

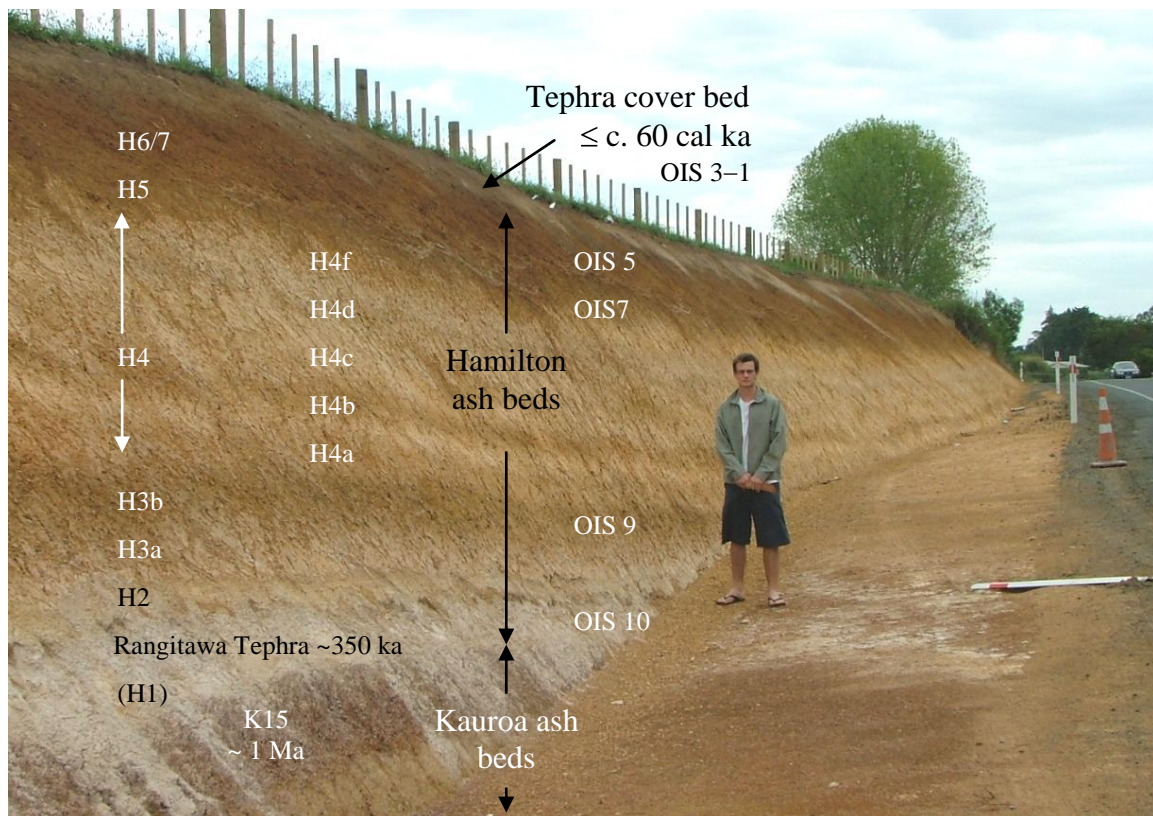
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## STOP 2 – KAINUI SILT LOAM & NAIKE CLAY, GORDONTON RD

Location S14 133859, elevation ~60 m asl, rainfall 1200 mm pa

*Please be very careful of traffic at this stop.*

At this stop are several remarkable features both stratigraphic and pedological, and a ‘two-storied’ soil, the Kainui silt loam alongside (in just a few places) the Naike clay. Both soils are Ultisols. The sequence of tephra beds and buried soil horizons spanning about 1 million years was exposed in 2007 by road works.



Provisional stratigraphy of Gordonton Rd section. Seb provides the scale. *Photo: David Lowe*

### Stratigraphy

(1) At the base of the section is the tiny remnant of an ancient landsurface represented by a buried, clay-rich soil >0.78 Ma on the basis of its reversed magnetism and other evidence (Horrocks, 2000; Lowe et al., 2001). Several undifferentiated beds visible beneath it are likely to be c. 1 Ma or older. These old tephra beds at the base of the Gordonton Rd section (northern end) are part of the so-called Kauroa ash bed sequence, the uppermost unit being the Waiterimu ash member or K15 (Ward, 1967; Lowe and Percival, 1993; Lowe et al., 2001).

(2) Overlying K15, with an unconformity, is the white ~0.5-m thick Rangitawa Tephra aged 0.35 Ma, one of the most widespread tephras in the southwest Pacific region that fell during Marine Oxygen Isotope (MOI) Stage 10. Rangitawa Tephra is overlain in turn by a ~3-m thick sequence of weathered, yellowish brown to brown to reddish brown clayey tephra beds and buried soils – the Hamilton ash beds – that represent MOI stages 9 to 5. The uppermost distinctive, dark reddish-brown buried soil, known as the Tikotiko ash member or bed H6/7 (Ward, 1967; see below), represents probably the Last Interglacial (OIS 5) paleo-landsurface.

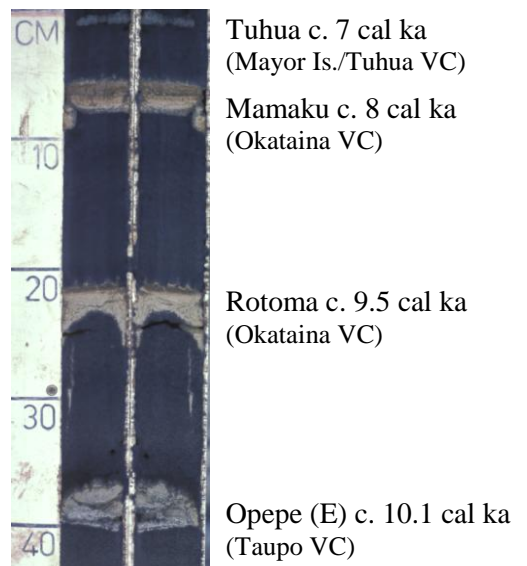
(3) At the top is a thin, silty cover bed mantle of intermixed late Quaternary tephras about 0.4-0.6 m thick, occasionally overthickened in hollows up to ~1.2 m in thickness, that have accumulated incrementally over the past c. 60,000 years (OIS 3-1). As at Pukekohe Hill, the base of the cover bed has been identified as Rotoehu Ash (c. 60 cal ka) but it is evident from detailed mineralogical and geochemical studies that the component tephras making up the composite mantle have been strongly intermixed during upbuilding pedogenesis (Lowe, 1981, 1986, 2000). Nearby lakes, formed c. 20–18 cal ka following deposition of the volcanogenic alluvium of the Hinuera Formation (see stops 3-4), have preserved >40 multiple, thin, visible tephra layers within their sediments (e.g. Green and Lowe, 1985; Lowe, 1988). These tephras each range in thickness from a few millimetres to several centimetres and in this area amount to an estimated ~37 cm in total thickness (Lowe, 1988). Together with tephras deposited between c. 60 and 20 cal ka, they form the parent material of the upper part of the Kainui soil (Lowe, 1986). The thin tephras preserved in the lake sediments are both rhyolitic (predominant) and andesitic and were derived from six volcanic centres 70 to 200 km away (Lowe, 1988). There are likely to be numerous very thin (< 1 mm) ‘non-visible’ tephras or sparse concentration zones of glass shards, known as cryptotephras (Alloway et al., 2007a), in the lake sediments as well as the visible layers. From recent work on lake cores and peat bogs, such cryptotephras are confirmed in the Waikato region (Gehrels et al., 2006, 2008) and thus probably were assimilated into the Kainui soil as ‘dustings’ from small-scale eruption plumes.

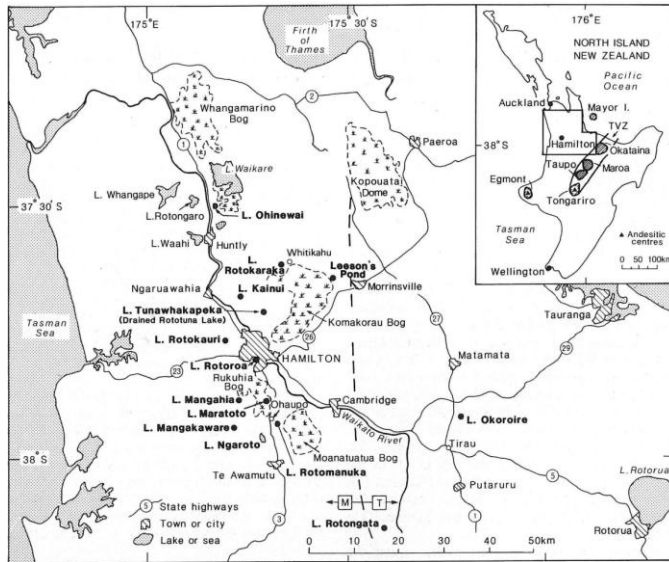


(Above)  
Lake Maratoto, south of Hamilton, was formed c. 20 cal ka. *Photo:* David Lowe

(Above right)  
The first core of 33 eventually taken from the lake (April 1979). Grey layer near base is alluvium overlying dark proto-lake lake sediment (near tape head) and pre-lake soil (Green and Lowe, 1985). *Photo:* Rex Julian

(Right)  
Close up of tephras in core from Lake Rotongata (SW of Putaruru). *Photo:* David Lowe

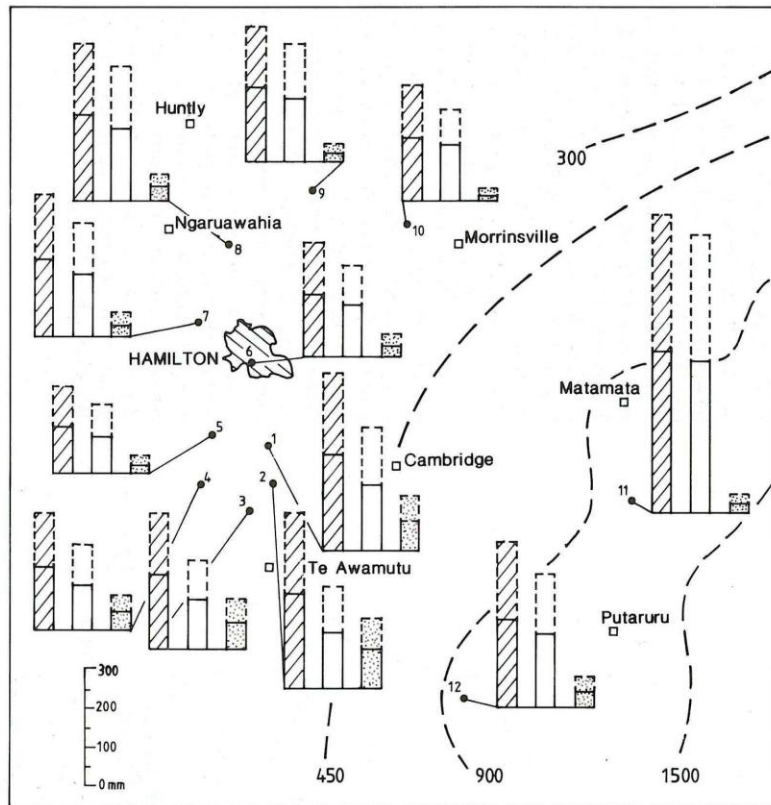




(Left) Central Waikato area showing locations of lakes cored to obtain detailed post-c. 20 cal ka tephra record. Gordonton Rd section is near L. Tunawhakapeka. (Right) Cores from Lake Rotomanuka sliced open to show tephra layers preserved in dark lake sediments (from Lowe, 1988).

Lake sites are: 1, L. Maratoto; 2, L. Rotomanuka; 3, L. Ngaroto; 4, L. Mangakaware; 5, L. Mangahia; 6, L. Rotoroa; 7, L. Rotokauri (thickness measurements do not include Rerewhakaaitu Ash); 8, L. Kainui; 9, L. Rotokaraka; 10, Leeson's Pond; 11, L. Okoroire; 12, L. Rotongata.

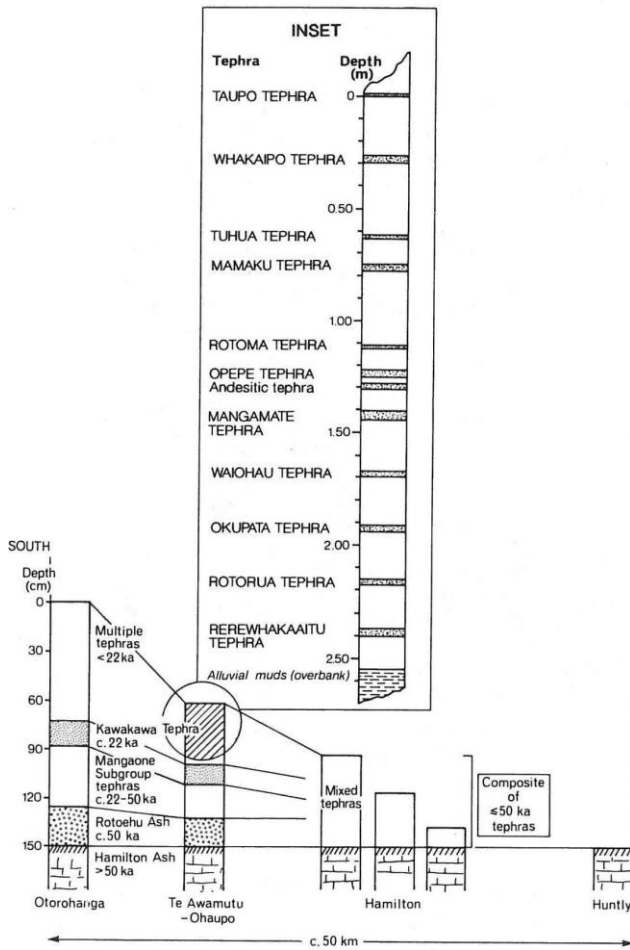
Thickness and compositional relationships based on measurements of tephras in lake cores. Bars with hatching = total thickness of all tephras  $\leq$  c. 20 cal ka; blank bars = rhyolitic tephras; stippled bars = andesitic tephra. Solid bars = actual measurements, dashed bars = thicknesses corrected for compaction and dissemination in sediment cores. Dashed lines = isopachs (in mm) of sum of tephras at subaerial sites deposited since c. 20 cal ka (from Lowe, 1988; see also data p.71).



Total thicknesses of tephras < c. 20 cal ka in central Waikato area based on lake core measurements and estimated 'dry-land' (subaerial) thicknesses (values in centimetres) (from Lowe, 1988)

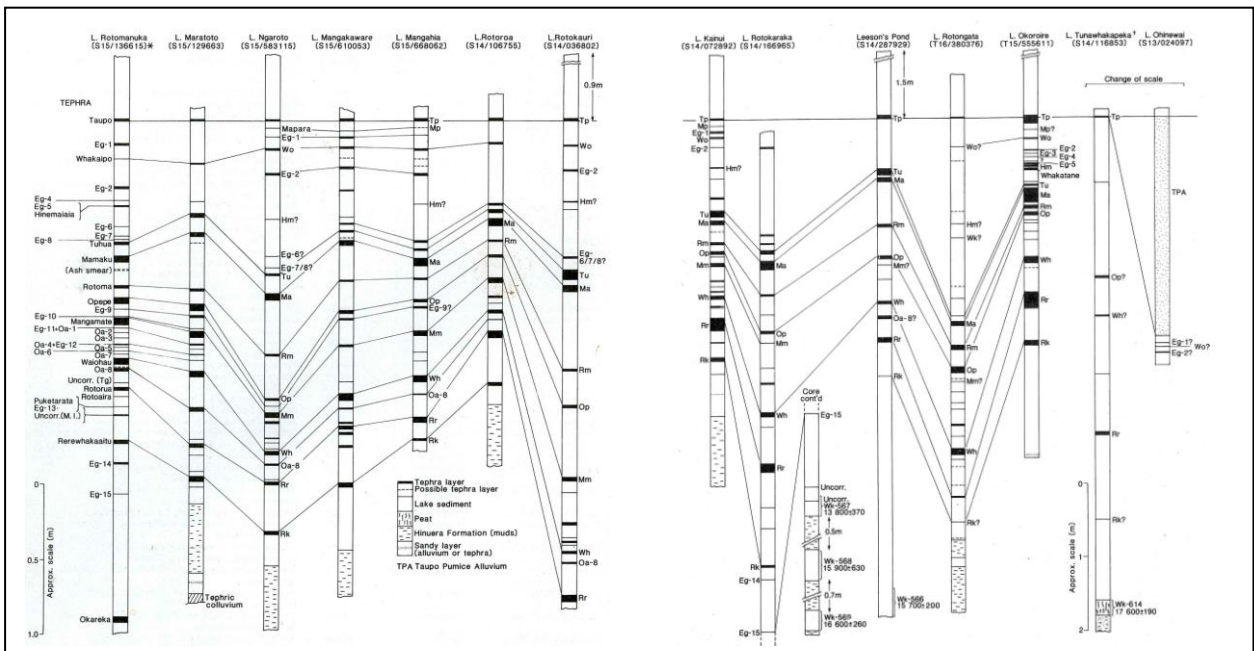
Area	Total visible thickness in cores (average)	Compaction - corrected thickness (visible x1.75)	Estimated dissemination thickness (visible x0.1)	Total equivalent dry-land thickness (approx.)
Hamilton–Ohaupo	25	44	2.5	47
Whitikahu–Morrinsville	20	35	2.0	37
Okoroire–Tirau	42	74	4.2	78

\*Assumed to represent airfall material only, with no modification to thickness by postdepositional reworking or catchment erosion.



**Figure 10.4** Transect across the Hamilton Basin showing the simplified stratigraphy and age of late Quaternary tephra deposits overlying Hamilton Ash on the low hills. Marker beds are distinguishable in the field in the south (Otorohanga and Te Awamutu-Ohaupo profiles) but around Hamilton the tephra deposits, thinning away from their sources, become intermixed to form a composite cover bed with no distinguishable marker beds. Where this cover bed is eroded, exhumed Hamilton Ash occurs at the surface, as for the Huntly profile, but thin late Quaternary tephras are present further north towards Auckland. The inset shows the stratigraphy of prominent tephra layers preserved in lake sediments in a core from Lake Maratoto, a 17 000-year-old peaty lake about midway between Ohaupo and Hamilton (see Figure 10.5). It indicates potential contributions of specific tephras as probable parent materials in the upper soil profile (hatching). ka = 1000 years BP. After Lowe (1986).

Ages in  $^{14}\text{C}$  yr ka. Otorohanga and Ohaupo soils (Hapludands) occur at sites marked by columns 1 and 2; Kainui soils (Udults) at site marked by columns 3-5 ('Hamilton'  $\cong$  Gordonton Rd); and Naikē soils (Humults) at site marked by column 6 ('Huntly') (from Selby and Lowe, 1992).



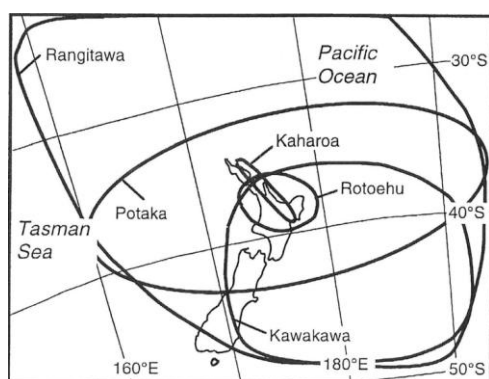
Stratigraphy and correlation of post- c. 20 cal ka visible tephras in cores from 14 Waikato lakes (from Lowe, 1988)

### Kauroa and Hamilton ash bed sequences

The *Kauroa Ash Formation* comprises a sequence up to ~12 m thick of extremely weathered, clay-rich (~70–90% <2- $\mu$ m clay), multiple tephra deposits and associated buried soil horizons, together with interbedded loess (Ward, 1967; Pain, 1975; Horrocks, 2000; Lowe et al., 2001, 2008). The formation was defined in the Waikato area by Ward (1967). The sequence near Raglan is underlain by basaltic deposits dated at c. 2.25 Ma (Briggs et al., 1989), and overlain by the Hamilton Ash Formation, of which the lowermost member (H1 or Rangitawa Tephra) is dated at c. 0.35 Ma (see below). Salter (1979) divided the Kauroa ash sequence into 15 major members, K1 (base) to K15 (top), and this framework, modified in part, has been used subsequently (Briggs et al., 1994; Horrocks, 2000; Lowe et al., 2001). Distinctive sand-sized ‘micaceous’ or platy minerals in beds K3 and K12 are kaolinite books and stacks (Salter, 1979). K1 was dated at  $2.24 \pm 0.29$  Ma by Lowe et al. (2001) using the zircon fission-track method, confirming the previous age. Members K2 and K3 gave indistinguishable ages between  $1.68 \pm 0.12$  and  $1.43 \pm 0.17$  Ma. Member K12, a correlative of Oparau Tephra and Ongatiti Ignimbrite, was dated at  $1.15 \pm 0.15$  Ma, consistent with an age of 1.2–1.3 Ma obtained by various methods on Ongatiti Ignimbrite (Briggs et al., 2005). From palaeomagnetic measurements, members K13 to K15 (top unit) are aged between c. 1.2 Ma and 0.78 Ma (Horrocks, 2000; Lowe et al., 2001). We use an age of c. 1 Ma.

The *Hamilton Ash Formation* comprises a sequence, up to ~6 m thick, of strongly weathered, clay-textured (~60–85% <2- $\mu$ m clay) multiple rhyolitic tephra beds and associated paleosols (Lowe and Percival, 1993; Briggs et al., 1994; Lowe et al., 2001). The sequence may also contain intercalated loessic beds at some sites. The beds are widespread throughout the Waikato and Coromandel regions and extend northward to the Pukekohe area. The sequence is underlain, usually with a marked erosional unconformity, by the Kauroa Ash, of which the uppermost member has an age of ~ 1 Ma (noted above). In turn the Hamilton ash beds are overlain by the composite cover bed of younger multi-sourced tephras, the basal tephra being Rotoehu Ash c. 60 ka (e.g., see age models in Berryman et al., 2000; Newnham et al., 2004; Wilson et al., 2007).

Ward (1967) divided the Hamilton Ash Formation into members numbered from H1 (basal unit) to H9. However, members H8 and H9 (formerly defined as the ‘Mairoa Ash Member’, but now known to comprise Rotoehu Ash and younger tephras) are redundant, and so the uppermost beds are H6 and H7 (top unit). These two beds together define the Tikotiko Ash Member. The basal member in the sequence, the Rangitawa Tephra (known previously in the Waikato region as Ohinewai Ash, and elsewhere as Mt Curl Tephra), is characteristically pinkish- to brownish-grey in colour, silty, halloysitic, and contains distinctive sand-sized golden ‘platy’ minerals identified as 2:1:1 interstratified micaceous-kaolinite intergrades (Lowe and Percival, 1993, after Shepherd, 1984). A thin (c. 5 cm) yellowish layer containing coarse sand-sized quartz crystals marks the base of the tephra.



Map showing distal isopachs of five tephras: Potaka (~1 Ma), Rangitawa (~350 ka), Rotoehu (~60 cal ka), Kawakawa (~27 cal ka), and Kaharoa (~1314 AD) (from Shane, 2000)

Rangitawa Tephra is a distal correlative of Whakamaru-group ignimbrites of similar age derived from Whakamaru caldera (Kohn et al., 1992). Correlation was based on similarities of stratigraphic position and mineralogy, and on major element compositions of glass (Lowe et al., 2001). The tephra was dated by Lowe et al. (2001) using the zircon fission-track technique at  $0.38 \pm 0.04$  Ma. This age matches those obtained by various methods on Rangitawa Tephra of 0.34–0.35 Ma (Pillans et al., 1996; Alloway et al., 2007a), supporting correlation. Member H5 is estimated to be c. 240–190 ka in age, and the youngest members of the sequence, H6–H7, are estimated to be c. 180–80 ka in age (Lowe et al., 2001) (an approximate age of c. 100 ka is used here for the paleo-landsurface).

### Pedological interest

Other interesting features at this site include the markedly irregular boundary between the uppermost cover bed and the dark reddish brown ‘Last Intergacial’ or OIS 5 buried soil – probably the hollows represent tree-overturn pits. Secondly, prominent, approximately horizontal to wavy, thin (1–3 cm), grey clay veins are evident in upper parts of the sequence. They seem to more or less lie along the lower boundary of the dark reddish brown Last Interglacial unit (bed H7/6) and the underlying buried brown soil horizon/unit, probably bed H5. Following Shepherd (1994), Lowe et al. (2001) considered that bed H5 represented soil formation during OIS 7. If so, then it is speculated here that the veins may mark impeded drainage along the OIS 7 paleo-landsurface which is wavy and in places irregular like the tree-overturned surface at the top of the OIS 5 soil now buried by the cover bed tephras (Rotoehu Ash and younger deposits). Manganese concretions (redox segregations or concentrations) occur commonly near the base of this cover bed where drainage is impeded for several months each year by the slowly permeable underlying clayey soil (e.g. Lowe, 1986, 1991; McLeod, 1992). Perhaps the grey veins then are equivalent reductimorphic features – i.e. low chroma mottles (redox depletions) – that developed in tephric materials deposited during OIS 6 over the antecedent clayey and slowly permeable soil formed in OIS 7. Several of the veins tested at this site are currently reduced based on the Childs’ test and so may represent both relict and modern features (sometimes the veins mimick the concave curvature marking the base of the overlying cover beds lying on the OIS 5 paleosurface). The grey clay veins are commonplace in the uppermost weathered Hamilton ash beds sub-parallel to and near the modern land surface in other parts of the Hamilton Basin. Ward (1967) attributed them to soil-forming processes rather than a relict of parent material variations and noted an association with dense root mats in places. He also tentatively linked them with vegetation assemblages containing kauri (*Agathis australis*).



Possible tree overturn features shown up by contrasting colours and textures of pale cover bed tephras (OIS 3-1) and dark reddish-brown soil in weathered upper Hamilton Ash unit H6/7 (OIS 5). Layers of grey (low chroma) clay veins are evident at top of brown unit H5 (OIS 7?) level with Seb’s head. Naike soils occur infrequently where the cover bed is missing. *Photo:* David Lowe

### Kainui soil

The main (modern) soil evident at this site is the *Kainui silt loam* which comprises two parts, the uppermost silty cover bed of late Quaternary tephras, the base of which is Rotoehu Ash (c. 60 ka), and part of the buried clay-rich soil developed on strongly weathered Hamilton ash bed H7/6. In 'Soils of New Zealand' Part 3 (1968) the 'Hamilton clay loam' at Church Rd site is better considered as part of the Kainui series (Lowe, 1981). Kainui soils have been mapped and described by Bruce (1979), Wilson (1980), and McLeod (1984, 1992). The data below are from McLeod (1992) (see also Lowe, 1981). The upper subsoil horizons formed in the tephra cover bed are often sufficiently pale and weakly structured to qualify as E horizons in Clayden and Hewitt (1989) because they contrast with darker buried Bt horizons below. In other cases they are better considered perhaps as pale Bw horizons and occasionally BE horizons. In many instances they exhibit redox features including few to abundant manganese concretions especially towards the boundary with the buried Bt horizon, and subhorizons are labelled accordingly. McLeod (1992) suggested that the upper subsoil horizons are eluvial, which might imply that the underlying Bt horizon complements them as part of a sequum. However, the boundary between the lower E and the 2bBt is a lithological discontinuity (Lowe, 1986) and so the E and Bt horizons have not been 'connected' throughout the entire period of soil genesis. If unrelated, then a 'pale' Bw notation might be more suitable than Ew.



The two-storied Kainui soil is a classic example of the result of progressive upbuilding pedogenesis (Lowe, 2000). The rate of accumulation of tephras since the fall of c. 60-cal ka Rotoehu Ash (~ 25 cm thick here based on a mineralogical abundance model of Lowe, 1981) is on average only about 1 mm per century (about the same rate as very slow loess accumulation on the West Coast, South Island) (Lowe et al., 2008). Thus topdown processes have operated continuously for the past c. 60,000 years while the land surface has been rising very slowly. Each part of the profile has at some point been an A horizon.

The tephra cover bed and the associated Kainui soil are typically halloysitic, not allophanic, because soil solution levels of silicon at this and other sites northward of Hamilton remain high (>~10 ppm) because of slow permeability of the underlying buried soil, markedly dry summers from time to time, and other reasons (Lowe and Percival, 1993; Lowe, 1986, 1995) (see also Singleton et al., 1989). For many years, the non-allophanic character of the relatively young tephra mantle (considered to be loess at one stage because of this character) was a puzzle because allophanic soils occur on late Quaternary tephras south of Hamilton and in upland areas to the west and east of the Hamilton Basin (McCraw, 1967).

However, the development of a rainfall-distribution based silicon leaching model by Parfitt et al. (1983, 1984), supported by stratigraphic and other evidence by Lowe (1986), provided an explanation (Lowe, 2002). As noted by Lowe (1991), the Kainui silt loam was ‘the leopard that changed its spots’ (i.e., it represents genesis in an environment sufficiently different for relatively recent tephra materials to weather directly to halloysite rather than to allophane as occurs not far to the south). Where the cover bed mantle exceeds about 1 m or so in thickness (typically in tree-overturn hollows), the drainage through the composite tephras is less constrained by the impermeable buried clayey soil on Hamilton ash because it is deeper, and consequently allophane can be found in the A and upper Ew (or Bw) horizons (Lowe, 1981, 1986).

### **Naike soil**

The *Naike clay* is formed on weathered Hamilton ash, i.e. without the silty cover bed mantle (apart from perhaps ~10-15 cm forming an A horizon with silt). It is very similar to soils of the Hamilton series. The Naike soils are thus exhumed buried soils (buried paleosols) from which any subsequent tephras have been eroded, and are likely to be at least c. 100-125 ka, possibly older if earlier beds in the Hamilton Ash sequence have been exhumed. Like the Pukekohe and Patumahoe soils, the Naike soil is sticky when wet and topsoils have very limited workability in this condition, but the Naike clay is firmer, denser and more compacted. Bulk densities exceed  $1 \text{ g/cm}^3$  in Bt horizons. The clay mineral assemblage of the Naike soil is predominantly halloysite without the ‘moderating’ influence of allophane and gibbsite that occur in the Pukekohe area. The Naike soil has a well developed, strong pedal microstructure with 90% of the material finer than  $20 \mu\text{m}$  (Bakker et al., 1996). Topsoils, however, tend to be more “cloddy” and never seem to attain the same level of “tilth” as Pukekohe or Patumahoe soils (G.E. Orbell pers. comm., 2008).

The Naike soil becomes more weathered with depth, suggesting upbuilding pedogenesis has predominated. Large quantities of microlaminated, anisotropic clay coatings (halloysite or kaolinite, the less-ordered character observed micromorphologically strongly favouring the former) are present in Bt horizons and are the result of clay illuviation (fine clay: total clay ratios of 0.7 to 0.8 support this inference) (Bakker et al., 1996). The clay coatings have been responsible for impeding drainage (and thus further reducing loss of Si and favouring more halloysite production). Cutans in a bBtg horizon have iron hypocoatings. The gleying is a more recent process than the clay illuviation because the hypocoatings are superimposed upon the clay coatings (Bakker et al., 1996). Large amounts of Fe oxide coatings observed in both Patumahoe and Naike soils provide the reddish brown to strong brown colours in the Bt horizons of both soils.

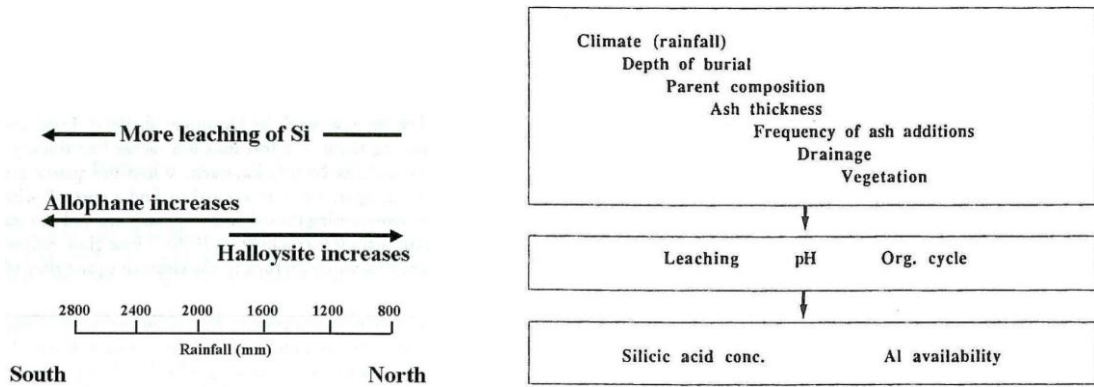
The differences between the Naike and Patumahoe soils, despite similar parent materials, were attributed by Bakker et al. (1996) to slightly different climatic and vegetation histories at each site: pollen studies have shown that the Pukekohe area has probably always been under forest cover, whereas the Hamilton Basin has additionally experienced a drier, grass or shrub-dominated vegetation cover during the last glacial period (e.g., Newnham et al., 1989, 1999; Alloway et al., 2007b) and presumably earlier glacial periods as well including OIS 6. Thus Bakker et al. (1996) inferred that the Patumahoe and Pukekohe sites were effectively warmer and wetter, thereby favouring the formation of allophane and presumably gibbsite and Fe oxides through enhanced Si leaching. In contrast, the postulated drier conditions (during the glacial) for the Naike site may have been sufficient to reduce Si leaching to levels favouring halloysite formation. Data on Naike are available in Parfitt et al. (1981, p. 78-83), Bakker et al. (1996), and in ‘Soils of New Zealand’ Part 3 (p. 90-91). Naike or Hamilton soils have been described and mapped in the Waikato area by Bruce (1978, 1979), Wilson (1980), McLeod (1984) and Singleton (1991).



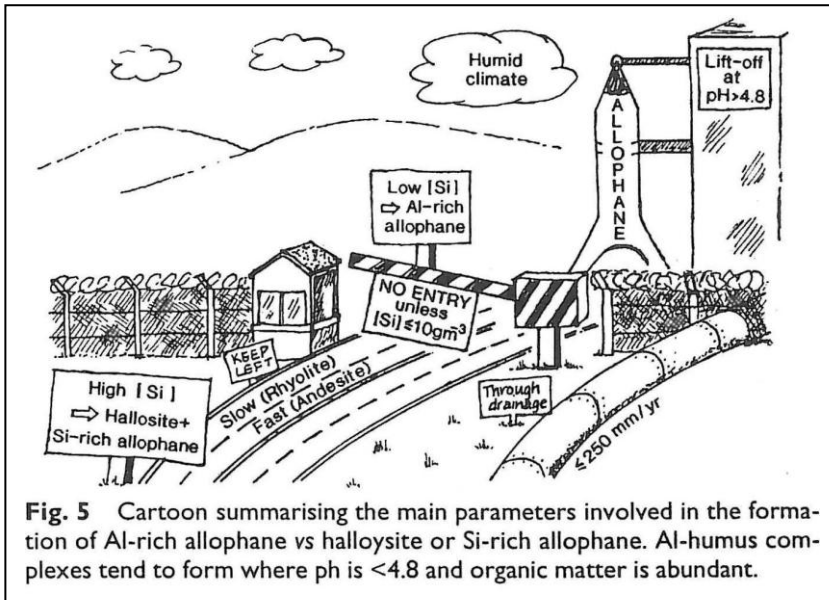
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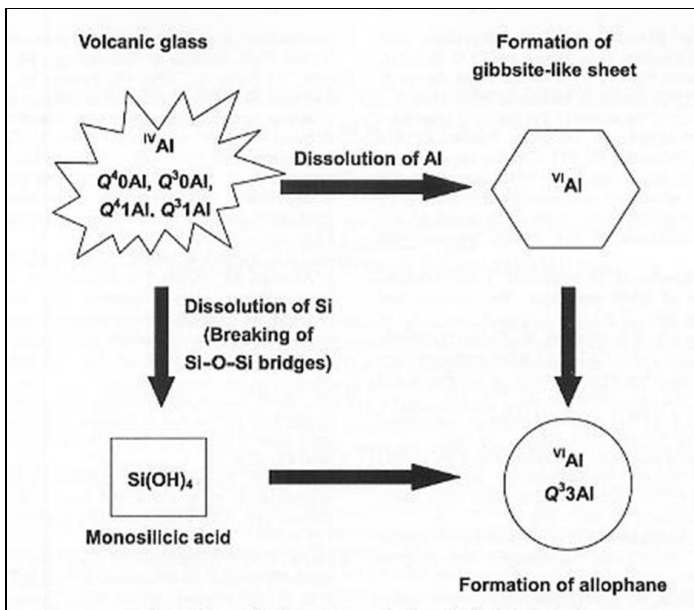
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(Left) Simplified rainfall-based Si-leaching model for the formation of Al-rich allophane and halloysite from weathering of tephras in the Waikato region (from Lowe, 2002, after Parfitt et al., 1983). A more comprehensive model is given by Lowe (1986) and Lowe and Percival (1993). (Right) Some factors governing clay formation in volcanic ash materials (humans could be added, e.g., via burning/deforestation) and the key 'elements' (!) of silicic acid concentration and Al availability (from Lowe, 1995).



Cartoon summarising model (from Lowe, 1995; see also Singleton et al., 1989).

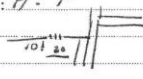


Model based on Japanese studies for the formation of allophane from glass (from Hiradate and Wada, 2005).

## Description and data for Kainui silt loam

### Hauraki Plains survey (by Malcolm McLeod and Brian Daly(?))

 B. Nos. SB9801A-F  
 Id Nos. HC12 9-F

 SOIL SET: \_\_\_\_\_ Est./Funct. \_\_\_\_\_ Mod./Var. \_\_\_\_\_  
 CLASSIFICATION (in full)—Common: \_\_\_\_\_  
 Technical: \_\_\_\_\_  
 SURVEY: Hauraki Plains County Collector: MM BD Date: 9-8-82 Pit/Comp. (\_\_\_\_ cores)  
 LOCATION—County: Hauraki Plains Survey District: H. P. Block: \_\_\_\_\_ Cult'd/Uncult'd/Virgin  
 Orientation: \_\_\_\_\_ Section: \_\_\_\_\_ Topdr./Untopdr.  
 Exact Location: Top NE corner of paddock  Farmer: \_\_\_\_\_  
 Grid Ref. NZMS 1 N52 900052  
 Altitude: \_\_\_\_\_ ft (30 m) Rainfall: 1200 - 1400 mm Raindays (>0.01"): \_\_\_\_\_ (>0.05"): \_\_\_\_\_ Mean Annual Temp.: 13.6 (1992)

Field No.	Lab. No.	Horiz.	Depth in cm	DESCRIPTION—Colour, Texture, Consistence, Structure, Boundary, etc.
HC12 a	9801 A	Ap	0-16	10YR 3/2 with some 10YR 4/2 worm mixing from below; silt loam; moderately weak; brittle; few fine pores; weak fine root breaking to crumbs; many fine roots; distinct irregular boundary.
HC12 b	9801-B	Ew1	16-32	10YR 5/3 silt loam; very weak; brittle; many medium pores; weak fine root breaking to crumbs; few fine roots; indistinct wavy boundary.
HC12 c	C	Ew2	32-47	10YR 5/4 clay loam; moderately weak; brittle; many medium & coarse pores; weak fine root structure; few fine roots; indistinct wavy boundary.
HC12 d	D	2bBt(g)	47-86	7.5YR 4/6 with horizontal veins 7.5YR 6/2 plus organic matter down cracks 7.5YR 4/2; clay; moderately firm; brittle; very few medium pores; abundant clay skins; moderately developed medium & coarse blocky breaking to fine blocky; few fine roots down cracks; distinct wavy boundary.
HC12 e	9801 3bB(F)	E	86-108	7.5YR 4/6 with few medium distinct 10YR 5/8 mottles; clay; brittle; moderately weak; few medium pores; very firm in situ; weak medium blocky; many clay skins; no roots.
	F		@ 190	
	DJL note			* Colour criteria qualify these upper subsoil horizons as E horizons (Clayden and Hewitt, 1989) but note that there is a lithological discontinuity at 47 cm depth where 2bBt(g) horizon is recognised. McLeod (1992) suggested that the upper subsoil horizons = eluvial horizon.

 SITE—Slope: 6 Nature of Slope: \_\_\_\_\_  
 Aspect: SE Exposure: \_\_\_\_\_  
 Microfeatures: \_\_\_\_\_  
 Erosion: Slight creep.  
 Disturbance: \_\_\_\_\_  
 Drainage: Moderately well drained  
 VEGETATION (over sample)—Height: 10cm Main Species: Pasture grasses  
 (at site)—Height: 10cm Main Species: \_\_\_\_\_  
 Type of Vegetation: \_\_\_\_\_  
 History: \_\_\_\_\_  
 Root Distribution: \_\_\_\_\_  
 PARENT MATERIAL: 47cm moderately argillised late Pleistocene rhyolitic and andesitic volcanic ash over strongly argillised Pleistocene rhyolitic and andesitic volcanic ash.  
 Parent-Rock: \_\_\_\_\_

### Classification: Kainui silt loam

NZSC: Podzolic<sup>1</sup> [or 'Buried-granular'] Yellow Ultic Soils; tephric, mixed rhyolitic and andesitic<sup>2</sup>; silty/clayey; moderate/slow

Soil Taxonomy: Clayey, halloysitic, thermic Aquic [or Oxyaquic] Kandiodults

<sup>1</sup>It is possible that the 'organic matter down cracks' noted for 2bBt(g) in above description might be MnO<sub>2</sub> (pyrolusite) coatings, abundant in lower subsoils (near boundary upper/lower parts of profile) of many Kainui soils. For 'Podzolic' subgroup Hewitt (1998) requires ≥10% humus coatings or coatings of colour value ≤4, and pH ≤4.8 in the E horizon if present. My preferred classification is to add a new 'Buried-granular' subgroup, rather than use Podzolic subgroup, to encompass widespread Kainui soils.

<sup>2</sup>See Clayden and Webb (1994) p. 14 – differentiated using ferromagnesian mineral assemblages of sand fractions (see also compositional data in Lowe, 1981, 1986, 1989)



Kainui

FABRIC-RELATED ANALYSIS

Kainui silt loam

Lab no.	Horiz. Depth (cm)	Sample Depth (cm)	As sampled		1/3 bar		COLE	Total porosity (%)	Large pores (%)	Water content (% v/v) at tensions (bar)					Field capacity (% v/v)	15 bar water (% v/v)	Available water
			w.c. (%)	Bulk Density (T/m <sup>3</sup> )	w.c. (%)	Bulk Density (T/m <sup>3</sup> )				0.025	0.05	0.1	0.2	0.4			
PA 113A	0-16	5-8	38.3	1.19				51.2	3.5	47.7	45.2	42.6	40.3	38.1	42.6	17.8	24.9
B		9-12	31.0	1.19				51.8	13.1	38.7	36.7	34.7	32.3	30.2	34.7	17.7	16.0
1114 A	16-32	21-24	24.0	1.45				42.5	6.8	35.7	34.7	33.6	31.9	29.3	33.6	20.5	13.1
B		25-28	24.3	1.48				41.9	5.4	36.5	35.6	34.4	32.6	29.6	34.4	20.8	13.6
1115 A	32-47	36-39	25.8	1.45				43.3	5.1	38.1	37.2	36.3	34.9	32.5	36.3	30.2	6.2
B		40-43	28.4	1.39				45.9	5.1	40.9	40.1	39.5	38.8	37.4	39.5	28.9	10.6
1116 A	47-86	63-66	42.3	1.20				54.0	2.1	51.9	51.1	49.2	48.0	46.2	49.2	50.3	0.0
B		67-70	47.0	1.14				56.0	1.2	54.8	54.7	54.6	54.5	53.8	54.6	47.8	7.0
1117 A	86-108	93-96	59.3	0.93				65.2	6.6	58.7	57.2	56.0	55.5	54.7	56.0	50.6	5.4
B		97-100	60.1	1.00				61.6	<1.0	62.4	62.1	62.0	61.6	60.9	62.0	54.8	7.3

CLAY MINERALOGY (%):

Lab. No.	Horiz.	Depth	Mica/illite	Chlorite	Vermiculite	Smectite	Kaolin Group	Halloysite	Interstratified Minerals				Short Range Order Min.		Feldspar	Quartz	Cristobalite	Geothite	Hematite	Gibbsite
									Mica-Verm	Mica-Smect	Mica-Chlor	Int. Hyd. Mica	Allophane & Imogolite	Ferrihydrite						
SB 9801 A	Ap	0-16					52							2	3					
B	Ew1	16-32	9		7	5	68							3	3					
C	Ew2	32-47	5		6	3	80							2	1					
D	2b Bt(g)	47-86	3		5	5	81							1						
E	3t Bt(f)	86-100	8		6	84														
Notes:																				
By Formamide Test 80% of the Kaolin group minerals is Halloysite																				
Wtd Av Control Section(95-100)			5		4.5	4.8	82													



Feeding out during Waikato drought 2008 (photo 4 April 2008 by David Lowe)

# Description and data for Naike heavy silt loam Rotowaro (near Huntly)

## NAIKE HEAVY SILT LOAM

Location: 11 m west of roadside pumphouse, north of woolshed  
 Aspect: 40°E Altitude (m): 100 Rainfall (mm): 1240 Slope: 8° Landform: Side slope of northern oriented spur of hill  
 Vegetation: Ryegrass, white clover, browntop, paspalum, thistles, after broadleaf/podocarp forest Drainage class: Moderately well drained  
 Land use: Sheep, dairying, (coal mining) Parent material: Hamilton Ash Formation Grid ref: N56/1

Horizon Depth (cm)	PROFILE DESCRIPTION	Horizon Depth (cm)	PROFILE DESCRIPTION
Ap 0-12	10YR 3/2 heavy silt loam; strong fine nut (peds very hard); moderately firm; brittle; abundant coarse pores; abundant roots, many clean quartz crystals or glass shards; diffuse wavy boundary,	Btg 97-131	7.5YR 5/6 (moist) 7.5YR 6/6 (rubbed) clay; moderately sticky; moderately plastic; moderately firm; brittle; many distinct fine and medium 5YR 4/6 mottles; few fine roots; moderately developed medium block structure; many coarse ar medium pores; few thin discontinuous cutans; many very fine pinkish white flecks; diffuse wavy bound
Bw 12-20	7.5YR 4/6 (moist) 10YR 4/4 (rubbed) clay loam; slightly sticky; slightly plastic; moderately firm; brittle; abundant 10YR 3/2 casts of Ap horizon; abundant roots; very few very thin cutans; strong fine nut structure; many coarse pores; diffuse wavy boundary,	Bwg 131-153	5YR 5/6 (moist) 7.5YR 6/6 (rubbed) clay; moderate sticky; very plastic; moderately firm; brittle; moderately developed medium block structure; few very coarse many coarse and medium pores; abundant fine and medium pinkish white flecks (? gibbsite) few fine and medium diffuse 5YR 4/4 mottles; few fine roots; few very thin discontinuous cutans; indistinct wavy boundary,
Bt1 20-48	7.5YR 4/6 (moist) 7.5YR 5/6 (rubbed) clay; moderately sticky; moderately plastic; moderately firm; brittle; few coarse many medium pores; many thin continuous cutans; (no grains showing through coatings); strongly developed medium nut structure; many roots; diffuse wavy boundary,	Cg1 153-165	7.5YR 5/8 (moist) 7.5YR 6/6 (rubbed) clay; slight sticky; very plastic; moderately firm; brittle; w developed coarse block structure; many coarse me medium pores; abundant coarse and medium pinkish white (7.5YR 8/2) (?gibbsite/halloysite) nodules; faint diffuse 5YR 4/4 patches; very few fine root indistinct wavy boundary,
Bt2 48-73	7.5YR 4/6 (moist) 7.5YR 5/6 (rubbed) clay; slightly sticky; moderately plastic; moderately firm; brittle; strongly developed medium block structure; many roots; many thin continuous cutans (no grains showing through); moderately firm; brittle; (peds are very firm); many fine and very fine pinkish white flecks; moderately developed medium block structure; diffuse wavy boundary,	Cg2 165-181	7.5YR 6/6 (moist) 7.5YR 7/6 (rubbed) clay; slightl sticky; very plastic; abundant very coarse and cc 7.5YR 7/4 distinct mottles; abundant fine and med 5YR 5/8 distinct mottles; many diffuse 2.5Y 7/4 patches; many coarse and medium pores; very few f roots; moderately firm; semi-deformable; moderate weakly developed coarse block structure; few ver discontinuous cutans; distinct wavy boundary,
Bt3 73-97	between 7.5YR 4/6-5/6 (moist) 7.5YR 5/8 (rubbed) clay; slightly sticky; moderately plastic; moderately firm; brittle; few roots; many fine pinkish white flecks; few faint diffuse fine 5YR 4/4 mottles; many very thin continuous cutans; moderately developed medium block structure; diffuse wavy boundary,	2Bt 181-215	5YR 4/6 (no change on rubbing) clay; slightly sti slightly plastic; moderately firm; brittle; many medium diffuse near 5Y 7/3 patches; many coarse a pores; weakly developed coarse block structure; many thin continuous cutans; few coarse prominent quartz grains.

CLASSIFICATION - N.Z. Genetic: Brown granular loam

### Classification: Naike heavy silt loam

NZSC: Typic Oxidic Granular Soils; tephric, rhyolitic; clayey; slow  
 Soil Taxonomy: Clayey, halloysitic, thermic Typic Kandihumults

CHEMISTRY		NAIKE																	
Sample No. SB	Depth (cm)	Hor.	pH			Exchangeable cations (meq/100 g)					Extr. Acidity (pH 8.2)	Acidity-Al (meq/100 g)	ECEC	CEC (meq/100 g)		Base saturation (%)			
			H <sub>2</sub> O	KCl	ΔpH	NaF	Ca	Mg	K	Na				H (KCl)	Al (KCl)	NH <sub>4</sub> OAc (pH 7)	Σ Cations (pH 8.2)	Σ bases CEC NH <sub>4</sub> OAc	Σ bases Σ Cations
9579 A	0-12	Ap	5.6	4.5	-1.1	8.7	10.8	1.83	0.86	0.28	0.26	27.8	27.5	14.1	25.4	41.6	54	33	
B	12-20	Bw	5.6	4.4	-1.2	9.3	6.3	1.46	1.15	0.43	0.32	20.7	20.4	9.6	17.8	30.0	52	31	
C	20-48	Bt1	5.3	4.1	-1.2	9.6	3.4	1.10	0.44	0.94	1.5	21.3	19.8	7.4	16.1	27.2	37	22	
D	48-73	Bt2	5.2	3.9	-1.3	9.6	1.9	0.88	0.10	1.15	2.9	23.4	20.5	6.9	16.0	27.4	25	15	
E	73-97	Bt3	5.3	3.9	-1.4	9.8	1.5	0.78	0.06	1.21	3.0	23.7	20.7	6.6	15.5	27.3	23	13	
F	97-131	Btg	5.5	3.9	-1.6	9.7	1.4	0.67	0.16	1.41	2.3	18.5	16.2	5.9	14.0	22.1	26	16	
G	131-153	Bwg	5.4	3.9	-1.5	9.7	1.2	0.47	0.13	1.28	2.8	18.1	15.3	5.9	12.7	21.2	24	15	
H	153-165	Cg1	5.3	3.9	-1.4	9.7	0.9	0.40	0.05	1.08	2.4	15.4	13.0	4.8	11.4	17.8	21	13	
I	165-181	Cg2	5.3	3.9	-1.4	9.7	0.9	0.37	0.03	0.96	2.0	13.5	11.5	4.3	10.1	15.8	23	15	

Sample No. SB	Depth (cm)	Hor.	Total C (%)	Total N (%)	P (mg/100 g)			P Retention (%)	Dithion. cit. (%)		Tamm ox. (%)			Pyrophos. (%)		Reserves (meq/100 g)		Extractable S (ppm)
					H <sub>2</sub> SO <sub>4</sub> (0.5 M)	Inorg.	Org.		Fe	Al	Fe	Al	Si	Fe	Al	K <sub>c</sub>	Mg <sub>r</sub>	
9579 A	0-12	Ap	6.6	0.48	39	45	56	52	2.8	0.79	0.49	0.32	0.03	0.64	0.32	0.07	1.5	17
B	12-20	Bw	2.5	0.16	8	11	14	63	3.2	0.82	0.39	0.35	0.02	0.81	0.46	0.06	0.9	24
C	20-48	Bt1	1.0	0.06	4	6	5	70	3.6	0.76	0.27	0.34	0.02	1.03	0.33	0.05	0.7	188
D	48-73	Bt2	0.7	0.03	4	5	6	75	3.6	0.80	0.24	0.38	0.02	0.97	0.32	0.04	0.7	329
E	73-97	Bt3	0.6	0.03	5	6	5	75	3.6	0.84	0.33	0.46	0.06	0.90	0.33	0.03	0.7	314
F	97-131	Btg	0.4	0.01	4	5	2	70	3.1	0.60	0.19	0.29	0.04	0.45	0.19	0.04	0.5	321
G	131-153	Bwg	0.3	0.01	4	4	0	64	2.3	0.47	0.18	0.29	0.04	0.27	0.13	0.04	0.6	279
H	153-165	Cg1	0.2	0.01	4	2	0	58	1.08	0.41	0.11	0.24	0.06	0.13	0.10	0.05	1.4	223
I	165-181	Cg2	0.2	0.01	3	2	0	51	1.59	0.35	0.09	0.21	0.04	0.09	0.11	0.06	2.2	186

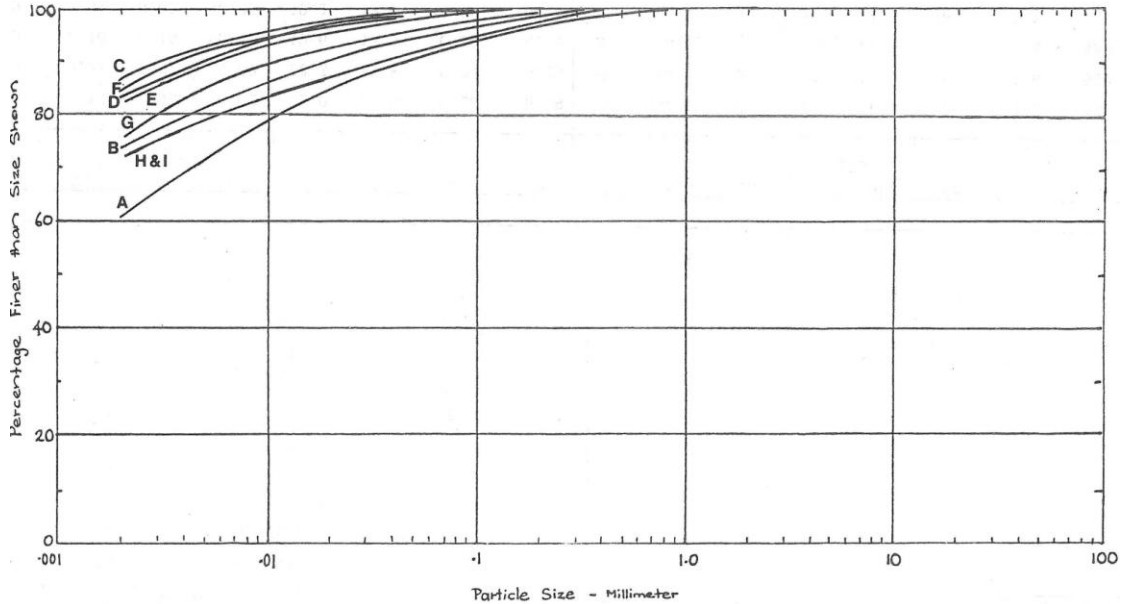
PARTICLE SIZE DISTRIBUTION (<2 mm) Naike

Sample No. SB	Depth (cm)	Hor.	Sand		Silt	Clay	Fine clay		Stones (%)
			2-0.1 mm (%)	0.1-0.05 mm (%)	0.05-0.002 mm (%)	<0.002 mm (%)	<0.0002 mm (%)	Fine clay Total clay (%)	
9579A	0-12	Ap	6	3	30	61	41	0.67	(<1)
B	12-20	Bw	3	3	19	75	60	0.80	
C	20-48	Bt1	1	0	12	87	70	0.80	
D	48-73	Bt2	1	1	15	83	63	0.76	
E	73-97	Bt3	1	1	16	82	59	0.72	
F	97-131	Btg	1	1	13	85	57	0.67	
G	131-153	Bwg	2	2	20	76	50	0.66	
H	153-165	Cg1	5	3	21	71	40	0.56	
I	165-181	Cg2	5	4	19	72	39	0.54	

PHYSICS

Hor. Depth (cm)	Hor.	15 bar water		Core Depth (cm)	Dry bulk density (T/m <sup>3</sup> )	Total porosity (%)	Large pores (%)	Field Cap. (at 0.2 bar) (% v/v)	Wilting Pt. (at 15 bar) (% v/v)	Available water (% v/v)
		Field moist (%)	Air Dry (%)							
0-12	Ap	28.7	24.8	3-5	0.85					
12-20	Bw	35.6	28.5	6-9	0.92					
20-48	Bt1	45.3	34.6	13-16	0.98					
48-73	Bt2	50.7	36.4	17-20	0.91					
73-97	Bt3	52.4	36.4	20-48	1.14					
97-131	Btg	57.0	40.2	48-73	1.11					
131-153	Bwg	53.4	39.3	73-97	0.94					
153-165	Cg1	48.4	36.6	97-131	0.93					
165-181	Cg2	42.8	33.4	131-165	1.01					
				165-181	1.02					

SB 9579 Naike





Sample No. SB	Depth (cm)	Hor.	Clay Fraction (%)														Sand Fraction (%)																			
			Mica-Smectite	Mica-Vermiculite	Smectite	Vermiculite	Interlayered Hydrrous Micas	Mica	Kaolinite	Halloysite	Gibbsite	Quartz	Cristobalite	Allophane	Feldspar	Anatase	Hematite	Quartz	Feldspar (acid)	Andesine	Glass	Muscovite	Riotite	Hornblende	Augite	Hypersthene	Epidote	Zoisite	Apatite	Magnetite	Plant opal					
9579A	0-12	Ap				15				20	50	3		1	11																					
B	12-20	Bw				22				10	55	2		3	8																					
C	20-48	Bt1				2					93	1			5																					
D	48-73	Bt2				6					88	1			5																					
E	73-97	Bt3				4					90	1			5																					
F	97-131	Btg				7					88	tr			5																					
G	131-153	Bwg									95				5																					
H	153-165	Cg1									93				7																					
I	165-181	Cg2									100				tr																					

Sample No. SB	Hor.	Total Element Analysis (%)										Total Element Analysis (ppm)								Ign. loss (%)
		Fe	Mn	Ti	Ca	K	P	Si	Al	Mg	Na	Cr	Ni	Cu	Zn	Rb	Sr	Y	Ba	
9579A	Ap	4.18	0.11	0.50	0.49	0.53	<0.02	23.0	10.6	0.26	0.59	34	<4.0	36	89	41	63	11.2	480	20.0
B	Bw	4.48	0.05	0.49	0.24	0.37	<0.02	22.3	13.8	0.24	0.36	32	<4.0	42	77	27	50	7.6	580	15.6
C	Bt1	4.95	<0.02	0.49	0.10	0.16	<0.02	19.6	17.3	0.22	0.20	29	4.0	57	60	12.7	28	2.8	869	15.7
D	Bt2	5.19	<0.02	0.49	0.04	0.07	<0.02	19.1	18.2	<0.20	<0.20	28	6.7	61	64	9.7	16.4	2.6	981	15.7
E	Bt3	4.86	<0.02	0.47	<0.02	0.06	<0.02	18.2	18.1	<0.20	<0.20	26	<4.0	58	66	9.3	8.8	3.8	1068	15.2
F	Btg	4.62	<0.02	0.47	0.02	0.06	<0.02	19.9	18.0	0.21	<0.20	25	18.7	44	54	5.9	7.1	2.1	931	14.2
G	Bwg	3.81	<0.02	0.41	<0.02	0.11	<0.02	20.5	18.2	<0.20	<0.20	26	18.2	19.1	48	14.5	5.0	2.8	922	13.9
H	Cg1	3.48	<0.02	0.36	<0.02	0.25	<0.02	21.4	17.4	<0.20	<0.20	19.7	15.8	6.5	44	46	6.3	7.8	807	13.5
I	Cg2	3.21	<0.02	0.35	0.03	0.32	<0.02	22.5	16.8	<0.20	<0.20	18.6	12.7	<4.0	39	71	9.0	11.2	778	12.8

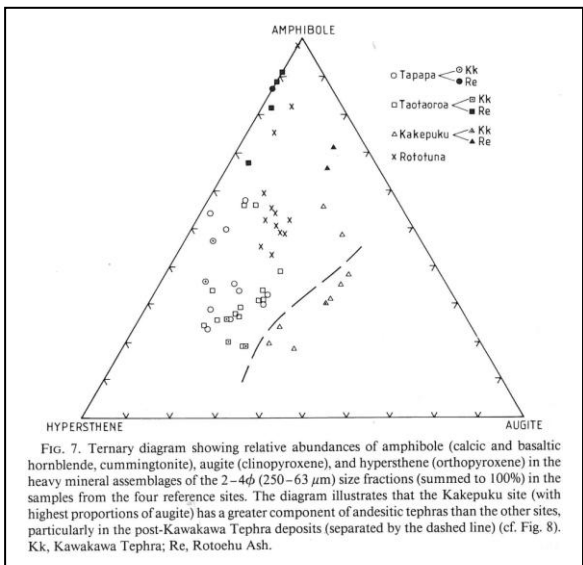
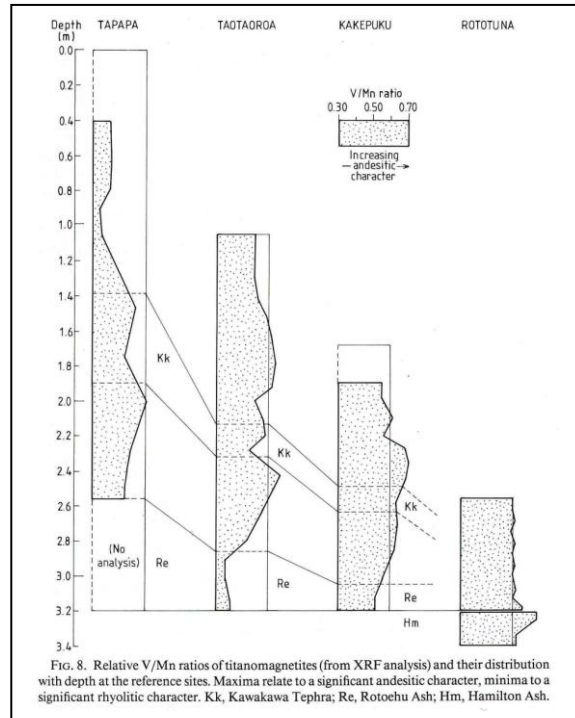
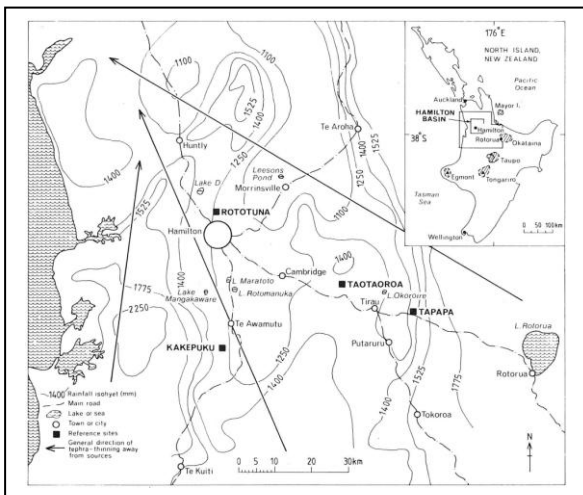
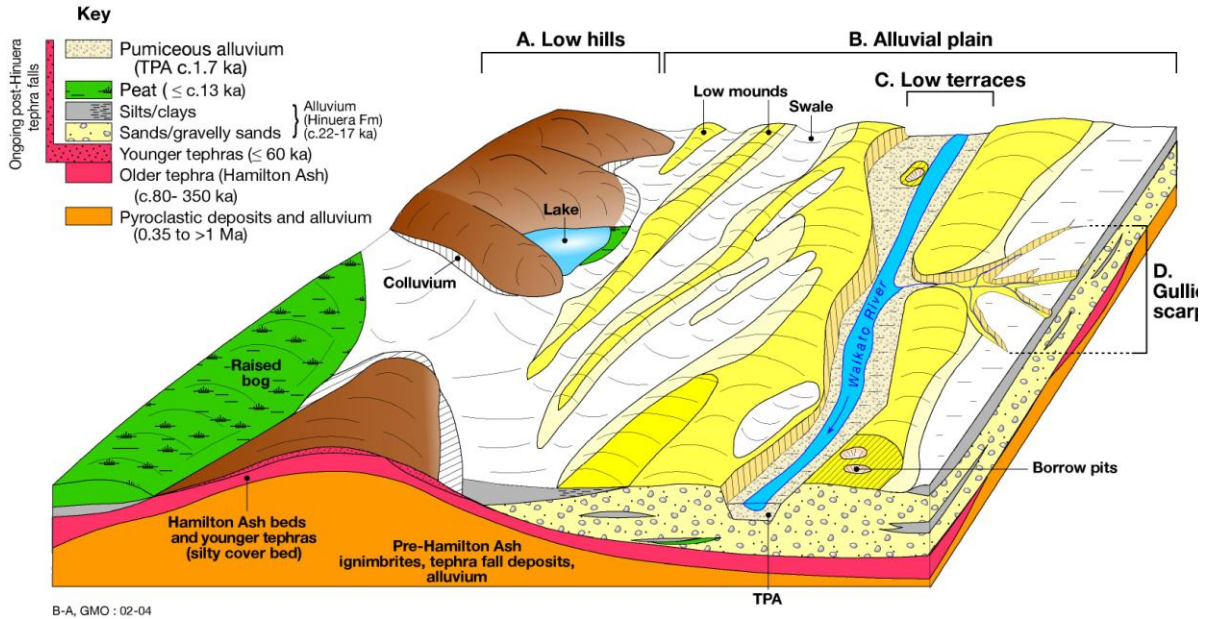


FIG. 8. Relative V/Mn ratios of titanomagnetites (from XRF analysis) and their distribution with depth at the reference sites. Maxima relate to a significant andesitic character, minima to a significant rhyolitic character. Kk, Kawakawa Tephra; Re, Rotoehu Ash; Hm, Hamilton Ash.

FIG. 7. Ternary diagram showing relative abundances of amphibole (calcic and basaltic hornblende, cummingtonite), augite (clinopyroxene), and hypersthene (orthopyroxene) in the heavy mineral assemblages of the 2-4 $\phi$  (250-63  $\mu$ m) size fractions (summed to 100%) in the samples from the four reference sites. The diagram illustrates that the Kakepuku site (with highest proportions of augite) has a greater component of andesitic tephra than the other sites, particularly in the post-Kawakawa Tephra deposits (separated by the dashed line) (cf. Fig. 8). Kk, Kawakawa Tephra; Re, Rotoehu Ash.

Map (above left) showing locations of four tephra-soil sequences and the relative andesitic vs rhyolitic character of samples for each based on (left) ferromagnesian mineral assemblages and (above) V/Mn ratios of titanomagnetites (from Lowe, 1986). All sites contain both rhyolitic and andesitic components but the proportion of subordinate andesitic material increases towards the southwest (Kakepuku). Analyses of tephras in lake cores, especially glass compositions, provided another measure of the contributions of rhyolitic vs andesitic fallout over the region (see p. 57).

Main landscape units and geological materials, Hamilton Basin

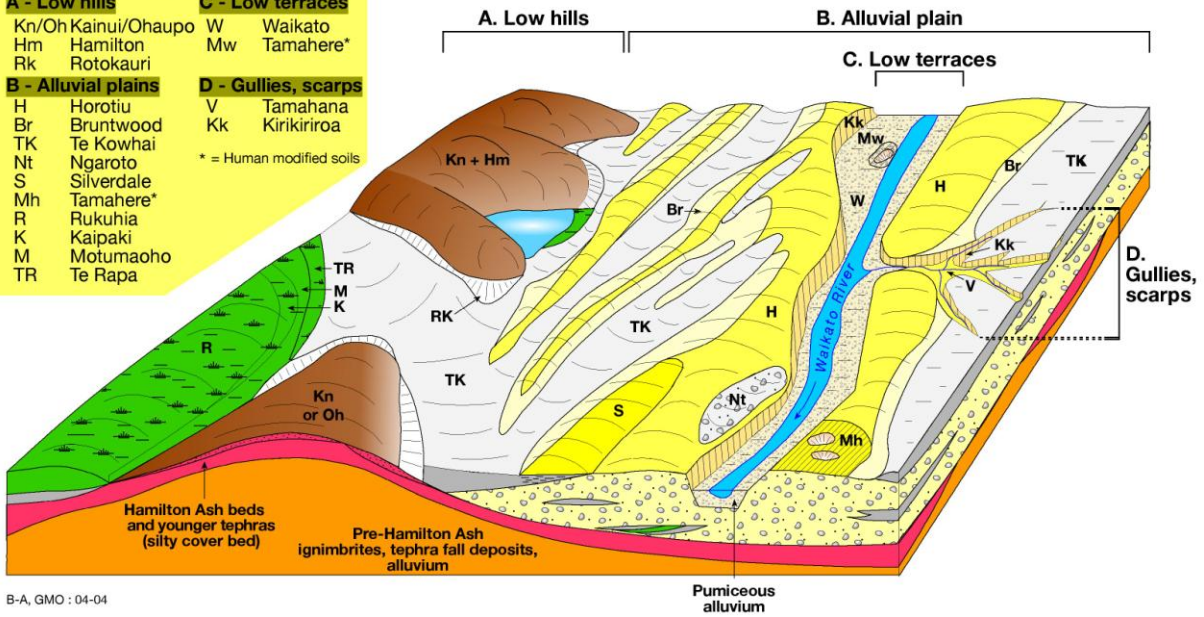


B-A, GMO : 02-04

**Soil Series**

<b>A - Low hills</b>	<b>C - Low terraces</b>
Kn/Oh Kainui/Ohaupo	W Waikato
Hm Hamilton	Mw Tamahere*
Rk Rotokauri	
<b>B - Alluvial plains</b>	<b>D - Gullies, scarps</b>
H Horotiu	V Tamahana
Br Bruntwood	Kk Kirikiriroa
TK Te Kowhai	
Nt Ngaroto	* = Human modified soils
S Silverdale	
Mh Tamahere*	
R Rukuhia	
K Kaipaki	
M Motumaoho	
TR Te Rapa	

Soil-landscape model, Hamilton Basin



B-A, GMO : 04-04

(Upper) Main landscape units and geological materials in the Hamilton Basin and (lower) associated soil series (constructed by D.J. Lowe after McCraw, 1967; Bruce, 1979; Singleton, 1991). Hamilton soils are similar to Naikē soils (not depicted on map). The regional geology was described by Kear and Schofield (1978) and Edbrooke (2005); the geomorphology was described by Selby and Lowe (1992).