Silleni, A., Giordano, G., Ort, M.H., and Isaia, R., 2024, Transport and deposition of the 39.8 ka Campanian Ignimbrite large-scale pyroclastic density currents (Italy): GSA Bulletin, https://doi.org/10.1130/B37500.1.

Supplemental Material

The isopach map

The isopach map was developed based on published data, fieldwork and the assessment of the paleotopographic control on thickness distribution. A database composed of published data and 97 outcrops from fieldwork was developed. The 0-m isopach was reconstructed through a first phase of revision of geological maps (Servizio Geologico d'Italia, 1963, 1965, 1966, 1967, 1971a, 1971b, 1975; ISPRA, 2009, 2010, 2011a, 2011b, 2011c, 2011d, 2014a, 2014b, 2016, 2018). The contact to distinguish the 0-m isopach was traced between the CI and older units and extrapolated where CI does not crop out. Then a statistical and morphological analysis of the actual slope of the top of the CI was applied to discriminate if the ignimbrite is covered by younger deposits or the CI was never emplaced there, and a comparison between the topography and the average slope of the CI top was carried out.

To determine the isopach locations, two different methods were used, one in the flat topographic zone (from the caldera to the base of the Apennine Mountains, including all the Campanian Plain) and one in the ridge topographic zone, farther from the vent. The almost complete lack of outcrops in the Campanian Plain and the valley-ponded depositional style in the ridge-valley topography of the Apennine Mountains (Rosi et al., 1996; Perrotta et al., 2010; Scarpati et al., 2015; Fedele et al., 2016; Silleni et al., 2020) make these different approaches necessary.

In the flat topographic zone, data from the literature (Ortolani and Aprile, 1985; Scandone et al., 1991; Bellucci, 1994; Rolandi et al., 2003; Milia and Torrente, 2007; Torrente et al., 2010; ISPRA, 2011d), consisting of more than 300 thickness values of CI from boreholes, outcrops, and geological sections, were used to fit isopachs on the map. In the distal area, the isopach locations were based upon our field observations and the reconstruction of the pre-CI topography. A series of profiles orthogonal to the center of the valley in the Apennine Mountains was drawn to outline the trend of the valleys. The base elevation of the paleovalleys is constrained by field data where the CI base has been measured. For greater detail on the method, see Silleni et al. (2020).

Methods

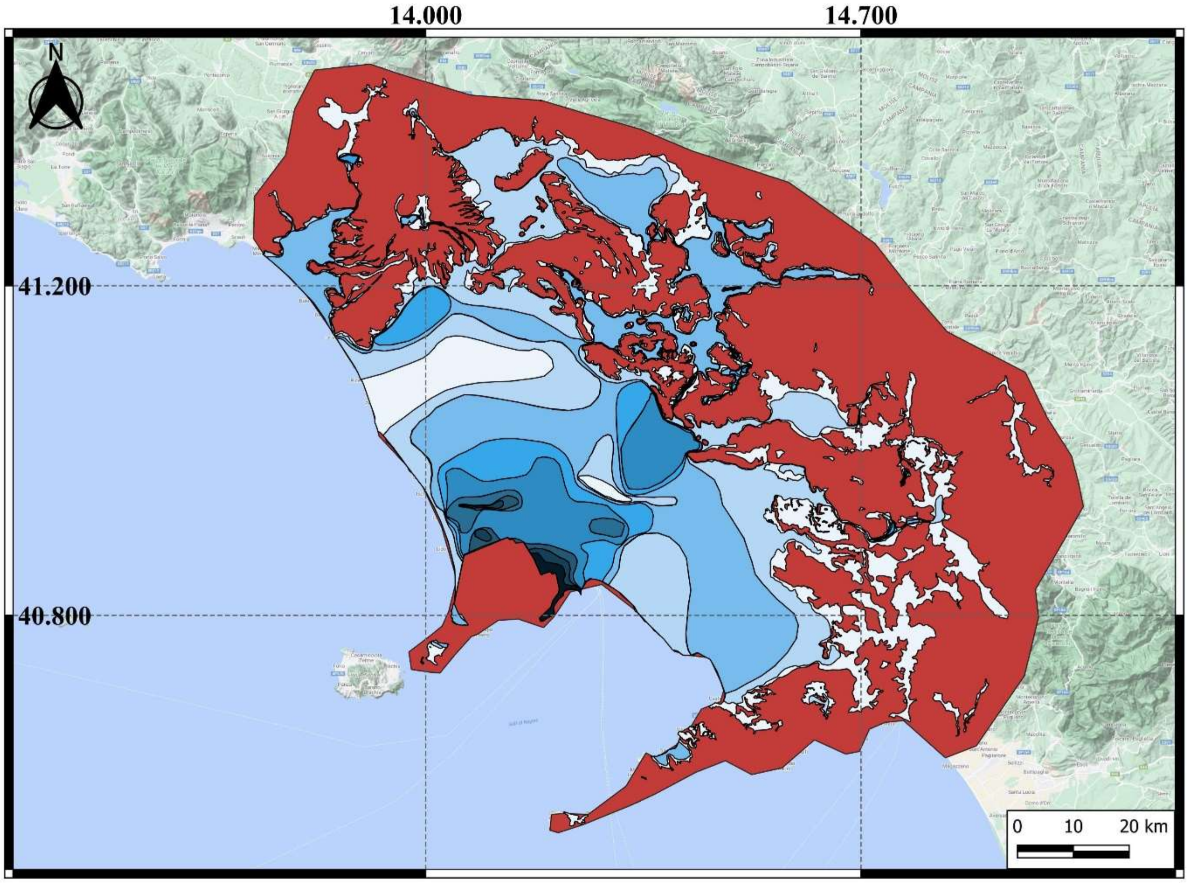

Figure S1. *Enveloped area of the Campanian Ignimbrite deposit.*

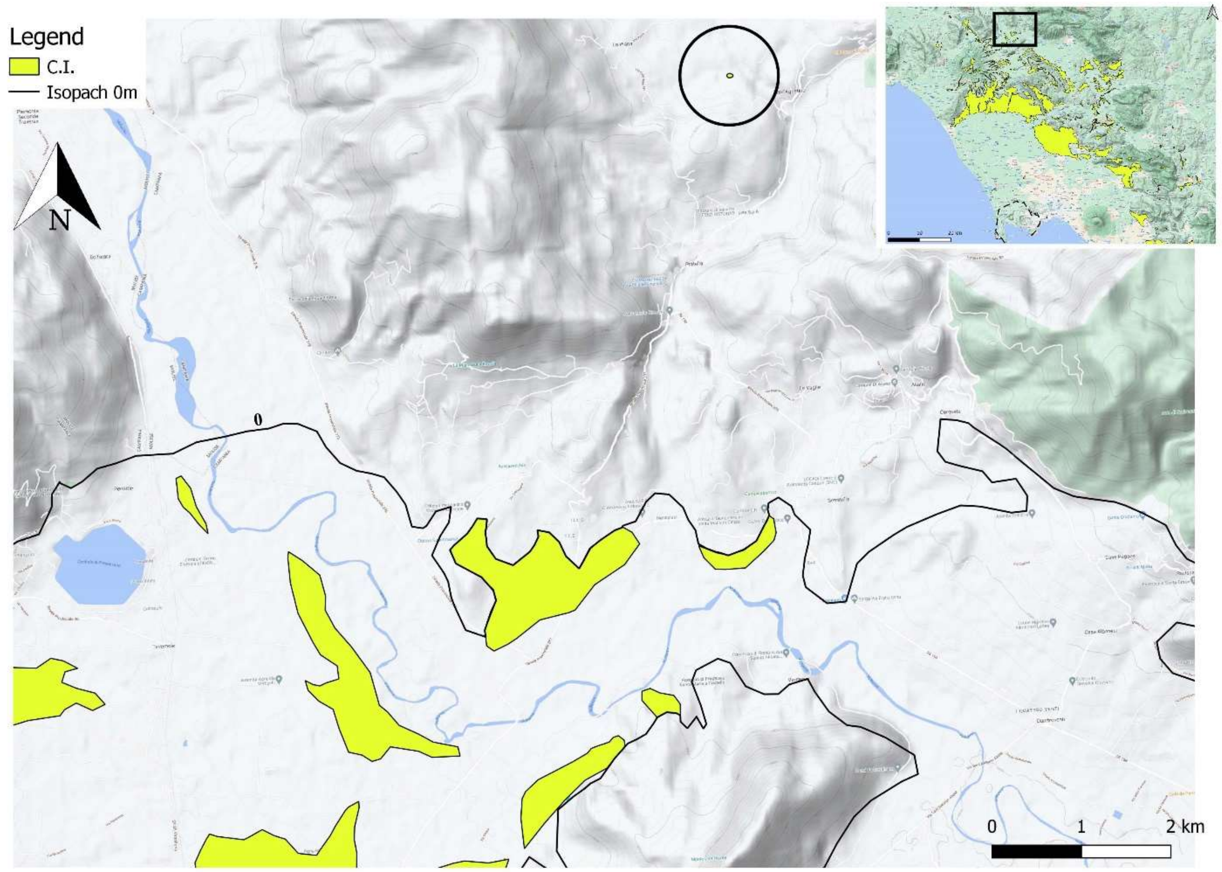

Figure S2. *Outcrop of Pratella. The outcrop is an example of the small outcrops found in secondary valleys updating the data published in Silleni et al. (2020).*

The center of the caldera was chosen as the vent area to consider a common starting point for all paths (as the final runout point is the most important, the real location of the emission point of the PDC, i.e. at the caldera center or the caldera rim, is not relevant for this work).

The database of hydrographic basins used in this work was initially larger (53 basins instead of 40), but many of the basins have an area between 6 and 8 km^2. Because we compare the features to basin size, we did not want the data to be affected by this sampling bias. Therefore, half of the basins with this area (13 basins) were selected randomly using a Matlab code and included in our dataset. This operation was repeated five times and results were compared for any deviations (none were found; this database variability is shown in detail later in this supplementary material), so the final database used in this work is the first produced by the code (Fig. S1).

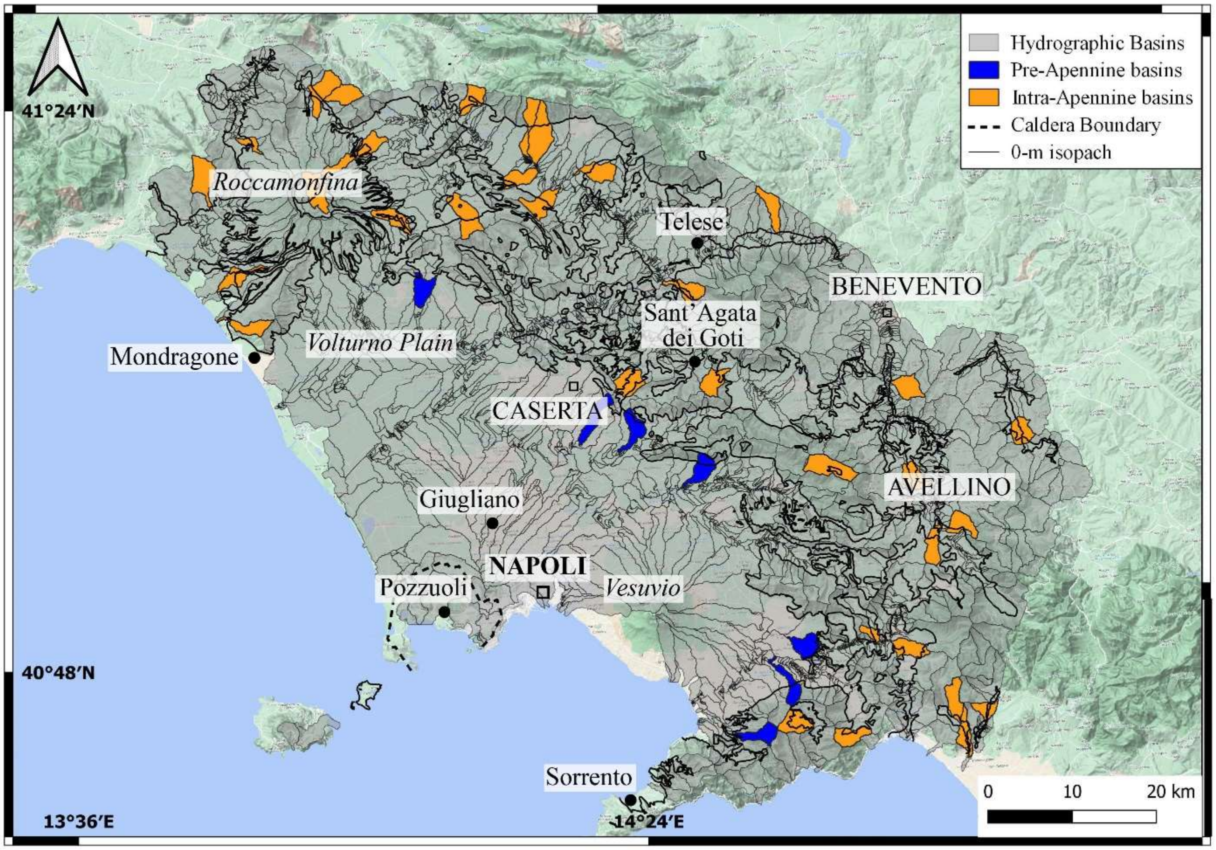

Figure S3. *Hydrographic catchment areas of the Campanian region, among the Campanian Ignimbrite extent, in light gray and the relation to the 0-m isopach drawn on it (solid black line). The analyzed basins located before the first Apennine ridge, and thus the first subjected to blocking, are shown in blue (pre-Apennine basins), while the other analyzed basins (beyond the first ridge) are shown in orange (intra-Apennine basins).*

Results: the topological aspect ratio (ARt)

The ARt has been calculated along flow paths that extend from the vent to the Apennine ridges in a straight line, called "primary" (A, B, C, D, E, F, G) (Fig. S2), and flow paths that arrived at the same final runout points, but with a sinuous, valley-constrained path, here called "secondary" (A', B', C', C'', D', E', F', G').

The plot of primary paths (Fig. S2) presents some points with ARt equal to 0 in areas on the Apennine ridge where there is no outcrop (if the thickness is 0 m, the ARt is 0). The plotted potential runouts reach less than 70 km, although there are CI distal outcrops, not considered by these paths, up to almost 80 km from the vent. The ARt gradient shows a variety of patterns, but all of them present a first general flat trend on the Campanian Plain before the Apennines (pre-blocking area), which means that the changes in thickness are negligible compared to the high potential runout, then a gradient decrease of at least one order of magnitude, near the ridge, and finally an increase until the final runout (post-blocking area). This simple trend is clear in paths B, C, E, and F (Fig. S2), while it is more complex in the other paths, where there are some irregularities in the gradient.

The secondary path plots show continuous lines due to the positive values of thickness, as the paths were traced along the valleys, following areas with CI deposits, included by the 0-m isopach (Fig. S3). Primary and secondary paths (A-A’, B-B’, C-C’-C’’, D-D’, E-E’, F-F’, G-G’) have comparable ARt trends with small differences in some cases (paths A-A’, D-D’, F-F’, Fig. S3). In other cases, the trends look different, as for the paths E and E’. All the paths, both primary and secondary, show the starting flat trend corresponding to the Campanian Plain and a final increase of the ARt gradients in the final runout (post-blocking area). In Fig. S4, path F-F’ has been chosen to show all gradient variations, from the vent to the final runout.

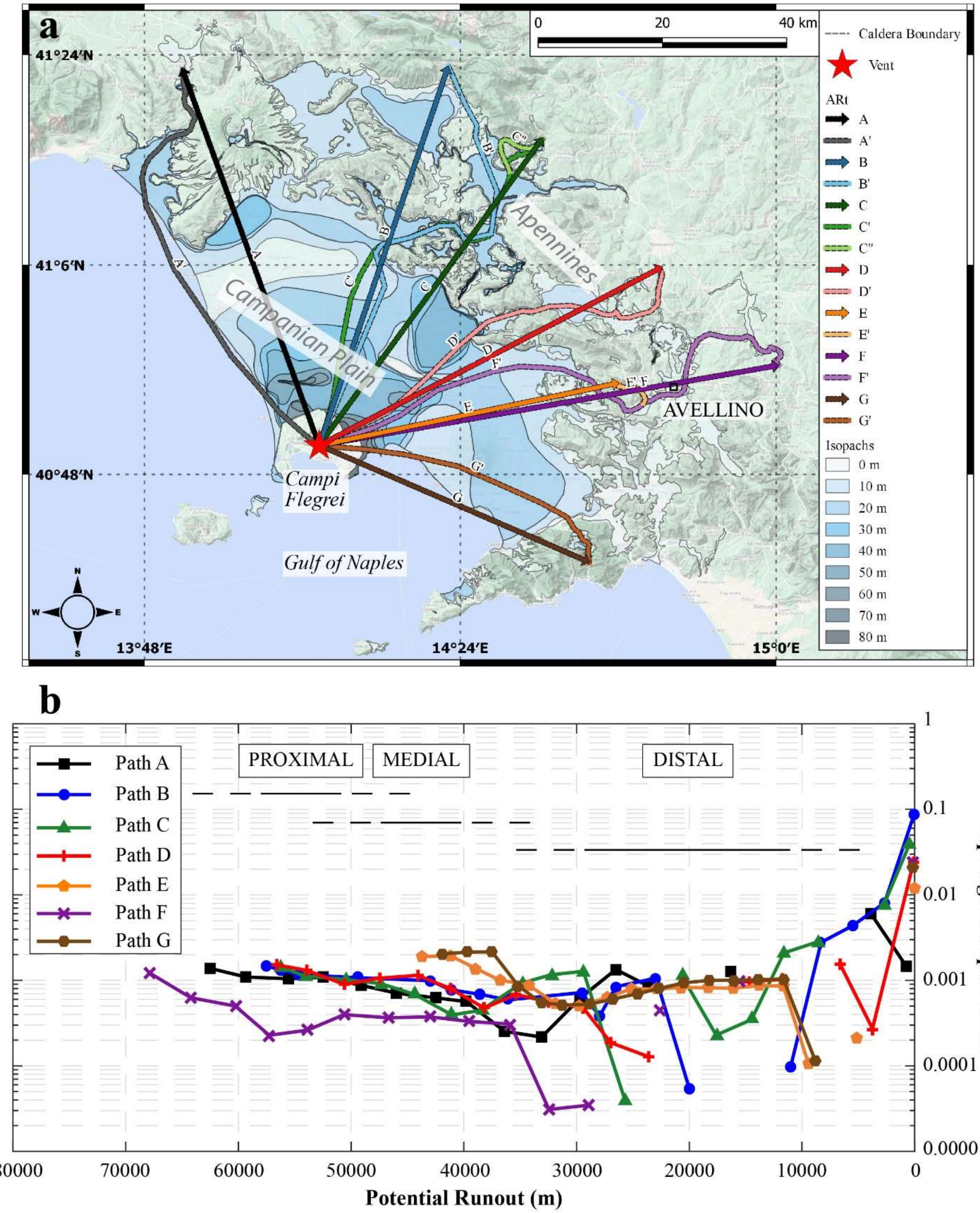

Figure S4. *Topological aspect ratio (ARt) of the Campanian Ignimbrite. a) Isopach map (in m, thicknesses in light blue) with paths along which ARt has been calculated. Each track goes from the vent (red star) out to the final runout, following a straight path (primary paths: A, B, C, D, E, F, G) or the bottom of the valleys (secondary paths: A', B', C', D', E', F', G'). b) Plot of the ARt vs. the potential runout of the primary paths. All paths show a starting flat ARt gradient.*

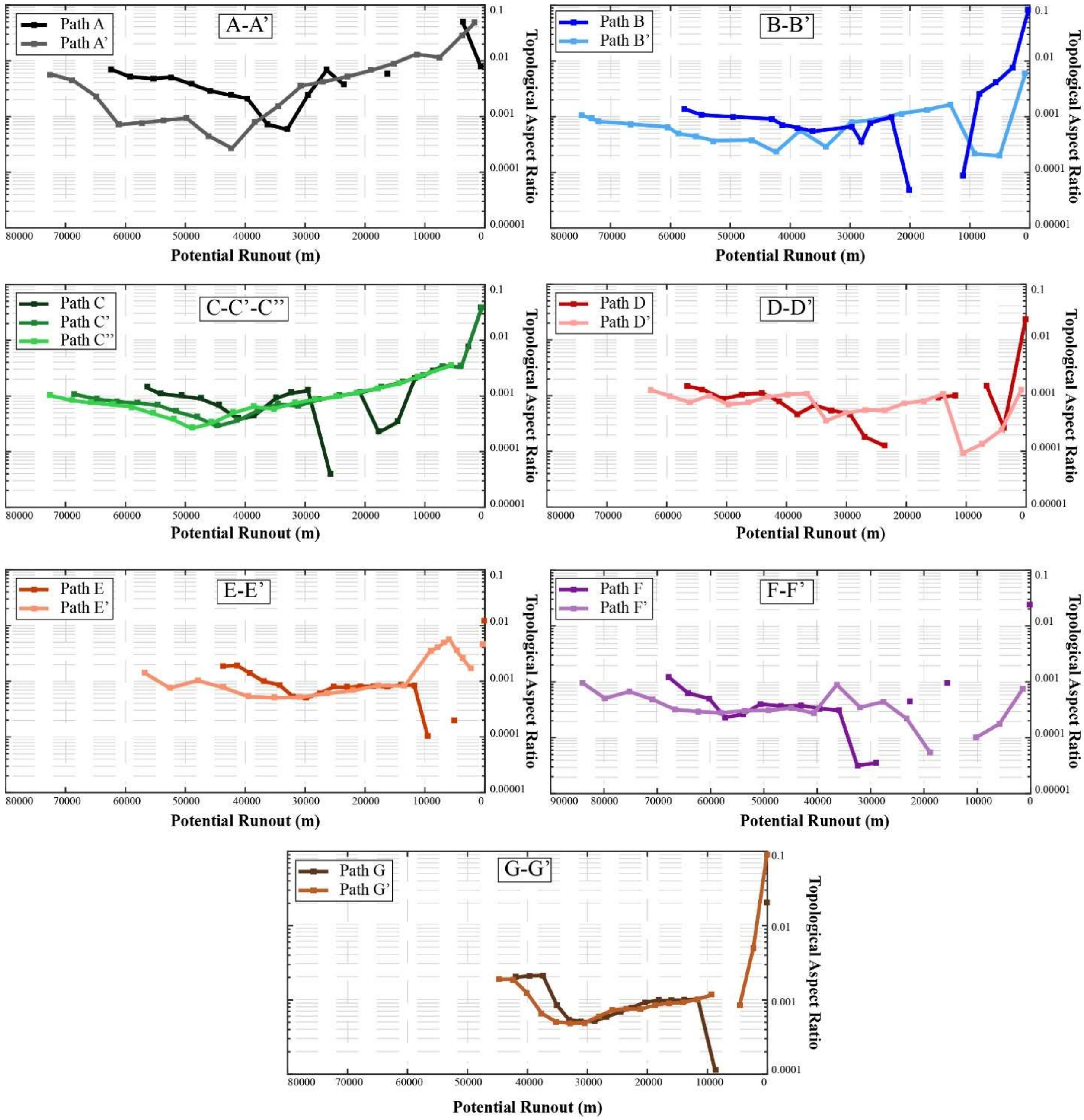

Figure S5. *Plot of topological aspect ratio versus potential runout. Comparison between primary paths in darker colors and secondary paths in lighter colors (A-A', B-B', C-C'-C'', D-D', E-E', F.F', G-G').*

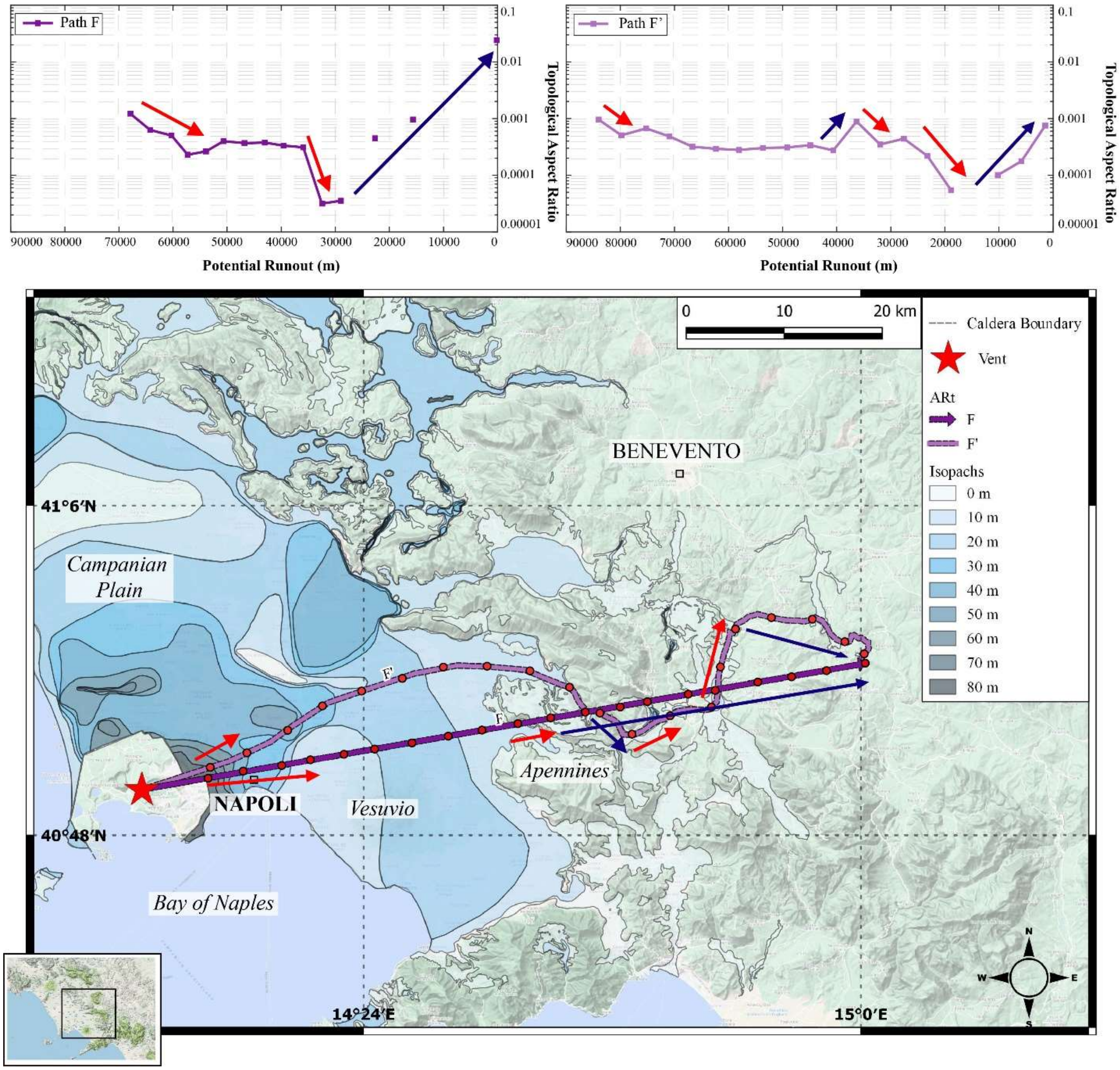

Figure S6. *Relation between the topological aspect ratio (ARt) and the topography for the paths F and F'. The flat gradient corresponds to the flat area of Campanian Plain. Path F has a decrease of the ARt gradient due to the Apennine foothills whereas path F' shows some variations due to the interaction with the topography. Both paths have a final increase of the ARt gradient.*

Discussion: the Competence Ratio (CR)

Detailed results of the Competence Ratio (CR) of all paths analyzed in this work are in Table S1.

Table S1. *Distance (km) from the vent of the maximum pumice (MP5) and maximum lithic (ML5) (cm), and the competence ratio (CR), respectively, for pumice (CRp) and lithic clasts (CRl) for all paths. CR is related to the potential final runout of 73 km (see main text for the definition).*

	Path A	
Distance (km)	**ML5 (cm)**	**CRl (cm/km)**
6.2	5.16	0.07
12.3	5	0.07
14.8	10	0.14
38.3	3.5	0.05
39.4	2.5	0.03
39	3	0.04
40.5	1.3	0.02
42	0.9	0.01
43	1.9	0.03
43.2	1	0.01
46.8	0.9	0.01
47.1	1.5	0.02
48.6	0.9	0.01
56.3	0.1	0.00
56.6	0.1	0.00
56.8	1.2	0.02
58.1	1	0.01
60.8	0.1	0.00
61.1	0.1	0.00
61.6	0.7	0.01
Distance (km)	**MP5 (cm)**	**CRp (cm/km)**
6.2	29.4	0.40
12.3	8.36	0.11
15	68	0.93
37.5	19.1	0.26
38.4	19	0.26
38.5	20	0.27
39.5	14.6	0.20
40.6	14	0.19
42	6.8	0.09
42.2	11.8	0.16
42.9	10	0.14
43.1	4.5	0.06
46.8	4	0.05

47.1	4.5	0.06
48.6	4	0.05
56.9	4.9	0.07
57.5	5	0.07
61.1	1.54	0.02
61.6	2.3	0.03
62.6	1.8	0.02
	Path B	
Distance (km)	**ML5 (cm)**	**CRl (cm/km)**
6.2	5.16	0.07
31.2	4.6	0.06
32.8	2.5	0.03
33.3	3	0.04
34.8	0.1	0.00
35.6	3.9	0.05
37.4	0.8	0.01
40.1	1.4	0.02
41.4	1	0.01
46	0.6	0.01
Distance (km)	**MP5 (cm)**	**CRp (cm/km)**
6.2	29.4	0.40
30.8	23.8	0.33
31.4	26	0.36
33	20	0.27
33.3	9	0.12
34.8	15	0.21
35.6	13	0.18
37.4	2.5	0.03
40.1	5.3	0.07
45.6	5	0.07
46	1.5	0.02
	Path C	
Distance (km)	**ML5 (cm)**	**CRl (cm/km)**
5	17	0.23
29.6	3	0.04
29.8	2.8	0.04
30.3	2.8	0.04
31	1.82	0.02
31.5	3.2	0.04
34.4	4	0.05
35.1	1.7	0.02
35.7	3	0.04
38.1	0.6	0.01

43.2	1.5	0.02
45.4	2.5	0.03
49.9	0.8	0.01
50.2	1.4	0.02
54	1.1	0.02
54.7	1	0.01
55.6	0.38	0.01
56.2	0.9	0.01
59.5	0.8	0.01

Distance (km)	**MP5 (cm)**	**CRp (cm/km)**
5	29.8	0.41
29.6	30	0.41
30	24	0.33
30.5	19	0.26
31	19.8	0.27
31.6	21	0.29
34.1	20	0.27
35.3	18.3	0.25
38.3	3.7	0.05
43.3	4.9	0.07
45.4	9.1	0.12
49.9	1	0.01
52.5	5	0.07
53.3	1.06	0.01
54.1	3.4	0.05
56.3	2.1	0.03
59	9	0.12
59.3	0.6	0.01
59.7	4.9	0.07

Path D

Distance (km)	**ML5 (cm)**	**CRl (cm/km)**
5	17	0.23
6.5	17	0.23
34.8	3	0.04
55.1	0.46	0.01
55.4	1.4	0.02
55.5	1	0.01
56	0.8	0.01

Distance (km)	**MP5 (cm)**	**CRp (cm/km)**
5	29.8	0.41
6.5	16.2	0.22
12.2	79	1.08
34.8	20	0.27

46.7	5	0.07
54.1	5	0.07
55.1	3.48	0.05
55.7	4.2	0.06
56	4.5	0.06

Path E

Distance (km)	**ML5 (cm)**	**CRl (cm/km)**
5	17	0.23
6.5	17	0.23
9.5	10.4	0.14
12.1	10.6	0.15
14.4	27.8	0.38
40.6	3	0.04
42.2	1	0.01
42.6	1	0.01
46.5	0.9	0.01
47.8	1	0.01

Distance (km)	**MP5 (cm)**	**CRp (cm/km)**
5	29.8	0.41
6.5	16.2	0.22
9.5	44.6	0.61
12.2	79	1.08
14.4	86.6	1.19
37	20	0.27
37.3	20	0.27
41.1	5	0.07
41.5	5	0.07
46.8	1.84	0.03
47.7	2.5	0.03
49.6	3.3	0.05

Path F

Distance (km)	**ML5 (cm)**	**CRl (cm/km)**
5	17	0.23
6.5	17	0.23
9.5	10.4	0.14
14.4	27.8	0.38
40.3	3	0.04
40.6	3	0.04
42.2	1	0.01
42.6	1	0.01
46.8	0.9	0.01
47.8	1	0.01
49.6	0.9	0.01

57.8	1.7	0.02
58.5	1.5	0.02
Distance (km)	**MP5 (cm)**	**CRp (cm/km)**
5	29.8	0.41
6.5	16.2	0.22
9.5	44.6	0.61
14.4	86.6	1.19
37	20	0.27
37.3	20	0.27
41.1	5	0.07
41.5	5	0.07
46.8	1.84	0.03
47.7	2.5	0.03
50.5	3.32	0.05
57.8	3.5	0.05
58.5	3.4	0.05

	Path G	
Distance (km)	**ML5 (cm)**	**CRl (cm/km)**
9.5	10.4	0.14
37.7	3	0.04
46.2	1.08	0.01
47	1.9	0.03
Distance (km)	**MP5 (cm)**	**CRp (cm/km)**
36.5	20	0.27
46.2	4	0.05
46.9	8.2	0.11
47.6	3.1	0.04
47.9	8.1	0.11

Sample location

Table S2. *Data on outcrop locations: ID, site name, latitude, longitude, altitude, observed units and observed thickness for each outcrop.*

ID	Site name	Latitude (°)	Longitude (°)	Altitude (m) a.s.l.	Units	Observed Thickness (m)
1	Stop 1 - Mignano Montelungo	41.40661	13.98082	95	WGI	8
2	Stop 2 - Mignano Montelungo	41.40628	13.98121	100	USAF, WGI	1
3	Stop 3 - Mignano Montelungo	41.40629	13.98113	110	USAF, WGI	1
4	Stop 4 - Roccamonfina	41.28944	13.99278	540	GL, USAF, WGI	50
5	Stop 5 - Roccamonfina	41.28952	13.99265	560	WGI	4
6	Stop 6 - Sessa Aurunca	41.24711	13.93903	185	WGI	12
7	Ponte Sant'Agata	41.22863	13.93258	139	WGI	30
8	SP14	41.27269	13.9621	545	WGI	25
9	Stop 7 - Tavola	41.29957	14.00002	610	USAF, WGI	2
10	Stop 8 - Torano A	41.27172	13.99416	440	WGI	1
11	Stop 8 - Torano B	41.269	14.04052	461	GL, USAF, WGI	30
12	Stop 9 - Furnolo	41.27165	13.99404	301	GL, USAF, WGI	2
13	Stop 10 - Furnolo	41.26993	14.0419	300	WGI	35
14	Comune Mignano Montelungo	41.40541	13.98322	130	WGI	6
15	Stop 11 - Sant'Angelo in Formis	41.12139	14.25682	57	USAF, WGI	15
16	Stop 12 - Triflisco	41.1362	14.25528	34	WGI	5
17	Stop 13 - Pontelatone A	41.18584	14.25546	83	WGI	1
18	Stop 13 - Pontelatone B	41.1854	14.25557	81	WGI	5
19	Stop 14 - Pontelatone	41.18474	14.2553	78	USAF, WGI	5
20	Stop 15 - Pontelatone SP189	41.1906	14.25493	98	WGI	7
21	Stop 16 - Ruviano	41.20994	14.4079	78	WGI	2
22	Stop 17 - Ruviano	41.20936	14.40745	70	WGI	21
23	Stop 18 - San Salvatore Telesino	41.23581	14.47714	104	WGI	2

24	Stop 19 - Puglianello	41.22433	14.4464	62	WGI	3
25	Telese terme	41.22982	14.53457	116	WGI	2
26	Ruviano 1	41.21043	14.41082	57	WGI	5
27	Ruviano Fosso	41.21167	14.41127	63	WGI	8
28	Ruviano 2	41.21055	14.41012	64	WGI	3
29	Stop 20 - San Lorenzello	41.26985	14.53162	190	USAF, WGI	19
30	Stop 21 - San Lorenzello	41.2692	14.53801	214	WGI	9
31	Stop 22 - Amorosi	41.20903	14.45779	60	WGI	2
32	Stop 23 - Casagiove	41.08671	14.30732	67	WGI	7
33	San Lorenzello	41.26818	14.53105	196	WGI	15
34	San Lorenzello - Cerreto	41.27637	14.55113	232	WGI	5
35	San Lorenzello Ristorante	41.2685	14.52962	191	WGI	10
36	Stop 24 - Casagiove	41.08662	14.30278	65	WGI	14
37	Stop 25 - Gradillo	41.12394	14.33669	166	WGI	24
38	Casagiove SS700	41.08747	14.30406	74	WGI	6
39	Gradillo	41.12054	14.33908	193	WGI	2
40	Ruviano 3	41.20775	14.40391	75	WGI	3
41	Ruviano 4	41.20849	14.40651	70	WGI	13
42	Ruviano 5	41.21053	14.41048	57	WGI	11
43	Ruviano - Cimitero	41.21192	14.42011	60	WGI	1
44	Ruviano 6	41.21258	14.42225	60	WGI	3
45	Stop 26 - Maddaloni	41.04716	14.37956	62	LYT	1
46	Cava abbandonata	41.06373	14.34691	56	LYT	5
47	Stop 27 - Caserta	41.06161	14.3455	53	LYT	4
48	Stop 28 - Sant'Anna	41.09116	14.44714	62	LYT	15
49	SP121	41.09902	14.46894	84	LYT	20
50	Stop 29 - Capellino	41.09769	14.48696	112	LYT	53
51	Ponte Sant'Agata dei Goti	41.08902	14.50297	148	WGI	40
52	Stop 30 - Durazzano	41.06417	14.45702	264	WGI	3
53	Sant'Agata dei Goti top	41.10065	14.50719	142	WGI	0
54	Stop 31 - San Pietro	41.09956	14.50764	126	WGI	43
55	Stop 32 - Castrone	41.09163	14.51141	147	LYT	3
56	Stop 33 - Sant'Agata dei Goti	41.09217	14.50656	107	USAF, GL, WGI	35
57	Stop 34 - Sant'Agata dei Goti	41.09167	14.50894	123	WGI, LYT	35
58	SP121 bis	41.10215	14.46956	84	LYT	2

59	Stop 35 - Tocco Caudio	41.12213	14.62599	485	LYT	1
60	Stop 36 - Tufara	41.05936	14.71026	198	PPF, WGI	20
61	Stop 37 - Altavilla Irpina B	41.00774	14.76531	260	LYT	20
62	Stop 37 - Altavilla Irpina A	41.00714	14.76552	244	PPF, GL, USAF, WGI, LYT	5
63	Lungofiume - Altavilla Irpina	41.00604	14.76601	222	WGI, LYT	14
64	Stop 38 - Monteforte Irpino	40.91418	14.67142	444	LYT	14
65	Stop 39 - Verdolino	40.85522	14.20769	153	PP, BM	50
66	Stop 40 - Monte di Procida	40.791	14.04602	0	PP, BM	3
67	Stop 41 - Mondragone	41.12515	13.91096	30	WGI	80
68	SS430 A	41.31125	13.89634	19	WGI	12
69	SS430 B	41.30749	13.89466	18	WGI	12
70	Stop 42 - Mortola	41.34702	13.88266	23	WGI	10
71	Stop 43 - Mortola 2	41.34902	13.88048	31	WGI	3
72	Stop 44 - Punta Marmolite	40.89635	14.13634	64	BM	7
73	Stop 45 - Acqua Fidia	40.92923	14.70025	958	PPF, GL, USAF, WGI	3
74	Piano Acqua Fidia	40.92281	14.7134	804	WGI	2
75	Cerreto Sannita	41.31006	14.53653	246	WGI	1
76	Stop 46 - Civitella	41.31012	14.5368	258	WGI	1
77	Stop 47 - Procida	40.76473	14.03531	0	BM	7
78	Stop 39 - Verdolino B	40.85571	14.20621	145	PP, LPFU	80
79	Stop 48 - Pianura	40.85935	14.18551	195	PP	10
80	Stop 49 - Vigna S. Martino 1	40.84231	14.24247	76	PPF, USAF, BM	8
81	Stop 50 - Vigna S. Martino 2	40.84301	14.24311	175	BM, UPFU	3
82	Stop 51 - Vigna S. Martino 3	40.84373	14.24292	152	PP	3
83	Stop 52 - Baiano	40.91548	14.66762	400	PPF	
84	Stop 53 - Cuma	40.84895	14.05028	55	BM, LPFU	20
85	Stop 54 - Lago Patria	40.93363	14.05399	37	WGI, BM	5
86	Stop 55 - Le Campole	41.23112	14.24032	583	WGI	1
87	Stop 56 - Liberi	41.22711	14.30978	421	WGI	1

88	Stop 57 - Statigliano	41.27991	14.24541	275	WGI	1
89	Stop 58 - Sant'Anna	40.77986	14.65101	124	WGI	10
90	Stop 59 - Paterno Sant'Arcangelo	40.67639	14.64385	167	WGI	5
91	Stop 60 - Polvica	40.69385	14.63513	278	WGI	4
92	Stop 61 - Monticchio	40.59983	14.35433	312	PPF, WGI	18
93	Stop 62 - Piano di Sorrento	40.6369	14.40127	18	WGI, LYT	25
94	Stop 63 - Fosso di Prepezzano	40.69748	14.88704	128	WGI	3
95	Stop 64 - Cologna	40.72163	14.7763	154	WGI	1
96	Stop 65 - Serino Cimitero	40.86696	14.85831	365	PPF, WGI	1
97	Stop 66 - Serino Ferrovia	40.85697	14.85926	390	WGI	2
98	Stop 67 – Sant’Angelo in Formis Cava	41.10810	14.26020	42	WGI, LYT	10
99	Stop 68 – Triflisco	41.13745	14.25312	35	USAF, WGI, CPF	4
100	Stop 69 – San Nicola La Strada	41.05347	14.34436	45	LYT	7
101	Stop 70 – Voscone	40.79708	14.65742	83	PPF, USAF, WGI	4
102	Stop 71 – Cava Zaccaria	40.90311	14.09316	33	BU, UPFU	4
103	Stop 72 – Trefola	40.89030	14.15922	128	LPFU	
104	Stop 73 – Ponti Rossi	40.87501	14.26354	201	BU, UPFU	6
105	Stop 74 - Pratella	41.42347	14.18476	226	WGI	1

Geometric features of the deposit – databases variability

The database of basins used in this work was initially larger (53 basins instead of 40 of the final database), but many of the basins have an area between 6 and 8 km^2. Because we compare the features to basin size, we did not want the data to be affected by this sampling bias. Therefore, half of the basins with this area (13 basins) were selected randomly using a Matlab code and included in our dataset. This operation was repeated five times and results were compared for any deviations (none were found, this database variability is shown in Fig. S5), the final database used in this work is the first produced by the code.

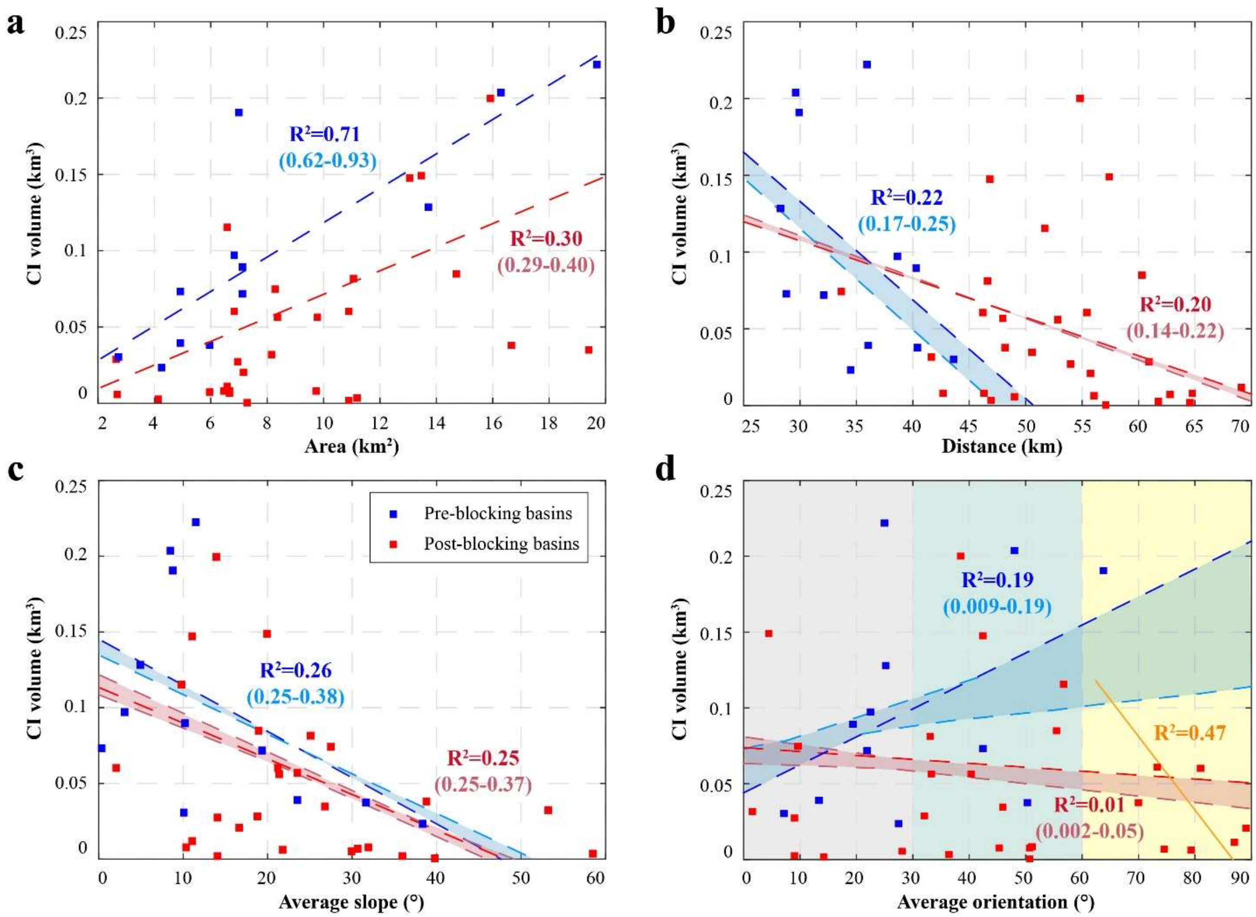

Figure S7. *Geometric features of the deposit. Relations between the Campanian Ignimbrite (CI) volume in the basins and different features of the analyzed hydrographic basins: area (a), distance (b), slope (c), and orientation (d). The basins located on the first ridge of the Apennine, and initially subjected to blocking (pre-blocking basins), are shown in blue and the other hydrographic basins considered in this work (here called post-blocking basins) are shown in red. Fit lines are represented by dashed lines (blue and red), while databases variability is shown by light blue and pink (both for fit lines and* R^2*). d) The orientation is subdivided into three different ranges (0-30° in gray, 30-60° in green, 60-90° in yellow). The solid yellow line is the fit line of the range 60-90°, with the relative* R^2 *(0.47).*

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