

**Geological Society of America Data Repository for:**

## **A way to hydrothermal paroxysm, Colli Albani Volcano, Italy**

published on the Geological Society of America Bulletin by

Gianluca Vignaroli <sup>(1)</sup>, Luca Aldega <sup>(2)</sup>, Fabrizio Balsamo <sup>(3)</sup>, Andrea Billi <sup>(4,\*)</sup>, Arnaldo A. De Benedetti <sup>(1)</sup>, Luigi De Filippis <sup>(1)</sup>, Guido Giordano <sup>(1)</sup>, and Federico Rossetti <sup>(1)</sup>

<sup>(1)</sup> Dipartimento di Scienze, Sezione di Geologia, Università Roma Tre, Rome, Italy

<sup>(2)</sup> Dipartimento di Scienze della Terra, Sapienza Università di Roma, Rome, Italy

<sup>(3)</sup> Dipartimento di Fisica e Scienze della Terra, Università di Parma, Italy

<sup>(4)</sup> Consiglio Nazionale delle Ricerche, IGAG, Rome, Italy

<sup>(\*)</sup> Corresponding Author: Andrea Billi, [andrea.billi@cnr.it](mailto:andrea.billi@cnr.it), at Dipartimento Scienze della Terra (CNR-IGAG), Sapienza Università di Roma, Piazzale A. Moro 5, Rome, 00185, Italy;

Below, we provide six tables, four figures, and related captions that supplement the article entitled “A way to hydrothermal paroxysm, Colli Albani Volcano, Italy” published on the Geological Society of America Bulletin. We provide also the captions of four movies that show some exposures and sites of the study area. The movies are stored in this data repository along with this document.

## Tables

**Table DR1.** In situ permeability (Darcy) measured with the TinyPerm II Portable Air Permeameter in different rock units and sites.

Imater quarry					Laurentina 1								Laurentina 2
unaltered					weakly altered			altered					altered
Pozzolanelle	Tufo Lionato	Tufo Lionato with joints	paleosol	Pozzolane Nere	Tufo Lionato	Tufo Lionato	Tufo Lionato	Tufo Lionato	Tufo Lionato	Tufo Lionato	Tufo Lionato	paleosol	Pozzolane Nere
3.088613658	0.008288468	3.455480198	0.026933631	2.920055979	0.309381799	0.309381799	0.366110337	0.176510545	0.122560349	0.409597	0.254209235	0.623950145	0.606685598
1.713378363	0.03467135	12.21483608	0.292497629	4.838857927	0.129635038	0.203096146	0.06250015	0.318185925	0.171626541	0.327241	0.589898755	1.812281631	1.762136241
4.089080306	0.445569472	6.229005553	0.049933432	8.970969617	0.240336047	0.203096146	0.208875685	0.149160361	0.557705682	0.606686	0.284404291	1.619872631	1.762136241
2.684309334	0.106517009	2.467595365	0.003996069	3.359867905	0.623950145	0.162260212	0.276534894	1.124760872	0.126048068	0.07396	0.097917507	0.527269511	0.527269511
1.093639014	0.327240593	0.849568004	0.977527927	3.176506825	0.261443307	0.214819693	0.376528797	1.489094474	0.309381799	0.07823	0.261443307	0.738358233	2.332929074
4.704967912	0.022760284	12.5624356	0.873744295	2.920055979	0.197476525	0.021518167	0.066107917	1.06337829	0.276534894	0.75937	0.589898755	0.717928041	0.197476525
3.865923264	0.10954818	0.950479969	0.512680092	3.865923264	0.192012398	0.433240674	0.214819693	1.258360336	0.327240593	0.589899	0.873744295	0.227219972	1.093639014
0.950479969	0.006621931	0.106517009	0.181533533	7.167203639	0.039893467	0.34613027	0.133324082	0.849568004	0.641705993	0.192012	0.030132817	0.47128958	2.399317605
1.407828788	0.017680797	3.865923264	0.659967122	4.448199484	0.157770512	0.557705682	0.34613027	0.950479969	0.080455717	0.109548	0.024074101	3.654944772	0.849568004
1.15676837	0.016253362	0.071913775	0.171626541	4.976558072	0.606685598	0.30082128	0.623950145	0.849568004	0.738358233	0.247175	0.738358233	1.665969602	1.489094474
0.849568004	0.082745258	18.09233065	0.849568004	8.481388858	0.129635038	0.276534894	0.717928041	0.950479969	0.036672723	0.376529	0.048551787	2.027545035	0.318185925
1.762136241	0.122560349	7.371161886	1.18968671	6.588569454	0.162260212	0.977527927	0.082745258	0.220932851	0.129635038	0.641706	0.498494359	2.920055979	1.713378363
4.704967912	0.011285545	15.72401647	1.093639014	4.838857927	0.166877677	0.233686007	0.366110337	0.15340504	0.186699462	0.240336	0.309381799	0.873744295	2.684309334
0.309381799	0.051354396	9.488810998		10.03654432	0.433240674	0.276534894	1.033954873	0.309381799	0.042196	0.826060665	0.149160361	0.048551787	
1.033954873	0.100703961	0.166877677		5.889064454	0.240336047	0.11266561		1.97144336	0.069923939	0.186699	1.294169695	0.826060665	2.610035151
0.92418042	0.014125772			5.263825537	0.149160361	0.318185925		0.157770512	0.044632026	0.12256	0.780979316	0.220932851	0.678747911
1.447891594	0.008288468			9.488810998	0.103569709	0.016253362			0.055864542	0.071914	0.009016394	0.47128958	1.258360336
0.309381799				7.167203639	0.376528797	0.284404291			0.031872207	0.12256	0.018701405	1.330998087	0.208875685
0.141020099				8.018526429	0.355980154	0.318185925			0.071913775	0.112666	0.06250015	0.898608574	0.33655293
1.093639014				12.91992682	0.826060665	0.284404291			0.030132817	0.055865	0.047208371	1.665969602	0.197476525
3.758954113				8.246710903	0.33655293	0.366110337			0.035657998	0.007408	0.220932851		0.157770512
4.838857927				11.87685455	0.085099953	0.261443307			0.030990311	0.181534			0.233686007
34.49667492				6.056650492	0.33655293	0.035657998			0.355980154	0.573576			0.254209235
27.56053187				6.056650492	0.977527927	0.126048068			0.085099953				0.106517009
48.30718146				13.6657183	0.247175327	0.080455717			0.103569709				0.34613027
				8.970969617	0.149160361	0.073960237			0.06798916				0.318185925
				2.760697149		0.659967122			0.029299049				0.197476525
				15.28893678		0.445569472							0.181533533
				0.623950145		0.076064935							0.484701142
				5.118176772		0.366110337							0.780979316
				6.776061416		0.276534894							
				6.776061416									
				17.10496169									
				5.889064454									
				2.684309334									
				7.796655763									
				7.580924205									
				5.726115481									
				1.762136241									
				3.176506825									
				1.15676837									
				1.916894004									

**Table DR2.** Samples, sampling sites, and laboratory analyses.

Samples	Location	Units	Degree of alteration	Meso-structure	Petrography	BSE-EDS	XRD	Geochemistry	He pycnometry
AGL 00	Imater quarry	Tufo Lionato	no	bedding	X	X	X	X	X
AGL01	Laurentina 1	Tufo Lionato	high	mushroom-like structure	X		X		
AGL 02	Laurentina 1	Tufo Lionato	high	mushroom-like structure	X	X	X	X	X
AGL 03	Laurentina 1	Tufo Lionato	medium-high	horizontal foliation			X	X	X
AGL 04	Laurentina 1	Tufo Lionato	medium-high	horizontal foliation	X	X	X	X	X
AGL 05	Laurentina 1	Tufo Lionato	no-very low	preserved lithon	X		X	X	X
AGL 06	Laurentina 1	paleosol	medium	bedding					
AGL 07	Laurentina 1	paleosol	medium	bedding					
AGL 08	Laurentina 1	Tufo Lionato	no-very low	preserved lithon					
AGL 09	Laurentina 1	Tufo Lionato	high	mushroom-like structure					
AGL 10	Laurentina 1	Tufo Lionato	medium-high	horizontal foliation					
AGL 11	Laurentina 1	Tufo Lionato	medium	concentric zonation halo					
AGL 12	Laurentina 1	Tufo Lionato	high	fracture in mushroom-like structure					
AGL 13	Laurentina 2	Pozzolane nere	medium-high	Liesegang-like bands					
AGL 14	Laurentina 2	Tufo Lionato	medium-high	alteration halo			X		
AGL 15	Laurentina 2	Tufo Lionato	medium-high	alteration halo			X		
AGL 16	Laurentina 2	Tufo Lionato	medium-high	alteration halo			X		
AGL 17	Laurentina 2	paleosol	medium-high	bedding					
AGL 18	Laurentina 4	Tufo Lionato	no-very low	preserved lithon					
AGL 19	Laurentina 4	Tufo Lionato	very low	preserved lithon					
AGL 20	Laurentina 4	Tufo Lionato	medium	horizontal foliation					
AGL 21	Laurentina 4	Tufo Lionato	medium-high	concentric zonation halo					
AGL 22	Laurentina 4	Tufo Lionato	medium-high	concentric zonation halo					
AGL 23	Laurentina 4	Tufo Lionato	medium-high	concentric zonation halo					
AGL 24	Laurentina 4	Tufo Lionato	very low	concentric zonation halo					
AGL 25	Laurentina 4	Tufo Lionato	no-very low	concentric zonation halo			X	X	X
AGL 26	Laurentina 4	Tufo Lionato	medium	concentric zonation halo	X		X	X	X
AGL 27	Laurentina 4	Tufo Lionato	medium-high	concentric zonation halo			X	X	X
AGL 28	Laurentina 4	Tufo Lionato	medium-high	concentric zonation halo			X	X	X
AGL 29	Laurentina 4	Tufo Lionato	medium-high	concentric zonation halo	X	X	X	X	X
AGL 30	Laurentina 4	Tufo Lionato	medium-high	concentric zonation halo	X		X	X	X
AGL 31	Laurentina 4	Tufo Lionato	medium-high	concentric zonation halo	X		X	X	X
AGL 32	Laurentina 4	Tufo Lionato	medium-high	fracture with oxides					
AGL 33	Laurentina 1	Tufo Lionato	high	actual sulphides					
AGL 34	Laurentina 1	Tufo Lionato	high	mushroom-like structure					
AGL35a	Laurentina 3	Tufo Lionato	medium-high	breccia structure	X				
AGL35b	Laurentina 3	Tufo Lionato	medium-high	breccia structure					
AGL35c	Laurentina 3	Tufo Lionato	medium-high	breccia structure	X				
AGL35d	Laurentina 3	Tufo Lionato	medium-high	breccia structure					
AGL36a	not used	Tufo Lionato	high	mushroom-like structure					
AGL36b	not used	Tufo Lionato	high	mushroom-like structure	X				
AGL 37a	Zolforata di Pomezia	Tufo Lionato	medium-high	breccia structure	X				
AGL 37b	Zolforata di Pomezia	Tufo Lionato	medium-high	breccia structure				X	X
AGL 37c	Zolforata di Pomezia	Tufo Lionato	medium-high	breccia structure	X				
AGL37d	Zolforata di Pomezia	Tufo Lionato	medium-high	breccia structure					
AGL ps1	Zolforata di Pomezia	paleosol	high	Liesegang-like bands	X				
AGL ps2	Zolforata di Pomezia	paleosol	high	Liesegang-like bands				X	X
AGL ps3	Imater quarry	paleosol	no	bedding				X	X
AGL ps4	Imater quarry	paleosol	no	bedding	X				
AGL 45	Zolforata di Pomezia	Pozzolane Nere	high	Liesegang-like bands			X	X	X
AGL 46	Zolforata di Pomezia	Tufo Lionato	high	breccia structure			X	X	X
AGL 47	Zolforata di Pomezia	Pozzolanelle	no-very low	bedding			X	X	X
AGL 48	Imater quarry	Pozzolanelle	no	bedding			X	X	X
AGL 49	Imater quarry	Pozzolane nere	no	bedding			X	X	X

**Table DR3.** X-ray diffraction mineralogical assemblages for the Tufo Lionato. Keys: Ab: Albite; Am: amorphous material; Anl: Analcime; Aug: Augite; Brt: Barite; Cbz: Chabazite; Gr: Greigite; Gt: Goethite; Hal-7: Halloysite-7Å; Hal-10: Halloysite-10Å; Jar: Jarosite; Kfs: K-feldspar; Lct: Leucite; Mgh: Maghemite; Mrc: Marcasite; Ph: Phlogopite; Phl: Phillipsite; Py: Pyrite; Qtz: Quartz; S: native Sulfur; and Sm: Smectite.

Sample	Locality	Unit	Meso-structure	Whole rock mineral composition																				
				Ph	Phl	Cbz	Aug	Lct	Anl	Kfs	Ab	Qtz	Sm	Hal-7	Hal-10	Mgh	Gt	Gr	Mrc	Py	S	Jar	Brt	Am
AGL48	Imater quarry	Pozzolanelle	bedding	*			*	*	*						*	*								
AGL00	Imater quarry	Tufo Lionato	bedding		*	*	*	*	*				*		*									
AGLps3	Imater quarry	paleosol	bedding	*			*				*	*	*		*									
AGL49	Imater quarry	Pozzolane Nere	bedding	*			*	*	*						*	*								
AGL47	Zolforata di Pomezia	Pozzolanelle	bedding	*			*	*							*	*						*		
AGL37	Zolforata di Pomezia	Tufo Lionato	breccia fractures								*				*	*				*	*	*	*	*
AGL46	Zolforata di Pomezia	Tufo Lionato	breccia fractures								*					*				*	*	*	*	*
AGLps2	Zolforata di Pomezia	paleosol	Liesegang-like band	*			*				*	*	*			*		*						*
AGL45	Zolforata di Pomezia	Pozzolane Nere	Liesegang-like band					*												*	*	*	*	*
AGL01	Laurentina1	Tufo Lionato	mushroom-like alteration	*											*	*			*	*		*	*	*
AGL02	Laurentina1	Tufo Lionato	mushroom stem												*	*		*	*	*		*	*	*
AGL03	Laurentina1	Tufo Lionato	horizontal foliation	*											*	*					*	*	*	
AGL04	Laurentina1	Tufo Lionato	horizontal foliation	*											*	*					*	*	*	
AGL05	Laurentina1	Tufo Lionato	preserved lithon	*			*								*	*						*	*	
AGL14	Laurentina2	Tufo Lionato	alteration halo										*		*	*		*				*		*
AGL15	Laurentina2	Tufo Lionato	alteration halo										*		*	*		*				*		*
AGL16	Laurentina2	Tufo Lionato	alteration halo										*		*	*						*		*
AGL25	Laurentina4	Tufo Lionato	concentric zonation halo				*								*	*	*						*	*
AGL26	Laurentina4	Tufo Lionato	concentric zonation halo	*			*								*	*							*	*
AGL27	Laurentina4	Tufo Lionato	concentric zonation halo	*											*	*							*	*
AGL28	Laurentina4	Tufo Lionato	concentric zonation halo				*						*		*	*							*	*
AGL29	Laurentina4	Tufo Lionato	concentric zonation halo	*			*								*	*		*						*
AGL30	Laurentina4	Tufo Lionato	concentric zonation halo				*						*		*	*		*						*
AGL31	Laurentina4	Tufo Lionato	concentric zonation halo										*		*	*						*		*

Table DR4. Results from the whole rock geochemical analysis.

Facies Unit Location Structure		u TL ImQ bedding	a TL L1 ms-like	a TL L1 hor fol	a TL L1 hor fol	lu TL L1 pres lith	lu TL L4 pres lith	a TL L4 czh	a TL L4 czh	a TL L4 czh	a TL L4 czh	a TL L4 czh	a TL L4 czh	a TL Zolf fp	a TL Zolf hor fol	u Pn ImQ bedding	a Pn Zolf vah	u Pzz ImQ bedding	lu Pzz Zolf bedding	u Ps ImQ bedding	a Ps Zolf vah
Samples		AGL 00	AGL 02	AGL 03	AGL 04	AGL 05	AGL 25	AGL 26	AGL 27	AGL 28	AGL 29	AGL 30	AGL 31	AGL37b	AGL 46	AGL 49	AGL 45	AGL 48	AGL 47	AGL ps3	AGL ps2
SiO <sub>2</sub>	(%)	43.95	41	45.32	46.52	46.54	37.69	47.88	42.13	37.08	41.27	37.21	49.2	45.14	38.16	48.13	82.06	45.27	45.83	46.73	56.3
TiO <sub>2</sub>	(%)	0.725	0.642	0.75	0.767	0.726	0.895	0.886	0.779	0.752	0.782	0.644	0.938	0.683	0.596	0.708	1.187	0.823	0.887	0.999	1.33
Al <sub>2</sub> O <sub>3</sub>	(%)	17.78	17.99	17.39	16.19	19.61	22.51	20.62	20.63	19.42	19.19	12.25	19.14	17.53	30.46	18.68	2.63	17.79	20.65	21.56	9.85
Fe <sub>2</sub> O <sub>3</sub> (T)	(%)	8.05	6.95	7.74	3.51	6.28	9.37	3.74	7.92	9.96	10.69	18.84	4.98	6.3	2.75	7.31	1.12	8.08	6.82	9.59	4.6
MnO	(%)	0.175	0.015	0.007	0.004	0.034	0.108	0.021	0.025	0.036	0.011	0.013	0.011	0.01	0.003	0.179	0.005	0.171	0.103	0.147	0.008
MgO	(%)	2.17	0.06	0.15	0.06	0.74	0.8	0.7	0.69	0.65	0.53	0.44	0.49	0.17	0.07	2.35	0.06	3.67	2.99	1.68	0.22
CaO	(%)	4.81	0.16	0.52	0.11	1.05	1.14	1.08	0.89	0.65	0.64	0.7	0.79	0.13	0.1	5.32	0.29	8.23	6.32	2.44	0.21
Na <sub>2</sub> O	(%)	0.71	0.07	0.11	0.07	0.1	0.11	0.17	0.14	0.13	0.12	0.1	0.16	0.11	0.04	0.77	0.02	2.44	0.16	0.62	0.81
K <sub>2</sub> O	(%)	5.35	0.58	0.94	0.74	0.75	0.8	1.48	1.07	0.83	1.1	0.77	1.46	0.79	1.14	8.74	0.51	3.73	0.87	2.36	4.03
P <sub>2</sub> O <sub>5</sub>	(%)	0.18	0.26	0.32	0.31	0.28	0.16	0.47	0.25	0.2	0.28	0.46	0.19	0.39	0.65	0.35	0.25	0.45	0.36	0.35	0.23
LOI	(%)	13.54	30.4	24.34	29.76	21.47	24.95	19.98	23.34	28.95	23.2	27.2	21.89	28.66	26.3	5.41	10.63	6.97	14	13.09	20.6
Total	(%)	97.44	98.13	97.58	98.04	97.58	98.53	97.02	97.87	98.63	97.8	98.63	99.25	99.9	100.2	97.95	98.77	97.61	98.99	99.56	98.19
S	(p.p.m.)	bdl	na	na	na	na	na	na	na	na	na	na	na	na	14000	100	5700	400	1800	200	21800
As	(p.p.m.)	22	35	77	43	69	51	61	43	46	140	191	64	51	33	33	29	15	10	74	57
Cs	(p.p.m.)	30	21.8	21	24.8	34.5	1.7	13.8	9.6	6.2	8.9	8	15.6	56.2	4.6	32.4	25.9	34.2	54.4	28.3	28.8
Rb	(p.p.m.)	244	44	62	45	65	37	123	71	46	65	54	88	314	39	413	111	655	144	147	186
Ba	(p.p.m.)	3055	491	4002	3955	3428	2155	8058	4197	2298	3520	2366	5389	3255	6665	3801	4202	3180	2411	1002	1461
Sr	(p.p.m.)	5185	458	640	453	399	395	1190	582	339	413	729	461	416	1891	1249	970	853	676	741	601
Pb	(p.p.m.)	173	166	149	180	210	231	232	170	161	173	233	227	283	118	37	305	55	35	153	52
Ga	(p.p.m.)	21	17	21	23	22	26	26	24	23	22	18	27	19	24	24	7	22	24	24	12
Ge	(p.p.m.)	2	1.4	1.3	1.8	1.8	2.3	2.3	2.6	3.1	2.3	1.6	2.4	1.7	1.3	1.6	0.8	2.1	1.8	3.2	0.7
Zn	(p.p.m.)	130	< 30	60	< 30	80	140	90	110	170	100	90	90	< 30	30	100	< 30	90	100	110	< 30
Bi	(p.p.m.)	2.3	1.5	1.7	2	2.7	3.6	3	2.3	1.8	2.2	2.1	2.6	0.3	3.5	0.3	11.6	0.5	0.2	1.5	< 0.1
U	(p.p.m.)	12	24.2	12.9	14.1	15.2	22.1	18.6	31.7	27.9	31	24.1	31.2	20.7	24.3	18	4.3	17.9	23	18.8	9.72
Zr	(p.p.m.)	461	402	480	470	441	546	537	488	481	503	399	603	420	417	392	587	381	459	454	487
Hf	(p.p.m.)	7.6	7.1	8.1	8.2	7.9	9.7	8.9	7.9	7.9	7.7	6.2	9.7	7.8	8.1	7.8	12.7	8.5	9.8	11.2	11.4
Y	(p.p.m.)	39.6	15.8	21.3	36.7	72.6	42.8	28.9	39	52.8	20.9	21.1	26.1	16.6	4.2	31.6	2.3	42.5	30.3	41.3	6.8
Nb	(p.p.m.)	44.9	42.4	47.6	49	39.6	56.5	48.1	49.5	50.7	51.9	39	62.8	46.3	37	54.4	53.7	36.6	46.1	31.6	40.7
Ta	(p.p.m.)	1.85	1.68	2	2.07	1.77	2.42	2.3	2.22	1.89	2.08	1.58	2.53	2	1.63	2.05	2.57	1.52	1.84	1.79	2.25
Th	(p.p.m.)	99.7	87	93.6	116	99.9	127	125	109	105	107	87.7	136	83	130	104	35.8	86.5	99	85.5	19.4
Tl	(p.p.m.)	3.49	4.82	3.02	4.7	1.17	0.57	2.02	1.69	1.25	1.57	2.03	4.43	0.35	2.04	0.25	5.44	0.74	2.75	2.17	2.79
La	(p.p.m.)	205	157	195	264	279	253	181	265	285	108	219	151	50.5	473	218	141	186	138	167	33.5
Ce	(p.p.m.)	315	212	255	420	519	415	276	511	567	177	278	249	90.7	769	377	169	326	238	323	47.8
Pr	(p.p.m.)	37	19.6	24.4	43.9	60.5	47.4	28.4	55.6	58.3	17.9	21.6	30.3	10.2	68	38.1	12.1	38.1	27.3	34.2	4.11
Nd	(p.p.m.)	129	62.3	74.7	146	217	163	96.6	189	209	58.7	64.2	104	38	158	125	28.2	136	96.3	125	13
Sm	(p.p.m.)	21.5	10.3	11	24.6	36.6	27.2	16	31.1	35.5	10	9.18	17.4	7.22	11	19.2	2.33	23.4	16.8	21.8	1.92
Eu	(p.p.m.)	3.95	1.97	2.14	4.64	7.37	5.28	2.57	5.47	6.68	1.62	1.65	2.92	1.46	1.53	3.81	0.327	4.68	3.3	4.22	0.593
Gd	(p.p.m.)	13.8	5.82	6.86	15.8	24	17.7	8.57	14.6	19.7	5.54	5.35	8.33	5.91	3.52	12.8	1.06	15.8	11.4	15.6	1.49
Tb	(p.p.m.)	1.75	0.7	0.86	1.95	3.26	2.27	1.11	1.94	2.62	0.79	0.75	1.12	0.82	0.31	1.56	0.15	1.98	1.45	1.94	0.21
Dy	(p.p.m.)	8.14	3.25	4.13	8.97	15.4	10.5	5.89	9.38	12.8	4.29	4.46	5.65	3.79	1.48	7.1	0.66	9.14	7.04	9.16	1.17
Ho	(p.p.m.)	1.42	0.58	0.7	1.42	2.62	1.71	1.02	1.55	2.07	0.77	0.86	0.96	0.62	0.24	1.18	0.11	1.56	1.12	1.51	0.23
Er	(p.p.m.)	3.75	1.55	1.8	3.64	7.15	4.28	2.58	3.83	5.08	2.05	2.45	2.4	1.68	0.67	3.01	0.3	4.06	2.83	3.89	0.72
Tm	(p.p.m.)	0.498	0.22	0.247	0.467	0.985	0.552	0.324	0.491	0.691	0.297	0.357	0.357	0.232	0.088	0.403	0.046	0.526	0.386	0.532	0.114
Yb	(p.p.m.)	3	1.4	1.53	2.95	5.98	3.31	1.9	2.93	4.22	1.95	2.33	2.39	1.4	0.5	2.32	0.26	2.87	2.42	3.25	0.83
Lu	(p.p.m.)	0.469	0.227	0.221	0.418	0.876	0.472	0.285	0.438	0.617	0.301	0.37	0.374	0.207	0.062	0.319	0.029	0.417	0.344	0.497	0.14
density	(g/cm3)	2.416	2.353	2.327	2.280	2.439	2.571	2.368	2.421	2.454	2.123	2.614	2.389	2.266	2.483	2.618	2.121	2.704	2.589	2.299	2.583
s.d.	(g/cm3)	0.005	0.005	0.002	0.007	0.002	0.012	0.005	0.005	0.008	0.004	0.008	0.011	0.004	0.008	0.003	0.004	0.003	0.005	0.004	0.004

Keys: TL: Tufo Lionato; Ps: paleosol; Pn: Pozzolane Nere; Pzz: Pozzolanelle; u: unaltered; lu: likely unaltered; a: altered; ImQ: Imater quarry; L1: Laurentina 1; L4: Laurentina 4; Zolf: Zolforata di Pomezia mine; ms: mushroom-like; hor fol: subhorizontal foliation in yellow and whitish zoned domains; pres lith: preserved. unaltered lithon; czh: concentric zonation halos; vah: Liesegang-like bands; fp: non-systematic fracture pattern; na: not analysed; and bdl: below detection limit.

**Table DR5.** Results from mass balance calculation using the software GEO-ISO (Coelho, 2005), with reference to Fig. 8.

Unit	Sample pair	Volume change (%)	Mass change (%)	Regression function	Regression Index	Inerts
Pzz	AGL48-AGL47	-3.09	-7.22	$Cf = -0.418 + (1.206 * Co)$	0.9999993	Zr, Ge, $TiO_2$
TL	AGL00-AGL46	18.34	21.64	$Cf = -0.285 + (0.905 * Co)$	0.99999956	Zr, Ge, $TiO_2$
Ps	AGLps3-AGLps2	-15.63	-24.88	$Cf = 0.028 + (1.287 * Co)$	0.99999975	$TiO_2$ , $Na_2O$ , Nb
Pn	AGL49-AGL45	-26.37	-40.35	$Cf = -0.736 + (1.499 * Co)$	0.99999675	Zr, Ge, $TiO_2$

Keys: Pzz: Pozzolanelle; TL: Tufo Lionato; Ps: paleosol; Pn: Pozzolane Nere; Cf: concentration of the component "i" in the transformed rock; and Co: concentration of the component "i" in the original rock.

**Table DR6.** Results from mass balance calculation using the software GEO-ISO (Coelho, 2005), with reference to Fig. DR3.

Unit	Sample pair	Volume change (%)	Mass change (%)	Regression function	Regression Index	Inerts
TL	AGL00-AGL02	17.76	14.68	$Cf = -0.167 + (0.872 * Co)$	0.99999971	Zr, Ge, TiO <sub>2</sub>
TL	AGL00-AGL03	-0.29	-3.96	$Cf = -0.394 + (1.042 * Co)$	0.99999901	Zr, Ge, TiO <sub>2</sub>
TL	AGL00-AGL04	3.93	-1.91	$Cf = -0.106 + (1.020 * Co)$	0.99999988	Zr, Ge, TiO <sub>2</sub>
TL	AGL00-AGL05	10.76	4.54	$Cf = -0.040 + (0.957 * Co)$	0.99999996	Zr, Ge, TiO <sub>2</sub>
TL	AGL00-AGL25	-23.89	-18.99	$Cf = -0.016 + (1.184 * Co)$	0.99999999	Zr, Ge, TiO <sub>2</sub>
TL	AGL00-AGL26	-16.53	-18.17	$Cf = 0.006 + (1.165 * Co)$	0.99999999	Zr, Ge, TiO <sub>2</sub>
TL	AGL00-AGL27	-7.12	-6.93	$Cf = 0.248 + (1.058 * Co)$	0.99999965	Zr, Ge, TiO <sub>2</sub>
TL	AGL00-AGL28	-5.10	-3.59	$Cf = 0.505 + (1.042 * Co)$	0.9999983	Zr, Ge, TiO <sub>2</sub>
TL	AGL00-AGL29	5.52	-7.29	$Cf = 0.054 + (1.091 * Co)$	0.99999998	Zr, Ge, TiO <sub>2</sub>
TL	AGL00-AGL30	4.05	12.58	$Cf = -0.057 + (0.866 * Co)$	0.99999995	Zr, Ge, TiO <sub>2</sub>
TL	AGL00-AGL31	-21.85	-22.71	$Cf = -0.113 + (1.308 * Co)$	0.99999996	Zr, Ge, TiO <sub>2</sub>
TL	AGL00-AGL37b	13.17	6.15	$Cf = -0.050 + (0.911 * Co)$	0.99999996	Zr, Ge, TiO <sub>2</sub>

Keys: TL: Tufo Lionato; Cf: concentration of the component "i" in the transformed rock; and Co: concentration of the component "i" in the original rock.



## Figures

**Figure DR1.** Photographs of alteration meso-structures from the Laurentina 1 to 4 (distal) outcrops.

(a) Panoramic view (photomosaic) of the main exposure from the Laurentina 1 locality. (b) Zoned alteration within the Tufo Lionato ignimbrite (Laurentina 1). Note the draped upper edge of the altered area. (c) Zoned alteration within the Tufo Lionato ignimbrite (Laurentina 1). Note the mushroom-like structure with stem and domal cap, and the draped upper edge of the altered area. (d) Mushroom-like structures in the Tufo Lionato ignimbrite (Laurentina 1). Note that these structures root into the cap of underlying similar structures. (e) Subvertical stem of a mushroom-like structure developed along a visible fracture (Tufo Lionato, Laurentina 1). (f), (g), and (h) Subvertical and subhorizontal fractures surrounded by a halo of incipient alteration (Tufo Lionato, Laurentina 1). (i) Panoramic view (photomosaic) of the Laurentina 4 exposure. (j) and (k) Close-up views from the previous photograph showing the cloud-like alteration structure with upward fringes along the upper edge of the alteration cloud (Tufo Lionato, Laurentina 4). (l) Panoramic view (photomosaic) of the Laurentina 2 exposure. (m) Contact between the altered Tufo Lionato ignimbrite (above) and the altered paleosol (below) (Laurentina 2). Note that the Tufo Lionato is brecciated and the alteration structures (halos, zoning) are confined by the underlying paleosol. (n) Alteration structures within the Tufo Lionato, paleosol, and Pozzolane Nere (Laurentina 2). Note also, in this case, the confinement of these alteration structures within each unit. (o) Tufo Lionato ignimbrite altered and affected by a subhorizontal foliation fabric, which mainly consists of serrate and narrowly-spaced subhorizontal fractures accompanied by alteration and mineralization bands (Laurentina 3). (p) The subhorizontal foliation shown in (o) is, in places, undulated along subvertical bands (Laurentina 3). (q) Subvertical and steep fluid-conductive fractures (bordered by a red halo) cut across the subhorizontal foliation shown in previous photographs (Laurentina 3). At the upper tip of the fractures, subhorizontal mushroom-like alteration structures can form analogously to the Laurentina 1 exposures (see Figs. DR1a to DR1d). (r) Close-up view of the previous photograph (Laurentina 3). Small mushroom-like alteration structures can form from the domal cap of underlying mushroom-like structures.

**Figure DR2.** X-ray diffraction patterns for the unaltered Tufo Lionato from the Imater quarry (a) and the altered counterparts from the Laurentina outcrops (b-d). (a) unaltered Tufo Lionato; (b) Laurentina 1 outcrop; (c) Laurentina 2 outcrop; (d) Laurentina 4 outcrop. Keys: Ab: Albite; Anl: Analcime; Aug: Augite; Brt: Barite; Cbz: Chabazite; Gr: Greigite; Gt: Goethite; Hal-7: Halloysite-7Å; Hal-10: Halloysite-10Å; Jar: Jarosite; Lct: Leucite; Mrc: Marcasite; Ph: Phlogopite; Phl: Phillipsite; Py: Pyrite; and Qtz: Quartz.

**Figure DR3.** Results from the chemical mass balance analysis where, unlike Fig. 8, Sulfur is omitted to highlight other element gains and losses (Tables DR4 and DR6). (a) Pozzolanelle; (b)-(f) different alteration structures within the Tufo Lionato; (g) paleosol; (h) Pozzolane Nere. Numbers on the y-axis refer to a factor of loss (negative) or gain (positive) in mass (i.e., +1 stands for +100% of enrichment of the  $i$  component).  $\Delta M_i$  is the mass change in element  $i$ ,  $C_0^i$  is the original concentrations of the  $i$  component within the unaltered rocks.

**Figure DR4.** Color version of Fig. 9. Conceptual scenario of hydrothermal alteration progression eventually leading to the formation of a fluid barrier (caprock) and to consequent fluid overpressure, hydro-fracturing, and possible paroxysm in a progressive and cyclic fashion.



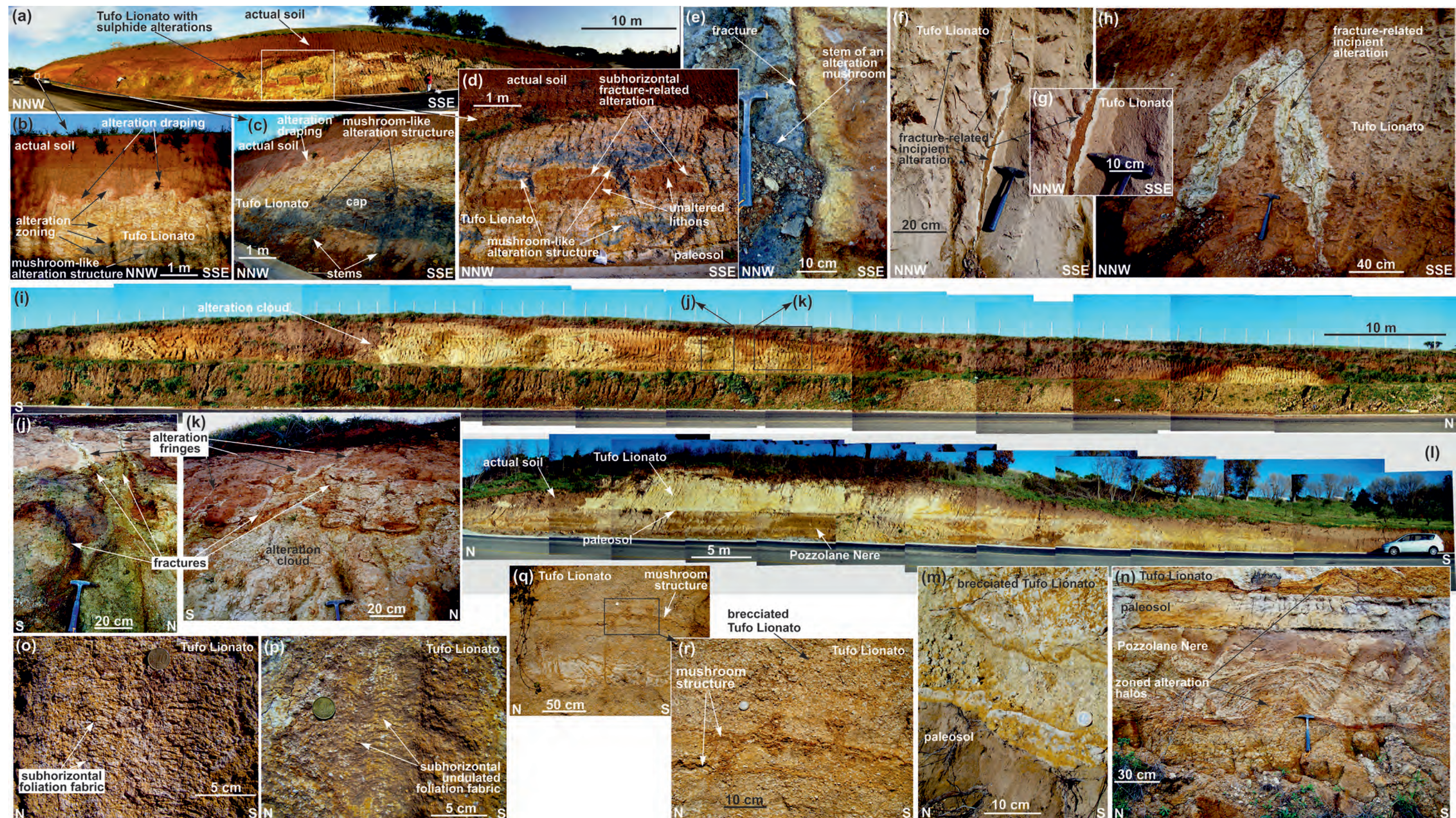


Figure DR1



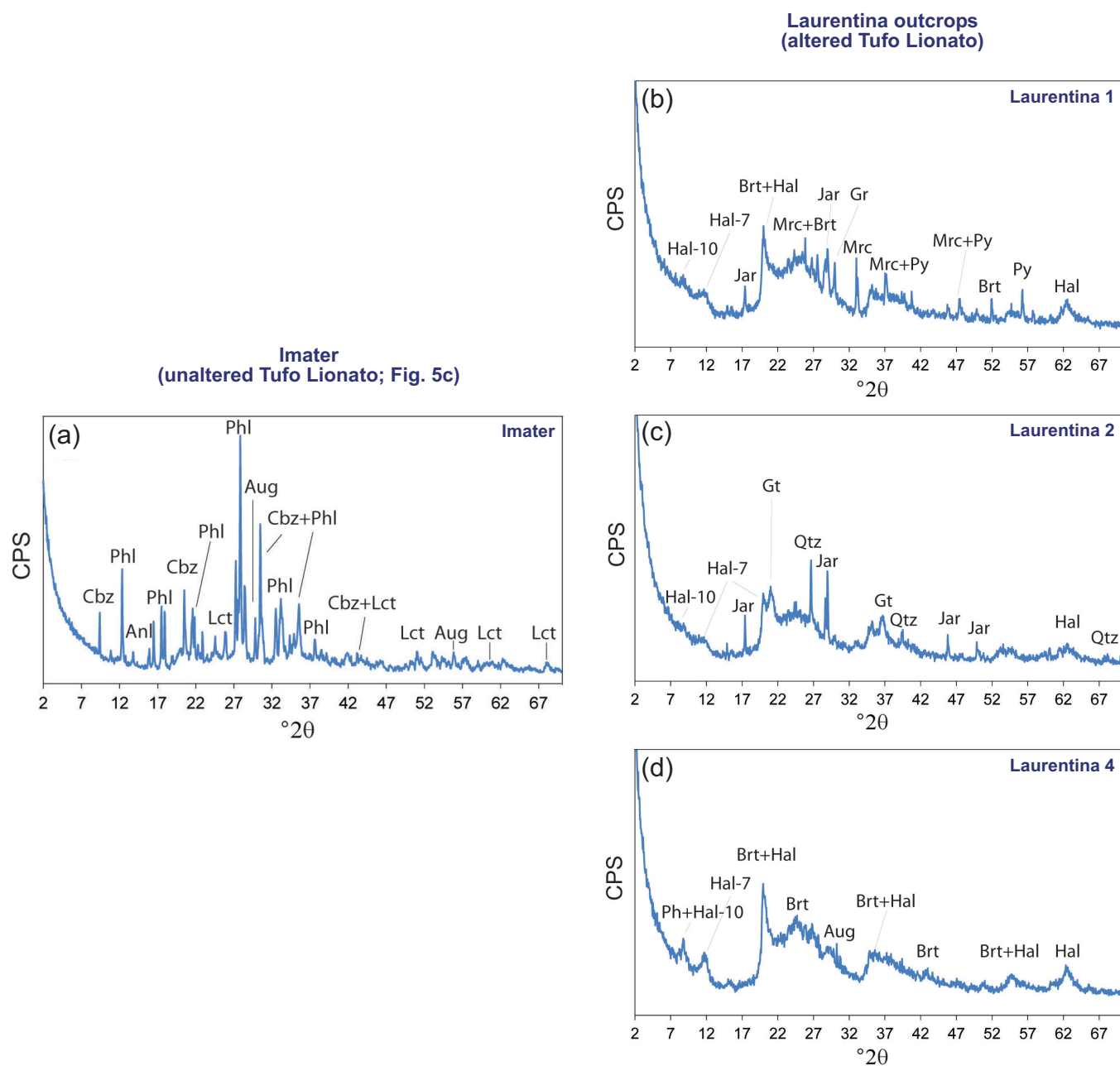


Figure DR2

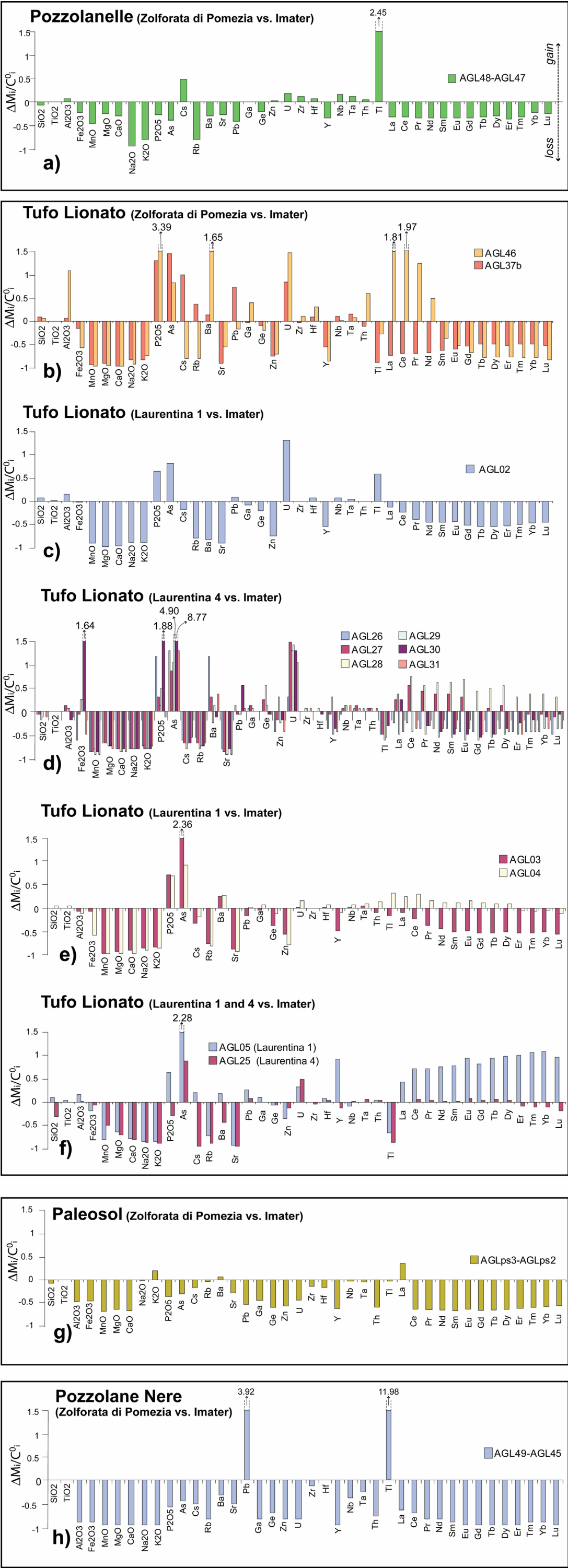


Figure DR3

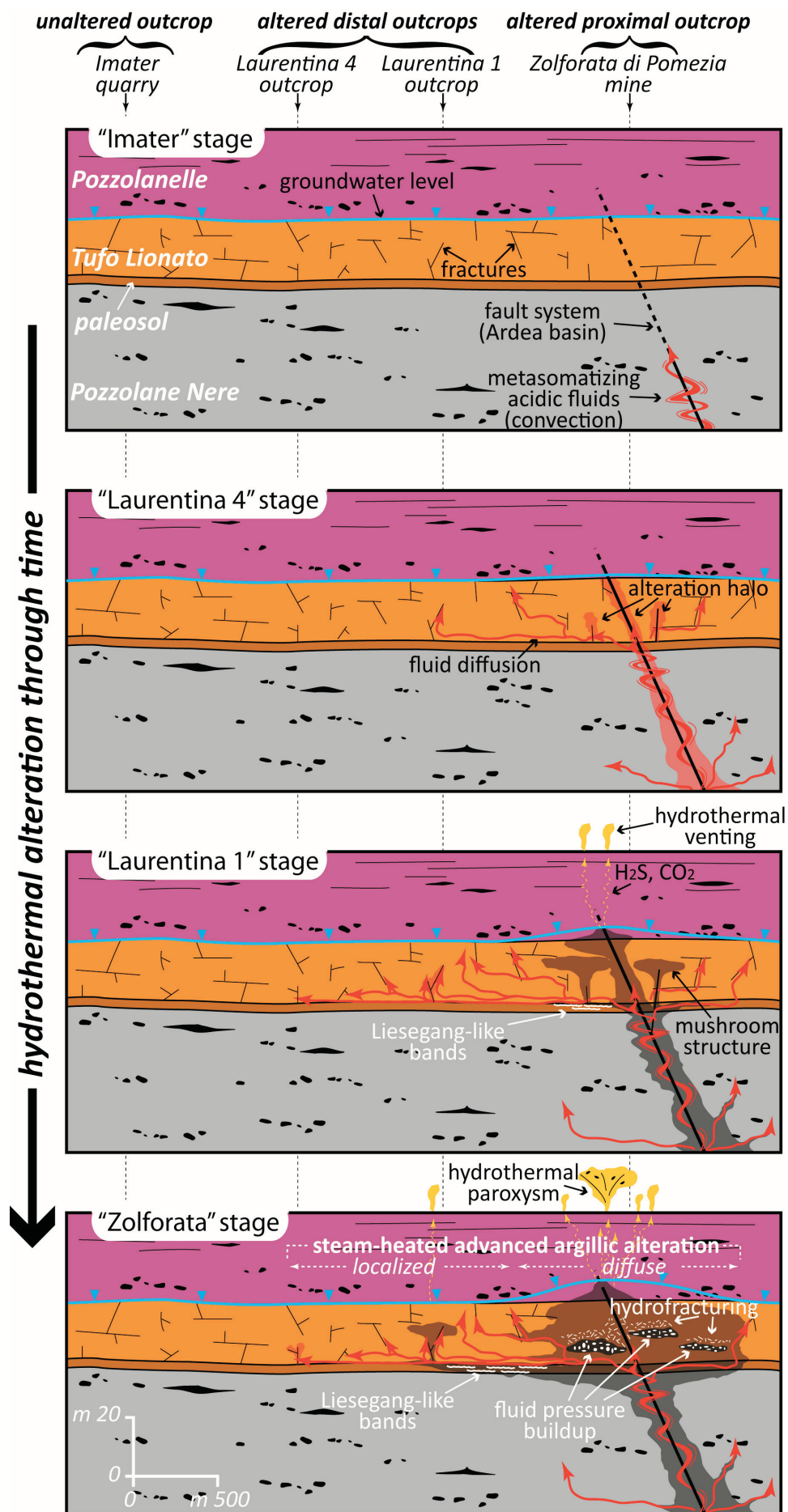


Figure DR4

## Movies

**Movie DR1.** Movie showing an actively-degassing pond within the Zolforata di Pomezia area. This pond is visible also on Google Maps and it is located 600-700 m to the southwest of the red lake in the Zolforata di Pomezia former mine area.

**Movie DR2.** Movie showing an actively-degassing small pond within the Zolforata di Pomezia area, close to the pond shown in the Movie DR1.

**Movie DR3.** Movie showing a panoramic view within the the Zolforata di Pomezia former mine area. Note the S-rich mineralizations and connected hydrothermal alterations of the Tufo Lionato and Pozzolanelle ignimbrites.

**Movie DR4.** Movie showing the southern bank of the red lake within the Zolforata di Pomezia former mine area (Fig. 3). Note the Liesegang-like bands in the altered compact paleosol (Figs. 3i to 3k) and, above, the brecciated state of the altered Tufo Lionato ignimbrite (Figs. 3l to 3n).