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New Zealand's own Pompeii? The Sunde site, Motutapu Island, through a geoarchaeological lens

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Abstract

The Sunde site, at Pūharakeke on Motutapu Island, is one of New Zealand's most remarkable archaeological sites. Evidence of Māori occupation is deeply buried beneath tephra erupted from the adjacent Rangitoto volcano around 1397 CE, and fossil footprints of people and their dogs are preserved in between the ash layers. The eruption was clearly witnessed by Māori but surprisingly, no traditional account of the event appears to exist. Archaeological excavations undertaken in 1963 and 1981-2 have been interpreted as providing evidence that a kāinga (settlement) existed at the site at the time of the eruption. Claims that the occupants survived the eruption, and engaged in gardening activities between ash showers, have also been made. A review of the site from a geoarchaeological perspective reveals inconsistencies with key aspects of these existing narratives, primarily due to misidentification of geological structures and natural deposits as archaeological features. These include soft sediment deformation structures associated with dewatering of the tephra, and two marine inundation deposits. One of these is a possible tsunami washover deposit dating from the early 14th century CE; the other appears to be associated with a significant storm surge event during the mid-16th century.

***Keywords*:** Geoarchaeology; tephra; tsunami; seismite; modified soil

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1. Introduction

In 1981-2, Reg Nichol undertook excavations at the Sunde site (R10/25) on Motutapu Island as part of his doctoral research. Initial observations by Rudy Sunde in 1958, and a subsequent investigation in 1963 by Scott (1970), had shown the site to be both significant and early. The first phase of occupation was clearly buried beneath a deposit of tephra up to a metre deep. This tephra had erupted from the nearby Rangitoto volcano some hundreds of years ago. Publicity surrounding Scott's findings (Trickett 1973) drew parallels with the Roman town of Pompeii, and these continue to appear in popular media.

Nichol's research was primarily focussed on archaeozoology. However, during the course of the fieldwork he made a remarkable discovery. Progressive removal of layers of solidified ash revealed fossil casts of footprints of people and dogs preserved on the interfaces between the layers. This provided tangible and unequivocal evidence that Māori had been there while the volcano was active. Nichol also observed signs of disturbance within the tephra deposits. These he interpreted as attempts by Māori to create garden soils in the recently fallen ash, during pauses in the eruption. In addition, Nichol argued that further attempts were made to create modified soils by adding beach materials, after the eruptions had ceased.

The discoveries at the Sunde site created something of a sensation. Artists impressions (Gaskin 1990a, b) and a museum diorama (Davidson 1987: 43) portrayed a kāinga (settlement) with multiple whare (dwellings) and other structures located on the beach flat and subsequently buried under ash, in a scene reminiscent of Te Wairoa after the Tarawera eruption. But the idea that Māori living on Motutapu could have ignored a major eruption that was taking place nearby, survived the ash showers, and busied themselves with garden making, was widely met with incredulity (Nichol 1986: 136; 1988: 429, 436). Nevertheless, the purported evidence of gardening and soil modification has been cited in a number of academic and popular publications (e.g. Anderson and Petchey 2020: 359; Barber 2004:188; Hayward *et al.* 2011: 102; Hayward 2019: 55; Leach 1984: 49). Other authors of works on pre-European Māori gardening (Furey 2006: 51, 60; Gumbley 2021) appear, by omission, not to have been fully convinced by Nichol's interpretation of the site.

2. The Sunde Site

The Sunde site is located at West Point beach at Pūharakeke on Motutapu Island in the inner Hauraki Gulf (Figure 1, 2). The name Pūharakeke has been formally attributed to the West Point locality by Ngāi Tai ki Tāmaki (Auckland Council 2018) since the archaeological excavations were undertaken. Motutapu is a 1,510 ha island formed of Waipapa Terrane greywacke basement rocks, overlain by more recent Waitematā Group sedimentary rocks of Miocene age in the southwestern part of the island. It lies immediately to the northeast of Rangitoto Island, the most recent volcano in the Auckland Volcanic Field (AVF). West Point beach, on the western side of Motutapu, is separated by a sea gap of 1.5 km from the northern shoreline of Rangitoto.

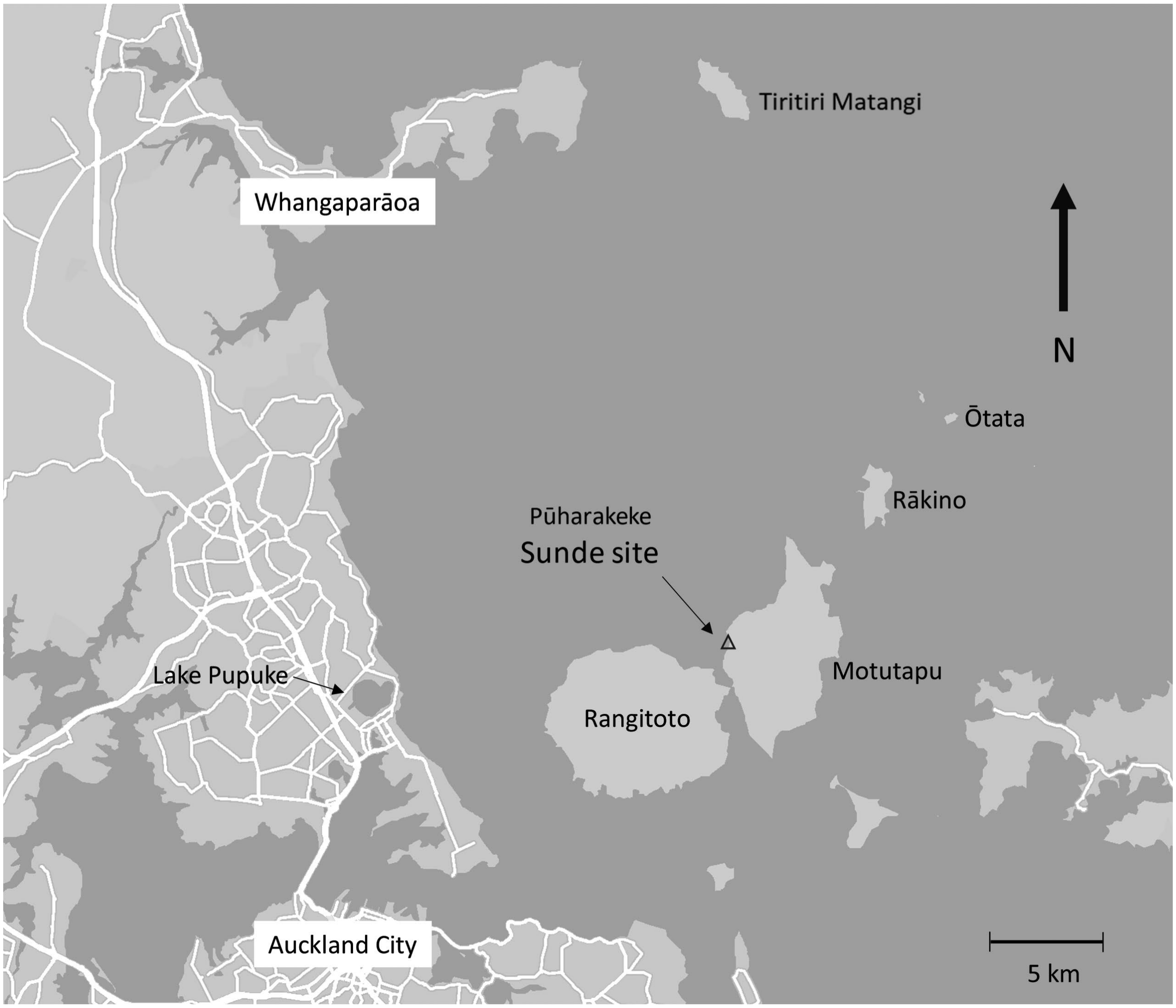

Figure 1: Location of Sunde site and other places referred to in text

Behind the beach is a coastal flat, through which a small permanent stream discharges onto the foreshore. Prior to the eruption of the Rangitoto volcano, the stream may have emerged up to 80m further to the north-east of its current position (Brassey 2009: 9). Midden deposits that predate the eruption are present on the surface of sand dunes that underly the tephra on the flat, to the northeast of the stream's present location, and are exposed intermittently in the back beach escarpment created by coastal erosion. The middens, including the 'oyster lens' midden investigated by Nichol, provide evidence for use of the site during the second half of the 14th century as a base for birding, fishing, and exploitation of a range of other marine and terrestrial food sources. Flake quality greywacke cobbles/boulders within the intertidal zone were also used to manufacture adze and chisel blades. Later use of the site and wider landscape after eruptions ceased is also evident. Indeed, the friable soils which developed from the air-fall tephra were well suited to traditional cultivation, and subsequently supported intensive Māori occupation on Motutapu.

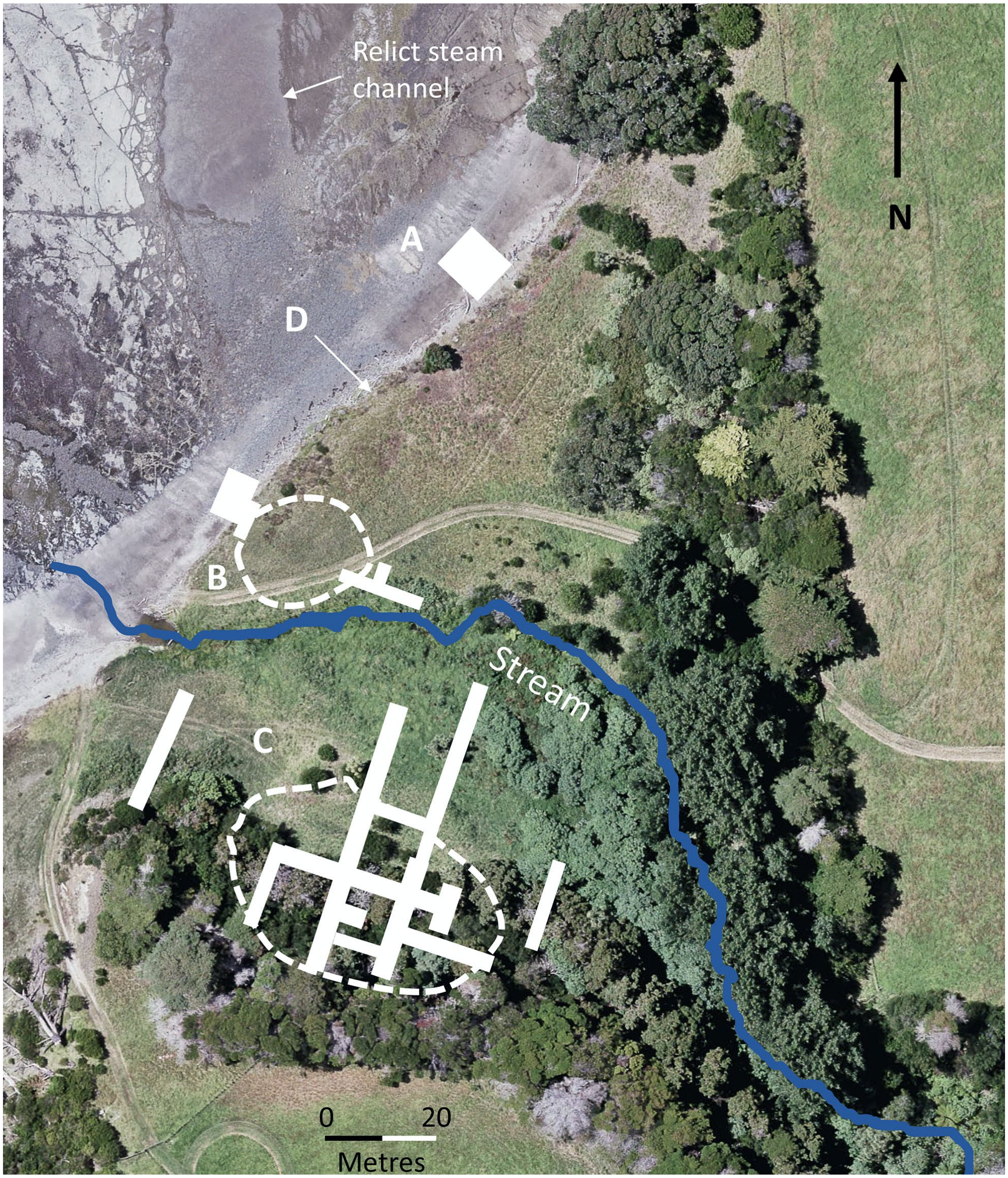

Figure 2: Pūharakeke/West Point beach (at low tide) and flat showing locations of the principal archaeological excavations and Nichol's gravel sheet (dashed circles). A: Scott 1963; B: Nichol 1981-2 North bank of stream, including 'oyster lens'; C: Nichol 1981-2 South bank of stream; D: Inundation deposit sample location (2009). The back-beach escarpment has retreated since the excavations of Scott and Nichol were undertaken.

As the coastline at West Point is vulnerable to episodic erosion associated with storm events, attempts have been made to protect the Sunde site, most recently by beach nourishment undertaken by the Auckland Regional Council in conjunction with the Department of Conservation in 2009 (Brassey 2009). This project provided a limited opportunity to re-examine the exposed face of the site and blocks of tephra detached by erosion. The observations undertaken during this work form the basis of the discussion that follows.

3. Archaeology of Motutapu Island

There is a dense and well-preserved archaeological landscape comprising nearly 400 recorded sites associated with Māori occupation on Motutapu Island. These include numerous undefended kāinga, 13 pā (fortifications), midden deposits, rua kūmara (storage pits), agricultural areas, and several sites associated with greywacke adze manufacture. There are several early 'Archaic' sites predating ca 1500 CE, including the nearby Pig Bay site (R10/22) (Dodd 2008). While the Sunde site is the only site on Motutapu where conclusive evidence of occupation predating the Rangitoto eruption has been identified, it is not unlikely that other sites from this period exist, or previously did exist.

4. Eruption of the Rangitoto volcano

Rangitoto Island did not exist when the Sunde site was first occupied. The eruption of the Rangitoto volcano commenced around 1397 CE with a violent explosive phreatomagmatic (wet) eruption of ash and steam, as basaltic magma came into contact with seawater in a shallow marine environment (Hayward 2017, 2019: 54; Needham *et al.* 2011). Air-fall tephra, designated Rangitoto 1, was deposited over much of nearby Motutapu, and over-water base surges also reached parts of the island (Cronin *et al.* 2018). The stratigraphy and archaeological evidence at Pūharakeke/West Point beach indicates that deposition of tephra was not a continuous event. Rather, the eruptions occurred in four major pulses interspersed by three pauses of undetermined but likely short duration. This first phase of the eruption also involved eruptions of scoria, which produced the north scoria cone on the Rangitoto volcano, but these did not reach Motutapu.

A longer hiatus was followed by a second phase, which included a smaller eruption of tephra (Rangitoto 2) of different geochemical composition. The tephra has been dated to around 1446 CE, although there are indications that the time gap was potentially much shorter (Needham *et al.* 2011: 127). This eruption also produced the lava flows and the main and southern scoria cones of the Rangitoto volcano, largely burying the earlier cone and producing the characteristic shield shape that exists today (Hayward 2019).

The first eruptive phase deposited in total up to a metre of tephra, comprising four substantial layers, at Pūharakeke/West Point beach. Nichol designated these layers Ashes 1 – 4, 1 being the earliest. Nichol (1981: 239) also noted multiple thin bands of coarse ash above Ash 4. This is possibly the Rangitoto 2 tephra, which is also present at the Sunde site (Figure 3). During Scott's earlier excavation, which focussed on a natural terrace at the base of the hill slope at the northern extent of the site, the tephra was largely left in situ and no internal stratigraphy or later deposit was noted (Scott 1970: 16).

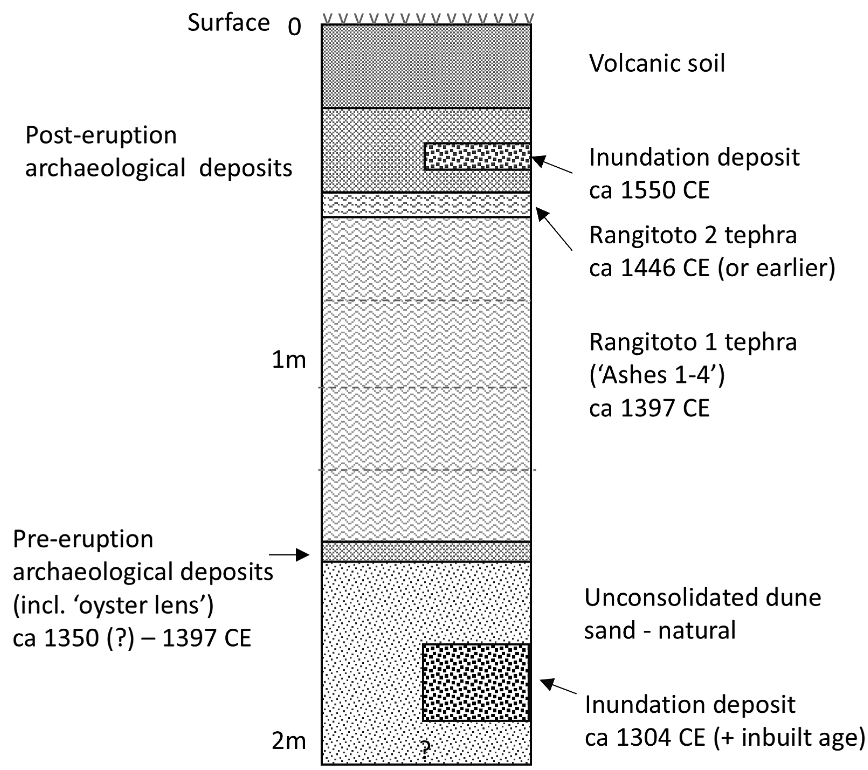

Figure 3: Composite stratigraphic column showing the relationship between natural and cultural deposits at the site

The total duration of the ash showers associated with the first eruptive phase appears to have been short, perhaps no more than a few weeks. There is evidence, discussed below, that the tephra layers deposited at Pūharakeke/West Point remained saturated with water and did not have an opportunity to dry out and lithify prior to the end of this phase. Another indication that little time elapsed between the ash falls are the remarkably well-preserved surfaces of ash layers 1-3. Apart from the human and dog footprints, and the purported evidence of gardening, intact interfaces between layers show little sign of bioturbation, erosion, or deposition of organic material or windblown or alluvial sediment indicative of prolonged exposure. Furthermore, the distribution of tephra deposits on Motutapu Island and extending to Rākino Island (site R10/1292) and Ōtata in The Noises islands (R10/139), is strongly directional. Only trace amounts are present, or at least reported, in other directions (Hayward 2019; Horrocks *et al.* 2005; Needham *et al.* 2011: 127-8). This points to winds being from a persistent south-westerly direction for the duration of the phreatomagmatic eruptions. This is the predominant airflow direction in the Hauraki Gulf, particularly during winter and spring. However during summer-early autumn the proportion of winds from the northeast increases, and sea breezes add to the proportion of easterlies (Chappell 2014: 13; MetOcean Solutions 2019). The lack of evidence of winds originating from these directions is consistent with the first eruptive phase taking place during the cooler months, rather than summer-early autumn.

5. Gardening between the ash showers

After initially detecting the fossil footprint casts, Nichol opened up trenches to progressively strip off the tephra layers and follow the tracks of the prints (Figure 2). Excavating across the face of the tephra, which sloped towards the sea, Nichol encountered parallel linear rows of hummocks with an amplitude of 10-15cm, about 70 cm apart, and in rows about 70 cm apart and following the line 20-200° magnetic (Nichol 1981: 248; 1988: 414). Nichol also found patches of disturbance on the surface of Ash 1. These he noted were generally associated with the hummocks in the ash. Nichol interpreted these as the remains of a garden made by digging sand into the surface of Ash 2 (Nichol 1981: 252-3). The source of the sand was not identified, but Nichol considered that borrow pits were probably dug into the dune sand upon which the tephra was deposited.

Along with the footprints of a small group of adults, children and their dogs, Nichol found three holes in the surface of the tephra. These he interpreted as evidence of the use of a forked digging stick and a spade, and the tracks of footprints, the result of people engaged in gardening activity. Nichol also observed 'streaks of red sand like that below the ash' on the surface of Ash 2 (Nichol 1981: 239).

5.1. Analysis and alternative interpretation/s

Observations made during the 2009 site protection works provide an alternative explanation for the disturbance of the tephra, and potentially for some other features identified by Nichol as being of anthropogenic origin. Examination of the back-beach section through the tephra and dunes revealed the presence of soft sediment deformation structures (SSDS) (Figure 4, for example). These are clearly natural features, and are associated with dewatering of the underlying dune sand. Excavation records in Nichol's thesis (Nichol 1988) confirm that SSDS are indeed what Nichol encountered. His photographs of patches of disturbance (Figure 5) unambiguously show that the sand supposedly added to hummocks in the ash was in fact injected upwards from the dunes below. The 'hummocks' overly dewatering structures and are blisters that are clearly associated with deformation from below, while the 'streaks of red sand' occur where liquified sand has spread laterally along interfaces between the major ash layers.

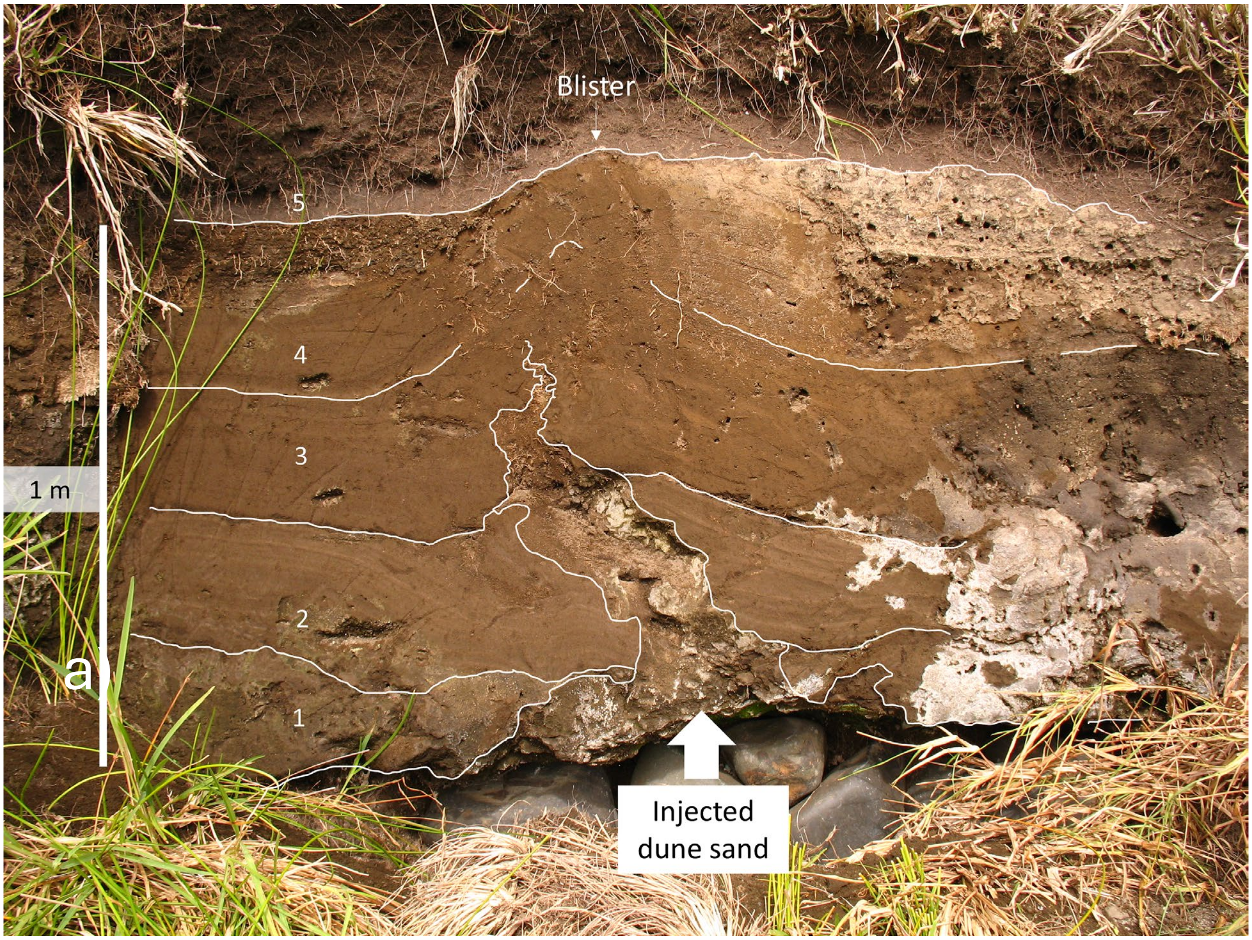

Figure 4. Fluid-escape SSDS and associated blistered surface ('hummock') exposed at the Sunde site, 2009. Layers 1-4 comprise consolidated Rangitoto 1 tephra and approximate the four layers identified by Nichol. Layer 5 is unconsolidated ash from the second phase Rangitoto 2 eruption (Needham 2009). The dune sand underlying the tephra had recently been eroded out by wave action at the time this photograph was taken.

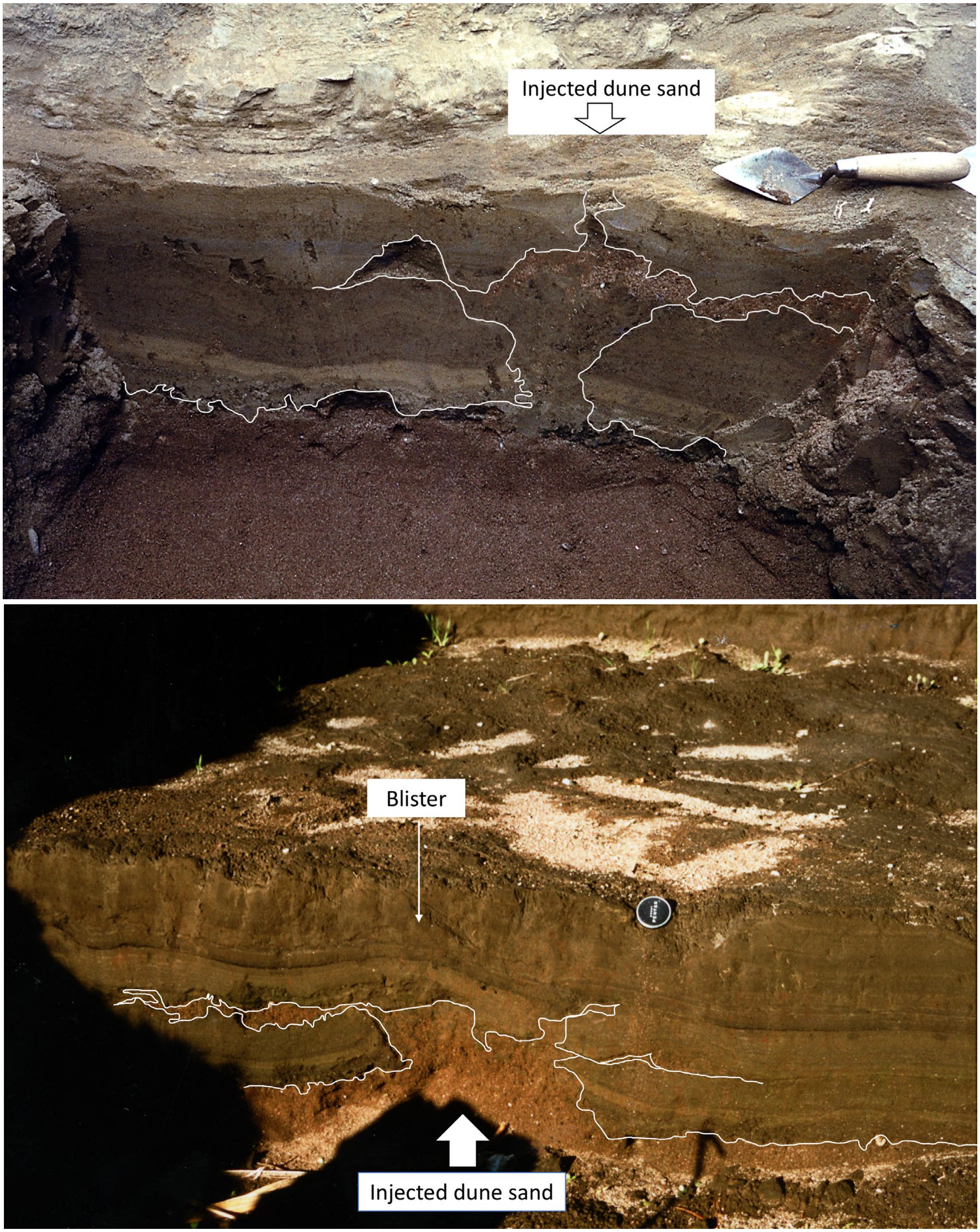

Figure 5: Examples of small fluid escape SSD structures visible in Nichol's 1981-2 excavation photographs. Source: Nichol (1988: 434), markup added.

SSDS develop during the initial stages of consolidation in sediments that are water saturated and buried at shallow depth (Alessandretti *et al.* 2020). They can exhibit a range of different morphologies, with those observed at the Sunde site best described as fluid-escape or injection structures (also known as diapirs). They have formed during the liquefaction-induced upward escape of pore water as a sediment-water mixture, from the underlying dune sand.

Factors involved in the development of the SSDS at the Sunde site can be inferred to be overloading (also known as loading consolidation) during the rapid deposition of the dense, less permeable tephra on top of the unconsolidated sand; combined with a rapid increase in pore water. The latter was potentially derived both from compaction seepage from the waterlogged tephra, and escape of stream water into the underlying dune sand. As the stream outlet and foreshore became choked with ash, the ponded water was likely forced into the highly porous sand and unable to easily escape through gravity.

Liquefaction and formation of SSDS in waterlogged unconsolidated sediments, including tephra, can also be generated by moderate to strong (magnitude ≥ 4.5–5.0) seismic shaking (Yu and Miaou 2013). The resulting structures are known as seismites. A well-publicised example is the seismites that developed in parts of Christchurch during the 2010-11 earthquakes. These 'sand volcanoes' were highly variable in size but ranged mostly from 0.5 to 2.0 m diameter, with the cones often aligned in places (Bastin *et al.* 2015; Reid *et al.* 2012).

While seismic activity is a common feature of volcanic eruptions or unrest, volcanic earthquakes, particularly those associated with shield volcanoes, are typically weak. However, this is not always the case (Nishimura 2018). Moreover, they can be more intense close to the source and when they are connected with explosions or magma flow during an eruption, when the focus is at shallow depth (Zobin 2001). The eruption of the Rangitoto volcano was influenced by the Islington Bay Fault, a major basement fault that passes between Rangitoto and Motutapu (Luthfian *et al.* 2023). Activity along the Islington Bay Fault is another potential source of seismicity at the time of the eruption.

Identification of palaeoliquifaction features as seismites can be problematic since similar structures can be generated by either seismic or non-seismic events, and the triggers are not preserved (Moretti *et al.* 2014; Shanmugan 2016). However, as the Sunde site structures are contemporaneous with the eruption of the Rangitoto volcano, and the blisters/hummocks are reportedly aligned, the possibility that seismic shaking during that eruption triggered the formation of the SSDS observed at the Sunde site should be further explored.

Other features within the tephra identified by as being of anthropogenic origin by Nichol must also be regarded as questionable. Shallow, inter-cutting, truncated and infilled circular bins or small huts found in the tephra appear from Nichol's descriptions and records (Nichol 1988: 377-388) consistent with patches of disturbance created by liquefaction, rather than unusual cultural features of unknown function dug into wet mud (i.e. saturated freshly fallen tephra) and in some cases through to the sand, during an eruption. Features identified as truncated postholes in the tephra are potentially vertical dewatering pipes. Small items of cultural material and charcoal noted by Nichol in or between layers (1988: 422-3, 474) may have been transported from the underlying dune surface during injection of the liquified sand through the tephra sequence. The supposed digging implement holes identified by Nichol are consistent with moulds of branch wood material, perhaps from shrubs growing on the beach flat that were destroyed and buried during the base surges and ash eruptions. Such voids are not uncommon in the tephra (pers. obs.). Possible evidence of a tidal surge and small tsunami between eruptions (Nichol 1988: 466; 471-2) must also be reconsidered as doubtful in light of the unrecognised evidence of disturbance of the tephra by SSDS.

6. The gravel sheet 'plaggen soil'

Nichol (1988: 368-71) observed an extensive sheet of water (beach) rolled greywacke gravel & shell within a yellow soil, that post-dated the tephra layers at the Sunde site (Figure 3). A radiocarbon date (NZ 6954) on shell within the deposit produced a calibrated radiocarbon age of 1535 CE (1450-1620 at 2s). The full extent of the gravel sheet was unable to be defined. It was clearly present on both banks of the stream, near the mouth (Figure 2) (Nichol 1988: Fig. 9.5). Nichol estimated its extent to be several hundred square metres.

Analysis of the introduced material present in the soil revealed the grain size distribution of the gravel sheet to be somewhat different to material found on the adjacent beach at the time of the excavation, with a slight weighting towards finer material. Nichol suggested that the 'added' gravel might have been picked over to remove larger stones. Mollusc species present were broadly similar to those found on the beach.

The gravel sheet was not encountered during Scott's 1963 excavation, which was located beyond the extent defined by Nichol (Figure 2), and at a higher elevation above sea level (Scott 1970: Fig. 1, 16).

6.1. Analysis and alternative interpretation/s

Addition of gravel or sand to gardens by Māori has been well documented in parts of New Zealand, notably in the Waikato. It is often associated with the growing of Polynesian cultivars, primarily kūmara, in marginal locations (Gumbley 2021). However, there are few if any compelling reports of this practice having taken place in the temperate to subtropical Auckland region (Nichol 1988: 488; Sullivan n.d.: 79), where there are extensive areas of friable volcanic or sand-based soils that are ideal and clearly were favoured for, growing kūmara. At this point in time in the natural history of Motutapu (i.e. around 150 years after the Rangitoto 1 eruption), soils would have developed from the ash deposits. As Nichol has acknowledged, these soils and the climate on Motutapu were very well suited to cultivation by Māori. The main limitation associated with such soils is their coarse sandy texture and inability to retain moisture (Wright *et al.* 1951). Adding sand and gravel would further diminish that capacity and be counterproductive. An anthropogenic origin for the gravel sheet therefore seems unlikely.

Nichol's conclusions based on grain size analysis of the gravel sheet and of the adjacent beach cannot be relied upon. Accessible beaches on Motutapu have been modified by the extraction of materials for construction and roading during the first half of the 20th century by commercial enterprises, and for the construction of defence installations and infrastructure during World War 2. Pūharakeke/West Point beach was identified in 1926 as an available source of "large quantities of hard black shingle", which no longer exist. This is attributable to removal by quarrying, and a subsequent lack of natural replenishment. The latter is due in part to changes in local coastal processes since the emergence of Rangitoto (Brassey 2009: 12-13), leaving slow erosion of resistant greywacke in situ as the only significant source of clasts larger than sand. Therefore differences in grain size distribution between the gravel sheet and the 1980s beach cannot be used as evidence of selective gathering or removal by Māori. Even without this complication, the absence of larger stones would not exclude the possibility that the gravel sheet was a natural deposit, since the size of clasts that can be transported by marine events is proportionate to the wave energy, which in this case may have been insufficient to mobilise clasts larger than those observed by Nichol.

The ca 16th century beach gravel spread over the back-beach flat has clearly originated from the adjacent beach, so if it was not emplaced by Māori, then the only potential mechanisms that could carry beach materials inland at that scale are a storm surge, or a tsunami event. The distribution of the Sunde site gravel on either side of the stream near its mouth is consistent with deposition during a marine inundation/washover during which onshore wave energy was channelled inland through the lowest point in the back beach escarpment, up the stream bed and over the flat.

This would have required a significant event. Pūharakeke/West Point beach is not directly exposed to wave energy from the southwest as the fetch from this direction is largely blocked by Rangitoto Island, which existed in its present form in the 16th century. The shoreline is exposed to wave energy from episodic tropical storms, typically from the northern and north eastern sectors, and the effects of these can be increased when they combine with higher tide levels. However, wave energy from northerly directions is partially dissipated by a wide surrounding inter-tidal wave cut platform (Figure 2). The maximum nearshore significant wave height, based on the extent of fetch to the north-west, and a windspeed of 60 mph (100 km/h) is estimated to be 1.6 m during high water levels, with the worst-case scenario being a significant wave height of about 1.9 m from that direction (Brassey 2009: 11). Even allowing for potentially different beach and shoreline profiles prior to the mid-16th century, it would require an extraordinary storm surge to cast a sheet of beach material over the flat.

Perhaps the most compelling evidence that the Sunde site gravel sheet was deposited during a marine event is the existence of an inundation deposit at a contemporaneous archaeological site at Wharf Bay on Tiritiri Matangi Island to the north of Motutapu Island. Excavation of site R10/279 in 1997 revealed the presence of a layer of marine gravel sandwiched between two cultural layers (Layers 5 and 3) (Brassey 2024). Calibrated radiocarbon ages for these cultural layers below and above the deposit are 1550 CE (1450-1650 at 2s) [Wk 5803] and 1555 CE (1460-1650 at 2s) [Wk 5868] (McIvor 2024). These dates accord well with that of Nichol (i.e. 1535 CE), particularly when the inbuilt age of the beach shell in that sample is considered. Events of this magnitude are clearly infrequent in the inner Gulf, since there appear to be no other inundation events represented in the post-1400 CE stratigraphy at either site.

In order to test the proposition that the gravel is an isochronous deposit present in both sites, a Bayesian analysis was undertaken of the sequence of 15 radiocarbon and obsidian hydration rind age determinations from the Tiritiri Matangi site, together with Nichol's NZ 6954 date (McIvor 2024). This confirmed that it is chronologically plausible that the gravel sheet at the Sunde site dated by NZ 6954 is the same layer observed as Layer 4 in the Tiritiri Matangi site. The modelled age for the event that deposited the gravel is 1490–1570 CE at 2s. Allowing for some inbuilt age on the beach shell, this suggests that the event occurred around 1550 CE.

Whether the Tiritiri deposit (and by inference the Sunde gravel sheet) was the result of a storm surge or a tsunami as proposed by McFadgen (2007: 145) is difficult to determine without further research, including a review of other potentially related known inundation deposits (e.g. de Lange and Moon 2007). A potential location to detect further intact evidence associated with the Tiritiri/Sunde site event exists along the unprotected north-facing coast of Rangitoto Island. This coastline is formed of erosion-resistant basalt, which helpfully provides a terminus post quem of ca 1400 CE for any overlying material. To the northwest of Boulder Bay this includes marine deposits with sand, shell and large water-rounded boulders up to and exceeding 40 kg perched on basalt flows at an elevation of 4-6m or more above mean sea level (per. obs.).

7. Pre-ash inundation deposit

Nichol (1988: 351) uncovered a layer of rounded pebbles on a sandy slope in the dunes underlying the Rangitoto 1 tephra. The pebbles, which Nichol interpreted as a pavement, were found just to the north and seaward of the oyster lens which was the primary focus of his investigations. The stratigraphic relationship between the pebbles and the 'oyster lens' midden is unclear from Nichol's description. However, his use of the term 'pavement' suggests that it was below the midden. During the period from 2000 - 2009, bird bones were observed to be eroding from an apparent natural context 250mm below the base of the ash and underlying midden in the dunes in this general area (Figure 2, 3) (pers. obs.). No correlative of either deposit/feature was found on a natural terrace surface around 2 m above high water mark that was the focus of Scott's 1963 excavation at the northern end of the bay.

The source of the bird bone was investigated during the 2009 erosion control work. It was identified as another, earlier, inundation deposit which predates the archaeological evidence of use of the site by Māori (i.e. the midden) during the second half of the 14th century (Figure 3). There is some evidence to suggest that it was emplaced during a tsunami washover.

The exposure of the deposit in the back beach escarpment was examined and found to comprise coarse shelly beach sand, cobbles, gravel and cockle (*Austrovenus stutchburyi*) shell, along with a well-preserved catastrophic death assemblage of white-fronted terns (*Sterna striata*). A 0.023 m3 sample of the deposit excavated from the back beach section contained a minimum of 17 adult birds.

The concentration of terns, in particular, is consistent with a tsunami deposit. This species typically roosts and nests in dense colonies in low-lying locations that are vulnerable to flooding. They are reluctant to leave their nests during rising water levels, and their plumage is not water repellent. Colonies of white-fronted terns also have a habit of facing into the prevailing wind (Guthrie-Smith 1925; New Zealand Birds Online n.d.). While adults could readily vacate a colony during the gradual rise in water level that precedes a building storm, they would be at risk during a tsunami inundation, particularly during the nesting season. The vulnerability of seabird colonies during tsunami events was dramatically demonstrated during the 2011 Tōhoku tsunami, which killed 280,000 albatrosses and petrels on Laysan and Midway atolls (Reynolds *et al.* 2017).

A radiocarbon age determination (NZ 25535: 1304 CE, 1222-1385 at 2s) from cockle shell (fresh in appearance but non-articulated) present in this deposit indicates that it was emplaced in or around the early 14th century. This date, allowing for some inbuilt age, is consistent with the estimated close date range of 1305-1345 CE (McFadgen 2007: 222) for the eruption of the James Healy seamount, a submarine volcano at the southern end of the Kermadec Trench. McFadgen's age range is based on the arrival of the sea-rafted Loisels pumice, which appears to have originated from that eruption, on New Zealand shores.

Pumice lapilli are abundant within the pre-ash archaeological sequence at the Sunde site, but the age of initial arrival was unable to be clearly defined during the 2009 beach protection works. However, as pumice was not observed in the dune sand underlying the inundation deposit, while small amounts were present within the overlying sand, this also appears consistent with McFadgen's close date range. The presence of lapilli within the subsequent midden horizon (the stratigraphic equivalent of Nichol's "oyster lens") can be attributed to ongoing or subsequent release of pumice from the James Healy seamount or another source, or persistence or remobilisation of earlier strand deposits in the environment up until the time of the Rangitoto eruption. Since the lapilli underlie the Rangitoto 1 tephra, this provides an earlier minimum age of 1404 CE (at 2s) for the arrival of Loisels pumice than previously reported by McFadgen (2007: 70), i.e. 1440 CE.

8. Overall interpretation of the site

The Sunde site was once portrayed as a "prehistoric Pompeii village" from which the terrified inhabitants fled in panic, leaving behind most of their possessions as the "cataclysmic eruption" overwhelmed their settlement (Trickett 1973). This perception has been reinforced by the artists impressions and diorama of the site depicting a kāinga with substantial-looking whare and other structures on the beach flat prior to the eruption, and largely buried afterwards. This long-standing interpretation of the site, inspired by the findings of Scott and in particular some of the claims made by Nichol, has remained unchallenged. Indeed, it has been widely disseminated in print, online, and in museum and visitor centre displays, and elements of Nichol's interpretation of the site have appeared in iwi narratives (Ngāi Tai ki Tāmaki 2015: 11).

In reality, neither Nichol nor Scott found post moulds or building elements attributable to such structures, nor did they find assemblages of abandoned functional tools or other cultural items. Indeed, Nichol (1981:252) concluded that the part of the site on the south bank of the stream, which he initially thought had been the living area at the time of the eruption, was unlikely to have been occupied when the ash falls commenced. Nichol eventually reached the conclusion that the occupation at the Sunde site represented a temporary seasonal campsite associated with the preservation of fish and birds for consumption elsewhere (Nichol 1988: 357). However, this interpretation of the site only appeared in his thesis and was never published. Meanwhile, Nichol continued to assert that the fossil footprints provided evidence that people were able to survive the effects of the ash eruptions (1981: 254; 1988: 475), and "had been in residence in the valley at the time the ash fell, or had been very close to it…" (1988: 414). This cannot reasonably be inferred from any existing archaeological evidence.

8.1. Analysis and alternative interpretation

The Sunde site is located a short (ca two hour) waka trip from the mainland, where there were soils well suited to traditional cultivation, for example in the Devonport-Takapuna or Tāmaki Isthmus areas. As Nichol pointed out, such locations would have provided more suitable places for primary settlements or "home bases". This settlement pattern, involving seasonal movements between winter settlements with gardens, and temporary campsites at coastal or island locations, characterised settlement patterns during the late period (late 18th and early 19th century) in Tāmaki (Nichol 1988: 356; Sullivan n.d.).

The archaeology and context of the Sunde site prior to the Rangitoto eruption is consistent with a seasonal campsite, likely occupied periodically during the summer in cycles of resource depletion and recovery, and visited to procure greywacke for adze manufacture at other times as required. It does not provide evidence that Motutapu was permanently occupied at this time, or that Māori were on the island during ash eruptions and were able to survive the effects of these.

The presence of well-preserved dog coprolites adhering to the base of the tephra gives the impression that the site location had been recently visited prior to commencement of the ash eruptions, as it clearly was during subsequent pauses between ash showers. These visits may well have been brief, inspired by curiosity (Nichol 1981: 254), or a desire to observe the volcanic activity and its effects from a perceived safe distance.

9. Conclusions

Nichol was undertaking investigations at the Sunde site during a period that followed McFadgen's (1980) influential research on plaggen soils of Māori origin. McFadgen's work had generated heightened enthusiasm for locating, recording and investigating soils that had potentially been modified. During excavations at the Sunde site, perturbation associated with natural dewatering structures within Rangitoto tephra deposits has been misidentified as archaeological evidence of gardening and other activities and features, and this has influenced interpretation of the site. It is unlikely that such geological structures had ever previously been encountered in an archaeological context in New Zealand, so it is perhaps understandable that they could be mistaken for anthropogenic features.

A later gravel sheet interpreted by Nichol as a modified/plaggen soil is also likely to be a natural feature, deposited during a storm surge or tsunami washover that occurred around the mid-16th century. In addition, Nichol seems to have also encountered an early 14th century marine deposit, but misidentified this as a pebble pavement. While such features are not archaeological, they do contribute to an understanding of the site context, and are a pertinent reminder that the Sunde site has many layers of significance. This is reflected in the statutory recognition and protection afforded to the site and its setting in Auckland's planning framework for its outstanding natural heritage, landscape and historic heritage values; and its considerable significance to Ngāi Tai ki Tāmaki associated with the presence of tangible evidence of Māori ancestors in the form of tapuwae (footprints).

The Sunde site is not the only New Zealand archaeological site buried beneath or containing tephra deposits (Lowe *et al.* 2000; Nichol 1988: 355; Worthy & Brassey 2000). The archaeological remains at the Sunde site are, however, exceptionally well preserved due in part to the characteristics of the overlying lithified tephra. Together with the wider site context, they have contributed much to our knowledge of the Rangitoto volcano and the AVF generally.

There is clearly more to be learnt from the site about other past natural events, including coastal inundations. Deposits associated with such events can be of considerable archaeological value as isochrons. Documentation of the presence (or absence) of dateable storm surge and palaeotsunami deposits in archaeological sites and their contexts, and application of analytical techniques such as hindcasting (recreating and evaluating climatic and other events that occurred in the past), also has the potential to provide data that may be unavailable from other sources. The knowledge generated can make an important contribution towards predicting future events and hazards, and managing the risk to coastal communities and development, particularly in densely populated places such as the Auckland region (Clark & Morgenstern 2022).

Radiocarbon age calibration

Radiocarbon ages cited in relation to the gravel sheet (NZ 6954, Wk 5803, Wk 5868) were calibrated using the SHCal20 (Hogg *et al.* 2020) and Marine20 (Heaton *et al.* 2020) curves in the OxCal v.4.4 program (Bronk Ramsey 2009). Wk 25535 was calibrated using OxCal v3.10 (Bronk Ramsey 2005) and a Delta R value of 31 +/-13.

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Data Availability Statement

Data sharing not applicable – no new data generated

Partnerships

This research did not use any primary data from indigenous contexts. Engagement with iwi and interested or affected parties was undertaken prior to the beach nourishment works undertaken in 2009.

The scope and outcome of that engagement is detailed in Brassey (2009: Appendix 5: Record of consultation).

Conflicts of Interest

The author declares no conflicts of interest

Author Contributions

Conceptualisation, R.B.; investigation, R.B.; writing—original draft preparation, R.B.; writing—review and editing, R.B.; visualisation, R.B.

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