Supporting Information

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SI Text

Response of Humans to Abrupt Environmental Transitions Project. The Response of Humans to Abrupt Environmental Transitions (RESET) Project is a Consortium research initiative launched in 2008 and funded by the Natural Environment Research Council (United Kingdom). It brings together archaeologists, volcanologists, geochemists, tephrochronologists, and stratigraphers to investigate the chronology of major phases of human dispersal and development in Europe and North Africa during the past 100,000 y and examine the degree to which these phases were influenced by abrupt environmental transitions (http://c14.arch.ox.ac.uk/reset/). To achieve these aims, the RESET Project has been constructing an improved chronological framework for Europe based on the tracing of important volcanic ash layers (tephra horizons). Where these ash layers can be shown to be stratigraphically discrete and chemically distinctive, they provide time-parallel signatures that can be used to synchronize archaeological and geological records. A key feature of the RESET Project is the importance attached to tracing cryptotephra layers. Composed of tiny fragments of volcanic glass that are not visible to the naked eye (Fig. 1), some of these layers have been widely dispersed throughout Europe and the Mediterranean (see below). In partnership with a network of collaborating scientists from across Europe, the RESET Project is compiling a comprehensive database of the stratigraphic occurrence and chemical differentiation of distal tephra layers spanning (primarily) the last 100,000 y, the results of which will be made available to the wider scientific community through the RHOXTOR (Royal Holloway and Oxford Tephrochronology Research Network) website (http://c14.arch.ox.ac.uk/rhoxtor).

The RESET Project set out to establish whether cryptotephra layers could be traced to important archaeological and geologic sites in Europe, the fringe of North Africa and the Middle East, and the Mediterranean Sea, with a key objective being to synchronize records that span the Middle Paleolithic (MP) to Upper Paleolithic (UP) transition. Until present, the project has led to the discovery of multiple cryptotephra layers in sites that encompass a range of time periods and sedimentary contexts, including lacustrine, peat bog, colluvial, paleosol, eolian, marine, and cave deposits. Cryptotephra layers are more widespread and numerous than previously supposed (1, 2). Where possible, numerous single tephra shards extracted from these layers are systematically analyzed for geochemical composition using EPMA WDS (major and minor elements) and laser ablation inductively coupled plasma MS (LA-ICP-MS; trace element) methods, with key layers compared directly with the geochemical signatures of proximal volcanic deposits to determine their origin and age (*Methods*). As of June 1, 2012, the RESET database contained contextual information for about 969 sites (mostly in Europe) and geochemical data for the products of 317 European volcanic eruptions, the youngest being tephra from the A.D. 1947 Hekla eruption and the oldest being from the stage 9 RHY-1 layer (~330 ka B.P.), both sourced from Iceland. Applications of results published so far have focused on refining the chronology of the Last Termination (*ca.* 14–11 ka B.P.) by extending the known distributions of Icelandic cryptotephra as far south as Switzerland and north Italy (3–5), determining the precise temporal relationship between important cryptotephra isochrons originating from Icelandic and Italian sources found coregistered in the same sediment sequence (6), and constraining the chemistry of proximal volcanic deposits to provide robust comparisons with distal records (7, 8).

This article presents data for discoveries of the Campanian Ignimbrite volcanic ash found at sites in Europe and the Mediterranean. Table S1 provides summary data for the RESET sites shown in Fig. 2, whereas Tables S2–S5 provide the chemical data on which Fig. 3 is based.

Transitional MP to UP Industries and Period. Over recent decades, varying technological and typological definitions of MP to UP transitional industries have been advanced. Implicit in the term transitional is the belief that such industries contain a mixture of MP and UP technotypological features, although different authors identify different proportions of such attributes (9). Industries perceived to have strong similarities to preceding local late MP industries are often assumed to be of Neanderthal manufacture, whereas others are held to be technotypologically intrusive. Well-known examples of transitional industries include the Châtelperronian, Szeletian, Bohunician, Uluzzian/Klissoura initial UP, Bachokirian, and initial UP industries of the Russian Plain. The last five fall within our study region, but so far, we have not found Campanian Ignimbrite (CI) in Szeletian or Bohunician deposits. Associated hominin skeletal remains are rare: Neanderthal remains seem to be associated with a few Châtelperronian and Szeletian assemblages, whereas the Uluzzian, Bachokirian, and some Russian Plain initial UP industries seem to be associated with anatomically modern humans. The Bohunician has no skeletal associations, but it has been linked to the Emiran transitional UP industry (likewise with no skeletal associations) in the Levant on technotypological grounds (10).

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8. Tomlinson E, et al. (2012) Geochemistry of the Phlegrean Fields (Italy) proximal sources for major Mediterranean tephras: Implications for the dispersal of Plinian and co-ignimbritic components of explosive eruptions. *Geochim Cosmochim Acta* 10.1016/j.gca.2012.05.43.
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Table S1. Sites in which the CI has been newly discovered or in the case of Franchthi Cave, confirmed geochemically (locations shown in Fig. 1)

Site	Archive	Latitude	Longitude	Altitude (m)	Tephra	Archaeological context of CI	No. of other tephras*
Haua Fteah	Paleolithic cave	32° 49′ 60″ N	22° 10′ 0″ E	60	Crypto-	Dabban industry (lower)	3
Klissoura	Paleolithic cave	37° 41′ 23″ N	22° 48′ 27″ E	114	Crypto-	Separates UP Uluzzian from Aurignacian occupations	3
Kozarnika	Paleolithic cave	43° 39′ 06″ N	22° 42′ 09″ E	481	Crypto-	Within early UP	1
Franchthi	Paleolithic cave	37° 25′ 20″ N	23° 07′ 53″ E	11	Visible	Overlies MP	0
Golema Pesht	Paleolithic cave	41° 47′ 01″ N	21° 09′ 03″ E	460	Crypto-	Within early UP	0
Tabula Traiana	Paleolithic cave	44° 39′ N	22° 18′ E	90	Crypto-	Within early UP	1
LC21	Marine core	35° 39′ 43″ N	26° 34′ 58″ E	−1,522	Visible	—	>10
Tenaghi Philippon	Peat bog core	40° 58′ 24″ N	24° 13′ 26″ E	40	Visible	—	>5

*This column represents the number of additional tephra layers (mostly cryptotephra) discovered so far at each site.

Table S2. Representative glass composition data for the CI proximal units (ref. 1)

Locality (unit)	Voscone (CI fall)					Mondragone (CI lower and intermediate flow)					San Marco (CI upper flow)				
Major elements (WDS-EPMA, wt %)															
SiO_2	60.79	61.21	59.76	60.69	61.25	61.11	61.36	61.40	61.50	61.87	59.06	59.78	60.58	60.79	61.11
TiO_2	0.47	0.45	0.46	0.50	0.47	0.46	0.48	0.42	0.37	0.41	0.40	0.36	0.46	0.47	0.48
Al_2O_3	19.34	19.12	19.85	19.40	18.76	18.73	18.88	18.86	18.81	18.79	18.13	18.11	18.07	18.18	18.34
FeO	2.93	2.89	3.17	2.97	2.86	3.01	2.91	2.92	2.81	2.74	3.27	3.38	2.90	2.74	2.94
MnO	0.19	0.24	0.24	0.21	0.25	0.22	0.23	0.19	0.23	0.19	0.11	0.10	0.18	0.21	0.27
MgO	0.32	0.33	0.54	0.28	0.32	0.31	0.31	0.30	0.32	0.32	0.64	0.73	0.35	0.34	0.32
CaO	1.71	1.71	2.10	1.82	1.82	1.74	1.57	1.62	1.65	1.52	2.36	2.23	1.65	1.45	1.60
Na_2O	6.18	5.96	5.73	6.20	6.30	6.31	6.22	6.20	6.24	6.04	2.91	3.06	4.77	4.55	4.70
K_2O	7.35	7.40	7.48	7.16	7.27	7.18	7.19	7.19	7.16	7.26	9.65	9.61	8.07	7.93	8.49
P_2O_5	0.06	0.07	0.13	0.08	0.04	0.05	0.05	0.05	0.06	0.08	0.14	0.07	0.06	0.09	0.04
Total	97.22	96.52	94.09	94.13	95.82	97.26	97.56	97.69	96.52	97.24	96.92	97.68	97.65	97.27	98.84
Cl (ppm)	5,400	5,200	4,300	5,700	5,200	7,000	6,700	6,900	6,900	6,400	1,958	2,121	4,732	4,324	4,569
Trace elements (LA-ICP-MS, ppm)															
Rb	500	470	410	450	440	430	430	450	430	430	286	295	413	437	470
Sr	46	29	94	33	30	39	27	39	25	40	226	392	23	71	17
Y	51	50	46	54	53	51	51	49	46	52	20	19	54	36	54
Zr	660	600	600	670	660	620	620	580	560	620	186	173	651	405	652
Nb	120	112	109	121	120	112	112	110	112	116	32	29	122	74	123
Ba	24	19	67	16	15	13	13	19	17	13	269	453	17	73	14
La	121	115	106	126	121	119	118	115	113	122	46	44	124	85	127
Ce	228	220	188	238	229	226	228	219	215	233	88	83	237	162	239
Pr	24	22	21	24	23	23	23	22	22	24	9	9	24	16	24
Nd	84	79	72	83	80	80	79	75	72	81	35	33	84	59	86
Sm	14	14	13	15	14	13	14	13	12	15	6	6	14	10	15
Eu	1.1	1.2	1.1	1.3	1.3	1.2	1.2	1.2	1.3	1.3	1.9	2.0	1.4	1.6	1.4
Gd	10.7	10.4	9.1	11.4	10.8	10.1	10.7	9.9	9.9	10.0	4.8	4.5	10.2	7.6	10.9
Dy	8.3	9.5	8.4	9.8	9.6	8.7	9.3	8.6	8.5	9.3	4.1	4.0	9.5	6.6	10.0
Er	5.1	4.7	4.7	5.4	5.2	5.1	5.1	5.0	4.9	5.2	2.0	1.9	5.5	3.6	5.5
Yb	5.1	4.8	4.8	5.7	5.2	5.5	5.2	4.9	4.6	5.4	1.9	1.9	5.4	3.7	5.7
Lu	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.7	0.8	0.3	0.3	0.8	0.5	0.8
Ta	5.2	5.2	5.2	6.0	5.7	4.9	5.3	5.0	4.9	5.5	1.6	1.5	5.6	3.5	5.9
Th	44	45	43	53	50	48	49	45	43	50	14	13	52	32	53
U	16	17	14	19	18	17	18	16	16	18	5	5	19	12	19

1. Tomlinson E, et al. (2012) Geochemistry of the Phlegrean Fields (Italy) proximal sources of major Mediterranean tephras: Implications for the dispersal of Plinian and co-ignimbritic components of explosive eruptions. *Geochim Cosmochim Acta* 10.1016/j.gca.2012.05.043.

Table S3. Representative glass composition data for distal CI tephra detected in the archaeological sites of Haua Fteah, Kozarnika, and Franchthi

Locality (unit)	Haua Fteah (cryptotephra)					Kozarnika (cryptotephra)					Franchthi (visible layer)				
Major elements (WDS-EPMA, wt %)															
SiO_2	60.31	60.57	60.84	60.97	61.13	61.45	61.95	62.18	62.40	62.75	60.74	60.84	61.00	61.19	61.38
TiO_2	0.53	0.47	0.42	0.44	0.48	0.49	0.34	0.46	0.43	0.49	0.42	0.42	0.39	0.43	0.41
Al_2O_3	19.17	18.90	18.59	18.91	18.58	19.28	19.08	18.50	18.34	18.39	18.83	18.92	18.71	18.73	18.77
FeO	3.02	3.07	2.90	2.92	2.97	3.00	2.63	2.82	2.93	2.89	2.97	2.85	2.95	2.80	2.86
MnO	0.25	0.19	0.12	0.21	0.22	0.14	0.18	0.22	0.20	0.17	0.19	0.18	0.25	0.20	0.21
MgO	0.32	0.28	0.31	0.25	0.33	0.33	0.27	0.29	0.28	0.33	0.33	0.34	0.35	0.30	0.35
CaO	1.95	1.75	1.92	1.80	1.71	1.65	1.74	1.73	1.63	1.74	1.76	1.70	1.73	1.76	1.68
Na_2O	6.14	6.30	6.22	6.34	6.23	6.41	6.19	6.35	6.70	6.19	6.56	6.57	6.21	6.54	6.30
K_2O	7.40	7.51	7.74	7.19	7.48	7.26	7.62	7.45	7.08	7.05	7.28	7.30	7.54	7.20	7.18
P_2O_5	0.03	0.07	0.07	0.03	0.07	—	—	—	—	—	0.06	0.05	0.03	0.05	0.03
Total	97.52	99.48	97.94	96.94	98.89	98.57	98.27	99.42	98.71	98.43	96.35	97.19	98.81	98.02	95.12
Cl (ppm)	7,200	7,200	7,200	7,700	6,600	—	—	—	—	—	6,900	6,800	6,800	6,600	6,700
Trace elements (LA-ICP-MS, ppm)															
Rb	450	450	410	440	440	470	430	440	460	490	410	390	400	440	430
Sr	18	19	17	19	21	21	19	20	20	22	22	20	25	23	24
Y	53	54	51	51	55	56	54	55	55	58	52	42	45	49	50
Zr	640	640	610	610	660	670	650	670	670	700	600	530	560	610	590
Nb	117	118	114	115	116	123	118	124	123	126	110	99	103	113	111
Ba	14	17	13	14	15	16	14	14	17	17	17	17	22	19	21
La	123	126	119	119	127	129	123	126	127	134	120	107	109	117	116
Ce	233	237	226	229	242	247	240	246	247	255	227	205	203	218	221
Pr	24	24	23	23	24	25	24	25	25	26	24	20	21	22	22
Nd	81	83	77	79	87	87	83	84	85	91	79	71	74	81	78
Sm	15	14	14	13	16	14	14	14	15	16	12	12	13	13	13
Eu	1.3	1.4	1.2	1.3	1.4	1.4	1.3	1.4	1.4	1.4	1.2	1.5	1.3	1.3	1.3
Gd	10.4	10.7	10.0	10.4	11.1	12.3	12.0	11.8	12.0	11.7	9.5	10.5	9.9	9.7	10.3
Dy	9.9	9.5	9.0	9.0	9.8	10.3	9.8	10.0	9.9	10.0	9.3	7.5	8.4	9.3	8.7
Er	5.3	5.4	5.2	5.4	5.9	5.6	5.2	5.5	5.6	5.8	5.6	4.6	5.1	5.1	5.3
Yb	5.5	5.6	5.5	5.4	5.7	6.0	5.6	5.8	5.6	5.9	5.2	4.6	5.2	5.4	5.1
Lu	0.8	0.8	0.8	0.7	0.9	0.9	0.8	0.8	0.9	0.9	0.7	0.7	0.6	0.7	0.8
Ta	5.6	5.5	5.2	5.3	5.6	5.9	5.5	5.7	5.7	5.9	5.5	4.3	5.0	5.5	5.2
Th	51	51	48	48	54	54	50	53	53	55	47	41	45	48	47
U	18	18	17	17	18	20	18	19	19	19	17	15	16	18	17

Table S4. Representative glass composition data for distal CI tephra detected in the archaeological sites of Klissoura, Golema Pesht, and Tabula Traiana

Locality (unit)	Klissoura (cryptotephra)					Golema Pesht (cryptotephra)					Tabula Traiana (cryptotephra)				
Major elements (WDS-EPMA, wt %)															
SiO_2	59.94	60.35	60.49	60.68	61.18	60.57	60.88	60.88	61.04	61.11	60.96	61.00	61.30	61.40	61.63
TiO_2	0.39	0.45	0.41	0.47	0.46	0.38	0.40	0.46	0.45	0.44	0.43	0.40	0.43	0.34	0.43
Al_2O_3	19.21	18.66	18.89	18.52	19.00	18.79	18.70	18.51	18.46	18.31	18.55	18.44	18.28	18.69	18.47
FeO	3.03	3.25	2.93	3.00	3.11	2.93	2.93	2.99	3.00	3.06	2.89	2.86	3.47	2.87	2.65
MnO	0.31	0.21	0.29	0.26	0.18	0.25	0.16	0.20	0.23	0.23	0.26	0.26	0.08	0.16	0.24
MgO	0.34	0.32	0.33	0.33	0.33	0.32	0.31	0.33	0.32	0.31	0.33	0.30	0.62	0.34	0.30
CaO	1.81	1.94	1.78	1.76	1.72	1.67	1.80	1.72	1.71	1.70	1.73	1.80	2.70	1.63	1.66
Na_2O	6.77	5.41	6.17	5.96	6.31	6.97	6.85	6.67	6.66	6.87	6.84	6.90	3.56	6.38	6.70
K_2O	7.29	8.49	7.61	7.98	6.63	7.25	7.17	7.44	7.35	7.14	7.09	7.07	8.77	7.19	7.02
P_2O_5	0.04	0.04	0.05	0.00	0.04	0.08	0.04	0.03	0.03	0.06	0.05	0.06	0.12	0.04	0.03
Total	97.32	96.00	98.08	97.51	95.64	96.14	98.28	97.57	98.36	98.68	97.74	99.06	97.42	98.45	99.17
Cl (ppm)	7,100	7,100	8,600	8,500	8,500	—	—	—	—	—	7,113	7,431	5,425	7,634	7,040
Trace elements (LA-ICP-MS, ppm)															
Rb	370	290	380	410	430	410	430	430	430	420	407	411	—	417	427
Sr	14	18	19	20	16	17	19	19	22	18	18	20	—	22	22
Y	34	32	50	51	51	54	52	52	51	53	52	49	—	54	53
Zr	450	400	590	620	630	640	640	630	620	640	610	582	—	611	627
Nb	93	86	106	114	115	112	114	113	113	115	107	111	—	108	116
Ba	15	23	15	19	12	12	14	15	19	13	13	17	—	16	16
La	87	74	113	120	120	120	121	121	119	122	117	112	—	116	122
Ce	167	155	213	224	225	233	234	230	229	232	225	214	—	228	233
Pr	17	15	21	22	23	23	23	23	23	23	24	22	—	23	24
Nd	63	49	73	77	77	80	82	79	80	81	77	79	—	78	84
Sm	10	11	13	12	13	13	14	14	14	15	15	12	—	14	13
Eu	1.5	1.3	1.4	1.4	1.1	—	—	—	—	—	—	—	—	—	—
Gd	9.8	8.0	11.7	10.0	12.6	10.8	10.9	10.9	9.9	10.7	9.5	8.3	—	8.9	9.8
Dy	5.9	5.6	8.3	9.0	9.5	9.6	9.5	9.4	9.1	9.7	9.0	9.0	—	8.4	9.4
Er	4.0	3.9	4.9	4.7	5.0	5.3	5.5	5.3	5.1	5.4	5.4	4.9	—	5.1	4.9
Yb	4.8	3.8	5.0	5.3	5.4	5.7	5.3	5.3	5.1	5.5	5.2	4.9	—	5.7	5.3
Lu	0.7	0.6	0.8	0.9	0.8	—	—	—	—	—	—	—	—	—	—
Ta	3.2	3.7	5.5	5.3	5.7	5.3	5.4	5.4	5.3	5.7	5.3	4.7	—	4.7	5.5
Th	30	25	44	48	47	50	50	51	48	51	50	43	—	44	48
U	12	11	16	17	18	17	18	18	17	18	17	15	—	15	16

Table S5. Representative glass composition data for distal CI tephra detected in marine core LC-21 and the Tenaghi Philippon paludal sequence

Locality (unit)	LC21 marine core (visible layer)					Tenaghi Philippon (visible layer)					Secondary standard	StHs6/80-G		ATHO-G	
												Mean	2σ	Mean	2σ
Major elements (WDS-EPMA, wt %)											WDS-EPMA ($n > 50$)				
SiO_2	61.98	62.19	62.09	61.79	62.00	59.82	60.80	61.01	61.24	61.69		63.74	0.76	75.46	0.87
TiO_2	0.46	0.41	0.43	0.49	0.44	0.67	0.42	0.35	0.40	0.37		0.72	0.10	0.25	0.07
Al_2O_3	18.06	17.94	18.11	17.97	17.88	18.24	18.88	18.42	18.87	18.64		17.79	0.31	12.33	0.28
FeO	3.09	3.17	2.98	3.08	3.29	4.29	3.02	3.56	3.03	2.83		4.34	0.28	3.27	0.33
MnO	0.21	0.17	0.29	0.20	0.32	0.12	0.27	0.14	0.18	0.17		0.09	0.08	0.11	0.09
MgO	0.34	0.35	0.29	0.28	0.31	1.07	0.30	0.70	0.30	0.32		1.99	0.12	0.10	0.05
CaO	1.81	1.81	1.84	1.86	1.78	3.99	1.76	2.64	1.63	1.73		5.28	0.23	1.72	0.11
Na_2O	6.63	6.51	6.82	6.86	6.72	3.78	6.50	2.76	5.78	6.09		4.50	0.33	3.99	0.29
K_2O	7.41	7.45	7.16	7.46	7.25	7.45	7.09	9.89	7.56	7.23		1.30	0.09	2.71	0.11
P_2O_5	—	—	—	—	—	0.17	0.03	0.17	0.08	0.04		0.17	0.07	0.03	0.05
Total	94.79	96.56	94.91	96.71	94.65	97.61	95.37	96.37	97.52	95.54		—	—	—	—
Cl (ppm)	—	—	—	—	—	3,300	7,700	2,900	7,600	7,300		200	190	364	275
Trace elements (LA-ICP-MS, ppm)											LA-ICP-MS ($n > 10$)				
Rb	480	490	490	480	460	290	460	280	430	450		31	1.0	67	3.4
Sr	20	21	20	21	20	427	19	564	19	26		480	19	96	3.9
Y	49	56	55	59	47	19	53	20	54	53		11	0.5	91	4.1
Zr	598	693	674	715	580	190	660	180	630	660		110	5.0	500	24
Nb	121	128	123	131	119	31	120	28	118	118		6.6	0.7	60	4.3
Ba	17	15	17	15	15	372	15	657	15	26		300	15	560	23
La	118	135	133	139	113	47	125	46	125	127		12	0.7	56	2.6
Ce	235	259	248	267	221	87	240	86	233	239		25	1.3	123	7.0
Pr	23	27	24	27	21	9	24	9	23	24		3.0	0.2	14	1.0
Nd	77	90	83	90	75	34	83	34	81	83		12	1.0	62	3.5
Sm	16	17	15	16	14	—	—	—	—	—		3.6	1.7	15	1.6
Eu	—	1.5	1.4	1.4	1.2	2.0	1.4	2.0	1.3	1.4		1.0	0.1	2.6	0.2
Gd	12.3	10.7	10.5	11.3	9.9	4.9	9.8	4.6	9.8	11.0		3.3	1.7	15	1.6
Dy	8.8	10.3	10.0	10.6	7.7	3.9	9.6	3.8	9.4	9.3		2.2	0.3	17	0.9
Er	5.1	5.8	5.4	6.1	4.5	1.8	5.5	2.1	5.6	5.1		1.2	0.2	10	0.5
Yb	—	5.8	5.6	5.9	4.9	1.9	5.7	1.8	5.4	5.0		1.4	0.6	10	0.7
Lu	—	0.9	0.8	0.8	0.7	0.3	0.8	0.3	0.9	0.8		0.2	0.1	1.5	0.1
Ta	5.0	6.2	5.4	6.2	5.3	1.8	5.5	1.3	5.1	5.8		0.5	0.2	3.8	0.2
Th	42	55	50	55	42	15	50	13	49	54		2.2	0.2	7.3	0.6
U	17	20	18	20	17	5	17	5	17	19		1.0	0.2	2.3	0.2

Representative mean and 2σ precision from analysis of the StHs6/80-G and ATHO-G MPI-DING secondary standard glasses are also shown.