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Prehistoric Horticultural Adaptation of Soils in the Middle Waikato Basin: Review and Evidence from S14/201 and S14/185, Hamilton

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ABSTRACT

The middle Waikato basin contains extensive evidence, reviewed here, for the modification of soils for horticulture (gardening) by pre-European Maori. We investigated an area of Maori gardens at archaeological sites S14/201 and S14/185 in Hamilton City. Two groups of multiple, near-circular hollows, each about 0.3 m in diameter and infilled with gravelly sand, were exposed during the site excavations. The hollows, extending through modified A horizon materials into upper B horizon materials, are interpreted as representing the lower part of small truncated mounds (puke) that had been built up by early Maori for growing kūmara (*Ipomoea batatas*). The hollows were grouped in a distinctive quincunx-like pattern in which four hollows formed the corners of a square with one hollow in the centre. The characteristics and layout of the hollows match historical descriptions of mounds used by Maori gardeners. We also used particle-size analysis to quantify the extent to which upper horizons of the antecedent soils had been modified by the addition of gravel and sand excavated from borrow pits in adjacent volcanogenic alluvium (Hinuera Formation). A radiocarbon date obtained from charcoal found in a fireplace under the modified A horizon and near the hollows suggests that the site was occupied in the late fifteenth century. Identification to species level of charcoal fragments found in the modified soil suggests that site S14/201 may have been cleared of large podocarp trees not long before gardening activities began. This conclusion is supported by similar evidence from another site on the same stretch of the Waikato River. If so, such late (localised) deforestation contrasts with evidence from other palaeoenvironmental studies that shows regional deforestation began considerably earlier (about AD 1300) in the Waikato region.

Keywords: MAORI GARDENS, PLAGGEN SOILS, ANTHROPIC SOILS, PREHISTORIC HORTICULTURE, KŪMARA, PUKE, BORROW PITS, WAIKATO, HAMILTON, TAMAHERE SOILS.

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INTRODUCTION

The archaeological study of prehistoric horticulture, or Maori gardening, is one of the enigmatic aspects of New Zealand prehistory. It is reliant on inference from indirect evidence perhaps more than any other area of New Zealand's prehistoric archaeology. Very few physical remains of cultigens have been found in archaeological contexts and rarely in a prehistoric garden area (e.g., Horrocks *et al*. 2000). Instead, we rely upon inferring the function of archaeological features such as storage pits, stone rows, and the properties of modified soils to interpret the development of prehistoric gardening through time and across New Zealand. Historical and ethnographic sources (e.g., Colenso 1880; Best 1976) have provided additional information.

The majority of sites that provide evidence of prehistoric gardening are coastal. The most extensive inland area containing evidence of such gardening, primarily for growing kūmara (*Ipomoea batatas*), is in the Waikato region. Here, the archaeological evidence is found in both the middle and the lower Waikato basins (Selby and Lowe 1992) and is dominated by sites comprising soils modified by early Maori by the addition of coarse volcanoclastic alluvium. These Maori-modified soils cover about 3000 ha of the middle Waikato Basin (Grange *et al*. 1939; Taylor 1958; Clarke 1977). Several writers have suggested that the addition of alluvial materials improved the friability and heat retention of the soil, reduced the likelihood of frost damage, improved fertility, provided a disease-free growing medium, and created a sharp interface between the added materials and buried horizons to encourage larger tuber formation (Best 1976; Singleton 1988). Together these modifications made soils more suitable for growing the subtropical kūmara in New Zealand's temperate environment (Taylor 1958). It is also possible that the addition of gravels and sand to topsoils annually may have become a religious or traditional requirement, following Pacific Island custom, with the new material providing a clean, undefiled medium in which to grow the sacred kūmara (Allbrook 1997).

Such modified soils have been referred to variously as 'Maori soils', 'plaggen soils', 'anthropic soils', 'modified soils', 'man-made' or 'made soils', and 'created soils' (e.g., McFadgen 1980; Singleton, 1988, 1991). In the New Zealand Soil Classification (NZSC) (Hewitt 1998), they are usually classed as Artifact Fill Anthropic Soils where material ≥30 cm in thickness has been added to the original soil, or as Mixed Anthropic Soils where the characteristics of the original soil horizons have been largely destroyed by deep subsoil excavation or some similar practice. In some studies, Maori-modified soils have been mapped as named soil types within a defined series but qualified with the name of the original soil series. For example, many Maori-made soils in the middle Waikato Basin are classified in the Tamahere series, the two named soil types being 'Tamahere gravelly sand (on Horotiu soils) (Mh)' or 'Tamahere gravelly sand (on Waikato soils) (Mw)' (Bruce 1978, 1979). In this paper we refer to them as plaggen soils and the archaeological context within which they occur as Maori gardens.

PREVIOUS ARCHAEOLOGICAL STUDIES OF MAORI GARDEN SOILS IN NEW ZEALAND

The archaeological literature on Maori gardens is dominated by discussion of field systems (Leach 1979, 1984; Sullivan 1972, 1974) and modifications to the antecedent soils. It is the latter which is the subject of this investigation.

Plaggen soils are those whose characteristics are changed by the addition of gravel or sand, or both, either (1) to the surface as mulch (or puke [mounds]), or (2) well mixed into the upper part of the soil (i.e., topsoil and upper subsoil parts of the profile). These soils have been found all over New Zealand, more commonly in coastal areas or river flats and terraces (Rigg and Bruce 1923; Law 1968, 1975a, 1975b; Peters 1975; McFadgen 1980; Nichol 1981; Walton 1982; Horrocks *et al*. 2000; Trotter and McCulloch 2001). In the middle Waikato Basin, sands and gravels were added to a range of pre-existing soils, especially the Horotiu soils (formed on *ca*. 18,000–20,000-year-old volcanogenic alluvium [Hinuera Formation] overlain by a cover of thin, multiple tephra-fall deposits) and the Waikato soils (formed on 1800-year-old coarse pumiceous alluvium [Taupo Pumice Alluvium]) on terraces near the Waikato River (Grange *et al*. 1939; Taylor 1958; Lowe 1988; Singleton 1988; McCraw 2002). Walton (1983) identified Maori gardens on a 'light' soil (formed on dune sands containing admixed tephra-fall materials) around Aotea on the west coast of the North Island. The associated plaggen soils, 40–50 cm deep, contain additions of sand quarried from the underlying sand deposits. Near Waitara, soils were modified to a depth of 50 cm (Walton 1984). At Makara (Wellington) the thickness of the modified soil material is 25–30 cm; at Okoropunga (east coast Wairarapa) it is 20–35 cm thick; at Pauatahanui (Wellington) it is 20–30 cm thick; and at two sites near the Clarence River mouth (South Marlborough) the modified soil materials are 30–55 cm thick (McFadgen 1980).

As noted previously, various features result from the addition of sands and gravels to soils. Soil drainage may also be affected. In the middle Waikato Basin, the Maori-modified soils, the Tamahere series, are classed as well drained (Milne *et al*. 1995). Such free drainage does not seem to be a disadvantage, and may even have been desirable because the original soils for the Waikato Maori gardens are usually (but not always) well drained to moderately well drained and with loamy sand or sandy loam textures. Challis (1976) showed that in Motueka the textural modifications and associated mounding of the soil extended the growing period in early spring by a week or more by improving heat retention and reducing frost incidence by improving cold-air drainage (also noted by Singleton 1988). The addition of ash from burning may have improved nutrient levels (Grange *et al*. 1939; Taylor 1958; McCraw 2002), particularly levels of potassium and nitrogen which, together with phosphorus, are important nutrients for kūmara growth (Singleton 1988). The addition of sand and gravel was useful as well because it created a sharp interface between the new materials and the buried soil that encouraged the old kūmara varieties to form larger tubers (Singleton 1988).

HORTICULTURE IN THE WAIKATO

There is a paucity of information about horticulture in the Waikato region in both the ethnographic and early historic literature. Best (1976) included some information from informants in the region, principally Karaka Tarawhiti of Huntly and Hari Wahanui of Otorohanga, who commented mainly on the layout of kūmara plots and the role of women in plot preparation (Best 1976: 151, 155). Early European travellers in the Waikato described crops of maize, wheat, potatoes and kūmara in the 1830s and 1840s (Williams [in 1834], cited in Clarke 1977; Yate 1835; Johnson [1847] cited by Clarke 1977 [Kaniwhaniwha Valley and Ngati Koroki gardens near Maungatautari]; Meurant 1845 cited in Clarke 1977; Shortland 1842, 1856; Angas 1850; Best [in Taylor 1966]). Only Shortland

(1842) provided a detailed description of any aspect of the physical process of gardening. He related information given to him by Pohepohe (paramount chief of Ngati Haua, apparently the oldest chief in the Waikato according to Rev. Ashwell and Rev. Brown (Clarke 1977: 216)), and by Tuwhare during a journey from Matamata to Mangapakiaka (see Clarke 1977) on the Waipa River in 1842. Pumice gravel was dug from pits "and mixed with the soil to render it fit for the cultivation of the kumara" (Shortland manuscript book 4, 3/10/1842). The pits and gravelled soils were close to kāinga (villages) that had been occupied in Pohepohe's "younger day", presumably around the end of the eighteenth century. Shortland later wrote that 'borrow' (excavation) pits were "formed by those who resorted there, year after year, to procure sand…" (Shortland 1856: 203), implying that the gardens surrounding the pits were used for consecutive years.

Other sources from the 1830s and 1840s emphasise how dispersed gardens were from the place people considered to be their main pā (fortified village). Yate (1835), for instance, described scattered cultivations in relation to kāinga and pā in the 1830s and Williams in 1834 (Clarke 1977) described the Waikato River as lined with cultivations for nearly fourteen miles "from" Ngaruawahia. Ensign Best, Dieffenbach and Meurant each described the cultivation of gardens around Whatawhata by people from the Ngaruawahia and Taupiri areas in the early 1840s (Dieffenbach 1843; Meurant cited in Clarke 1977; Taylor 1966). Angas and Meurant both mentioned the cultivation of kūmara at Whatawhata at that time and Meurant, who was accompanying Te Wherowhero, also noted having to wait a week at Rangiriri for the completion of kūmara planting ceremonies. Ensign Best noted gardens of maize, potatoes and kūmara around the population centre of Kaitote, near Taupiri, and added that the smallest plots were kūmara (Best 1976). Johnson ([1847] cited in Clarke 1977) also referred to this feature.

It is evident that by the 1830s and 1840s the population of the middle Waikato Basin was concentrated on the Waipa River since this was the major river thoroughfare. The only settlement noted on the Waikato River between Karapiro and Ngaruawahia at that time seems to have been Kirikiriroa (Hamilton), which Shortland visited in 1842. Clarke (1977: 215) suggested that this reflected the relative depopulation of this area following warfare between Ngati Haua, Ngati Raukawa, and Waikato tribes that peaked in the first decades of the nineteenth century. Nevertheless, there are abundant borrow pits and associated plaggen soils flanking the Waikato River as well as the Waipa River (see maps in Grange *et al.* 1939; Taylor 1958; Clarke 1977; McLeod 1984; Singleton 1988), indicating that gardening by Maori was a more widespread practice in earlier times. It is possible that the name 'Kirikiriroa', meaning 'long gravel', may relate to the early gardening activities.

THE SITES: S14/201 AND S14/185

Our archaeological investigation (Gumbley and Higham 2000) was undertaken because of plans for a new road, which would impinge upon two areas of plaggen soils on adjacent banks of the Kirikiriroa Stream, a tributary of the Waikato River now encompassed within Hamilton City (Fig.1).

Site S14/201, on the eastern side of the Kirikiriroa Stream gully, was 1.2 ha in extent and included three large borrow pits (1 to 3 in Table 1). It had originally been part of a much more extensive garden, 6.7 ha in area, with nine borrow pits, but much had been destroyed by urban development before we began our study. This area had been farmed (by European descendants) before the expansion of the city and the presence of foundations for what

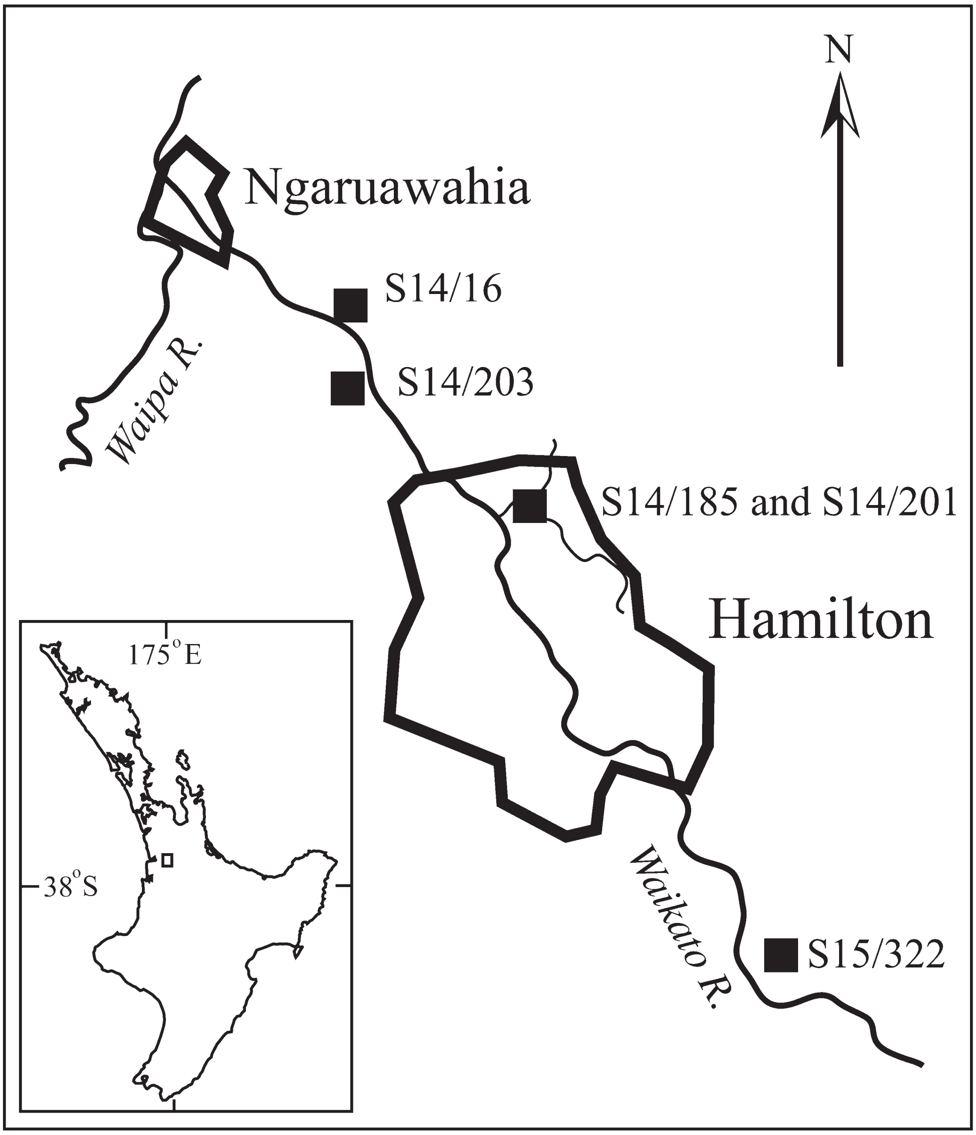

Figure 1: Locations of Waikato archaeological sites mentioned in the text.

appeared to a milking shed indicated that this had been a dairy farm, common in the Waikato region.

S14/185, the site on the western side of the Kirikiriroa Stream gully, also covered 1.2 ha and included four smaller borrow pits visible on the ground surface as shallow depressions (4 to 7 in Table 1). Little is known about the previous land use, although the site was part of an area grazed by horses immediately prior to the excavation. Before that it was also farm pasture.

TABLE 1

Dimensions of borrow pits at the two sites

Site	Pit	Surface area (m^2)	Estimated volume (m^3)
S14/201	1	370	518
S14/201	2	630 (780)†	1386 (1716)
s14/201	3	540	756
S14/185	4	65	45.5
S14/185	5	40	28
S14/185	6	30	21
S14/185	7	40	28

† The original area of pit 2 would have been approximately 780 m^2.

Unmodified soils adjacent to the study areas are mainly well-drained Horotiu sandy loams and imperfectly drained Bruntwood silt loams, two widely-occurring soils developed on a thin mantle of tephra-fall deposits overlying *ca.* 18,000 year old volcanogenic alluvium of the Hinuera Formation (Singleton 1991; Lowe and Percival 1993; Bakker *et al*. 1996). The Horotiu soils are classed as Typic Orthic Allophanic Soils and the Bruntwood soils as Typic Impeded Allophanic Soils using NZSC (Hewitt 1998).

The soils were mapped on the basis of results from a series of test pits. One borrow pit at each site was trenched. The plaggen soils, which formed the topsoil, were then removed using hydraulic earth movers, before the construction phase of the road development.

At S14/185, a trench was excavated through the easternmost pit (pit 4 in Table 1) to provide a cross-section. The other three pits were to be preserved and were not excavated. Pit 4 was 1.3 m deep and 6 m in diameter (Fig. 2). Fill comprised a mixture of soil material recognisable as being originally from the A, B, and 2C horizons of the pre-existing soils (soil horizon designations follow Clayden and Hewitt 1994), together with charcoal. No layers were evident, indicating a single episode of back-filling in the borrow pit with no subsequent reworking of these blended materials. The trench showed that approximately 0.7 metre depth of sand and gravel had been excavated (‘borrowed’) from that pit. The results from pit 4 were applied to the other three pits to provide a reasonable approximation of volume (Table 1).

In S14/201, the borrow pits were more easily identifiable because of their larger size (see Figs 6 and 7 below). Two of the three borrow pits at this site were to be preserved and so were not trenched but pit 3, which was to be directly affected by the road, was trenched. However, archaeological features of pit 3 were difficult to determine because it had been used as a farm dump. The depths of the other two borrow pits were determined using an auger. Pit 1 was found to be 2 m deep with 1.4 m of added sand and gravel (2C horizon materials)(the base of the B horizon was 0.6 m below the ground surface in this area). Pit 2 was found to be 2.8 m deep with 2.2 m of added sand and gravel. The result from pit 1 was applied to pit 3 as both pits were similar in size. The inconclusive results from the trench through pit 3 tended to support this similarity.

These results were generally consistent with results from Te Rapa Dairy Factory site (S14/203) (Gumbley and Higham 1999) where two borrow pits were sectioned — approximately 1 m depth of sand and gravel had been excavated (borrowed) from the 2C horizons there.

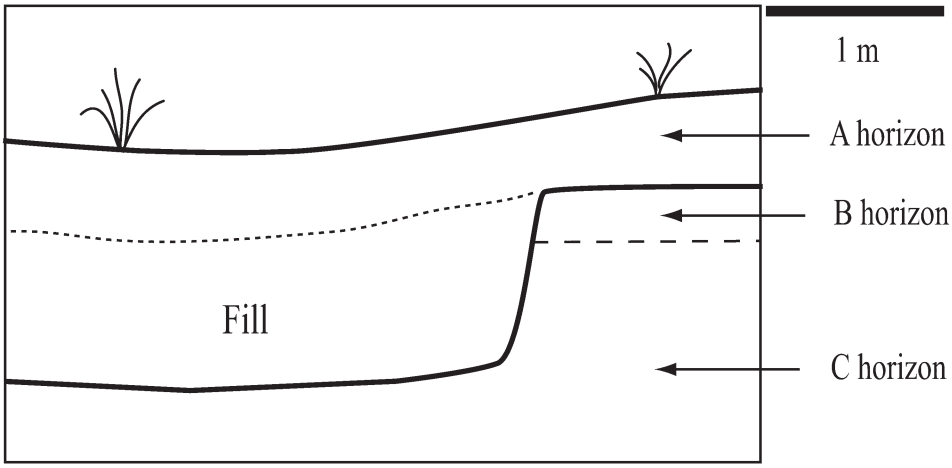

Figure 2: Cross-section of borrow pit 4 at S14/185.

During stripping of the plaggen soil material (modified A horizon) at S14/201, a group of gravelly sand-filled near-circular 'hollows' were exposed at the interface between the A and B horizons. The hollows had been dug into the top of the B horizon and were filled with gravelly sand derived from the adjacent alluvium of the Hinuera Formation. The diameters of the hollows varied between 0.26 m and 0.34 m, with an average of 0.3 m, and the depth of the hollows into the top of the B horizon (i.e., below the boundary between the A and B horizons) varied from 0.03 m to 0.1 m (Figs 3 to 5). Two groups of hollows could be identified within the upper B horizon. These groups were contiguous with each other, one northern and one southern. The two sets of hollows were similarly regular in their layout, but varied in the spacing between the hollows and in the orientation of the rows. Both had a series of parallel rows oriented on an axis 125° east of magnetic North but they varied in the orientation of the 'perpendicular' rows. Hollows in the northern set were oriented along axes 40° east of magnetic North, whereas in the southern set the hollows were oriented along axes of 18° east of magnetic North. The northern set measured 8.7 m x 5.8 m in extent, with an average of 0.5 m between the centres of each hollow in the north-south rows and 0.55 m between the centres of the perpendicular rows. The southern set measured 9 m x 5.8 m in extent. In this set there was an average of 0.43 m between centres within north-south rows and 0.33 m between the centres of the perpendicular rows. The northern set had an approximate density of 40 hollows per 10 m^2 and the southern 50 hollows per 10 m^2.

Similar sandy patches were also recognisable within the deeper part of the modified topsoil material itself during excavation of the topsoil with the hydraulic excavator[4]. None was seen to be extending into the hollows in the B horizon. These patches were seen only briefly in the shallow profiles created by the excavator before they collapsed. Time constraints meant that hand excavation to investigate these features further was not possible. The

[4] We suspect that the reason these were only detectable in the deeper part of the A horizon is a result of later soil disturbance, probably ploughing.

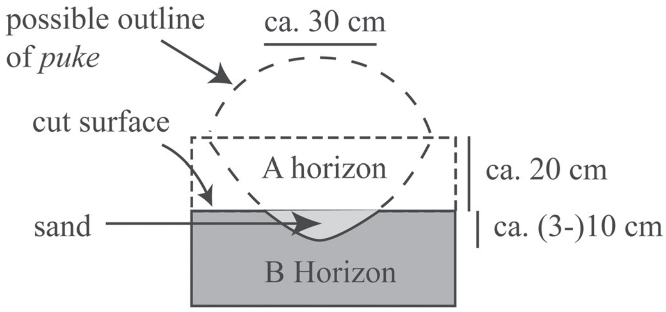

Figure 3: A speculative and schematic cross-section of a 'hollow' or 'puke'.

occurrence of sandy additives within the plaggen topsoil indicates that there were many more hollows than just those forming the two groups identified within the upper B horizons. Although these remains within the A horizon were close to the two areas containing depressions in the B horizon their actual relationship with the two groups could not be determined; they could have been extensions of one or both of the two groups, where the depressions had not been excavated into the B horizon, or they may have been the remains of separate successive gardening events. It is likely, therefore, that these sand-filled depressions in the A and B horizons are the remnants of infilled Maori excavations dug either into or through the original soil surface materials (A horizon) or through this into the subsoil (B horizon).

A group of four features (collectively called XVIII) was also identified 1.5 m to the west of the edge of the area containing the hollows at S14/201. The features comprised black charcoal-rich material infilling depressions excavated between 0.07 and 0.11 m into the B horizon. These depressions were arranged linearly with the three large ones (dimensions ranged from 32 to 60 cm) in a row and a smaller feature (diameter 25 cm) offset from the others. The southwestern-most depression in the row contained 23 cobbles (all approximately 7 cm in diameter). The XVIII depressions are interpreted as a group of scoop hearths with the southwestern-most, cobble-filled one probably a small umu (earth oven).

A series of 16 postholes was also identified within 15 m of the gully edge. Thirteen of these were rectangular in plan and were aligned along the edge of the gully, and one of them included a fence staple, nails and a cow's shoulder blade. The 13 postholes were interpreted as belonging to a post-European fence. The other three postholes were approximately circular with diameters (15–18 cm) and it is possible they were associated with prehistoric occupation.

SAMPLING OF SOIL MATERIALS

In order to quantify the amount of material added to pre-existing soils, and hence the degree of soil modification, we collected soil samples from modified A horizon materials in S14/201 and S14/185 from the same test-pits used to determine the extent of the plaggen soils. We measured the content of gravel (>2 mm) and coarse (0.5–2 mm) and medium (0.25–0.5 mm) sand using standard particle size analysis. At intervals along a transect line (see below), the turf was removed and discarded, and a bulk sample from the entire

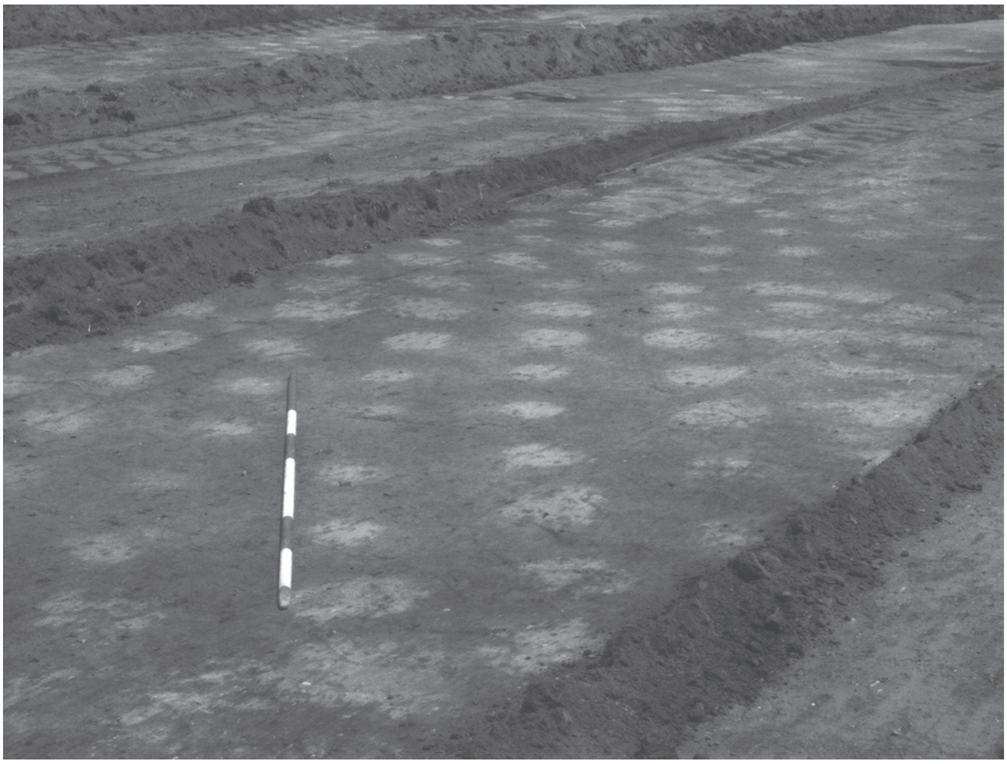

Figure 4: The sand-infilled 'hollows' at site S14/201. The northern set are in the foreground and the southern set can be distinguished in the background. The range poles are 2 m long. Photograph: W. Gumbley.

modified A horizon was taken from a spade-dug test-pit (*ca*. 40 x 40 cm). The thickness of the modified A horizon and the depth of the B horizon were recorded. Samples of the modified A horizon materials were collected both for particle size analysis and to extract charcoal for palaeoenvironmental studies. At S14/201, 13 samples were collected at 20 m intervals along a 250 m transect (Fig. 6), and two further samples were collected in the slightly elevated areas around the two well-preserved borrow pits. At S14/185, 12 samples were collected at 30 m intervals along a transect (Fig. 7). A horizon materials from unmodified Horotiu and Bruntwood soils were sampled from close to the western end of the S14/185 transect for comparison (unmodified material was not available at S14/201).

At the same time as the test pits were dug, the parent soil types were determined, and confirmed on a physiographic basis: Horotiu soils occur at slightly higher elevations than Bruntwood soils which in turn are slightly more elevated than Te Kowhai soils (Singleton 1991).

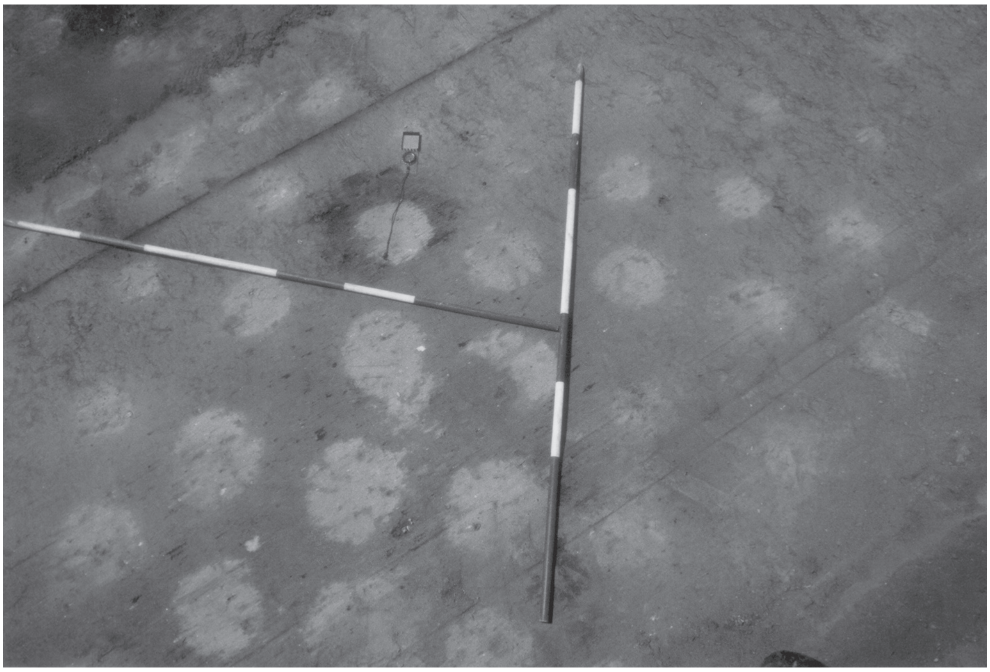

Figure 5: Part of the southern set of sand-infilled 'hollows' (i.e., remnants of puke) at site S14/201. The range poles are 2 m long. Photograph: W. Gumbley.

TABLE 2

Sieve sizes used in the particle size analysis

Gravel (≥ 2 mm)				Sand (0.25–2 mm)		
16 mm	8 mm	4 mm	2 mm	1 mm	0.5 mm	0.25 mm
-4ϕ	-3ϕ	-2ϕ	-1ϕ	0ϕ	1ϕ	2ϕ

LABORATORY ANALYSIS

Each sample was well mixed and a 0.5 litre split taken for particle size analysis. The sample was dried and passed through a series of graduated sieves at one phi intervals (Table 2). The weight of the residue in each sieve was recorded. The remaining part of each sample was dried and immersed in a water bath and the charcoal floated off.

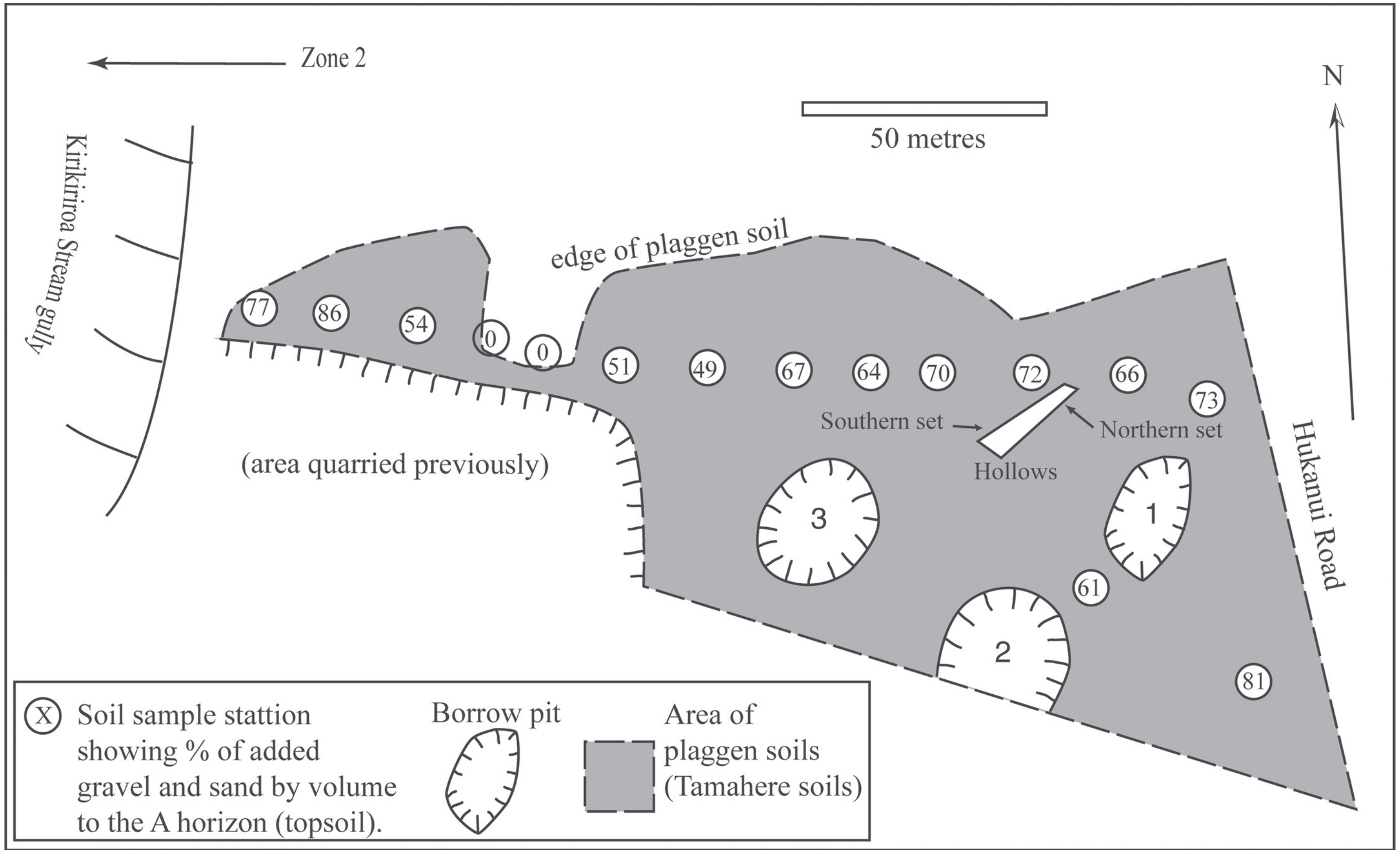

Figure 6: Percentage of added sand and gravel at each soil sample station in S14/201.

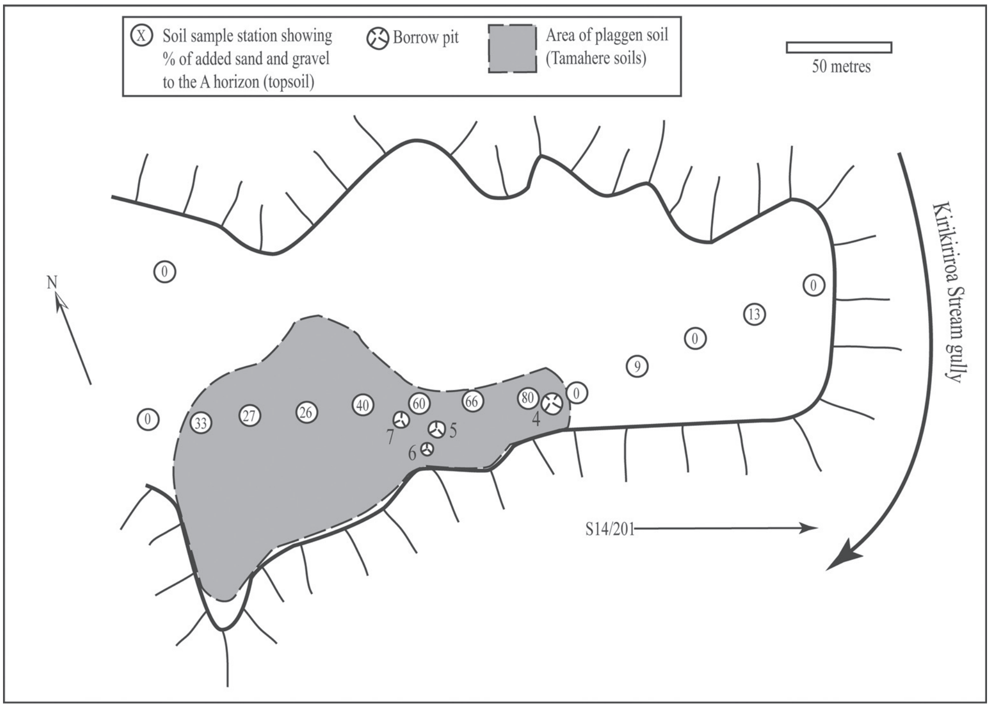

Figure 7: Percentage of added sand and gravel at each soil sample station in S14/185.

RESULTS

The unmodified A horizons of the Horotiu and Bruntwood soils normally contain ≤20% of medium sand and coarser particles (Tables 3 and 4). By this standard, our control samples 9 and 10 from S14/201 (Fig. 6, Table 3), and samples 17 to 20 from S14/185 (Fig. 7, Table 4) are classed as unmodified.

We calculated the percentage of added Hinuera Formation-derived sand and gravel for each sample of modified soil using the following formula:

$$p = \frac{k_m - k_o \times 100\%}{k_a - k_m}$$

where:[5]

p is the percentage of material borrowed (excavated) from the alluvium (2C horizon) of the Hinuera Formation

k_m is the percentage by weight of >0.25 mm sand and gravel in the modified soil

k_o is the percentage by weight of >0.25 mm sand and gravel in the original unmodified A horizon

k_a is the percentage by weight of >0.25 mm sand and gravel in the borrowed material used as an additive.

The value p was converted to a simple percentage showing the percentage material at each sample site derived from the material excavated from the Hinuera Formation (Tables 3 and 4).

Any soils in which 70% or more of the sample is derived from added sand or gravel have clearly been substantially modified. To achieve this degree of modification, approximately four parts of sand and gravel from the underlying alluvium (Hinuera Formation) would have been added to each part of the original A horizon. We found that the soils in S14/201 were more heavily modified than those in S14/185 suggesting more intensive use, or perhaps more episodes of repeated use, or both (Tables 3 and 4).

To determine the possible number of episodes of gardening or puke formation, we carried out the following calculations. The A horizon of the Horotiu soil is approximately 0.18 m thick on the average (McLeod 1984), giving an average of 1800 m^3 of A horizon material per hectare. Using Walsh's figures for the dimensions of puke (20 cm high by 50–60 cm across) (quoted in Best 1976: 149), each would have contained approximately 30 litres of sand and gravel. Hence, based on the spacings of the puke identified in S14/201, ≈3750 m^3 of sand and gravel would have been used per hectare.

The average percentage of added sand and gravel within the modified A horizon found in S14/201 is 67% (range of 49–86%). This is equivalent to about 2 litres of sand and gravel per litre of original A horizon and, by the standard adopted above, is regarded as substantially modified. In S14/185 the average is 47% (range of 31–80%), equivalent to about 1 litre of sand and gravel per litre of original A horizon. Given the relatively small size of the borrow pits in S14/185, this value is reasonable. Figure 7 demonstrates that there was more substantial modification to the soils between the borrow pits, suggesting that this area was a small garden and that some other more recent mechanism (e.g., ploughing) may have been responsible for spreading the modified soils beyond the edges of the prehistoric garden.

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[5] We have assumed that the A and B horizon materials from the borrow pits were not added. However, it is not possible to confirm this. Similarly, we assumed that no material <0.25 mm has been lost from the plaggen soil and that none of the >0.25 mm has weathered to a smaller size.

TABLE 3

Degree of modification to soil samples from at S14/201 (by weight)

Sample	Medium Sand & Coarser Particles Percent	Added Sand & Gravel Percent	Parent Soil
1	68	76	Horotiu
2	64	71	Horotiu
3	67	75	Horotiu
4	63	69	Horotiu
5	61	67	Horotiu
6	65	72	Horotiu
7	51	53	Horotiu
8	52	55	Bruntwood
9	13	0	Bruntwood
10	21	0	Bruntwood
11	56	60	Horotiu
12	77	88	Horotiu
13	73	82	Horotiu
14	74	81	Horotiu
15	61	67	Horotiu

TABLE 4

Degree of modification to soil samples from S14/185 (by weight)

Sample	Medium Sand & Coarser Particles Percent	Added Sand & Gravel Percent	Parent Soil
16	21	0	Horotiu
17	25	0	Horotiu
18	26	0	Horotiu
19	26	0	Horotiu
20	10	0	Horotiu
21	73	82	Horotiu
22	61	67	Horotiu
23	58	63	Horotiu
24	45	46	Horotiu
25	35	32	Horotiu
26	36	34	Horotiu
27	33	30	Horotiu
28	5	0	Bruntwood
29	10	0	Horotiu

TABLE 5

Plant species identified from charcoal recovered from S14/201

Plant Type	**Species**	**No.**	**Percent**
Ferns			*2*
	Bracken fern root	1	
Shrubs			*26*
	Shrub species	1	
	Patē (*Schefflera digitata*)	2	
	Māhoe (*Melicytus ramiflorus*)	2	
	Māpou (*Myrsine australis*)	1	
	Olearia sp.	9	
Vine			*2*
	Supplejack (*Ripogonum scandens*)	1	
Broadleaf Trees			*50*
	Tītoki (*Alectryon excelsum*)	1	
	Taraire (*Beilschmiedia tarairi*)	13	
	Rātā (*Metrosideros* sp.)	1	
	Rewarewa (*Knightia excelsa*)	2	
	Maire (*Nestegis* sp.)	1	
	Pūriri (*Vitex lucens*)	1	
Conifers			*20*
	Mataī (*Prumnopitys taxifolia*)	11+	

PALAEOENVIRONMENTAL INTERPRETATION FROM CHARCOAL ANALYSIS

Charcoal fragments recovered from modified A horizon materials in both zones were identified to species. The charcoal assemblages included a high proportion of trees (Tables 5 and 6), particularly at S14/201, and scarce pioneer (seral) species (e.g., mānuka and bracken fern) that would colonise after forest clearance by humans or by natural events (e.g., McGlone 1989; Newnham *et al*. 1998; Ogden *et al*. 1998; Wilmshurst *et al*. 1999). The scarcity of pioneer species in the charcoal samples indicates that after initial burn-off, gardening was completed at each site before the revegetation of the areas by seral species. Moreover, it suggests that the areas of both sites may have been vegetated by broadleaf/podocarp forest at the time of burn-off. Conversely, it may be that burning of scrub and fern was so complete that there were no remaining fragments large enough to be identified. However, mānuka and fern charcoal are commonly found in other archaeological sites. Nonetheless, the recovery of these samples from the modified A horizon rather than discrete archaeological features means that conclusions must be tentative.

TABLE 6

Plant species identified from charcoal recovered from S14/185

Plant Type	Species	No.	Percent
Ferns			*6*
	Bracken fern root	2	
Shrubs			*38*
	Hebe sp.	2	
	Tutu (*Coriaria arborea*)	3	
	Pseudopanax sp. (cf. *crassifolius*)	2	
	Pseudopanax sp.	1	
	Pittosporum sp.	1	
	Olearia sp.	2	
	Mānuka (*Leptospermum scoparium*)	2	
Broadleaf Trees			*3*
	Kōwhai (*Sophora* sp.)	1	
Conifers			*50*
	Matāī (*Prumnopitys taxifolia*)	17	

RADIOCARBON DATE

We obtained a radiocarbon date on charcoal from short-lived species (patē *Schefflera digitata*, māhoe *Melicytus ramiflorus*, māpou *Myrsine australis*, taraire *Beilschmiedia tarairi*) from one of the hearths (feature XVIIIA) at S14/201 near the sand-filled hollows described earlier. Because this fireplace was exposed after the removal of the A horizon it is not possible to interpret the direct stratigraphic relationship of the feature with the garden soil. However, the presence of similar features within garden areas at two sites nearby, S14/203 and S14/16, indicates that such features are associated with prehistoric garden areas in the Waikato. On this basis we consider it is reasonable to assume there to be a close relationship with the gardening activity. The radiocarbon age is 440 ± 65 ^{14}C yr BP (Wk-7928). This corresponds to a calendar date range at one standard deviation from cal AD 1435 to 1510 (43 %) and cal 1580 to 1625 (20 %). At two standard deviations, the date range is cal AD 1420 to 1640 (95%) (Table 7 and Fig. 8).

This date might suggest an occupation at this site as early as the fifteenth century. However, even when identified to short-lived species, charcoal determinations can incorporate 'inbuilt' age (McFadgen 1982). This is a possibility here, and therefore we consider it more likely that this area of the site was occupied closer to the sixteenth century, perhaps late in the fifteenth century. Further radiocarbon determinations would assist in adding confidence to this age, but horticultural contexts are difficult to date because of the scarcity of datable material in contexts securely associated with prehistoric gardening. Furthermore, dating charcoal from modified soils may be unreliable because of the possibility of incorporating wood from non-cultural contexts that can significantly pre-date cultural activity (Higham and Hogg 1997).

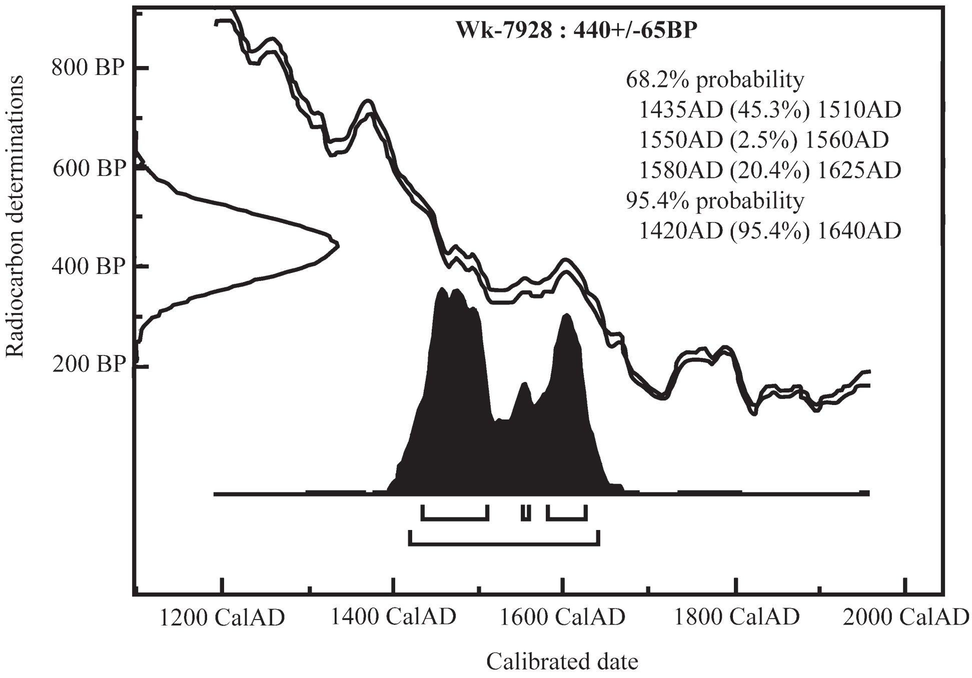

Figure 8: Radiocarbon determination from S14/201 (calibrated using OxCal; see Table 7).

TABLE 7

Radiocarbon dates from two Waikato garden sites

Lab. No.	**Site**	**Material**	**CRA**	**$\delta^{13}C$**	**Calib age 1σ†**	**Calib age 2σ**
Wk-503	Horotiu	Shell	670 ± 45	+1.9	1590–1690	1520–1725
Wk-7928	S14/201	Charcoal	440 ± 65	-28.3	1435–1510	1420–1640
					1550–1560	
					1580–1625	

† Calibrated using OxCal 3.6 (Bronk Ramsey 1995) and the Southern Hemisphere dataset of Hogg *et al*. (2002). The marine shell sample was calibrated using the marine dataset of INTCAL98 (Stuiver *et al*. 1998) with a ΔR offset of 12 ± 15 (see www.calib.org).

It is interesting to compare this age with dates from similar garden sites in the vicinity. At Horotiu (S14/16), a reservoir-corrected radiocarbon assay of shell within modified soil contexts yielded an age of 670 ± 45 ^{14}C yr BP (1520–1660 cal AD) (Wk-0503), which suggested use of the site from perhaps the sixteenth/seventeenth centuries AD. Other dates obtained from sites with borrow pits at Arapuni and Horotiu were affected by inbuilt age (Higham and Hogg 1997). There are few reliable dates in all, but it appears on the limited evidence available that horticultural adaptation in the Waikato was under way by the sixteenth century.

DISCUSSION

The discovery of the distinctive gravelly-sand-infilled hollows was a unique result of our investigation (see also Higham and Gumbley 2001). The layout and size of the hollows is consistent with historical descriptions of puke used to grow kūmara by Maori, in particular Walsh's description of puke as "about 9 in. high and 20 in. to 24 in. in diameter, set quite close together" (20 cm high and 50–60 cm diameter) (in Best 1976: 149). On this basis we have interpreted them as the 'scalped' remains of puke. The depth of the hollows appears to have varied. At S14/201 most were excavated into the A horizon but some extended up to 0.1 m into the upper part of the B horizon. Although the average diameter of the hollows/puke as represented at the boundary between the A and B horizons was 0.3 m, about half the diameter typically reported in the historic literature, it should be borne in mind that our measurements were made ≈0.2 m below the ground surface, where the hollows are naturally smaller. Projected upwards towards the ground surface, the hollows become enlarged and the original puke would have been comparable in size with those in the historic descriptions.

Although only the subterranean aspect of the garden was preserved, the layout of the sand and gravel filled hollows found at S14/201 was certainly regular within each of the two groups identified. However, the layout of the two recognisable areas differed to some degree and neither fitted the 'true' quincunx pattern laid out on a rectangular grid with two principal axes at 90°, nor the equilateral layout with three axes at 120°.

The nature and degree of soil modification follows a pattern similar to that found at another site (S14/203 at Te Rapa Dairy Factory) 4.5 km downstream on the Waikato River, and at Tamahere (S15/322) 16 km upstream. The soils have had similar amounts of sand and gravel added to them. Also, the amounts of sand and gravel additives at S14/203 and S15/322 indicate that any area of ground had only a single episode of sand and gravel addition. This does not necessarily mean that each area of garden soil was cultivated in entirety in the same season. Instead, we believe it is likely that each area of modified soils represents the accumulation of a number of seasons of gardening on separate but contiguous plots. It should also be borne in mind that kūmara require significant levels of potassium and phosphorus to produce effectively and that many Waikato soils are naturally depleted in these (the Horotiu and Bruntwood soils tend to have high phosphorus fixation because of their allophanic nature, resulting in P becoming unavailable to plants) and other elements (e.g., Singleton 1991). Therefore the ability to provide K (and N) was probably an important function in the preparation of the gardens, along with the addition of sand and gravel. Because the burning of woodland provided K, a garden area was likely to have been abandoned once potash levels had become too low, and not used again until vegetation had regenerated. Such a pattern of gardening by prehistoric Maori is typical of shifting slash and burn agricultural systems. That there appear to have been only single episodes of sand and gravel addition to form the plaggen soils at S14/201 is consistent with possible low fertility levels after an episode of gardening, and this points to a single season of gardening before abandonment of the garden plot.

It is evident that the sand and gravel excavated from the natural soils' 2C horizons was used to fill the excavated hollows up to 0.3 m deep. We could not determine from the investigation whether there was a puke on top of the ground nor what happened to the material excavated from the hollows. However, we believe it is reasonable to assume that puke were formed as described in historical records. If so, (1) were the puke formed from borrowed/excavated sand and gravel, and the material it replaced disposed of, or (2) was the material excavated from the hollows stock-piled, with the hollows filled with the borrowed sand and gravel, and the stock-piled material then used to form the mound? We believe that (2) is the more likely possibility for several reasons. The amount of borrowed sand and gravel was sufficient to fill the hollows but not to create the puke as well. The important nutrients acquired from the burn-off would have been made available if material excavated from the hollows were used to form the puke, whereas it would be lost if that soil material was disposed of and sand and gravel used. The re-use of the excavated soil also makes sense from an energy conservation perspective. It would have been easier to excavate the soil from each hollow, placing it adjacent to the hollow which would have been filled with sand and gravel, and then to have used the excavated soil to form the puke before work began on the next row of hollows. In addition, the pale sand and gravel, if it had been used to form the puke, would have absorbed less warmth from the sun than the substantially darker soil, which would have been an important consideration in growing kūmara in the marginal climate of the middle Waikato Basin. Nonetheless, we acknowledge that this proposition conflicts with the description by Stack (1893: 184–185) of the process used in Canterbury, another climatically marginal area, where gravels and sands were mounded to form the puke traditionally used to grow kūmara.

The majority of the pre-existing soils modified by prehistoric gardening in the middle Waikato Basin are well drained, comprising the Horotiu soils (on higher terraces) or Waikato soils (on the lower terraces) near the Waikato River. These provided the antecedents soils for approximately 90% of the known plaggen soils in the Waikato. Most of the remaining plaggen soils were formed on imperfectly drained Bruntwood soils, which occur at slightly lower elevations in the landscape alongside Horotiu soils (Singleton 1991; Lowe and Percival 1993). Plaggen soils have rarely been found on the poorly to very poorly drained Te Kowhai soils, but some areas occur at Arapuni (D. J. Lowe, unpublished data) and on the margins of the garden area S14/203 at Horotiu. Figure 9 shows the distribution of plaggen soils and adjacent unmodified Horotiu and Bruntwood soils around the study area. It is clear that although considerable areas of land were used as Maori gardens in the Waikato, there remained a substantial reservoir of unmodified soils that were potentially useful for horticulture, including both the preferred Horotiu soils and the less favoured but potentially suitable Bruntwood soils.

Given the relatively widespread availability of soils with good drainage, and the ongoing need for potash to augment the low natural reservoir in these soils, it is conceivable that the gardens were abandoned after a season of use. If so, this, along with the radiocarbon date for the site, suggests the following possibilities:

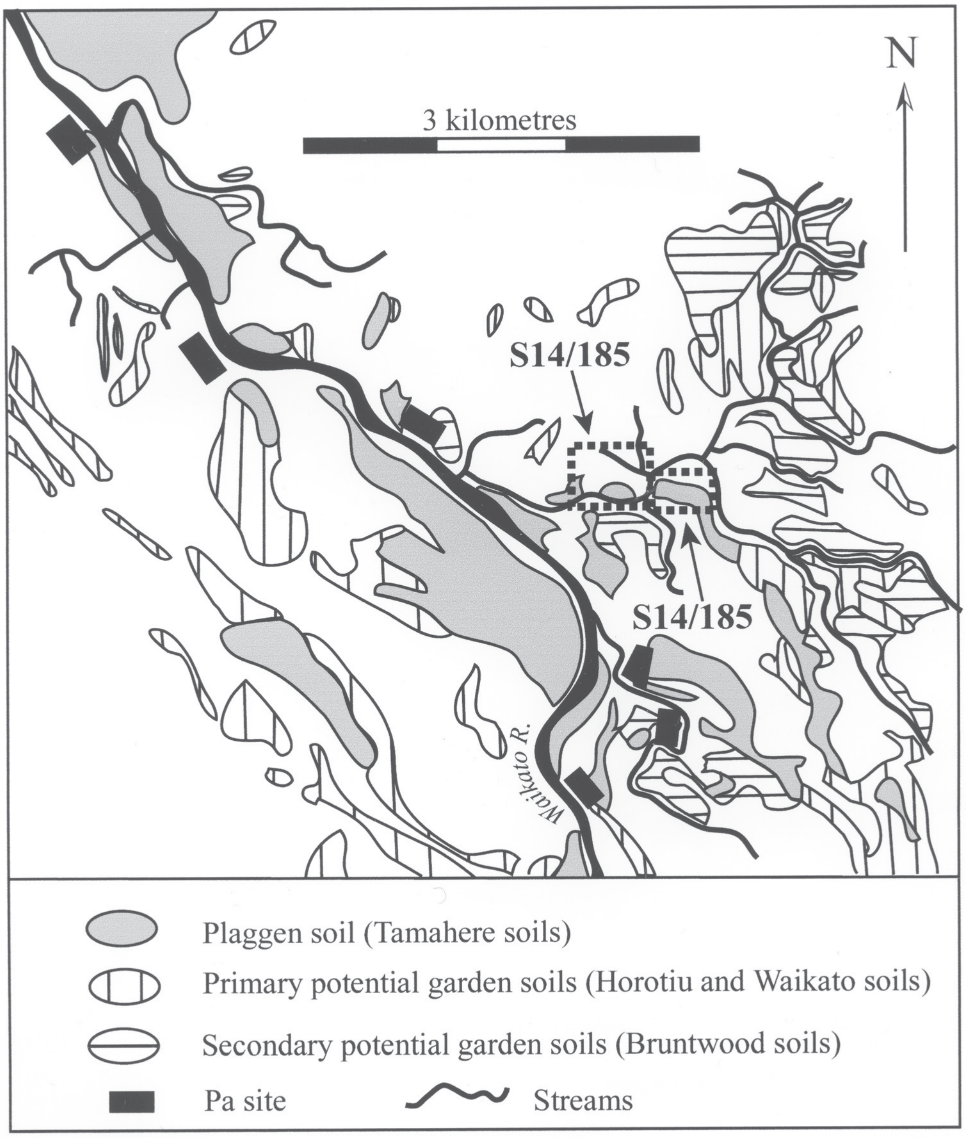

Figure 9: Distribution of pā, plaggen soils and unmodified, but potentially usable soils in the area surrounding S14/185 and S14/201.

1. Population densities were low and thus there was a slow usage of potential garden soils even with long periods of occupation;

2. The population density was not low but occupation of any garden area was episodic for unknown reasons.

In the middle Waikato Basin, pā are typically closely associated with areas of modified garden soil which may even be within the defences of larger pā. However, the archaeological relationship between pā and areas of modified soils has not been investigated.

The nature of the actual crops grown in plaggen soils remains poorly understood. While the radiocarbon date for S14/201 places this site in the prehistoric period, and therefore associates it with cultivation of kūmara, it remains possible that old methods continued to be employed for cultivating the new potato. Therefore, some of the areas of plaggen soils may have been formed after AD 1800 for this new crop.

Although palynological and other palaeoenvironmental data (Newnham *et al.* 1989, 1995; Green and Lowe 1992, 1994) indicate that initial Polynesian settlement in the Waikato region ≈700 years ago (*ca*. AD 1300) was accompanied by widespread deforestation from that time (Newnham *et al*. 1998; McGlone and Wilmshurst 1999; Lowe *et al*. 1998, 2000), the identification of wood charcoal from hearths and the plaggen soils indicates that the site may have been clad in mature forest with shrubs and small trees at the time preparations for gardening began. Consequently, it appears that site S14/201 may have remained as a remnant forested area for several hundred years after initial settlement. This raises the possibility that the middle Waikato Basin was a mosaic of vegetation types rather than completely forested (see also Nicholls 2002).

CONCLUSIONS

Archaeological research undertaken during this project adds to the base of knowledge of early Maori cultural adaptation in the middle Waikato Basin. The area examined yielded evidence for horticultural systems that once dominated many of the soils flanking the Waikato and Waipa Rivers. Careful removal of the plaggen soils using earth moving machines enabled features within and below the base of modified A horizons to be detected. These features included sand and gravel filled hollows interpreted as the remains of kūmara growing mounds or puke and hearth and umu features, as well as inferred *in situ* burning of larger trees and roots. To our knowledge, this is the first documented archaeological evidence for puke features in New Zealand (Higham and Gumbley 2001), and our identification of these features provides strong support for Best's (1976) ethnographic descriptions of the characteristic pattern of formation. The site itself appears to date from the late fifteenth century or sixteenth century and to have been subject to a series of single-use garden plots as part of a larger inferred slash and burn horticulture system.

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REFERENCES

Allbrook, R.F. 1997. Some aspects of the development of soil science in New Zealand. *Advances in GeoEcology* 29: 333–350.

Angas G. 1850. *Savage life and scenes in Australia and New Zealand*. Smith Elder, London.

Bakker, L., Lowe, D.J. and Jongmans, A.G. 1996. A micromorphological study of pedogenic processes in an evolutionary soil sequence formed on late Quaternary rhyolitic tephra deposits, North Island, New Zealand. *Quaternary International* 34–36: 249–261.

Best, E. 1976. *Maori Agriculture.* Dominion Museum Bulletin 9, Government Printer, Wellington (Reprint, repaginated but without textual alteration, of 1925 edition).

Bronk Ramsey, C. 1995. Radiocarbon calibration and analysis of stratigraphy: the OxCal Program, *Radiocarbon* 37: 425–430.

Bruce, J.G. 1978. Soils of part Raglan County, South Auckland. *New Zealand Soil Bureau Bulletin* 41.

Bruce, J.G. 1979. Soils of Hamilton City, North Island, New Zealand. *New Zealand Soil Survey Report* 31.

Challis, A.J. 1976. Physical and chemical analysis of a Maori gravel soil near Motueka, New Zealand. *New Zealand Journal of Science,* 19: 249–254.

Clarke A. 1977. Maori modified soils of the upper Waikato. *New Zealand Archaeological Association Newsletter* 20: 204–222.

Clayden, B. and Hewitt, A.E. 1994. *Horizon notation for New Zealand soils*. Manaaki Whenua Press, Lincoln.

Colenso, W. 1880. On the vegetable food of the ancient New Zealanders before Cook's visit. *Transactions of the New Zealand Institute* 13: 3–38.

Dieffenbach E. 1843. *Travels in New Zealand*. John Murray, London.

Grange L.I., Taylor, N.H., Sutherland, C.F., Dixon, J.K., Hodgson, L., Seelye, F.T., Kidson, E., Cranwell, L.M. and Smallfield, P.W. 1939. Soils and agriculture of part of Waipa County. *New Zealand Department of Scientific and Industrial Research Bulletin* 76.

Green, J.D. and Lowe, D.J. 1992. Paleolimnology in New Zealand. *Quaternary Australasia* 10: 25–34.

Green, J.D. and Lowe, D.J. 1994. Origin and development. *In* J.S. Claydon and M.D. de Winton (eds), Lake Rotoroa: Change in an Urban Lake, pp. 13–23. *National Institute of Water and Atmospheric Research Ecosystems Publication* 9.

Gumbley, W. and Higham, T.F.G. 1999. Archaeological investigation of a prehistoric garden (S14/203), Horotiu, Waikato. Unpublished report.

Gumbley, W. and Higham, T.F.G. 2000. Archaeological investigation of prehistoric garden complexes affected by R1 & N1 arterial routes, Chartwell, Hamilton. Unpublished report.

Hewitt, A.E. 1998. New Zealand Soil Classification (2nd edn). *Landcare Research Science Series* 1.

Higham, T.F.G and Gumbley, W.J. 2001. Early preserved Polynesian kumara cultivations in New Zealand. *Antiquity* 75: 511–512.

Higham, T.F.G. and Hogg, A.G. 1997. Evidence for late Polynesian colonisation of New Zealand: University of Waikato radiocarbon measurements. *Radiocarbon* 39: 149–192.

Hogg, A.G., McCormac, F.G., Higham, T.F.G., Reimer, P.J., Baillie, M.G.L. and Palmer, J.G. 2002. High-Precision radiocarbon measurements of contemporaneous tree-ring dated wood from the British Isles and New Zealand: AD 1850–950. *Radiocarbon* 44 (3): 633–640.

Horrocks, M., Jones, M.D., Carter, J.A. and Sutton, D.G. 2000. Pollen and phytoliths in stone mounds at Pouerua, Northland, New Zealand: implications for the study of Polynesian farming. *Antiquity* 74: 863–872.

Law, R.G. 1968. Maori soils in the Lower Waikato. *New Zealand Archaeological Association Newsletter* 11: 67–75.

Law, R.G. 1975a. Age and function of made soils: A comment on the state of knowledge. *New Zealand Archaeological Association Newsletter* 18: 180–182.

Law, R.G. 1975b. A garden soil at Rocky Bay, Waiheke Island, N43/72. *New Zealand Archaeological Association Newsletter* 18: 183–190.

Leach, H.M. 1979. Evidence of prehistoric gardens in Eastern Palliser Bay. *In* B.F. Leach and H.M. Leach (eds), *Prehistoric Man in Palliser Bay*, pp. 137–161. National Museum of New Zealand Bulletin 21.

Leach, H.M. 1984. *1000 years of gardening in New Zealand.* Reed, Wellington.

Lowe, D.J. 1988. Stratigraphy, age, composition, and correlation of late Quaternary tephras interbedded with organic sediments in Waikato lakes, North Island, New Zealand. *New Zealand Journal of Geology and Geophysics* 31: 125–165.

Lowe, D.J. and Percival, H.J. 1993. *Clay mineralogy of tephras and associated paleosols and soils, and hydrothermal deposits, North Island.* Guidebook for New Zealand Pre-conference Field Trip F.1. 10th International Clay Conference, Adelaide, Australia.

Lowe, D.J., McFadgen, B.G., Higham, T.F.G., Hogg, A.G., Froggatt, P.C. and Nairn, I.A. 1998. Radiocarbon age of the Kaharoa Tephra, a key marker for late-Holocene stratigraphy and archaeology in New Zealand. *The Holocene* 8: 499–507.

Lowe, D.J., Newnham, R.M., McFadgen, B.G. and Higham, T.F.G. 2000. Tephras and New Zealand archaeology. *Journal of Archaeological Science* 27: 859–870.

McCraw, J.D. 2002. Physical environment. *In* B. Clarkson, M. Merrett and T. Downs (eds), *Botany of the Waikato*, pp. 13–22. Waikato Botanical Society, Hamilton.

McFadgen, B.G. 1980. Maori Plaggen Soils in New Zealand, their origin and properties. *Journal of the Royal Society of New Zealand* 10: 3–18.

McFadgen, B.G. 1982. Dating New Zealand archaeology by radiocarbon. *New Zealand Journal of Science* 25: 379–392.

McGlone, M.S. 1989. The Polynesian settlement of New Zealand in relation to environmental and biotic change. *New Zealand Journal of Ecology (Supplement)* 12: 115–129.

McGlone, M.S. and Wilmshurst, J. 1999. Dating initial Maori environmental impact in New Zealand. *Quaternary International* 59: 5–16.

McLeod, M. 1984. Soils of the Waikato Lowlands. *New Zealand Soil Bureau District Office Report* HN11.

Milne, J.D.G., Clayden, B., Singleton, P.L. and Wilson, A.D. 1995. *Soil Description Handbook (revised edition)*. Manaaki Whenua Press, Lincoln.

Newnham, R.M., Lowe, D.J and Green, J.G. 1989. Palynology, vegetation and climate of the Waikato lowlands, North Island, New Zealand since c. 18, 000 years ago. *Journal of the Royal Society of New Zealand* 19: 127–150.

Newnham, R.M., de Lange, P.J. and Lowe, D.J. 1995. Holocene vegetation, climate and history of a raised bog complex, northern New Zealand, based on palynology, plant macrofossils and tephrochronology. *The Holocene* 5: 267–282.

Newnham, R.M., Lowe, D.J., McGlone, M.S. and Wilmshurst, J. 1998. The Kaharoa tephra as a critical datum for earliest human impact in northern New Zealand. *Journal of Archaeological Science* 25: 533–544.

Nichol, R. 1981. Preliminary report on excavations at the Sunde site, N38/24, Motutapu Island. *New Zealand Archaeological Association Newsletter* 24: 237–256.

Nicholls, J. 2002. History of the vegetation. *In* B. Clarkson, M. Merrett and T. Downs (eds), *Botany of the Waikato*, pp. 23–28. Waikato Botanical Society, Hamilton.

Ogden, J., Basher, L. and McGlone, M.S. 1998. Fire, forest regeneration and links with early human habitation: evidence from New Zealand. *Annals of Botany* 81: 687–696.

Peters, K.M. 1975. Agricultural gardens on Moturua Island in the Bay of Islands. *New Zealand Archaeological Association Newsletter* 18: 171–180.

Rigg, T. and Bruce, J.A. 1923. The Maori gravel soil of Waimea West, Nelson, New Zealand. *Journal of the Polynesian Society* 32: 85–92.

Selby, M.J. and Lowe, D.J. 1992. The middle Waikato Basin and hills. *In* J.M. Soons and M.J. Selby (eds), *Landforms of New Zealand*, pp. 233–255. Longman Paul, Auckland. 2nd edn.

Shortland, E. 1842. Manuscript book 4, 3/10/1842, cited in Clarke 1977.

Shortland, E. 1856. *Traditions and superstitions of the New Zealanders; with illustrations of their manners and customs.* Brown, Green, Longman and Roberts, London.

Singleton, P.L. 1988. Cultivation and soil modification by the early Maori in the Waikato. *New Zealand Soil News* 36: 49–57.

Singleton P.L. 1991. Soils of Ruakura — a window on the Waikato. *New Zealand Department of Scientific and Industrial Research Land Resources Scientific Report* 5.

Stack J.W. 1893. *Kaiopohia: The story of a siege*. Whitcombe and Tombs, Christchurch.

Stuiver, M., Reimer, P.J., Bard, E., Beck, J.W., Burr, G.S., Hughen, K.A., Kromer, B., McCormac, G., van der Plicht, J. and Spurk, M. 1998. INTCAL98 radiocarbon age calibration, 24,000–0 cal BP. *Radiocarbon* 40: 1041–1083.

Sullivan, A. 1972. Stone walled complexes of Central Auckland. *New Zealand Archaeological Association Newsletter* 15: 148–160.

Sullivan, A. 1974. Scoria mounds at Wiri. *New Zealand Archaeological Association Newsletter* 17: 128–143.

Taylor N.H. 1958. Soil science and prehistory. *New Zealand Science Review* 16: 71–79.

Taylor N.M. 1966. *Journal of Ensign Best 1837–43.* Government Printer, Wellington.

Trotter, M. and McCulloch, B. 2001. Once were borrowers. *Archaeology in New Zealand* 44: 206–214.

Walton A. 1982. Rethinking made soils. *New Zealand Archaeological Association Newsletter* 25: 16–29.

Walton A. 1983. Made soils in the vicinity of Aotea Harbour. *New Zealand Archaeological Association Newsletter* 26: 86–93.

Walton A. 1984. Made soils in the Waitara River valley, Taranaki. *New Zealand Archaeological Association Newsletter* 27: 56–63.

Wilmshurst, J., Eden, D.N. and Froggatt, P.C. 1999. Late Holocene forest disturbance in Gisborne, New Zealand: a comparison of terrestrial and marine pollen records. *New Zealand Journal of Botany* 37: 523–540.

Yate, W. 1835 *An account of New Zealand.* Seely and Burnside, London.

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