DATA REPOSITORY

for

The Rangipo Fault, Taupo Rift, New Zealand: An Example of Temporal Slip Rate and Single Event Displacement Variability in a Volcanic Environment

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TEPHRA IDENTIFICATION

TABLE DR1. MAJOR ELEMENT GLASS COMPOSITIONS OF KEY SILICIC TEPHRA LAYERS FROM RANGIPO FAULT TRENCH SITES COMPARED WITH THEIR TEPHRA CORRELATIVES

Sample number	Trench Locality	SiO_2	Al_2O_3	TiO_2	FeO	MgO	CaO	Na_2O	K_2O	Cl	H_2O	*n*
Waimihia Tephra and correlatives												
	Site 3 - Tank Track	76.28	13.20	0.22	1.84	0.20	1.31	4.08	2.76	0.12	2.91	12
		(0.23)	(0.12)	(0.07)	(0.06)	(0.04)	(0.08)	(0.17)	(0.10)	(0.06)	(0.92)	
R4	Tufa Trig S2	76.82	12.79	0.18	1.72	0.17	1.27	3.96	2.99	0.11	0.88	11
	(Donoghue 1991)	(0.24)	(0.08)	(0.04)	(0.12)	(0.04)	(0.09)	(0.24)	(0.11)	(0.02)	(0.66)	
5b	L. Tutira	77.23	12.80	0.20	1.78	0.16	1.35	3.53	2.79	0.17	2.44	6
	(Eden et al., 1993)	(0.31)	(0.12)	(0.04)	(0.16)	(0.02)	(0.03)	(0.24)	(0.13)	(0.01)	(1.63)	
Waiohau Tephra and correlatives												
	Site 3 - Tank Track	78.19	12.40	0.14	1.02	0.15	0.91	3.68	3.29	0.14	3.75	12
		(0.28)	(0.17)	(0.09)	(0.08)	(0.03)	(0.09)	(0.16)	(0.12)	(0.13)	(1.22)	
	Site 2 - Zone 3 lower	78.28	12.38	0.17	0.99	0.13	0.87	3.75	3.31	0.13	3.64	11
		(0.37)	(0.15)	(0.04)	(0.07)	(0.03)	(0.08)	(0.14)	(0.14)	(0.07)	(1.16)	
	Site 4 – Zone 19	78.13	12.44	0.14	1.07	0.15	0.90	3.75	3.24	0.18	3.73	10
		(0.25)	(0.19)	(0.05)	(0.06)	(0.02)	(0.06)	(0.15)	(0.08)	(0.10)	(1.46)	
R12	Missile Ridge	78.60	12.15	0.14	0.94	0.12	0.92	3.87	3.20	0.13	1.86	11
	(Donoghue, 1991)	(0.28)	(0.12)	(0.04)	(0.07)	(0.02)	(0.14)	(0.15)	(0.21)	(0.03)	(1.36)	
AT-194	Pukaki crater, Auckland	78.41	12.35	0.17	1.04	0.16	0.87	3.42	3.25	0.18	3.31	11
	(Sandiford et al., 2001)	(0.32)	(0.11)	(0.07)	(0.14)	(0.09)	(0.06)	(0.14)	(0.17)	(0.06)	(0.90)	
Wh	L. Rotomanuka, Waikato	78.61	12.35	0.13	0.92	0.14	0.89	3.60	3.26	0.10	4.99	10
	(Lowe, 1988)	(0.30)	(0.13)	(0.03)	(0.08)	(0.01)	(0.04)	(0.28)	(0.10)	(0.03)	(3.00)	

Note: All major element determinations were made on a JEOL JXA-733 electron microprobe housed at Victoria Un of Wellington. Analyses were determined using a beam current of 8 nA, beam diameter of 20 υm and 3 x 10 sec peak (meaned). Values are in weight-percent oxide, recalculated to 100% on a fluid-free basis. H_2O by difference from Total iron expressed as FeO; n = number of analyses. Analyst: Alan Palmer, Massey University.

FULL RESTORATION OF TECTONIC DEFORMATION IN TANK TRACK TRENCH

Here we describe the detailed restoration of the deformation in the Tank Track trench. The timing of individual earthquake events is based on the age of the deposits found on the trench. Because some of the members of the different sedimentary formations are difficult to identify in the southeastern sector of the ring plain, we made some assumptions with respect to the identification of some andesitic tephras. In the excavated trenches and for clarity, the unidentified tephric deposits within the Papakai Formation (Donoghue et al., 1995) are called Papakai units A to D. These are not formal names but have been used here to identify tephric deposits within the Papakai Formation that have different ages defined by the presence of known rhyolitic tephras. The unit labeled here as Ohinepango Member of the Mangamate Formation (Donoghue et al., 1995) could in fact be any of the following members within that formation: Wharepu, Ohinepango, Waihohonu or Oturere. We have used one of the names for simplicity, and it does not affect the bracketing ages for faulting events.

The restoration is presented in Figures DR1A-G. Each figure represents the geometry of the layers immediately prior to the next event. For example, Figure DR1B represents the trench wall before event TT_1 (last event or Event 1 in Tank Track trench) occurred, Figure DR1C represents the trench wall before TT_2 (penultimate event or Event 2) occurred, etc. Intermediate stages not represented in the figures are the subsequent erosion and deposition of new layers. For simplicity, we will not show these intermediate stages. In this fashion, the ground surface of each figure represents an event horizon.

Restoration

We first restore the base of reworked Taupo Tephra (reTp in Fig. DR1B; Table 2 of main paper) which is the youngest unit affected by faulting. This unit is only offset by F3, and its restoration is achieved by 0.10 m of displacement along that fault plane. This restoration brings Taupo Tephra into its original “un-faulted” configuration. The last event thus occurred after deposition of the basal part of reworked Tp (only part of it is displaced on Figs. 6, DR1A) and before deposition of Tufa Trig Formation (Ttt in Fig. DR1; non dated). The timing of event TT_1 is younger than 1.7 cal. ka BP.

After the first restoration, the paleosol on the Mangatawai Tephra (PMng in Fig. DR1B; Table 2) is still displaced. Because this layer is eroded on the upthrown side of the scarp (between vertical lines 18 and 26 on Fig. DR1A), we are not sure if erosion has removed evidence of faulting of PMng across F3 and F4. The geometry of a remnant of the Mangatawi Tephra (Mng) at vertical line 24 (Fig. DR1), which lies unconformably over older sediments, indicates that the Mangatawai Tephra was probably deposited on a steep eroded scarp (Fig. DR1C) and that if it was displaced across F3 and F4, the amount of displacement was not large. Thus in the restoration of Mng, we assume that there was no displacement of Mng across F3 and F4. This restoration (Fig. DR1C) implies only 0.14 m of displacement along F1, and does not restore any other layer older than Mng. Event TT_2 occurred sometime between the deposition of Mangatawai and Taupo Tephras, that is, sometime between 2.5 and 1.7 cal. ka BP.

After the second restoration, Papakai Unit (Pp in Fig. DR1C; Table 2) is the youngest layer that is displaced. On the hanging-wall side of F1 and F3, Pp is clearly displaced, but it has been eroded from the footwall-side of these faults. Pp has also been eroded from both sides of F4 (Fig. DR1C). The geometry of the small remnant of Pp at vertical line 21 (Fig. DR1) implies that Pp was most likely deposited conformably over the Orange lapilli Member (Olp in Fig. DR1) and $\text{Papakai}_{c\&d}$ Unit ($\text{Pp}_{c\&d}$). To restore the base of Pp we have to assume the following (Fig. DR1D):

- Across F1, the top of the $\text{Pp}_{c\&d}$ is used as the base of Pp (Pp on the footwall of F1 has been eroded). If we assume that $\text{Pp}_{c\&d}$ was not eroded before faulting and that Pp lay conformably over $\text{Pp}_{c\&d}$, we can then project the top of $\text{Pp}_{c\&d}$ (from vertical line 18 in Fig DR1D) westwards, following the shape of the slope. However, if we restore the base of Pp in this fashion, Ngamatea 1 Tephra (Nga1) ends up at a higher elevation on the downthrown side of F1 than on the upthrown side.

Therefore, $Pp_{c\&d}$ had to be eroded at F1 before deposition of Pp. If we use the current shape of the top of $Pp_{c\&d}$ as the base of Pp (with the erosional geometry shown between vertical line 18 and F1), we restore the base of Pp on F1 by 0.65 m. This now brings Ngamatea 1 into an unfaulted position on the eastern strand of F1 (Fig. DR1D).

- Across F3, we assume that the base of Pp east of F3 is the top of $Pp_{c\&d}$. We restore 0.15 m on F3. This is a minimum value because erosion of $Pp_{c\&d}$ implies that the base of Pp could have been higher on the upthrown (eroded) side.
- At F4, it is difficult to assess whether there was displacement of Pp because it is absent on both sides of F4. For simplicity and because the total offset on F4 is small, we will assume no displacement on F4.

Therefore, a total of 0.8 m of offset occurred during event TT_3 (Fig. DR1D). Event TT_3, under this favored interpretation, occurred sometime after deposition of Pp and before Mng, i.e., between 3.4 and 2.5 cal. ka BP.

After the third restoration (Fig. DR1D), $Pp_{c\&d}$ is still displaced. Restoration of $Pp_{c\&d}$ (Fig. DR1E; Table 2) implies only 0.35 m offset across F1 and does not bring any other layer into juxtapositon. The displacement of this event, TT_4, is small, similarly to event TT_1. Event TT_4 happened after deposition of $Pp_{c\&d}$ and before deposition of Pp, i.e., between 11.2 and 6.2 cal. ka. Unfortunately, $Pp_{c\&d}$ is not well dated so the uncertainty about the timing of event TT_4 is large (see Fig. 3).

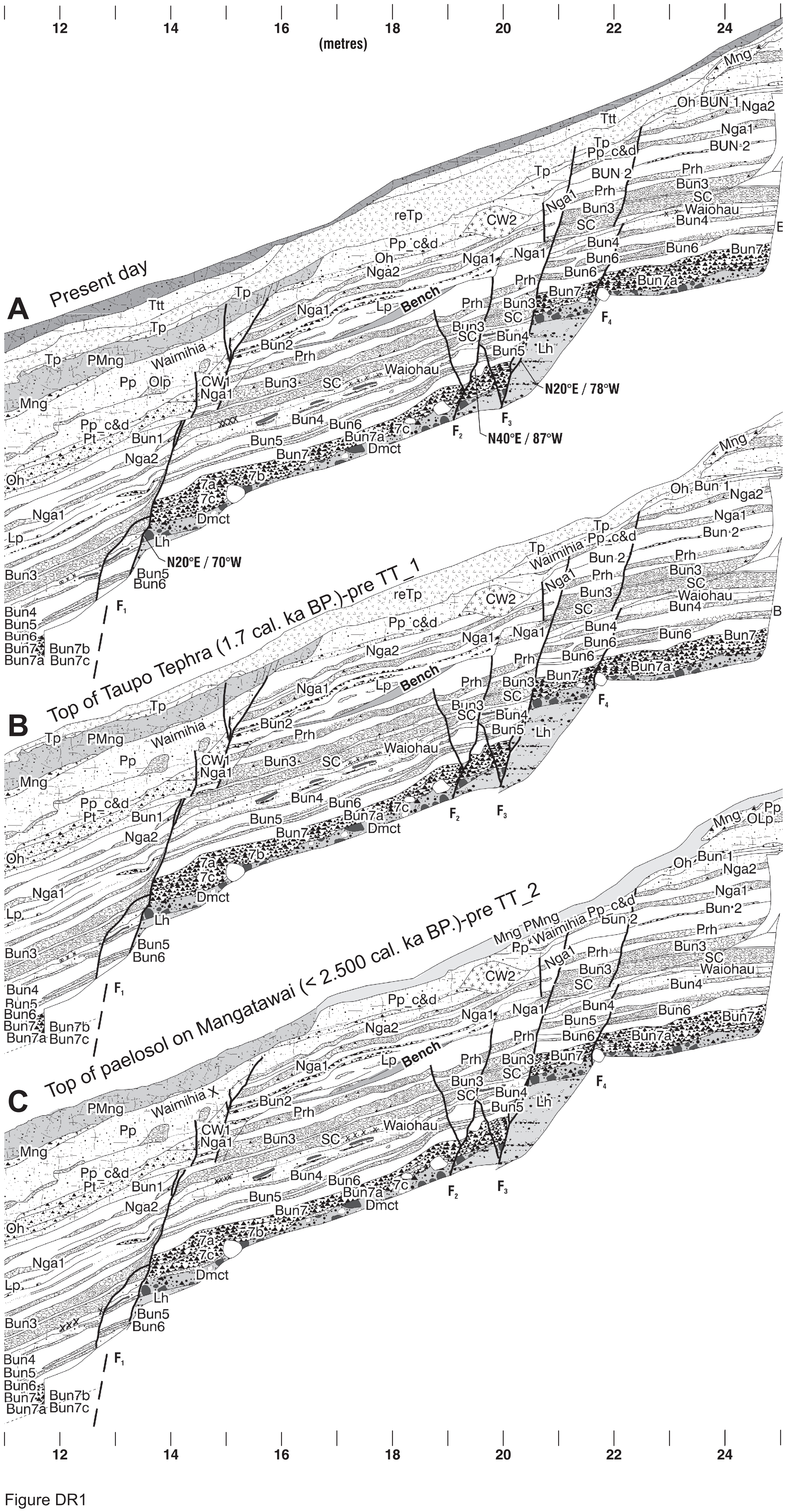
After restoration of the base of $Pp_{c\&d}$ (fourth restoration; Fig. DR1E: Table 2), the youngest displaced layer is Ohinepango Tephra (Oh) or possibly the younger Poutu Tephra (Pt). This uncertainty is a consequence of the lack of preservation of Pt on the eastern side of the trench, and for this reason, we use Oh to restore event TT_5. Where Oh is preserved, it always lies conformably over the Ngamatea 2 Tephra (Nga 2), suggesting little, if any, erosion occurred in the time bracketed by Nga 2 and Oh. Therefore, for the restoration depicted in Fig DR1F, we assume that Oh is comformable with Nga 2 along the entire trench wall, and we use the shape and thickness of Nga 2 to infer the location of the eroded Oh. The restoration is achieved as follows (Fig. DR1F):

- 0.9 m displacement on F1 (all the layers are now restored across F1).
- 0.2 m displacement on F3. There is no Oh at F3 but we have assumed that restoration of Oh will bring Nga_ 1 into juxtaposition.
- 0.1 m displacement on F4. The situation is similar to F1. All the layers are restored across F4.

A total net displacement of 1.2 m occurred during event TT_5. Along F3, all the layers down to Bullot unnamed tephra 2 (Bun 2) have been restored in Fig. DR1F. Event TT_5 happened after deposition of Oh, or possibly Pt, and before $Pp_{c\&d}$, i.e., between 11.2 and 6.2 cal. ka BP.

In addition to the restoration results, units CW1 and CW2 (Fig. DR1) are interpreted to be colluvial wedges, and could have been formed or preserved as a consequence of this event. CW1 and CW2 are interbedded between the Oh/Pt and $Pp_{c\&d}$ and are close to faults F1 and F3, respectively. It is possible that they formed as different colluvial wedges derived from the free face of F1 and F3 after event TT-5. Alternatively, they could have formed part of a larger colluvial unit or slope wash which has been largely eroded. In this alternative option, the colluvial unit formed before TT_5, was faulted during surface rupture of TT_5, and parts of it have been preserved in the space created on the hanging wall. In both of these cases, the presence of an extra unit suggests that an earthquake occurred at this stratrigraphic position.

The earliest event, TT_6, is restored by bringing Pourahu Tephra (Prh) into juxtaposition across F2 and F3 (Fig. DR1G). A displacement of 0.4 m is required to do this. All the exposed contacts are now restored. Event TT_6 occurred after deposition of Prh and before deposition of Bullot unmaned tephra 2 (Bun 2) just below Nga 1 Tephra, i.e., between 13.8 and 11.8 cal. ka BP.



(metres)
A
Present day
B
Top of Taupo Tephra (1.7 cal. ka BP.)-pre TT_1
C
Top of paelosol on Mangatawai (< 2.500 cal. ka BP.)-pre TT_2
N20°E / 70°W
N20°E / 78°W
N40°E / 87°W
Bench

Figure DR1

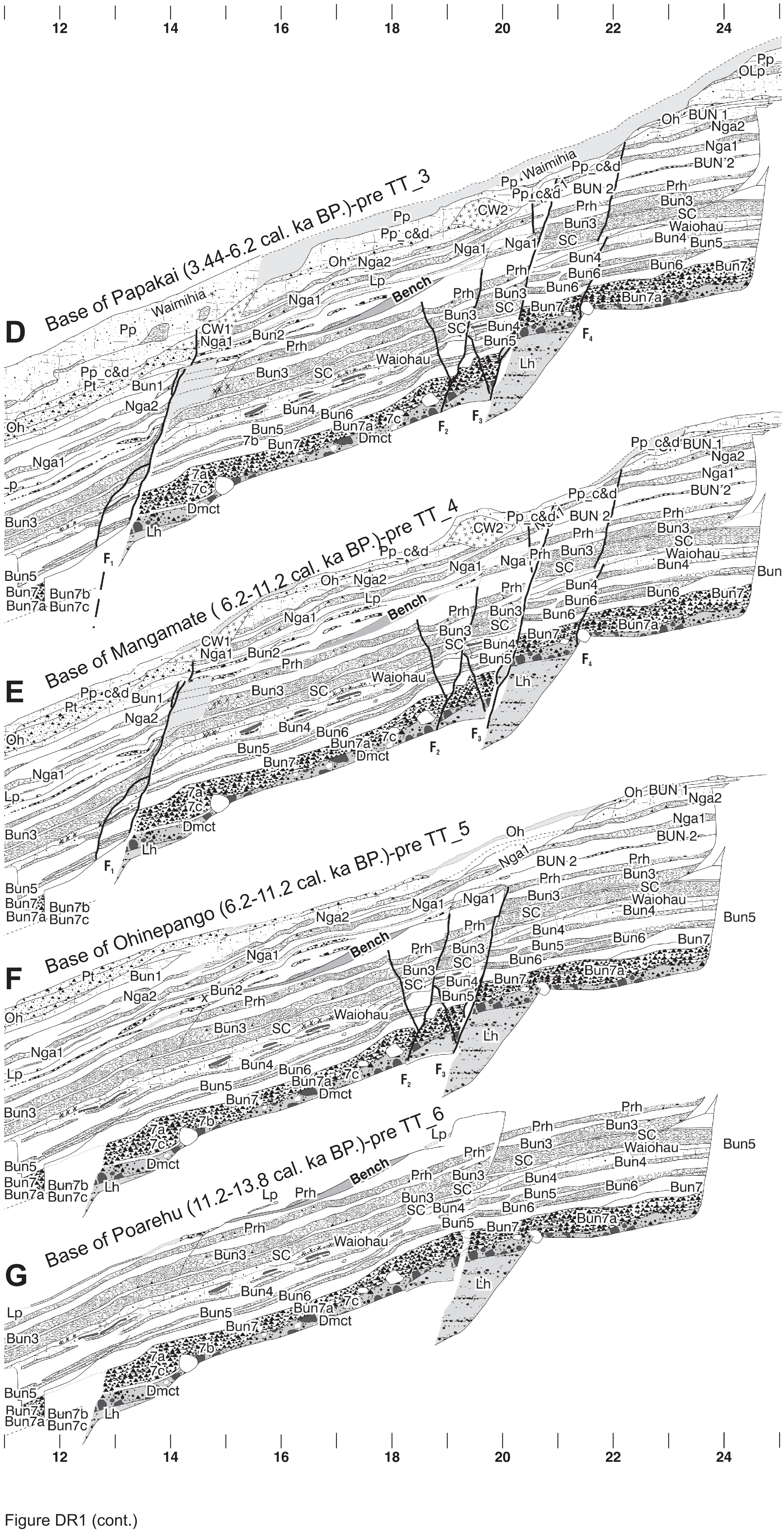


Figure DR1 (cont.)

Figure DR1. Restoration of Tank Track trench log. **(A)** Trench log before restoration. Progressively restored layers are: (**B)** Base of reworked Taupo Tephra (ReTp); (**C)** Base of Mangatewai Tephra (Mng); (**D)** Base of Papakai Unit (Pp); (**E)** Base of $Pp_{c\&d}$.; (**F)** Base of Ohinepango Tephra (Ohn); (**G)** Base of Pourahu Tephra (Prh).

References cited

Donoghue, S.L., 1991, Late Quaternary volcanic stratigraphy of the southeastern sector of the Mount Ruapehu ring plain, New Zealand [Ph.D. Thesis]: Palmerston North, Massey University, 336 p.

Donoghue, S.L., Neall, V.E., and Palmer, A.S., 1995, Stratigraphy and chronology of late Quaternary andesitic tephra deposits, Tongariro Volcanic Centre, New Zealand: Journal of the Royal Society of New Zealand, v. 25, p.115-206.

Eden, D.N., Froggatt, P.C., Trustrum, N.A., Page, M.J., 1993, A multiple-source Holocene tephra sequence from Lake Tutira, Hawke's Bay, New Zealand: New Zealand Journal of Geology and Geophysics, v. 36, no. 2, p. 233-242.

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, v. 31, no. 3, p.125-165.

Sandiford, A., Alloway, B., and Shane, P., 2001, A 28.000-6600 cal. yr record of local and distal volcanism preserved in a paleolake, Auckland, New Zealand: New Zealand Journal of Geology and Geophysics, v. 44, no.2, p. 323-336.