

# feature

## DISTINGUISHING RHYOLITIC AND ANDESITIC TEPHRA AS SOIL PARENT MATERIALS FOR SERIES DEFINITION

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I have been following the correspondence in *New Zealand Soil News* regarding the classification of the New Plymouth and Otorohanga series with considerable interest - all the comments and replies have been illuminating. In discussing the separation (at series level) of soils developed in andesitic tephra from those in rhyolitic tephra, Clayden *et al.* (1989, p. 44) ask the questions: (i)... "can we develop quantitative definitions for each of these materials", and (2)... "can they be consistently distinguished in the soil profile by field techniques when weathered to form the horizons of a yellow-brown loam?" The short answer to (1) is yes; the answer to (2) could be yes, but depends on the degree of quantitiveness required and the skill of the field scientist in mineral identification.

### Intrinsic properties of andesitic and rhyolitic tephra deposits

The only consistently reliable way to determine the parent tephra composition (andesitic *v.* rhyolitic) is through examination of the *primary minerals*, i.e., the sand fraction, because, as correctly noted by Clayden *et al.* (1989), other properties (e.g., colour, Tamm's Al, base saturation) are largely acquired rather than inherited and commonly vary according to

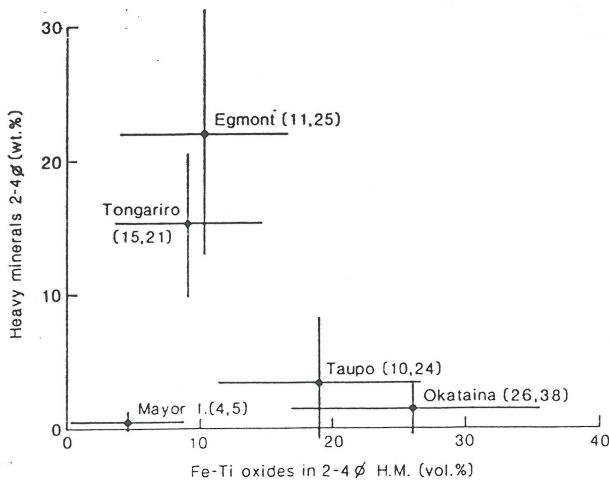


Fig. 1 Proportions of heavy minerals and Fe-Ti oxides (from Lowe 1988b, p. 115). Dots, bars = mean values  $\pm$  1 S.D.; numbers in brackets = no. of samples analysed for heavy mineral wt.%, for Fe-Ti oxide vol.%.

environment. (In some cases, such accessory properties may mirror the parent composition, e.g., Birrell & Pullar 1973; Pullar & Birrell 1973; Lowe 1986, but not always).

The ferromagnesian mineralogical assemblages and glass compositions (major elements) offer the best means of identifying tephra source volcanoes (e.g., see Stewart 1982; Lowe 1988a, p. 139). Andesitic tephra deposits typically contain more heavy minerals, but fewer Fe-Ti oxides (e.g., magnetite, titanomagnetite), than rhyolitic deposits (Fig. 1). The dominant ferromagnesian silicate minerals in tephra deposits younger than c. 20 000 years associated with the main volcanic centres are summarised in Fig. 2.

Glass composition may be determined by XRF (bulk samples) or, preferably, by electron microprobe. As a guide, Taupo and Okataina glasses (shards or rims around crystals) contain around 75-76 wt% SiO<sub>2</sub> (on a hydrous basis); Mayor Island, 75% (glass is peralkaline: [Na<sub>2</sub>O + K<sub>2</sub>O] > Al<sub>2</sub>O<sub>3</sub>); Egmont, 70%; and Tongariro, 60% (analyses of the glass from these last two centres are sparse). Other elements (as oxides) also aid in distinguishing eruptive sources (Table 1; Stokes & Lowe 1988). A potential shortcoming with glass analysis, however, is that Egmont, Tongariro, and Mayor Island-derived glass may be under-represented in soil environments because of its greater susceptibility to weathering (Kirkman & McHardy 1980; Lowe 1988a). Also, the question of compositional variations (e.g., resulting from mixed magma eruptions or chemically zoned magma bodies) in glasses has not been examined in detail in New Zealand eruptives.

The range of composition of feldspars in light fractions may be helpful. In the Waikato region, Taupo and Okataina-derived tephra deposits usually contain oligoclase and andesine whereas those from Tongariro and Egmont contain andesine, labradorite, and bytownite (i.e., are more calcic). Mayor Island eruptives contain alkali rather than plagioclase feldspars.

Chemical analyses of Fe-Ti oxide minerals have been used to only a limited degree to distinguish rhyolitic and andesitic parent materials (Kohn 1970). Lowe (1986) suggested that the V/Mn ratio of titanomagnetites (measured by XRF) could be used as a guide to 'andesitic character' (Fig. 3).

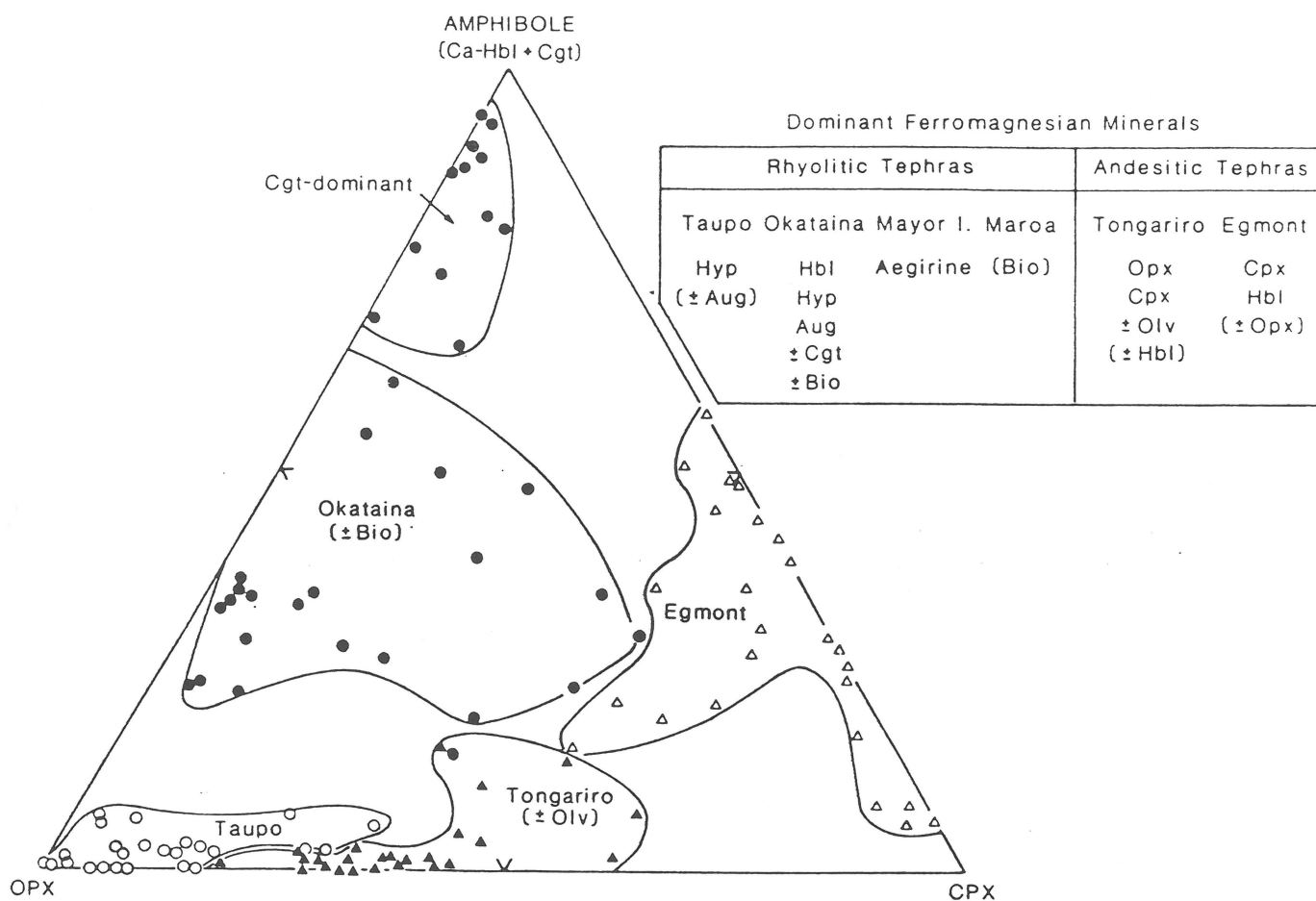


Fig. 2 Dominant ferromagnesian minerals associated with post-c. 20 000 year old tephra deposits from North Island source volcanoes (from Lowe 1988b, p. 116). Opx, orthopyroxene (mainly hypersthene); Cpx, clinopyroxene (mainly augite); Ca-Hbl, calcic hornblende; Cgt, cummingtonite; Hyp, hypersthene; Aug, augite; Bio, biotite; Oliv, olivine.

Table 1 Glass shard major element chemistry<sup>a</sup> of distal tephra deposits erupted from five North Island volcanoes over the past c.20 000 years (from Stokes & Lowe 1988, p. 272).

	Egmont	Mayor Island	Okataina	Taupo	Tongariiro
SiO <sub>2</sub>	68.61 (2.44)	74.82 (1.53)	75.89 (2.42)	75.07 (2.17)	60.17 (2.50)
Al <sub>2</sub> O <sub>3</sub>	14.76 (1.11)	9.37 (0.25)	11.94 (0.32)	12.59 (0.42)	17.38 (2.50)
TiO <sub>2</sub>	0.51 (0.11)	0.25 (0.07)	0.12 (0.05)	0.18 (0.04)	0.82 (0.24)
FeO <sup>b</sup>	2.22 (0.59)	5.45 (0.52)	0.91 (0.13)	1.63 (0.15)	5.33 (1.77)
MgO	0.59 (0.35)	0.01 (0.01)	0.12 (0.04)	0.17 (0.05)	2.17 (0.98)
CaO	2.11 (0.76)	0.22 (0.06)	0.80 (0.18)	1.23 (0.18)	7.00 (1.61)
Na <sub>2</sub> O	3.98 (0.55)	4.96 (0.36)	3.47 (0.30)	3.66 (0.25)	3.44 (0.28)
K <sub>2</sub> O	4.34 (0.75)	4.05 (0.36)	3.39 (0.38)	2.91 (0.21)	1.79 (0.43)
Cl	0.15 (0.06)	0.18 (0.06)	0.12 (0.03)	0.12 (0.03)	0.09 (0.04)
Total	97.27 (1.82)	99.30 (1.89)	96.75 (2.84)	97.56 (2.55)	98.19 (0.91)
n	32	28	92	69	16

a Means and standard deviations (in brackets) as determined by electron microprobe

b Total iron expressed as FeO

n Number of analyses

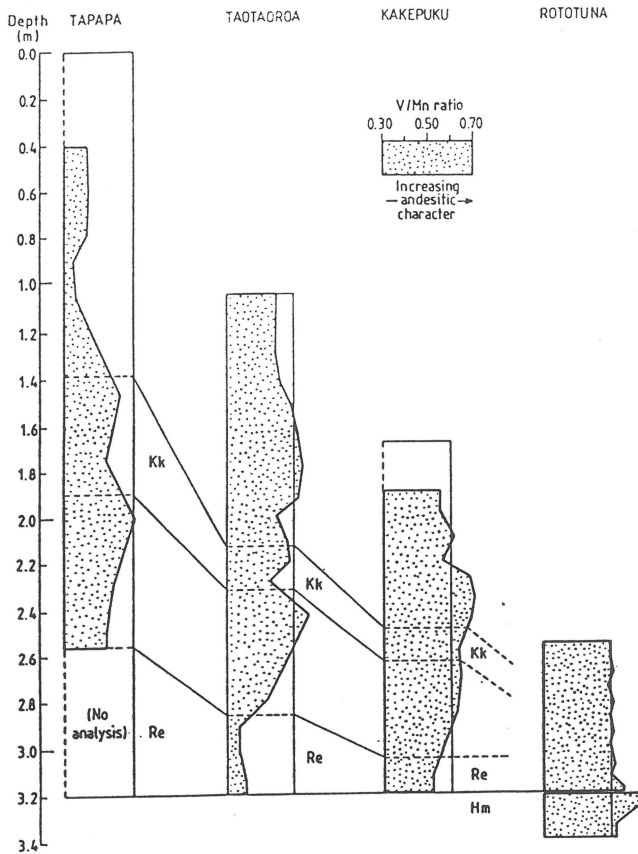


Fig. 3 V/Mn ratios of titanomagnetite and their distribution with depth at tephra sections in the Waikato region: Tapapa, T15/639522\*; Taotaoroa, T15/454635; Kakepuku, S15/103463; Rototuna, S14/101813. Maxima relate to a significant andesitic character, minima to a significant rhyolitic character (from Lowe 1986, p. 295). Kk, Kawakawa Tephra; Re, Rotoehu Ash; Hm, Hamilton Ash. \* Grid references for NZMS 260.

#### Boundaries between series

Where the boundaries between series should be placed is ideally determinable only when quantitative data on the andesitic vs rhyolitic components are available for all the soils in question. Because of the effects of weathering, pedoturbation, and winnowing (through aeolian fractionation) of the various mineralogical constituents, then the absence of certain minerals should not be used as a diagnostic tool. Consequently, multiple criteria should be used in any definition as far as practicable.

Yellow-brown loams in the Waikato region are composite and contain numerous thin, intermixed rhyolitic and andesitic tephra layers in proportions that vary markedly over relatively short distances, forming a compositional 'gradient' (Lowe, 1986, 1988a). Near Tirau, andesitic material makes up only 6% of the post-c.15 000 year old tephra deposits; at Ohaupo, it constitutes 35%; and near

Morrinsville it constitutes 11%. For classification purposes it is probably realistic to create only three or four groups. For example: (a) mainly rhyolitic (>85% rhyolitic tephra in parent material?) e.g. Tirau or Kereone series; (b) mainly andesitic (>85% andesitic material?) e.g. Egmont or New Plymouth series; (c) mixtures of both (>15% rhyolitic and >15% andesitic material?) e.g. Ohaupo or Otorohanga series. A fourth class could be: (d) mainly peralkaline rhyolitic tephra (i.e., from Mayor Island) e.g. Whangamata series. Presumably, soils derived from basaltic tephra (scoria) would be separated by differentia at subgroup level (e.g. red Orthic Allophanic [formerly Ash] soils such as the Papakauri series: Hewitt 1987).

**A field technique (is the past the key to the present?)**

Many of the quantitative mineralogical and geochemical analyses as outlined cannot yet be attained by field techniques, hence question (2) above provisionally has a negative answer. Perhaps the (commendable) principle in Hewitt (1987, p.2) that "differentia should allow field assignment of soils to classes, either directly, or by tested inferences" is too

Table 2. Ferromagnesian mineralogy of "panned residues" from tephra-derived soil profiles in the Mairoa district (from Taylor 1933, p. 201). Bed 1 is a composite of tephra deposits containing andesitic and rhyolitic constituents (the so-called "Mairoa ash beds"). Bed 2 is Kawakawa Tephra.

	Depth of sample (cm)	Hbl	Hyp	Aug
<b>Mairoa</b>				
Bed 1	8	35	25	40
	15	34	26	40
	33	30	32	38
	56	30	47	23
Bed 2	74	14	73	13
<b>Eight km north of Mairoa</b>				
Bed 1	8	-	-	-
	15	30	22	48
	33	-	-	-
	56	-	-	-
Bed 2	74	10	75	15
<b>Twenty four km east of Mairoa</b>				
Bed 1	5	37	30	33
	23	28	47	25
	-	-	-	-
	61	30	60	10
Bed 2	86	8	77	15

\* Hbl, calcic hornblende; Hyp, hypersthene; Aug, augite; - = not determined

demanding at this (series) level? It could be. In the long run, it may be easier for field staff to send appropriate samples off for laboratory analysis than to attempt mineralogical analyses in district offices. However, if considered desirable and accurate enough, a quick "field" test should be feasible, based on past experience. Some of this ground has been covered before (both literally and figuratively) during the early reconnaissance mapping by L.I. Grange and N.H. Taylor of tephra-derived soils and their parent materials in the North Island. The composite nature of the "allophanic" soils in the King Country-Waikato region was well appreciated early on (e.g. Grange 1931), and nicely demonstrated by Taylor (1933) using the approximate ratios of ferromagnesian minerals in three soils in the Mairoa district (Table 2). Taylor obtained these results in his field camp (read "District Office" today) using a gold panning technique to separate the heavy minerals. Comparable results should be obtainable today with a minimum of expensive apparatus in district offices. Equipment could include:

two sieves (62 and 250  $\mu\text{m}$ ) [most heavy minerals are concentrated in this size range]  
gold pan or similar  
portable balance  
polarising microscope and light source  
glass slides and clove oil [for mounting the heavy minerals]  
filter paper and water supply

The two most useful and easily measured parameters are:

- (1) the weight % of heavy minerals;
- (2) the proportions of
  - (a) clinopyroxenes (augite);
  - (b) amphiboles (hornblende and cummingtonite); and
  - (c) orthopyroxenes (hypersthene).

Figs. 1 and 2, or similar diagrams incorporating more data, could provide an initial guide for classification as rhyolitic or andesitic. In Fig. 1 these two 'end members' are clearly separable with a diagonal line. In Fig. 2, a boundary line can be drawn separating most of the andesitic (triangles) from the rhyolitic (circles) assemblages. Based on this, andesitic tephtras might be arbitrarily defined as having more than about 35-40% augite (as a percentage of the minerals depicted in Fig. 2). The overlap between some Taupo and Tongariro assemblages and some Okataina and Egmont assemblages means that minerals other than just augite should be looked at in some cases.

An alternative or additional approach is to infer the soil parentage using published tephtra isopach maps. This would provide only an approximate guide, however, because isopach maps are subjective extrapolations. Also, their use would seem to

contradict Hewitt's (1987) principle that "differentia should be based on soil properties that can be reproducibly and precisely measured or observed".

#### References

- Birrell, K.S.; Pullar, W.A. 1973. Weathering of paleosols in Holocene and late Pleistocene tephtras in central North Island, New Zealand. *N.Z. Journal of Geology and Geophysics* 16: 687-702.
- Clayden, B.; Hewitt, A.E.; Parfitt, R.L. 1989. On defining soils series - a reply. *N.Z. Soil News* 37: 43-45.
- Grange, L.I. 1931. Volcanic-ash showers. *N.Z. Journal of Science and Technology* 12: 228-240.
- Hewitt, A.E. 1987. New Zealand soil classification (version 1.0). *N.Z. Soil Bureau Soil Resources Report SR15*.
- Kirkman, J.H.; McHardy, W.J. 1980. A comparison of the morphology, chemical composition and weathering of rhyolitic and andesitic glass. *Clay minerals* 15: 165-173.
- Kohn, B.P. 1970. Identification of New Zealand tephtra layers by emission spectrographic analysis of their titanomagnetites. *Lithos* 3: 361-368.
- Lowe, D.J. 1986. Controls on the rates of weathering and clay mineral genesis in airfall tephtras: a review and New Zealand case study. Pp. 265-330 in: Colman, S.M.; Dethier, D.P. ed. Rates of chemical weathering of rocks and minerals. Academic Press, Orlando, Florida.
- Lowe, D.J. 1988a. Stratigraphy, age, composition, and correlation of late Quaternary tephtras interbedded with organic sediments in Waikato lakes, North Island, New Zealand. *N.Z. Journal of Geology and Geophysics* 31: 125-165.
- Lowe, D.J. 1988b. Late Quaternary volcanism in New Zealand: towards an integrated record using distal airfall tephtras in lakes and bogs. *Journal of Quaternary Science* 3: 111-120.
- Pullar, W.A.; Birrell, K.S. 1973. Parent materials of Tirau silt loam. *N.Z. Journal of Geology and Geophysics* 16: 677-686.
- Stewart, R.B. 1982. Sand mineralogy of North Island yellow-brown loams. Pp. 47-48 in: Neall, V.E. ed. Soil groups of New Zealand. Part 6, Yellow-brown loams. N.Z. Society of Soil Science, Wellington.
- Stokes, S.; Lowe, D.J. 1988. Discriminant function analysis of late Quaternary tephtras from five volcanoes in New Zealand using glass shard major element chemistry. *Quaternary Research* 30: 270-283.

#### Addendum

Taylor, N.H. 1933. Soil processes in volcanic ash-beds. *N.Z. Journal of Science and Technology* 14: 193-202.