The geology responsible for the recent slips on Maungakiekie/One Tree Hill

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Summary

Maungakiekie/One Tree Hill volcanic cone suffered 15 unprecedented landslips during a rainstorm in Jan 2023, whereas most of the other cones of Auckland had none or few slips. Examination of the stratigraphy exposed in the slip scarps shows that all were initiated at the outer edge of pre-European terraces and involved mostly water-saturated terrace fill and the underlying soil, held together by grass roots, flowing down slope. The water was unable to penetrate down through a thick mantling of hard clayey ash, that had been erupted from Three Kings Volcano 28,000 yrs ago, whereas on the other cones water drains away through the immediately underlying scoria.

Introduction

On Jan 27 Auckland was hit by a "weather bomb" or "atmospheric river" that dumped a city record of 240 mm of rain on the city in 24 hours. A few days later on Feb 1st a further drenching occurred. Many low-lying parts of Auckland were flooded and numerous coastal cliff slips were brought down by the usual culprits – the roots of large pohutukawa trees at the top of the cliffs could no longer hold the weight of the trees as the soil and weathered rock at the top of the cliff lost its strength when water-logged. The most unusual occurrence, however, was land slips on the steep slopes of Maungakiekie/One Tree Hill scoria cone.

This was the first time in living memory and possibly since the forest was cleared by humans that landslips have occurred here. Maungakiekie had 15 discrete landslips whereas a quick inspection of most of the other cones of Auckland showed that this was mostly a Maungakiekie phenomenon with one other obvious slip on Mt Albert' northern slopes. In an endeavour to determine why this was so, I spent several hours inspecting and mapping (Fig. 1) the Maungakiekie slips on Feb 10th, after 9 days of drying.

Distribution

The slips are most widespread on the northern and western slopes and all occur between 145 and 120 m above sea level on the steep (naturally 30°) slopes of the scoria cone. Nine occur on the outer slopes and six on the walls inside the two southern breached craters (Figs. 1-4). No slips are present where there is obvious lava flow fronts where viscous lava oozed out from the lower slopes of the cone, mostly around the southern, eastern and northwestern sides (Hayward, 2015).

Nature and stratigraphy exposed in the slips

All slips appear to have occurred where there are no trees on the slopes, except slip 9 (Fig. 5), which started above a large tree and has slipped around it, exposing scattered tree roots. The depth of all slips is shallow, typically the top 0.5-1 m of the ground (rarely up to 1.5 m) (Figs. 6-7). The material that has slipped, or flowed, is the long grass and its root zone plus some of the underlying soil and shell midden (Fig. 8). Almost always the top of the slip is at the outer edge of a man-made terrace and from there the slip extends down the slope (riser between terraces) for 5-10 m, often stopping at the back of the next terrace down (Fig. 6). Examination of several of the better-exposed scarps at the back of slips 1, 2, 6 and 14 (Figs. 9-11) showed the following stratigraphy (sequence of deposits, from bottom to top): >1 m thickness of slightly weathered hard, impermeable, clayey ash with dipping 1-3 cm thick

beds of hard, coarse volcanic ash (Figs. 10-11); overlain by 0.3-0.6 m of dark red-brown soil (Figs. 9, 11). This soil is overlain by 0.3-1.5 m of massive, cobbly soil containing angular cobbles, pebbles and granules of the underlying tuff (Fig. 9). This layer was thickest at the top of the slips near the terrace edge and thinned downslope. It was capped with abundant shell midden and modern soil.

Interpretation of the stratigraphy

None of the slips penetrated deep enough to encounter loose or weathered Maungakiekie scoria (erupted about 60,000 yrs ago) that the cone is largely made of.Thus everything exposed in the slips is a later addition. The bedded tuff is clearly Three Kings ash that was erupted about 28,000 yrs ago and is known to bury most of the One Tree Hill lava flow fields and was thought to possibly also mantle the steeper slopes of Maungakiekie (Hayward et al., 2011). This ash was erupted wet and as it dried out on the cone's slopes it hardened into the rock we call tuff. In some places (e.g. the steep lava flow faces around the eastern and southern sides of the maunga), most of this ash possibly was washed/eroded off the cone soon after eruption, but clearly this did not happen in everywhere. The thick dark-red soil on top of Three Kings tuff is inferred to be the soil that developed beneath native forest on the cone's slopes in the 27,000 odd years between Three Kings eruption and forest clearance by pre-European Maori. The massive, mixed cobbly layer is fill that was dug from the back of each terrace and deposited over the edge at the front of each terrace as they were cut into the naturally smooth slopes of the cone and the shell midden was later dumped over the top of this.

Inferred cause of the slips

A combination of factors has contributed to the slips. The unprecedented heavy rainfall water-logged the softer surface layers on the steep slopes and they failed. The material to fail was mostly fill that had been excavated from the back of the terrace above and used to built out the front of terrace by pre-European Maori, but also included some of the underlying soil. The above conditions occur on all the other cones where slips did not occur, but the one difference is that Maungakiekie was blanketed by thick volcanic ash from Three Kings, much of which did not wash off the steep slopes and instead hardened there into tuff. Near the surface this tuff has weathered into fine hard, impermeable clay which the rain water does not easily penetrate, unlike the loose scoria of the other cones. Te Kopuke/Mt St John and Ohinerau/Mt Hobson are also known to have been mantled with Three Kings volcanic ash, but being more distant would have received less ash than Maungakiekie, and likely a lot less still remains on the slopes of these two cones.

Thus the rain water-logged the upper loose soil layers, mostly of fill, and rain water could not penetrate deeper because of the Three Kings tuff. The grass roots held much of the water-logged soil together as it flowed and rolled downslope over the top of the hard Three Kings tuff.

References

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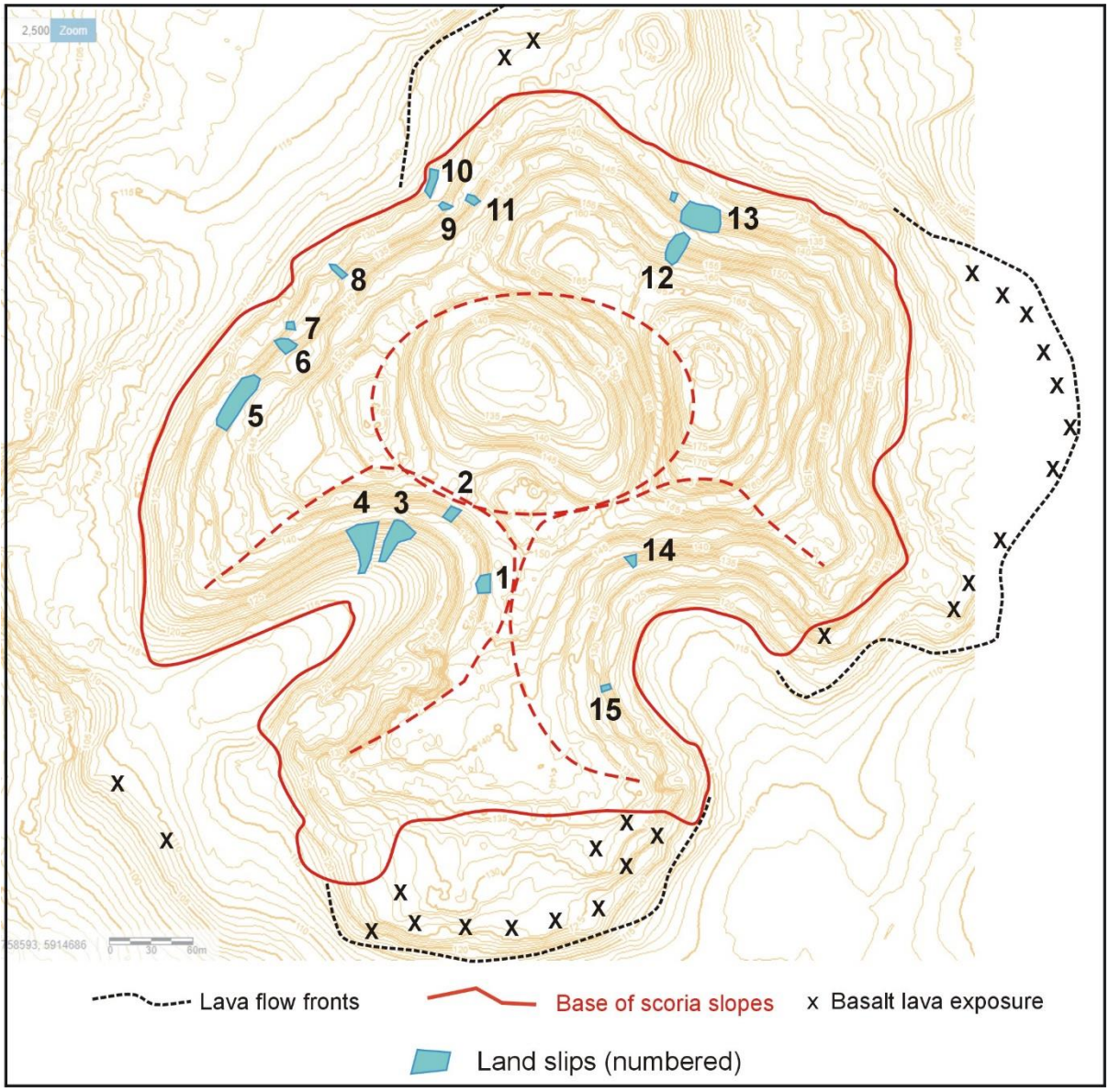

Fig. 1. Map showing the location and extent of numbered landslips on Maungakiekie cone.

Fig. 2. Slips 12 and 13 on the northern slopes, close to the Cornwall Park kiosk.

Fig. 3. The two largest slips (3-$) in the southwestern breached crater. Note how slip 3 (right) has started slipping at the top, just below the edge of the terrace above.

Fig. 4. The two small slips (14-15) in archery breached crater.

Fig. 5. Slip 9 is the only that has occurred near any tree, with some roots exposed by the slipping, which has started above and beyond the tree.

Fig. 6. Slip 1, in the southwest crater wall is an example of the kind of slips that have occurred on Maungakiekie, with failure of the rise between two terraces and only the upper 0.5-1 m of regolith failing and flowing down the slope with its toe extending across the lower terrace.

Fig. 7. Slip 6 shows the over steepened nature of the slope that failed and the shallow depth of regolith that has flowed down slope like a carpet of grass and topsoil developed in the terrace fill.

Fig. 8. Shell midden has been exposed and come down in most of the slips. Here in slip 1.

Fig. 9. Close up view of the upper scarp of slip 1 showing weathered fine tuff at the base overlain by darker red-brown soil in the middle overlain by terrace fill containing lumps of tuff dug out from the back of the terrace above by pre-European Maori.

Fig. 10. Stratigraphy exposed in slip 2 with obvious beds of harder coarse tuff within finer tuff (all erupted from Three Kings Volcano) in the lower part of the scarp. This is overlain by a darker red-brown soil and at the top the lighter terrace fill.

Fig. 11. Slip 7, on the western slopes, has exposed the freshest bedded Three Kings tuff (lower right) overlain by ref-brown soil and then lighter brown terrace fill.

Fig. 12. Looking up slip 12 which is a slope failure on the riser between two terraces.