Citation:
Lowe, D.J. 2000. Upbuilding pedogenesis in multisequal tephra-derived soils in the Waikato region. In *Soil 2000: New Horizons for a New Century*. Australian and New Zealand Second Joint Soils Conference Volume 2: Oral Papers. (Eds J.A. Adams & A.K. Metherell). 3-8 Dec 2000, Lincoln University. New Zealand Society of Soil Science. Pp. 183-184.

Upbuilding pedogenesis in multisequal tephra-derived soils in the Waikato Region

D.J. Lowe
Department of Earth Sciences, University of Waikato, Private Bag 3105, Hamilton, New Zealand
Keywords: Upbuilding, soil stratigraphy, multisequal soils, dynamic-rate model, tephrochronology
Abbreviations: NZ = New Zealand; TVZ = Taupo Volcanic Zone; ka, thousands of radiocarbon years ago

Introduction

Soil formation is classically regarded as a 'topdown' process whereby soil thickness, horizonation and vertical anisotropy increase steadily (not necessarily linearly) over time. However, where incremental additions to the land surface are common (e.g. loess, tephra, alluvium or colluvium), the process of soil upbuilding becomes important. The degree of soil expression is governed by the relative rates of pedogenesis and aggradation, which are unlikely to remain constant over time (Almond and Tonkin 1999). The interplay between these processes was examined by Johnson and Watson-Stegner (1987) and others. Soils on aggrading landscapes undergo 'developmental upbuilding' (progressive pedogenesis) if rates of addition allow assimilation of the deposits and profile deepening, or 'retardant upbuilding' (regressive pedogenesis) if rates are so rapid that horizonation is prevented. In upbuilding soils, each increment of soil below the A horizon has experienced processes that are characteristic of all horizons above it (Almond and Tonkin 1999).

Many Quaternary landscapes in NZ comprise well-studied stratigraphic sequences of deposits, including widespread loess and tephra, in which there are repetitions of soil horizons and buried paleosols within the vertical profile (multisequal soils). Rates of aggradation and the relative influence of soil upbuilding processes on soil evolution in such sequences have been examined closely in only a few studies. Using tephrochronology, I examine soil upbuilding in multisequal tephra-derived soils on a Waikato transect.

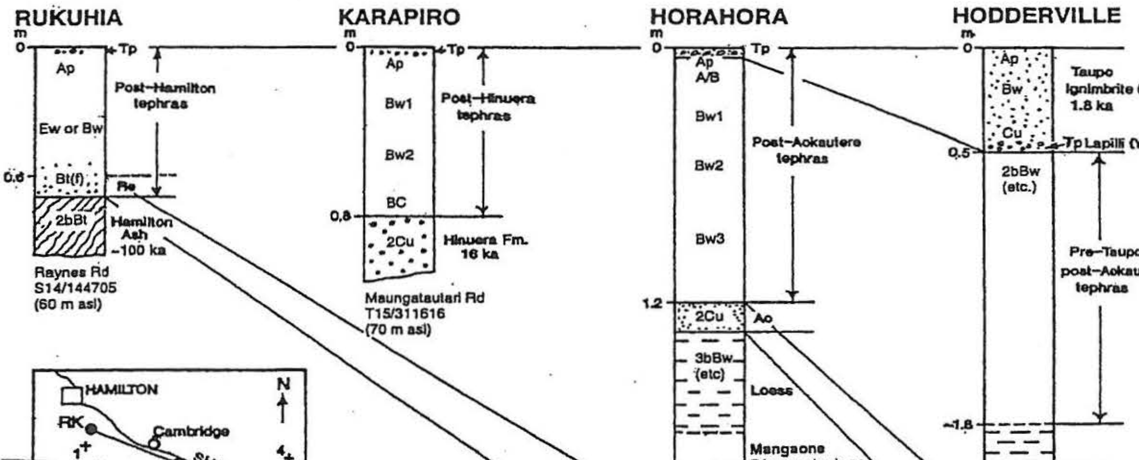

Figure 1: Stratigraphy and horizonation of four tephra-soil sequences on a 50-km transect in the Waikato region. Numbered lakes (inset) are: 1, Maratoto; 2, Rotomanuka; 3, Rotongata; 4, Okoroire. Grid references NZMS 260.

Tephrostratigraphy and Soils

The stratigraphy and ages of tephra–soil sequences at four sites are summarised in Fig. 1. A detailed record of tephra deposition in the Waikato region since *c.* 19 ka is available from lakes (Fig. 1; Lowe 1988). Sediment cores show that macroscopic tephras, a few millimetres to centimetres in thickness and from both rhyolitic and andesitic sources, are deposited once every ~400 years on average (more frequently if microscopic tephras are included). The rhyolitic tephras predominate in terms of thickness, especially towards the SE. Subsurface tephric loess occurs in two of the sequences. The most recent tephra identified is Taupo (*c.* 200 AD) but Kaharoa (*c.* 1350 AD) is likely to be present over the entire region as a microscopic deposit. Minor ashfalls from eruptions of Ngauruhoe (1975) or Ruapehu (1995-96) indicate that the sites are undergoing 'contemporary' aggradation.

As the tephra deposits increase in thickness from NW to SE (i.e. toward the main rhyolitic sources in central TVZ), the age span encompassed by the deposits making up the parent materials for each solum decreases. At

Rukuhia, the Kainui soil (NXMA: Hewitt 1998) is a composite soil developed both in the paleosol on Hamilton Ash and the multiple (intermixed) tephra layers deposited over it, i.e. the soil encompasses deposits aged *c.* 100 ka to the present. At Karapiro, the Horotiu soil (LOT) is composite, being developed in volcanogenic alluvium overlain by multiple tephras, i.e. the soil encompasses deposits aged *c.* 16 ka to the present. At Horahora, the Tirau soil (LOT) is composite and similarly developed in multiple tephra layers overlying Aokautere Ash. Taking this tephra arbitrarily as the 'base' of the soil profile, the soil encompasses deposits aged from *c.* 22.6 ka to the present. Including Aokautere Ash (2Cu horizon) in the profile qualifies the Tirau soil as a compound soil. At Hodderville, the Taupo soil (MOBL) is compound, being developed primarily in pumiceous ignimbrite emplaced *c.* 200 AD by the Taupo eruption and overlying a pre-Taupo paleosol on composite tephras younger than 22.6 ka. The greater part of the soil thus encompasses a single unit aged *c.* 1800 years with the lower part comprising deposits <22.6 ka.

Table 1. Tephra accretion and mass flux rates, Waikato tephra-soil sequences.

Site (Fig. 1)	Thickness (mm)	Deposit[1]	Period of deposition[2] (ka)	Interval of deposition (ka)	Accretion rate ($mm\ a^{-1}$)	Mass flux rate[3] ($g\ m^{-2}\ ka^{-1}$)	
Rukuhia	600	T	60–0	60	0.01	12 000	(1.2)
Karapiro	800	T	16–0	16	0.05	40 000	(0.8)
Horahora	1200	T	23–0	23	0.05	42 000	(0.8)
Horahora	800	L + T	60–23	37	0.02	20 000	(0.9)
Horahora	2200	T + L	60–0	60	0.04	33 000	(0.9)
Hod'ville	500	T	2–0	2	0.25	175 000	(0.7)
Hod'ville	2000	T + L	23–0	23	0.09	78 000	(0.9)

[1] Dominant type of material in sequence: T, tephra; L, tephric loess.

[2] Age differences between main tephrochronological marker units as given in Fig. 1.

[3] Tephra mass flux rate $Q_t = \frac{D}{T} \rho_b \times 10^4$

where D = thickness of tephra (+ loess) increment (cm), T = time for deposition of increment (ka), and ρ_b = bulk density ($g\ cm^{-3}$) (assumed ρ_b values shown in parentheses) (after Almond and Tonkin 1999).

Upbuilding Rates and Soil Evolution Pathways

Tephra accretion and mass flux rates (Table 1) are slowest at Rukuhia and fastest at Hodderville, with intermediate values evident at Karapiro and Horahora. The rates of accumulation are generally similar in magnitute to those of loess in the South Island (Almond and Tonkin 1999). The Kainui profile (at Rukuhia) is undergoing developmental upbuilding. Topdown pedogenesis has operated continually, assimilating frequent additions of thin tephra layers since *c.* 60 ka, but at probably reduced rates during cooler intervals (stadials). The upper parts of the Horotiu (Karapiro) and Tirau (Horahora) profiles are undergoing developmental upbuilding, each at a similar rate. Topdown pedogenesis has operated with little interuption since *c.* 16 ka or so in both soils. The lower part of the Tirau profile (including pre-23 ka loess) has a somewhat slower rate of developmental upbuilding; in the Horotiu profile, emplacement of the Hinuera Formation *c.* 16 ka is an extreme case of retardant upbuilding. In the Taupo profile (Hodderville) the sudden deposition of Taupo Ignimbrite represents a retardant upbuilding event. Topdown processes have been operating uninterrupted since. Previously, the soil was undergoing developmental upbuilding but before *c.* 15 ka (especially during the last stadial) the rate of tephra or loess accretion has generally overwhelmed topdown processes so that retardant upbuilding predominated.

The Kainui, Tirau and Horotiu soils are likely to continue along progressive upbuilding pathways unless a tephra layer of substantial thickness is deposited. The Taupo soil at Hodderville, the site nearest central TVZ and clearly just 'within range' of such depositional episodes (e.g. Taupo event), may experience regressive upbuilding occasionally but is likely to follow the developmental upbuilding pathway for substantial periods.

References

Almond, P.C. and Tonkin, P.J. (1999). Pedogenesis by upbuilding in an extreme leaching and weathering environment, and slow loess accretion, south Westland, New Zealand. *Geoderma* **92**, 1-36.

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

Johnson, D.L. and Watson-Stegner, D. (1987). Evolution model of pedogenesis. *Soil Science* **143**, 349-366.

Lowe, D.J. (1988). Stratigraphy, age, composition and correlation of late Quaternary tephras interbedded with organic sediments in Waikato lakes, North Island, NZ. *NZ Journal of Geology and Geophysics* **31**, 125-165.