**Table DR1 (Weibull parameters and references for Table 1)**

| ERUPTION | WB $\theta$ | WB $\lambda$ | WB $n$ | REFERENCE |
|---|---|---|---|---|
| Minoan (3.6ka BP) | 31.16 | 322.5 | 1.55 | Pyle, 1990 |
| Taupo (186AD) | 36.66 | 155.9 | 1.53 | Walker, 1980 |
| Askja D (1875) | 1.71 | 276.0 | 1.26 | Sparks et al., 1981 |
| Fontana Lapilli (>60ka) | 9.23 | 83.7 | 0.67 | Costantini et al., 2009 |
| Hudson (1991) | 1.02 | 333.4 | 0.59 | Scasso et al., 1994 |
| MSH (18 May 1980) | 2.44 | 169.9 | 1.38 | Sarna-Wojcicki et al., 1981 |
| Novarupta A (1912) | 11.18 | 150.7 | 0.93 | Fierstein and Hildreth, 1992 |
| Novarupta B (1912) | 9.38 | 125.1 | 1.18 | Fierstein and Hildreth, 1992 |
| Novarupta CDE (1912) | 26.10 | 62.6 | 0.78 | Fierstein and Hildreth, 1992 |
| Novarupta. FGH (1912) | 6.59 | 245.5 | 1.02 | Fierstein and Hildreth, 1992 |
| Quizapu (1932) | 3.43 | 256.7 | 0.50 | Hildreth and Drake, 1992 |
| Santamaria (1902) | 45.66 | 119.1 | 1.63 | Williams and Self, 1983 |
| AMS B1 (~4100BP) | 41.28 | 18.24 | 1.73 | Costa et al., 2009 |
| AMS D1 (~4100BP) | 21.52 | 29.7 | 1.76 | Costa et al., 2009 |
| Chaiten β (6 May, 2008) | 0.88 | 104.0 | 1.17 | Alfano et al., 2011 |
| Cotopaxi L3 (~820BP) | 192.03 | 15.66 | 1.74 | Biass and Bonadonna, 2011 |
| Cotopaxi L5(~1180BP) | 74.90 | 13.6 | 1.20 | Biass and Bonadonna, 2011 |
| Fogo (1563) | 162.13 | 13.8 | 1.28 | Walker and Croasdale, 1971 |
| Hatepe (186AD) | 21.26 | 44.8 | 1.52 | Walker, 1981 |
| Hekla (1947) | 51.60 | 9.8 | 0.41 | Thorarinsson, 1954 |
| Pululagua (2450BP) | 56.22 | 21.8 | 1.70 | Volentik et al., 2010 |
| Tarawera (1886) | 96.55 | 19.8 | 1.58 | Walker et al., 1984 |
| Cerro Negro (1992) | 100.04 | 4.2 | 0.78 | Connor and Connor, 2006 |
| Fuego (1974) | 25.55 | 8.9 | 0.67 | Rose et al., 2007 |
| VesuviusAP3B1 (2700BP) | 5.12 | 9.1 | 0.46 | Andronico and Cioni, 2002 |
| Vesuvius U3 (512AD) | 6.15 | 9.0 | 0.20 | Cioni et al., 2011 |
| Etna (1971) | 4030.0 | 0.1 | 0.58 | Booth and Walker, 1973 |
| Etna (1998) | 66.12 | 1.0 | 0.28 | Bonadonna and Costa, in press |
| MSH (22 July 1980) | 8.19 | 4.4 | 0.30 | Sarna-Wojcicki et al., 1981 |
| Ruapehu (1996) | 2.88 | 5.0 | 0.33 | Bonadonna and Houghton, 2005 |
| Montserrat (26/9/1997) | 2.82 | 3.62 | 1.39 | Bonadonna et al., 2002 |
| Montserrat (31/3/1997) | 0.46 | 5.7 | 1.76 | Bonadonna et al., 2002 |
| Montserrat (21/9/1997) | 0.14 | 14.3 | 1.19 | Bonadonna et al., 2002 |

**Table DR1.** Table summarizing the main parameters of Weibull fit ($\theta$, $\lambda$, $n$) and references of selected eruptions. Alternating shading indicates decreasing VEI from 6 to 1. In our calculations for the Weibulll fit we used $w_i = 1/T_i^2(\text{obs})$, except for Askja D, Montserrat (26/9/1997) and Vesuvius AP3B1 for which we used $w_i = 1/T_i(\text{obs})$. Generally, the best weighting factor is the one that yields a random residual plot with no functional dependencies.

### Table DR2 (Sensitivity test for the case of Ruapehu 1996)

| | No proximal data (6 isomass lines) | No medial data (6 isomass lines) | No distal data (8 isomass lines) |
|---|---|---|---|
| Exponential integration | -66% [1] | -59% [2] | -40% [2] |
| Power-Law integration | +450% | -24% | -7% |
| Weibull integration | -45% | +14% | -51% |

Sensitivity test for the case of Ruapehu 1996 (from Bonadonna and Houghton, 2005): total of 17 isomass lines (VEI2; 3 exponential segments; power-law exponent: 2.0; Table 1 in the main text and Table DR1). Discrepancies are calculated as percentage change between the volume obtained using the reduced and the complete dataset respectively, i.e. 100*(Volume of reduced dataset–Volume of complete dataset)/(Volume of complete dataset). The number of isomass lines considered in the calculation and the number of exponential segments are also indicated in round and square brackets respectively. For the Weibull integration we used a weighting method 1/*y* and $\lambda$, $\theta$ and $n$ varied in the same typical range of values reported in Table 1 (i.e., $\lambda$ = 0.1-1000; $\theta$ = 0.1-5000; $n$ = 0.2-2). See also Figure DR4 (supplementary material) and Fig. 9 of Bonadonna and Houghton (2005) for a full description of point distribution on a semi-log plot of mass/area versus square root of isopach area.

### Table DR3 (Sensitivity test for the case of Novarupta CDE 1912)

| | No proximal data (4 isopach lines) | No medial data (4 isopach lines) | No distal data (4 isopach lines) |
|---|---|---|---|
| Exponential integration | -4% [2] | -26% [2] | -70% [1] |
| Power-Law integration | -14% | -9% | +560% |
| Weibull integration | +99% | +19% | -58% |

Sensitivity test for the case of Novarupta CDE 1912: total of 8 isopach lines (VEI5; 3 exponential segments; power-law exponent: 1.7; Table 1 in the main text and Table DR1). Discrepancies are calculated as percentage change between the volume obtained using the reduced and the complete dataset respectively, i.e.: 100*(Volume of reduced dataset–Volume of complete dataset)/(Volume of complete dataset). The number of isomass lines considered in the calculation and the number of exponential segments are also indicated in round and square brackets respectively. For the Weibull integration we used a weighting method 1/*y* and $\lambda$, $\theta$ and $n$ varied in the same typical range of values reported in Table 1 (i.e., $\lambda$ = 0.1-1000; $\theta$ = 0.1-5000; $n$ = 0.2-2). See also Figure DR4 (supplementary material) for a full description of point distribution on a semi-log plot of thickness versus square root of isopach area.

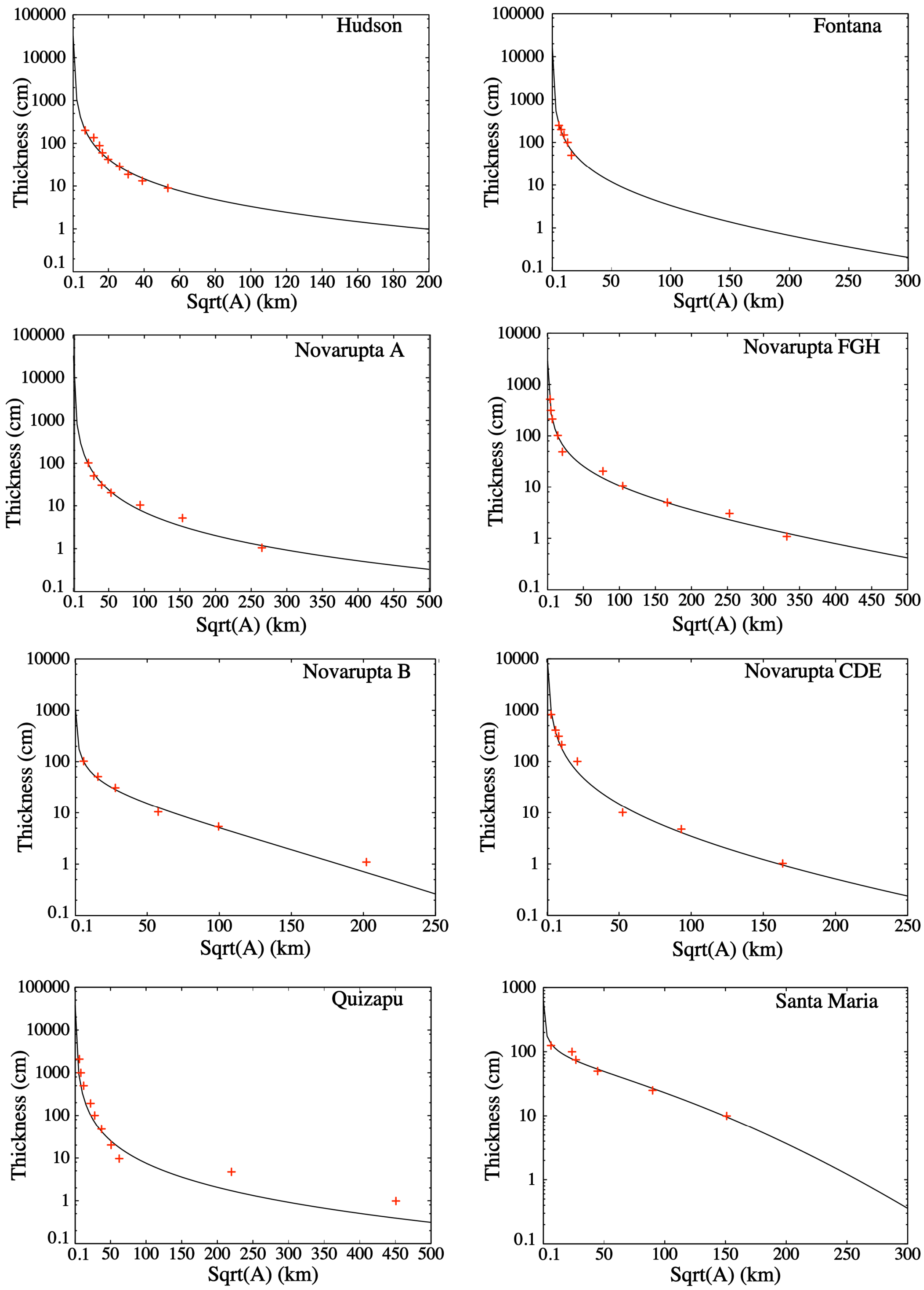


**Fig. DR1a.** Semilog plots of thickness versus square root of isopach area showing the Weibull best fit (black solid line) for the tephra deposits (red crosses) associated with the following eruptions: Hudson (Scasso et al., 1994); Fontana Lapilli (on-land data only) (Costantini et al., 2009); Novarupta A, B, CDE and FGH (Fierstein and Hildreth, 1992); Quizapu (Hildreth and Drake, 1992); Santa Maria (Williams and Self, 1983).

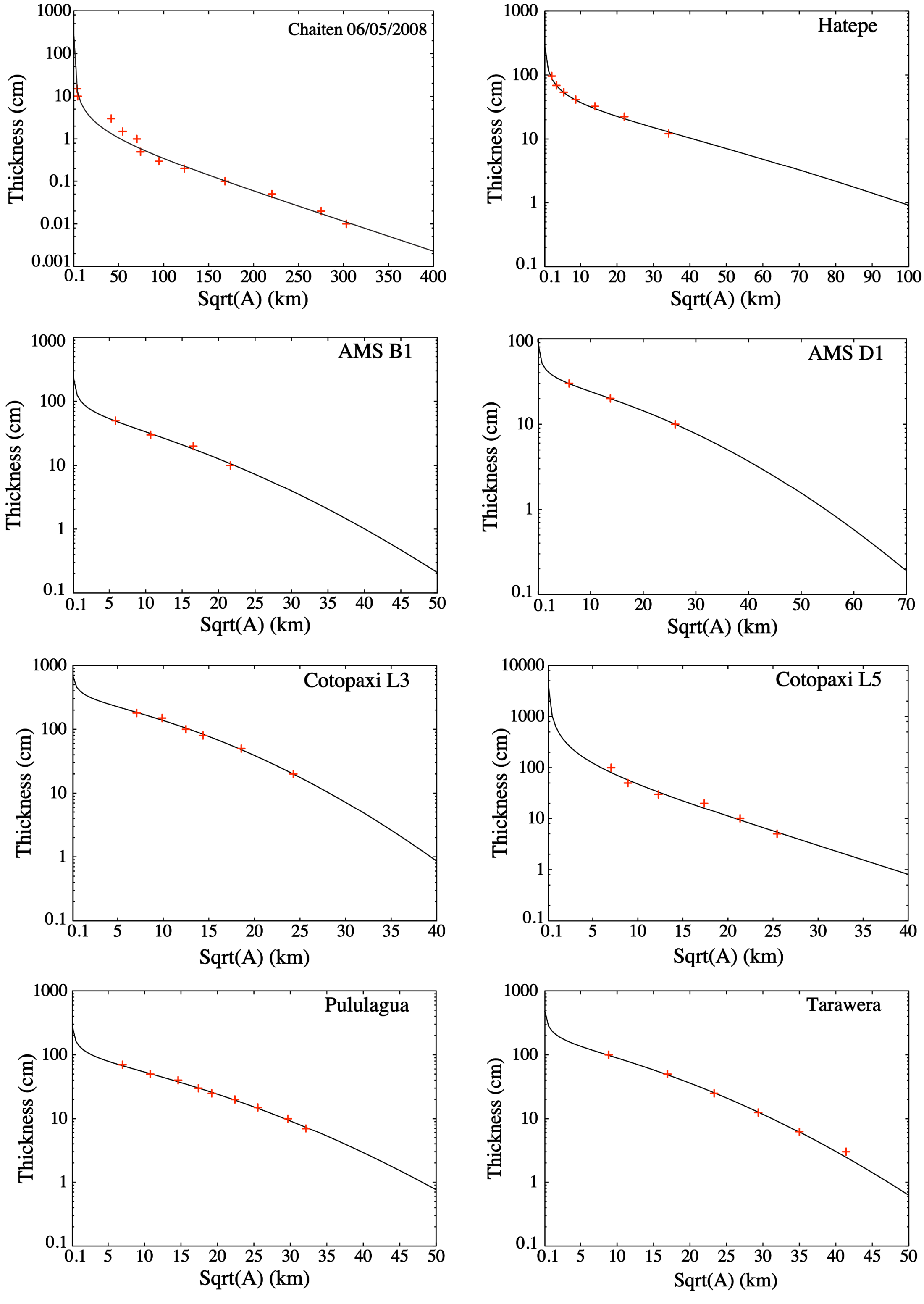


**Fig. DR1b**. Semilog plots of thickness versus square root of isopach area showing the Weibull best fit (black solid line) for the tephra deposits (red crosses) associated with the following eruptions: Chaiten β (Alfano et al., 2011); Hatepe (Walker, 1981); Agnano Monte Spina B1 and D1 (Costa et al., 2009); Cotopaxi Layer 3 and Layer 5 (Biass and Bonadonna, 2011); Pululagua (Volentik et al., 2010); Tarawera (Walker et al., 1984).

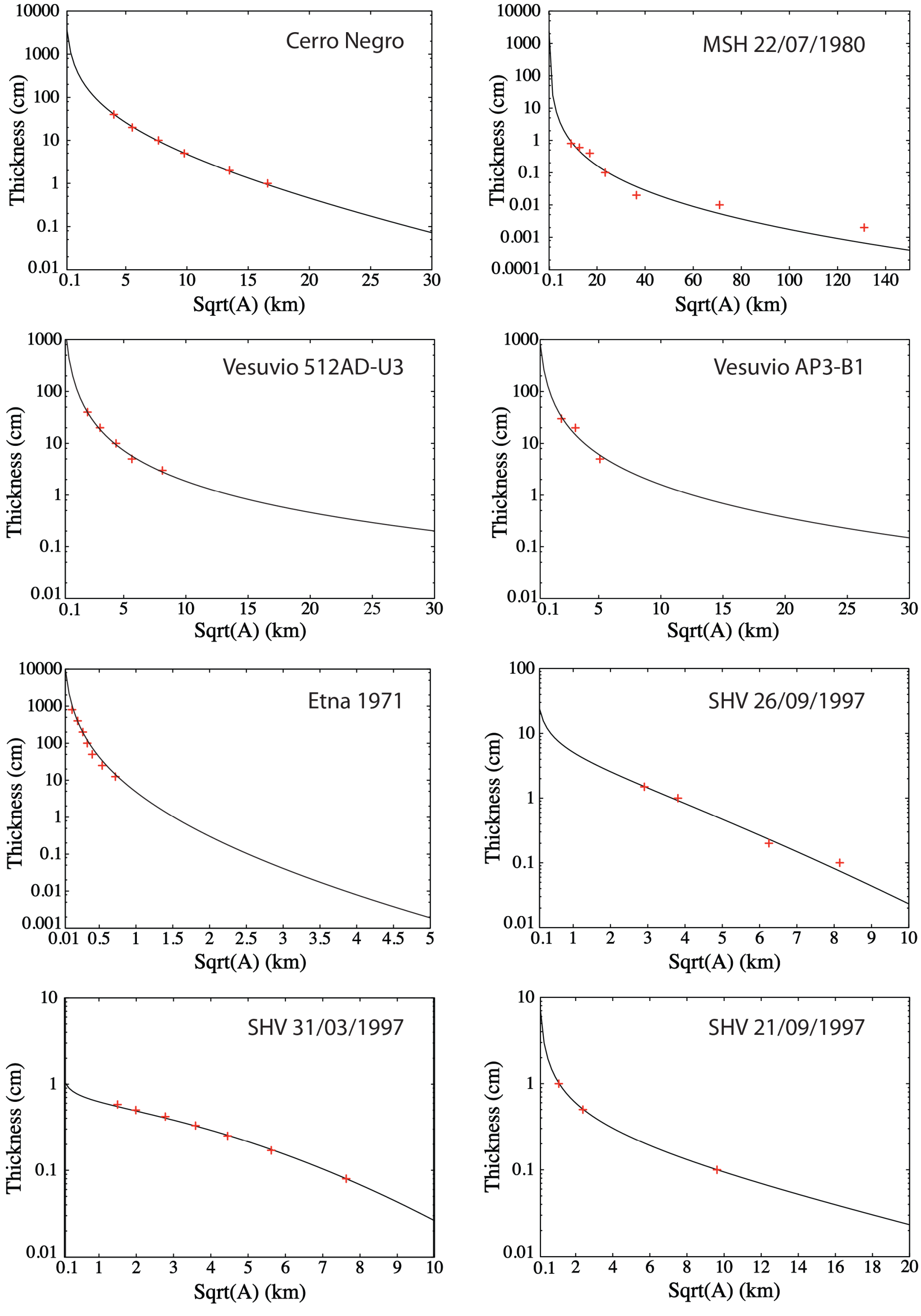


**Fig. DR1c**. Semilog plots of thickness versus square root of isopach area showing the Weibull best fit (black solid line) for the tephra deposits (red crosses) associated with the following eruptions: Cerro Negro (Connor and Connor, 2006); Mount St. Helens (22 July 1980) (Sarna-Wojcicki et al., 1981); Vesuvius U3 (512AD) (Cioni et al., 2011); VesuviusAP3B1 (Andronico and Cioni, 2002); Etna 1971 (Booth and Walker, 1973); Montserrat, Soufriere Hills Volcano (26/9/97: Vulcanian explosion; 31/3/97 and 21/9/97: dome collapses) (Bonadonna et al., 2002).

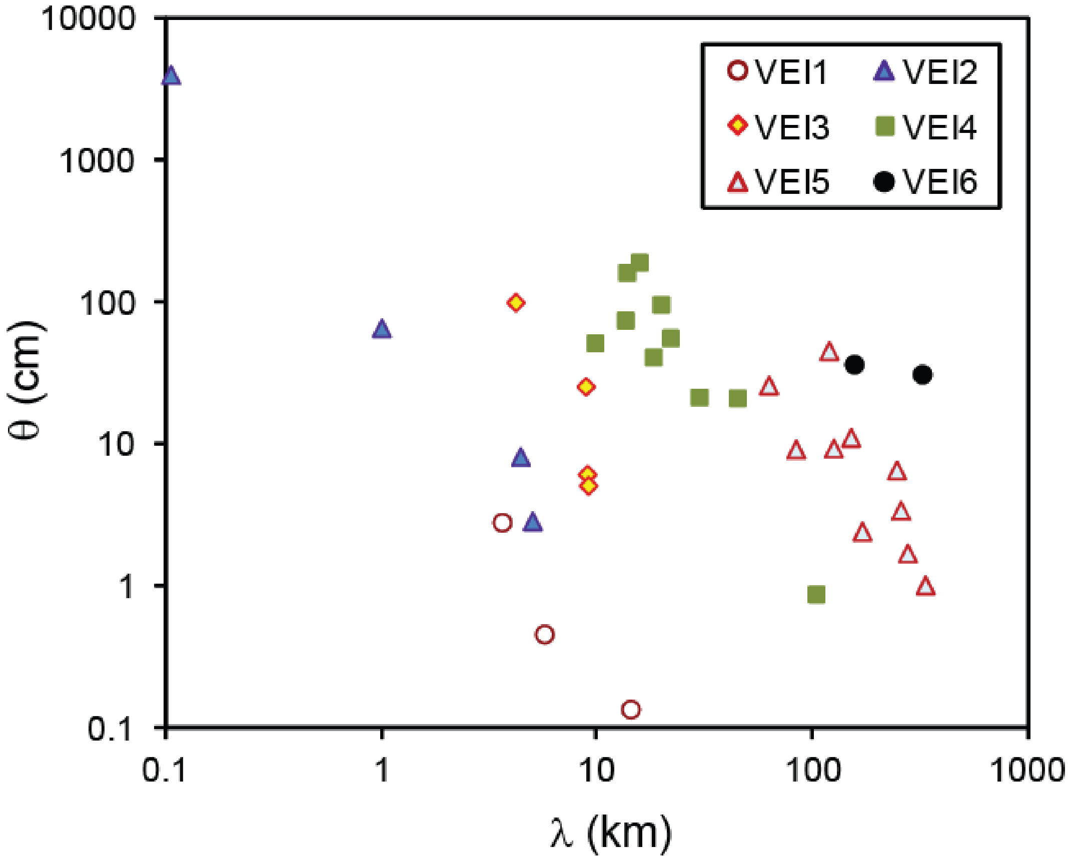


**Figure DR2.** Plots showing the relation between $\lambda$ (km), $\theta$ (cm) and VEI of all eruptions in Table 1 and DR1 (references are in Table DR1).

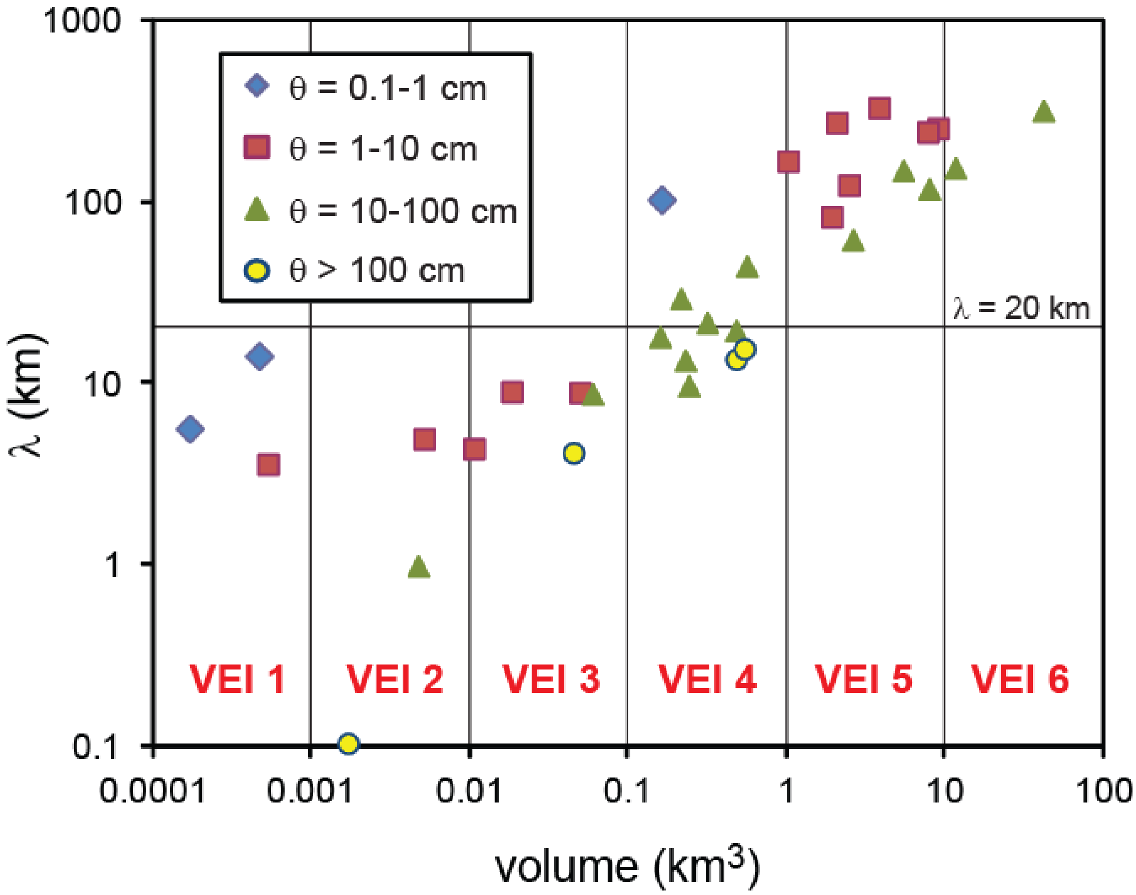


**Figure DR3.** Plot showing the relation between $\lambda$ (km), volume (km$^3$) and $\theta$ (cm) of all the tephra deposits described in Table 1 (main text) and Table DR1 (supplementary material). Boundaries between different VEIs are also shown. In particular, $\lambda$ increases with eruption magnitude for $3 \leq \text{VEI} \leq 5$; VEI 1-3 eruptions are characterized by $\lambda < 20$ km, while VEI 5-6 eruptions are characterized by 50 km $< \lambda < 400$ km (see also Fig. DR2).

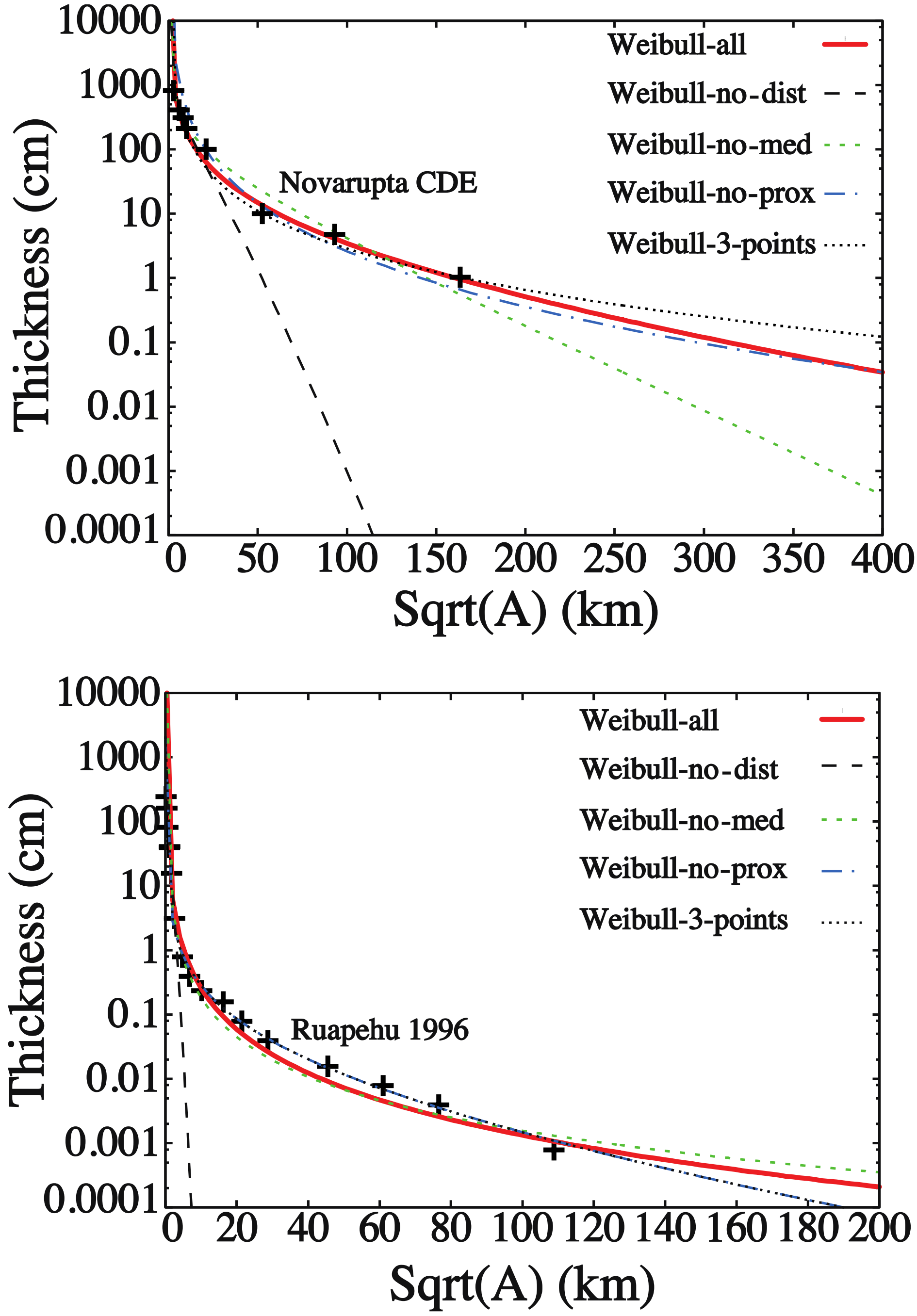


**Figure DR4.** Semilog plots of thickness versus square root of isopach area showing two sensitivity tests carried out on the exponential, power-law and Weibull integration based on the following tephra deposits**:** **a)** Novarupta CDE and **b)** Ruapehu 1996 (see main text for details). Black crosses are original data. See also Tables DR2 and DR3 for more details.

**Appendix DR1: Alternative formulation for recovering exponential thinning for *n*=1**

In this case the Weibull method is based on the assumption that thickness scales with square root of the isopach area according to the following relationship:

$$T = \theta\left(x/\lambda\right)^{n-1} \exp\left[-\left(x/\lambda\right)^{n}\right] \qquad \text{(DR1)}$$

where $\lambda$ represents the characteristic decay length scale of deposit thinning (typically expressed in km), $\theta$ represents a thickness scale (typically expressed in cm; note that $\theta = eT(\lambda)$ where $e$ denotes the Euler-Napier's constant), and $n$ is a shape parameter (dimensionless). For $n$=1 the exponential thinning relationship is recovered.

Accordingly to equations (1; main text) and (DR1) volume of tephra deposits can be calculated as:

$$V=\int_0^{\infty} T\,\mathrm{d}A = 2\int_0^{\infty} T(x)x\,\mathrm{d}x = \frac{2\theta\lambda^2}{n}\int_0^{\infty} x\frac{n}{\lambda}\left(\frac{x}{\lambda}\right)^{n-1} \mathrm{e}^{-\left(\frac{x}{\lambda}\right)^{n}}\,\mathrm{d}x = \frac{2\theta\lambda^2}{n}\int_0^{\infty} \mathrm{e}^{-\left(\frac{x}{\lambda}\right)^{n}}\,dx = \frac{2\theta\lambda^2}{n}\Gamma\left(\frac{1}{n}+1\right) \qquad \text{(DR2)}$$

$\Gamma$ is the Gamma function and the parameters $\theta$, $\lambda$ and $n$ can be empirically determined from observations. However, assuming (DR1), i.e. *T(x)* follows the Weibull probability density function, both parameter values and their physical meaning will be quite different with respect to the formulation described in the main text. Fitting quality is equivalent but there is no advantage to use such a more complex formulation. As a result, we recommend the formulation presented in the main text, i.e. $V(x) = \frac{2\theta\lambda^2}{n}\left[1-\mathrm{e}^{-(x/\lambda)^n}\right]$) follows the Weibull cumulative distribution function.

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