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Geotechnical characterisation of stratocone crater wall sequences, White Island Volcano, New Zealand

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Abstract

Geotechnical characterisation is undertaken for 3 broad units comprising the bulk of the stratigraphy identified on White Island Volcano, Bay of Plenty, New Zealand, an active island stratovolcano. Field and laboratory measurements were used to describe rock mass characteristics for jointed lava flow units, and ring shear tests were undertaken to derive residual strength parameters for joint infilling materials within the lavas. Rock Mass Rating (RMR) and Geological Strength Index (GSI) values were calculated and converted to Mohr–Coulomb strength parameters using the Hoek–Brown criterion. Backanalysis of known landslide scarps was used to derive strength parameters for brecciated rock masses and hydrothermally altered rock masses. Andesite lava flows have high intact strength ($\sigma_{ci}=184\pm50$ MN m^{-2}; $\gamma=24.7\pm0.3$ kN m^{-3}) and typically 3 wide, infilled joint sets, one parallel to flow direction and two steeply inclined, with spacings of 0.3–1.7 m. Joints are rough, with estimated friction angles for clean joints of $\phi_j=42$–$47°$. Joint infill materials are clayey silts derived from weathering of wall rocks and primary volcanic sources; they have low plastic (54%) and liquid (84%) limits and residual strength values of $c_r=0$ kN m^{-2} and $\phi_r=23.9\pm3.1°$. RMR values range from 70 to 73, giving calculated strength parameters of $c'=1161$–3391 kN m^{-2} and $\phi'=50.5$–$62.3°$. Backanalysis suggests brecciated rock masses have $c'=0$ kN m^{-2} and $\phi'=35.4°$, whereas GSI observations in the field suggest higher cohesion ($c'=306$–719 kN m^{-2}) and a range of friction angles bracketing the backanalysed result ($\phi'=30.6$–$41.7°$). Hydrothermally altered rock masses have $c'=369$ kN m^{-2} and $\phi'=14.9°$, indicating considerable loss of strength, especially frictional resistance, compared with the fresh lava units. Values measured at outcrop scale in this study are in keeping with other published values for similar volcanic edifices; backanalysed data suggest weaker rock mass properties than those determined at outcrop. This is interpreted as a scale issue, whereby rock mass characteristics of a large rock mass (crater wall scale) are weaker than those of small outcrops, due in part to the overestimation of friction angle from measurements on small exposures.

Keywords: Rock mass strength; Volcanic slope stability; Andesite; Hydrothermal alteration; White Island

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1. Introduction

White Island is an active stratovolcano situated in the Bay of Plenty, approximately 50 km offshore from the North Island of New Zealand (Fig. 1). The slopes of the crater wall are very steep, and appear to be quite unstable, especially the inner crater walls. Being within easy access distance from the mainland, White Island is a popular tourist destination, with daily guided tours of the crater floor being offered by several commercial ventures. Visitor numbers are thus high, yet the steep volcano slopes suggest that slope failure poses a real threat to activities within the crater. In order to assess the hazard associated with crater wall collapse, geotechnical data regarding the principal material units comprising the island's stratigraphy are essential.

Assessing the stability of an andesite stratovolcano is challenging as the geology is heterogeneous (Zimbelman et al., 2003), and active volcanoes also present a rather hostile working environment in which to study slope stability (Watters et al., 2000). In spite of these limitations, quantitative research into volcano stability has been pursued, with significant research developments taking place over the last decade. Authors, such as Voight et al. (1983), Elsworth and Voight (1995, 1996), Watters and Delahaut (1995), Voight and Elsworth (1997), Elsworth and Day (1999), Hürlimann et al. (1999, 2000, 2001), Reid et al. (2000, 2001), Voight (2000), Watters et al. (2000), and Zimbelman et al. (2003, 2004), have presented both theoretical considerations relevant to volcano stability assessment, as well as actual modeling of stability for volcanoes such as those in the Cascade Range (U.S.A.), Chile, Mexico, and Tenerife.

Various approaches to stability assessment have been undertaken, including remote sensing, geophysical work, geotechnical studies, and numerical modeling of edifice failure (Belloni and Morris, 1991; Reid et al., 2000; Watters et al., 2000; Zimbelman et al., 2003). Recently, Zimbelman et al. (2003, 2004) have suggested a volcano stability assessment method that involves geotechnical assessment of rock mass conditions, together with numerical modeling of edifice stability. This paper aims to derive geotechnical data

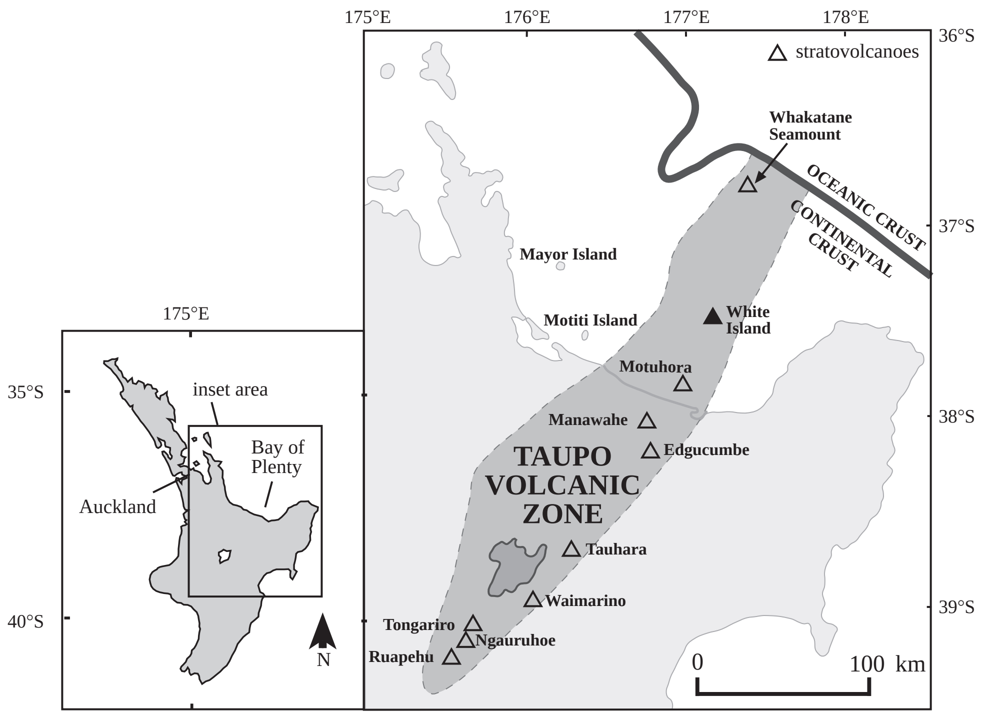

Fig. 1. Location map showing position of White Island within the Taupo Volcanic Zone, New Zealand. White Island lies approximately 50 km offshore of the North Island in the Bay of Plenty (after Cole et al., 2000).