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Shallow-seated explosions in the construction of the Motukorea tuff ring (Auckland, New Zealand): Evidence from lithic and sedimentary characteristics

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ABSTRACT

At least 52 eruption centres are scattered within the ~360 km^2 Auckland Volcanic Field (AVF). Motukorea, now an island in the Waitemata Harbour, is one of 39 AVF volcanoes that experienced a phreatomagmatic explosive phase, before a magmatic phase. The volcano erupted through a ~200–300 m-thick, consolidated, mudstone/sandstone sequence of the Miocene Waitemata Group, which overlies the Waipapa Terrane greywacke basement. Detailed field descriptions of the sedimentary characteristics of the early phreatomagmatic deposits were carried out, along with examination of lithics. The ejecta ring deposit comprises 55 to 60 vol.% lithics, of which Waitemata Group fragments constitute approximately 90 vol.%, whereas <10 vol.% are Waipapa fragments, suggesting a dominance of shallow fragmentation. The sedimentary characteristics of the stratigraphic sequence at Motukorea suggest a dominance of wet surges at the beginning of the eruption with progression into drier sequences upwards. This is reflected in increasing inter-bedded juvenile-pyroclast-dominated fall deposits up-sequence. These characteristics are attributed to the changing hydrogeological conditions within the diatreme and the host rocks. These findings shed light on the eruption dynamics of phreatomagmatic eruptions through consolidated rocks in the AVF and enable the depiction of a scenario of future eruptions within the field in similar substrates.

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1. Introduction

Many tuff rings and maar–diatreme volcanoes are the result of the explosive interaction of magma with groundwater or a body of water (Valentine and White, 2012). Fragmentation of ascending magma is primarily due to highly energetic, explosive, fuel–coolant interactions (FCI) (Sheridan and Wohletz, 1983; Wohletz, 1983, 1986; Zimanowski et al., 1991, 1997). These can occur under a range of conditions, from magma intruding rapidly into saturated soft sediments (e.g., Houghton et al., 1999; Auer et al., 2007; Ort and Carrasco-Núñez, 2009; Ross et al., 2011; Agustín-Flores et al., 2014), through to interacting with water in cracks within hard/brittle rock sequences (e.g., Sohn and Chough, 1989; Chough and Sohn, 1990; Aranda-Gómez and Luhr, 1996; Auer et al., 2007).

The study of the nature and proportion of lithics within the tephra ring can provide insights into the substrate from where these fragments were sourced (e.g., Auer et al., 2007; Carrasco-Núñez et al., 2007; Ross et al., 2011; Valentine, 2012; Lefebvre et al., 2013). In some cases the proportions of lithic types do not accurately represent the disrupted substrates (e.g., Valentine, 2012; Lefebvre et al, 2013), because not all disrupted host rock is directly deposited in the ejecta ring (Valentine and White, 2012). Deep explosions lift some of the deeper source material to the shallow portion of the diatreme via debris jets (Ross and White, 2006), but the deep lithics may not be ejected directly to the ejecta ring. Predominantly shallow-seated explosions source the growth of the ejecta ring, with lithic clasts comprising mostly shallow country rock, with rare deeper material.

This study aims to examine how the nature and proportion of lithics in a tuff ring, as well as the sedimentary bedforms and their distribution, can explain the depth and progression of explosion conditions during a phreatomagmatic eruption. Detailed field descriptions of the sedimentary characteristics of the Motukorea tuff ring were carried out, along with examination of lithics. This, combined with the sedimentary characteristics of the stratigraphic sequence, sheds light into the explosion and eruption dynamics of phreatomagmatic eruptions through consolidated rocks in the Auckland Volcanic Field (AVF) and enables the depiction of a scenario of future eruptions within the field in similar substrates.

2. The Auckland Volcanic Field and the Waitemata Group rocks

The AVF comprises at least 52 individual eruption centres over an approximate area of 360 km^2 (Kermode, 1992; Allen and Smith, 1994;

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Spörli and Eastwood, 1997; Hayward et al., 2011) (Fig. 1); the magmas involved are mostly olivine-rich alkali basalts and basanites (Smith et al., 2009). At least 1.7 km^3 of DRE magma was erupted in sporadic eruptions since 250 ka, with the last eruption < 600 years ago (Allen and Smith, 1994; Molloy et al., 2009; Bebbington and Cronin, 2011; Kereszturi et al., 2013).

Phreatomagmatism is common in the AVF, with tuff rings and maars, sometimes at the base of scoria cones, found at approximately 80% of the eruption centres. The AVF is also almost completely urbanised and covered by the city of Auckland (population ~1.4 million, 2013 census, Statistics New Zealand) (Fig. 1). Explosive phreatomagmatic eruptions producing violent base surges are considered to be the most hazardous events during future eruptions (Allen and Smith, 1994; Németh et al., 2012; Sandri et al., 2012; Brand et al., 2014).

In contrast to the distinctively low-lying landscape in the southern part of the field covered by Pleistocene–Recent soft sediment (Manukau

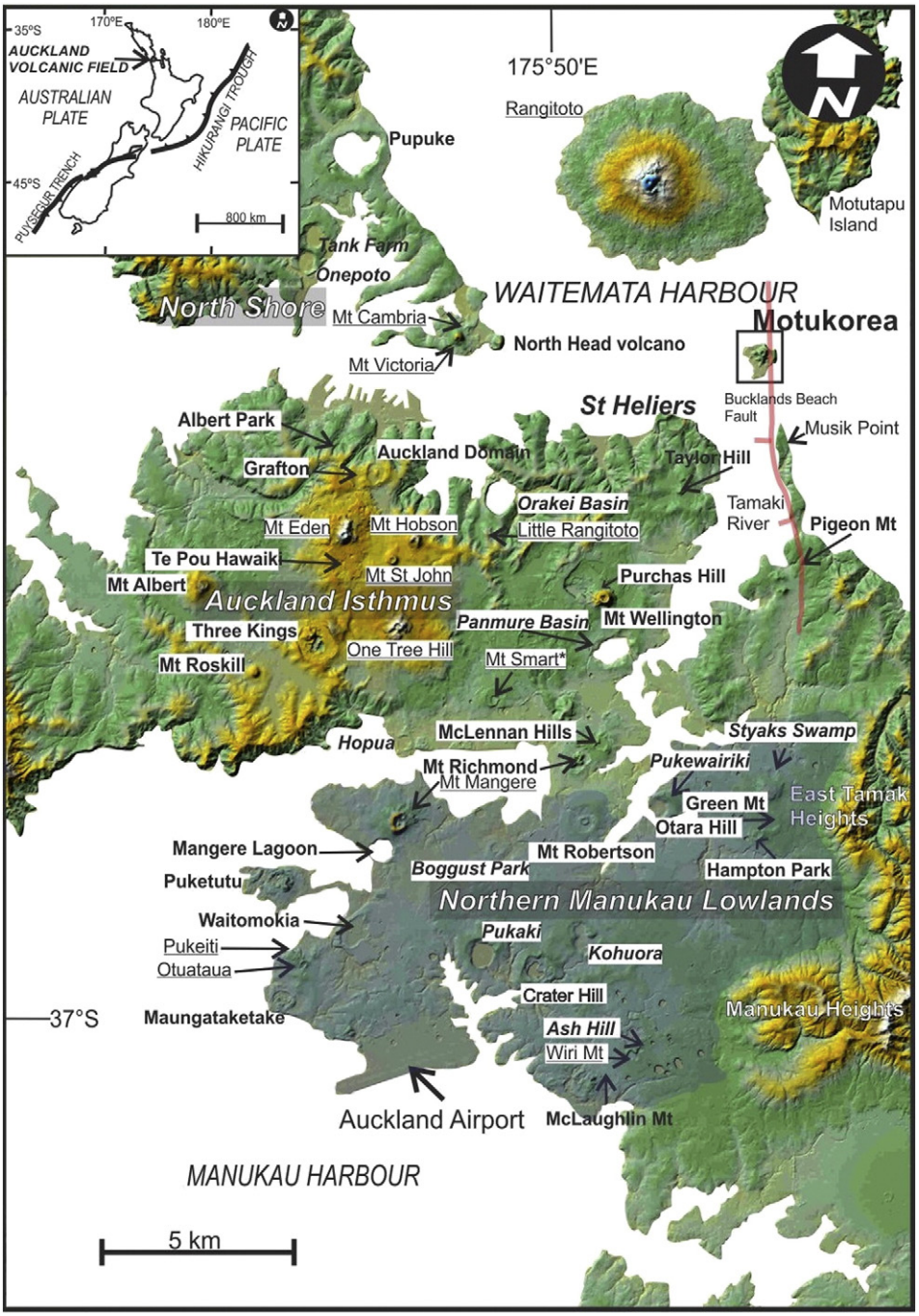

Fig. 1. Location of Motukorea volcano in the Auckland Volcanic Field, along with other volcanoes. Underlined names in regular fonts represent volcanoes that do not have evidence of phreatomagmatic activity (e.g., Mt. Hobson); names in bold fonts include both magmatic and phreatomagmatic activity (e.g., Motukorea); and names in italic bold fonts are those that show phreatomagmatic activity only (e.g., Onepoto). The City of Auckland urban area covers most of the displayed region. The red line is the N trending fault, down-thrown to the west, inferred by Kenny et al. (2012). The shaded area of the map which corresponds to the Northern Manukau Lowlands is characterized by the consolidated Waitemata rocks overlain by tens of metres of unconsolidated sediments, whereas the rest of the AVF lies in general on Waitemata rocks.

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