). Marine conditions prevailed with accumulation of limestone, and a period of non-deposition and erosion marked the end of the early Cenozoic. This unconformity can be traced along the Chatham region (Austin et al., 1973; Herzer and Wood, 1988; Wood et al., 1989). During the Paleogene, the Chatham Islands continued migrating north from approx. latitude 50°S (Molnar, 1975; Grindley et al., 1977) to its present position at 44°S. The stratigraphy of the Chatham Islands includes a well-preserved record of Late Cretaceous high-latitude Gondwana flora, fauna and environments (Stilwell et al., 2006; Pole and Philippe, 2010; Consoli and Stilwell, 2011; Mays and Stilwell, 2012), as well as an isolated post-Gondwana break-up volcanic oceanic archipelago in the Southwest Pacific Ocean during the Paleogene (Hay et al., 1970; Campbell et al., 1988; Stilwell, 1997; Sorrentino et al., 2011).

The Red Bluff Tuff Formation comprises a succession of upper Paleocene to lower Eocene volcanic and volcaniclastic deposits. It was initially described by Hay et al. (1970), and redefined and included as part of the

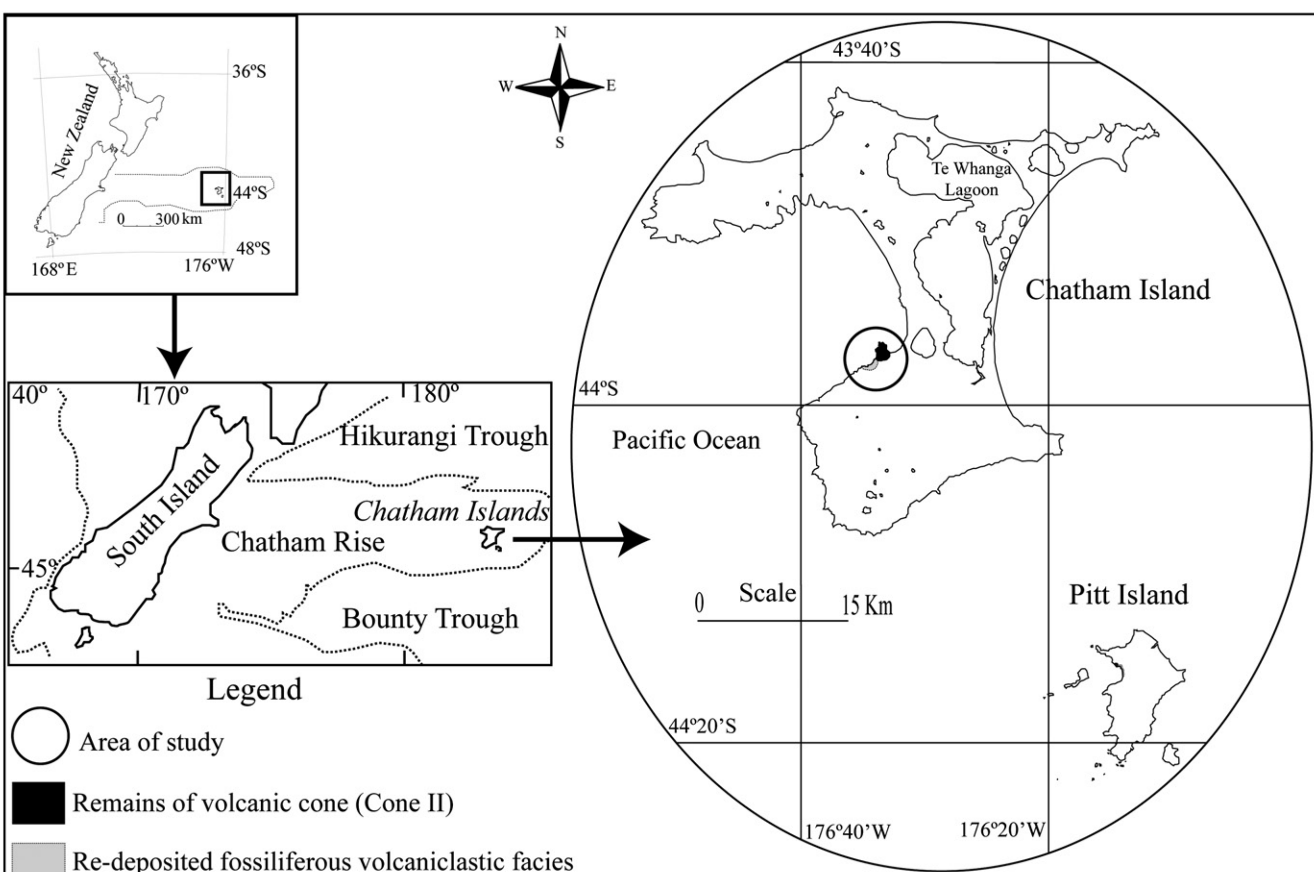

Fig. 1. Location of the Chatham Islands as an emergent segment of the Chatham Rise, east of South Island, New Zealand.