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Mapping the susceptibility of rain-triggered lahars at Vulcano island (Italy) combining field characterization, geotechnical analysis, and numerical modelling

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Supplementary material

Section 1: example of a recent lahar (September 2017 lahar)

A small lahar event occurred in September 2017, one month before our 2017 field work. The lahar source area was located on the NW cone flank in a funnel shaped area located above a small gully at an elevation of 159 m above sea level. The lahar flowed into a gully with an average width of 2 meter and a depth varying between 0.4 and 0.8 m (Fig. S1), formed levees on both sides and stopped on the La Fossa crater trail with a final runout of 120 m. The area of the front lobe deposit was measured with a handheld GPS (135.5 m^2) and approximate thickness estimated (0.3 m) in the field, which resulted in a volume of ~40 m^3. A second lahar flow pulse deposited a small deposit confined within the channel (Fig. S2). Two samples (V11 and V12) were taken from this recent lahar deposit in order to compare with the older lahar deposits.

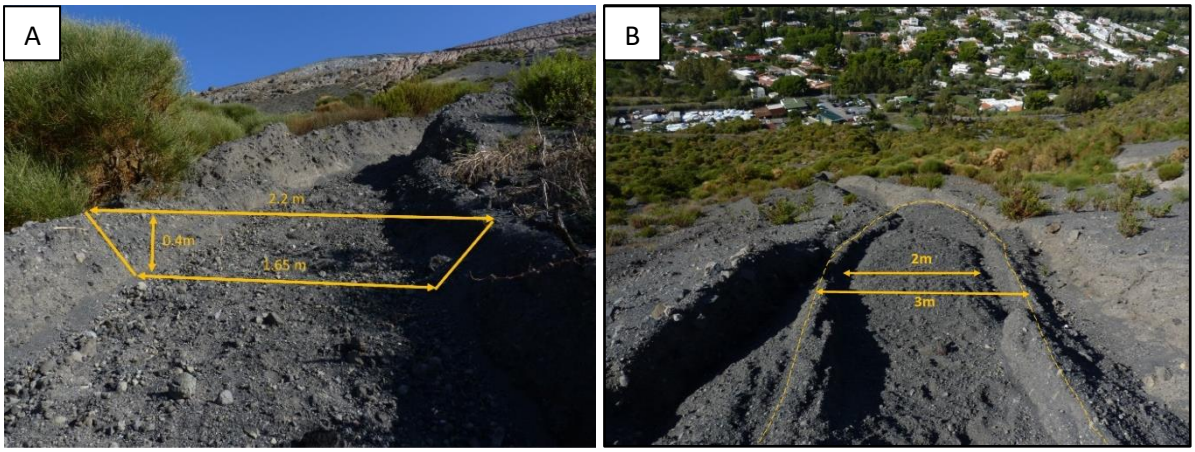

Figure S1: A) September 2017 lahar gully; B) September 2017 lahar deposit confined within the channel; the yellow lines mark the levee and the contour of the deposit.

Section 2: tephra-fallout and lahar properties

In this section the grainsize distribution of both tephra-fallout and lahar samples are shown (Fig. S3). Tables S1 and S2 describe the associated suction, thickness, slope angle and grainsize characteristics.

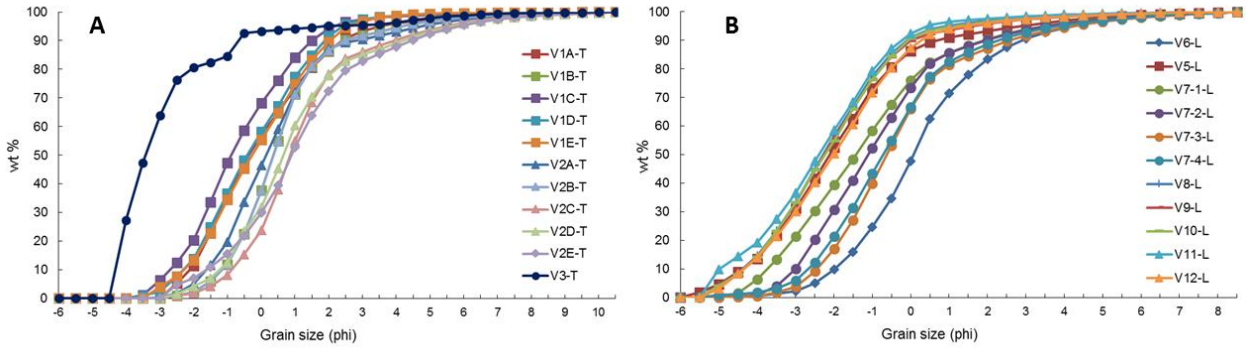

Figure S3: Grainsize distribution for A) primary and B) remobilised deposits (lahars). See Table S2 for a reference of sample numbers.

Table S1: Suction measured in the field on the 1888-90 tephra-fallout deposit and Mdϕ for Su5 and Su7 (Fig. 1, main text). NA = Not available

Location	Suction (kPa)	Mdφ
Su1	25	NA
Su2	24	NA
Su3	27	NA
Su4	14	NA
Su5/V01	15	-0.27
Su6	15	NA
Su7/V08	20	0.90

Table S2: Summary of the physical characteristics of the tephra-fallout and lahar samples analysed. 30*: slope is measured on GIS (Geographic Information System). *Thick*. refers to the total deposit thickness. *Unit* refers to the 1888-1890 eruption (1888-90), the Palizzi D eruption (Pal D) and lahars. For section V1 and V2, the horizon shows the sampled section interval. *F1* and *F2* refers to the weight sample fraction < 1mm and < 63 μm, respectively.

Site	Section	Name	Thick. (cm)	Horizon	slope (°)	Mdφ	σφ	F1	F2
unit				**1888-90 tephra-fallout deposit**					
S La fossa cone	V1	V1A	100	0-6	30	-0.37	1.80	35.13	3.23
		V1B	100	6-12	30	0.08	1.46	39.99	2.60
		V1C	100	12-18	30	-0.88	1.63	24.03	1.22
		V1D	100	18-24	30	-0.41	1.68	32.81	0.84
		V1E	100	24-30	30	-0.27	1.71	35.26	0.83
NW La fossa cone base	V2	V2A	50	0-6	10	0.14	1.49	40.81	5.63
		V2B	50	6-12	10	0.09	1.78	44.97	4.13
		V2C	50	12-18	10	0.85	1.51	62.09	7.86
		V2D	50	18-24	10	0.66	1.80	54.66	8.68
		V2E	50	24-30	10	0.90	2.10	60.41	9.71
unit				**Pal D tephra-fallout deposit**					
Pallizi valley	V3	V3	25	-	10	-3.42	1.55	6.31	2.83
unit				**Lahar deposit**					
Pallizi valley	V6	V6	15	-	5	2.07	1.78	84.12	12.38
S La Fossa cone	V5	V5	15	-	30	-0.12	1.83	37.46	5.73
Porto di Ponente	V7	V7A	26	-	0-3	0.58	2.04	51.65	7.71
		V7B	11	-	0-3	0.90	1.75	58.91	7.87
		V7C	10	-	0-3	1.38	1.73	72.86	10.31
		V7D	6	-	0-3	1.29	1.76	68.65	8.92
NW La fossa cone	V8	V8	30	-	30*	-0.29	1.67	33.27	2.51
	V9	V9	40	-	30	-0.27	1.69	34.04	3.29
	V10	V10	30	-	30	-0.24	1.68	34.02	2.85
	V11	V11	20	-	25*	-0.40	1.82	31.68	1.89
	V12	V12	20	-	25*	-0.02	1.82	39.42	3.16