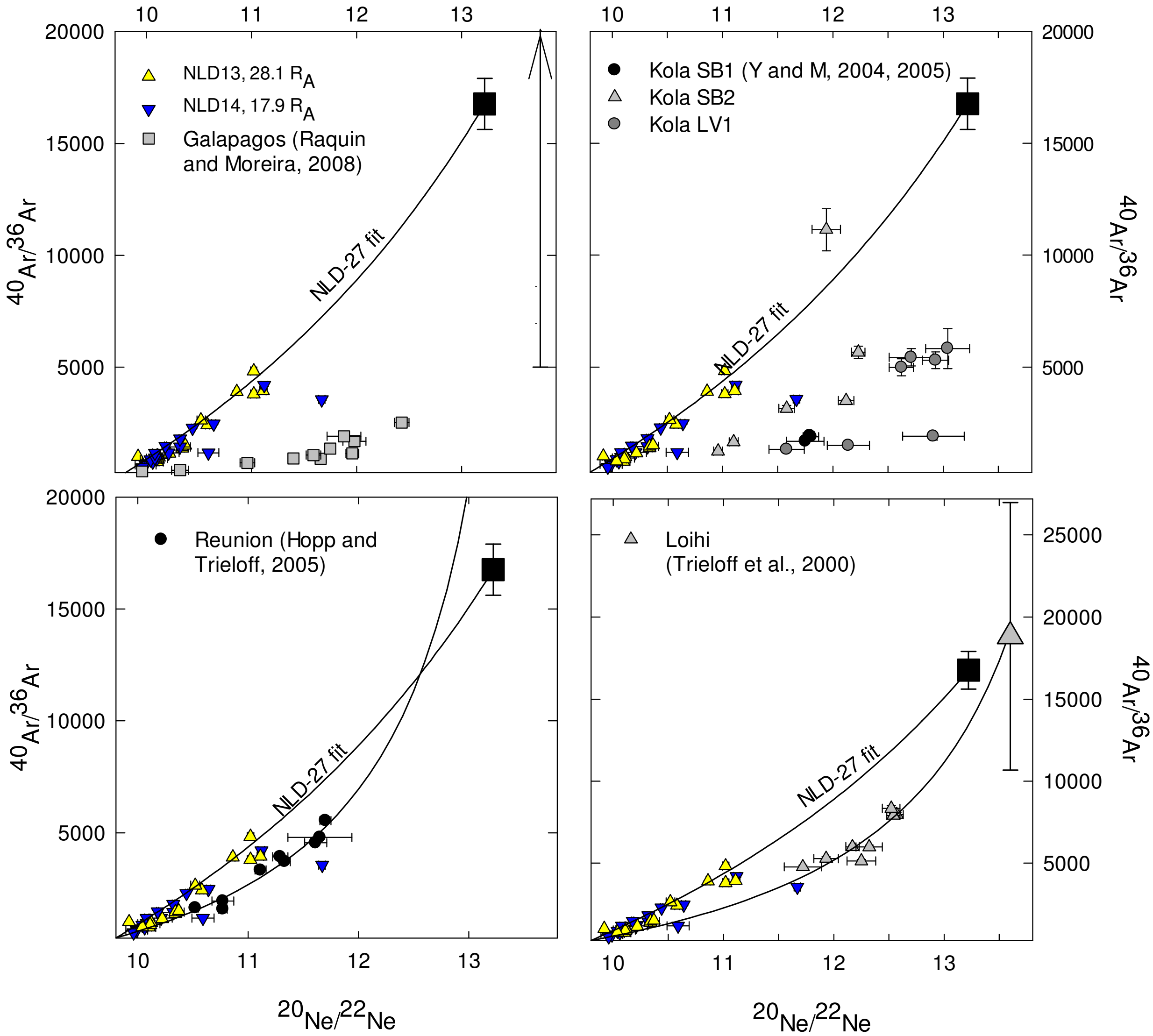
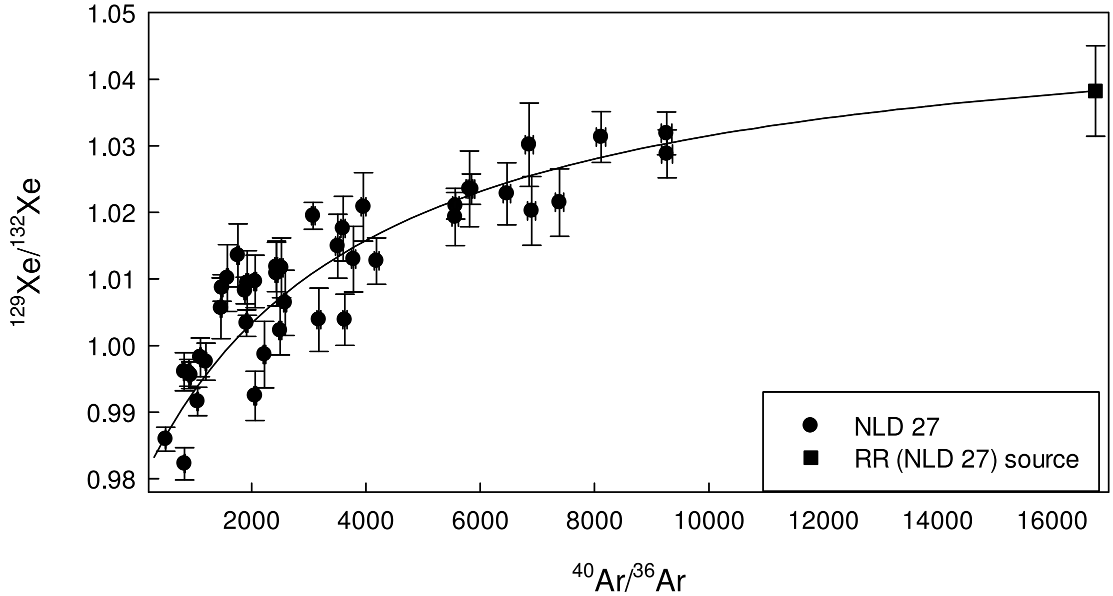
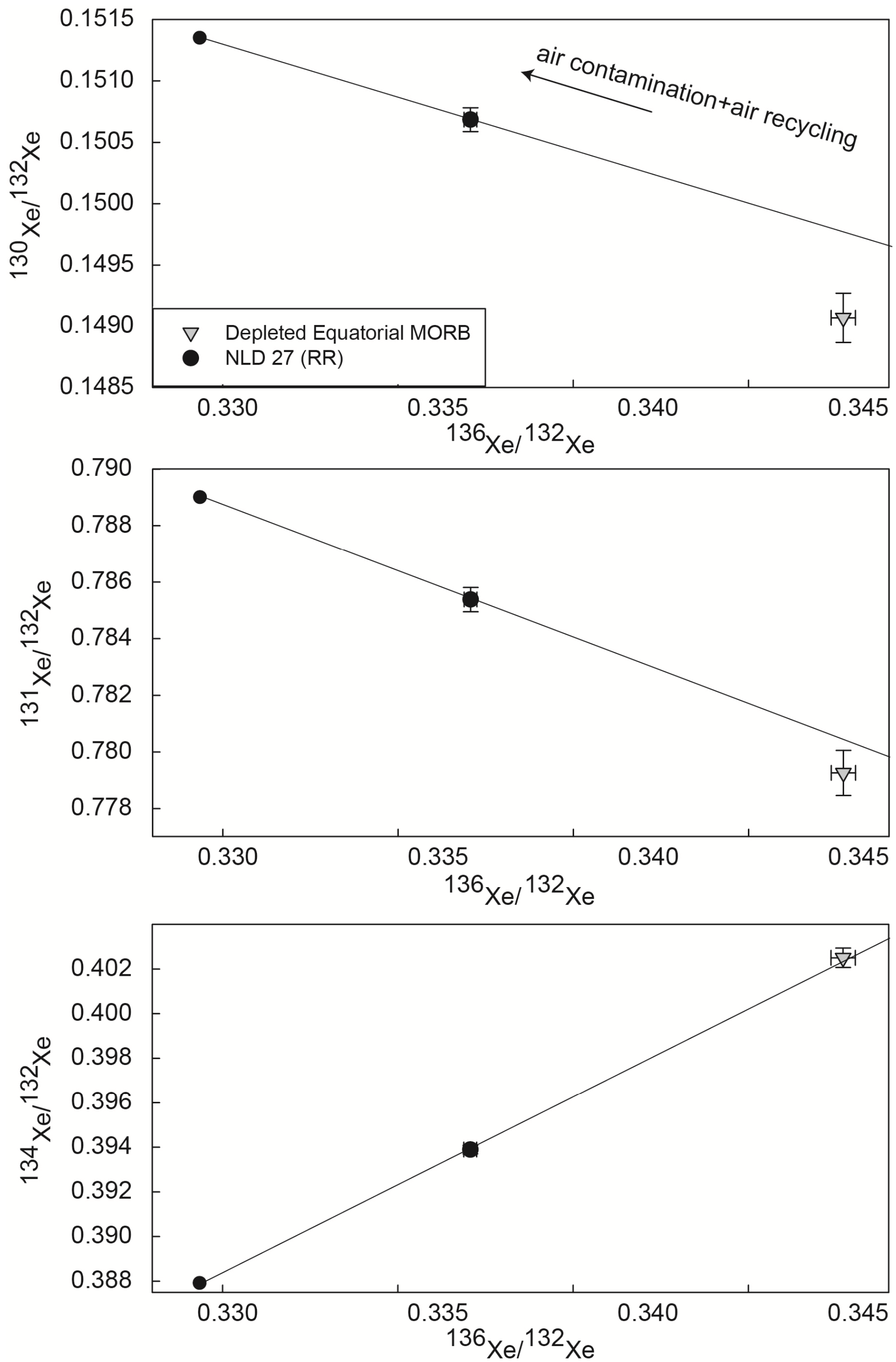
Supplemental Information



Supplemental Figure 1. ^{20}Ne/^{22}Ne and ^{40}Ar/^{36}Ar isotope data of individual crush steps from i) Galapagos (Raquin and Moreira, 2008), ii) Loihi (Trieloff et al., 2000), iii) Reunion (Hopp and Trieloff, 2005), and iv) Kola (Yokochi and Marty, 2004, 2005) plumes. The hyperbolic least square best fit of NLD- 27 and data of samples NLD-13 and NLD-14 from the RR are also shown for comparison. For a given ^{20}Ne/^{22}Ne ratio the ^{40}Ar/^{36}Ar ratios in the RR samples are higher than in the other plumes. This relationship could reflect i) a higher mantle source $^{40}Ar/^{36}Ar$ ratio, or ii) different mixing systematics between the mantle source and the shallow-level atmospheric contaminant. Different sets of mixing hyperbolas could be produced for the same mantle source composition if atmospheric noble gases were added to variably degassed magmas or if the atmospheric contaminant was elementally fractionated. Hyperbolic least square fits to available data do not yet allow us to test whether the Galapagos, Reunion, Kola and Loihi plumes have lower mantle source $^{40}Ar/^{36}Ar$ ratios. For example, the Ne-Ar correlation of the Galapagos sample studied by Raquin and Moreira (2008) shows good correlation, but the best fit hyperbola becomes asymptotic at a $^{20}Ne/^{22}Ne$ ratio ~12.9. The same is true for the Ne and Ar isotope data of Reunion (Hopp and Trieloff, 2005). Therefore, the mantle source $^{40}Ar/^{36}Ar$ ratio is not constrained for Galapagos and Reunion. Given the scatter of the Kola data, we did not fit a hyperbola. However, a minimum $^{40}Ar/^{36}Ar$ ratio of 11,140 ± 943 can be inferred for the Kola plume. For Loihi, at a $^{20}Ne/^{22}Ne$ ratio of 13.0, a value close to the maximum measured $^{20}Ne/^{22}Ne$ ratio in plumes, the best fit hyperbola yields a $^{40}Ar/^{36}Ar$ ratio of 10860 ± 1680 (point not shown for clarity). However, the same data yields a $^{40}Ar/^{36}Ar$ ratio of 18,830 ± 8160 (1σ) at a $^{20}Ne/^{22}Ne$ ratio of 13.6. The $^{20}Ne/^{22}Ne$ value of 13.6 for the Loihi mantle was determined by projecting the best fit line through the step crushes to the MORB-OIB end-member mixing line in $^{21}Ne/^{22}Ne$-$^{20}Ne/^{22}Ne$ space (see Figure 2 of main text). The OIB end-member was taken to have a solar $^{20}Ne/^{22}Ne$ of 13.8 and the least nucleogenic $^{21}Ne/^{22}Ne$ ratio of 0.0354 from Galapagos (Kurz et al., 2009).



Supplemental Figure 2. Hyperbolic mixing between shallow level atmospheric contaminants and mantle derived gases in $^{40}Ar/^{36}Ar$ and $^{129}Xe/^{132}Xe$ isotope space. Since the estimated mantle $^{40}Ar/^{36}Ar$ ratio of the NLD- 27 sample is 16,763 ± 1144 (1σ), a least-squares hyperbolic fit extrapolates the mantle source $^{129}Xe/^{132}Xe$ ratio to 1.0382 ± 0.0068 (1σ). Note that the estimated $^{129}Xe/^{132}Xe$ in the NLD- 27 mantle source is not sensitive to the exact choice of the mantle $^{40}Ar/^{36}Ar$ ratio, given the curvature in Ar-Xe space.



Supplemental Figure 3. The error-weighted average of the measured Xe isotopic composition of the NLD- 27 sample compared to depleted MORBs from the equatorial Atlantic (Tucker et al., 2012). The NLD- 27 sample is not co-linear with the atmospheric and depleted MORB compositions in $^{130,131}Xe/^{132}Xe$ - $^{136}Xe/^{132}Xe$ spaces, while it is co-linear in $^{134}Xe/^{132}Xe$-$^{136}Xe/^{132}Xe$ space.

Supplemental Table 1: He, Ne, and Ar abundance and isotopic ratios

Sample	crush#	^{4}He (10^{-6} cc)	1σ	^{22}Ne (10^{-12} cc)	1σ	$^{20}Ne/^{22}Ne$	1σ	$^{21}Ne/^{22}Ne$	1σ	^{36}Ar (10^{-12} cc)	1σ	$^{40}Ar/^{36}Ar$	1σ
NLD- 13 I	1st	1.3	0.04	9.2	0.3	10.34	0.02	0.0316	0.0002	180.9	4.7	1382	14
(3.19g)	2nd	1.7	0.05	16.5	0.5	9.92	0.01	0.0304	0.0001	323.1	8.4	1011	11
$^{3}He/^{4}He$	3rd	0.8	0.02	6.5	0.2	10.22	0.02	0.0310	0.0002	114.8	3.0	1147	12
28.1 R_A	4th	0.4	0.01	4.6	0.4	10.10	0.02	0.0306	0.0002	85.2	2.1	777	8
	5th	0.2	0.01	2.3	0.6	10.12	0.03	0.0302	0.0003	33.6	1.1	973	10
	6th	0.2	0.01	2.5	0.7	10.11	0.02	0.0305	0.0003	37.5	1.3	885	9
NLD- 13 II	1st	0.4	0.01	3.0	0.4	10.34	0.02	0.0314	0.0003	50.1	0.3	1457	17
(3.13g)	2nd	0.7	0.02	4.7	0.2	10.37	0.02	0.0313	0.0002	79.3	1.3	1511	16
	3rd	0.7	0.02	2.3	0.5	11.02	0.03	0.0347	0.0004	29.3	0.4	3800	38
	4th	1.2	0.04	3.9	0.3	11.02	0.03	0.0348	0.0003	39.1	1.0	4828	49
	5th	1.3	0.04	4.8	0.2	10.86	0.02	0.0336	0.0002	50.4	1.3	3909	41
	6th	0.6	0.02	3.2	0.3	10.58	0.02	0.0322	0.0003	39.8	0.5	2430	25
	7th	0.2	0.01	0.9	0.8	10.52	0.04	0.0325	0.0005	9.4	0.2	2645	26
NLD- 13 III	1st	0.6	0.02	1.9	0.2	11.11	0.03	0.0349	0.0004	30.3	0.1	3943	40
(2.86g)	2nd	0.9	0.03	13.8	0.1	10.04	0.02	0.0303	0.0001	276.2	2.0	789	8
						$^{21}Ne/^{22}Ne_E$ = 0.0454±0.0003							
NLD- 14 I	1st	1.8	0.06	7.2	0.2	11.12	0.03	0.0365	0.0002	81.7	2.1	4196	42
(3.82g)	2nd	2.2	0.07	6.5	0.2	11.67	0.03	0.0391	0.0002	98.0	2.5	3555	36
$^{3}He/^{4}He$	3rd	5.4	0.16	138.7	1.5	9.99	0.10	0.0300	0.0001	4461.1	115.4	644	7
17.9 R_A	4th	2.5	0.08	33.3	1.5	10.10	0.10	0.0310	0.0001	787.6	20.4	927	10
	5th	3.4	0.10	25.3	1.5	10.32	0.10	0.0320	0.0001	519.8	13.4	1441	15
	6th	3.4	0.10	64.6	1.5	10.06	0.10	0.0300	0.0001	1808.6	46.8	764	8
	7th	2.6	0.08	27.0	1.5	10.21	0.10	0.0310	0.0001	545.2	14.1	1179	12
	8th	4.8	0.14	24.1	1.5	10.59	0.10	0.0340	0.0001	1021.0	26.4	1179	12
	9th	1.8	0.05	10.9	0.4	10.64	0.02	0.0337	0.0002	119.7	3.1	2473	25
	10th	2.4	0.07	19.8	0.5	10.44	0.01	0.0325	0.0001	197.6	5.1	2283	23
	11th	2.0	0.06	21.8	0.5	10.32	0.01	0.0317	0.0001	232.2	6.0	1808	19
	12th	1.3	0.04	17.9	0.5	10.18	0.01	0.0306	0.0001	145.8	3.8	1473	15
	13th	1.3	0.04	25.9	1.5	10.04	0.10	0.0300	0.0001	348.1	9.0	871	9
	14th	0.5	0.02	12.2	0.4	10.08	0.02	0.0304	0.0001	104.2	2.9	958	10
	15th	0.6	0.02	12.4	0.5	10.08	0.02	0.0303	0.0001	91.8	2.5	1173	12
	16th	0.1	0.00	2.8	0.7	9.96	0.02	0.0295	0.0003	15.8	0.4	527	6
						$^{21}Ne/^{22}Ne_E$ = 0.0476±0.0002							

Sample	crush#	^{4}He (10^{-6} cc)	1σ	^{22}Ne (10^{-12} cc)	1σ	$^{20}Ne/^{22}Ne$	1σ	$^{21}Ne/^{22}Ne$	1σ	^{36}Ar (10^{-12} cc)	1σ	$^{40}Ar/^{36}Ar$	1σ
NLD- 20 I	1st	0.5	0.01	2.6	0.7	10.67	0.03	0.0316	0.0003	22.5	0.3	450	5
(3.78g)	2nd	0.8	0.02	2.0	0.5	11.75	0.03	0.0360	0.0004	9.4	0.1	944	10
	3rd	0.6	0.02	2.9	0.7	10.81	0.02	0.0324	0.0003	34.9	1.1	437	5
18.6 R_A	4th	0.6	0.02	2.8	0.7	10.81	0.02	0.0323	0.0003	22.1	0.4	491	5
	5th	0.7	0.02	2.7	0.7	11.09	0.03	0.0337	0.0003	22.6	0.5	523	6
NLD- 20 II	1st	0.1	0.00	0.5	0.1	10.57	0.06	0.0309	0.0006	6.8	0.1	468	5
(4.24g)	2nd	0.6	0.02	6.9	0.1	10.11	0.02	0.0302	0.0002	121.6	0.9	354	4
	3rd	0.6	0.02	2.0	0.2	10.76	0.03	0.0327	0.0004	38.5	0.5	453	5
	4th	0.6	0.02	0.9	0.1	11.89	0.03	0.0364	0.0005	6.7	0.1	1744	18
	5th	1.1	0.03	1.7	0.1	11.94	0.03	0.0367	0.0004	10.5	0.2	1328	14
	6th	1.9	0.06	3.5	0.2	11.69	0.03	0.0363	0.0003	30.3	0.3	1045	10
	7th	1.1	0.03	2.1	0.2	11.43	0.03	0.0355	0.0004	19.2	0.3	815	9
	8th	0.3	0.01	0.6	0.1	11.36	0.06	0.0336	0.0006	4.9	0.1	840	10
						$^{21}Ne/^{22}Ne_E$ = 0.0423±0.0004							
NLD- 27 I	1 st	2.7	0.08	22.7	1.5	10.33	0.10	0.0320	0.0001	659.1	17.0	1914	20
(3.86g)	2nd	2.3	0.07	18.4	1.5	10.28	0.10	0.0330	0.0001	448	1.2	1886	19
$^{3}He/^{4}He$	3rd	1.7	0.05	92.0	1.6	9.90	0.09	0.0290	0.0001	2767.3	71.6	540	6
15.4 R_A	4th	2.0	0.06	23.2	1.5	10.30	0.10	0.0310	0.0001	530.8	13.7	1483	15
	5th	3.0	0.09	7.9	0.3	12.15	0.03	0.0427	0.0002	145.5	3.8	9261	93
	6th	4.1	0.12	21.0	1.4	10.73	0.10	0.0340	0.0002	612.4	15.8	3080	31
	7th	3.5	0.10	13.4	0.4	11.32	0.01	0.0379	0.0002	256.6	6.6	5572	56
	8th	2.7	0.08	6.8	0.2	12.22	0.03	0.0430	0.0002	66.4	1.7	9269	93
	9th	3.5	0.10	10.9	0.4	11.59	0.02	0.0395	0.0002	152.3	3.9	5847	59
	10th	2.6	0.08	7.4	0.2	11.83	0.03	0.0407	0.0002	65.7	1.7	8116	82
	11th	0.8	0.02	5.4	0.1	10.56	0.02	0.0337	0.0002	64.9	1.7	2525	26
	12th	0.8	0.02	2.3	0.6	11.58	0.03	0.0397	0.0004	21.7	0.6	6885	69
	13th	0.4	0.01	1.2	0.4	11.58	0.03	0.0392	0.0005	11.3	0.3	6858	69
NLD- 27 II	1st	2.2	0.07	78.2	0.7	9.79	0.09	0.0290	0.0002	2578.5	66.3	638	7
(3.61g)	2nd	1.2	0.03	18.4	0.7	10.09	0.09	0.0310	0.0002	433.1	11.1	1106	11
	3rd	1.1	0.03	10.3	0.2	10.35	0.02	0.0327	0.0002	189.0	4.9	2063	21
	4th	1.2	0.04	19.7	0.7	10.16	0.09	0.0310	0.0002	450.7	11.6	1057	11
	5th	0.8	0.02	5.8	0.2	10.62	0.02	0.0336	0.0002	106.8	2.7	2591	26
	6th	1.1	0.03	6.2	0.2	10.85	0.02	0.0346	0.0002	107.8	2.8	3179	32

Sample	crush#	^{4}He (10^{-6} cc)	1σ	^{22}Ne (10^{-12} cc)	1σ	^{20}Ne/^{22}Ne	1σ	^{21}Ne/^{22}Ne	1σ	^{36}Ar (10^{-12} cc)	1σ	^{40}Ar/^{36}Ar	1σ
	7th	1.6	0.05	36.2	0.7	10.13	0.09	0.0300	0.0002	747.6	19.2	932	10
	8th	1.4	0.04	5.7	0.2	11.26	0.03	0.0372	0.0004	116.1	3.0	3633	37
	9th	2.2	0.07	10.1	0.1	11.12	0.02	0.0365	0.0001	163.3	4.2	4189	42
	10th	1.9	0.06	6.8	0.2	11.46	0.03	0.0382	0.0003	105.3	2.7	5563	56
	11th	1.2	0.04	62.4	0.7	9.82	0.09	0.0290	0.0002	1431.1	36.8	543	6
	12th	1.5	0.04	34.8	0.7	10.11	0.09	0.0300	0.0002	759.9	19.5	905	9
	13th	1.0	0.03	5.0	0.2	10.99	0.03	0.0356	0.0004	79.6	2.0	3785	38
	14th	1.1	0.03	17.5	0.7	10.01	0.09	0.0310	0.0002	368.6	9.5	1203	12
	15th	0.7	0.02	4.6	0.2	10.76	0.02	0.0344	0.0003	65.8	1.7	3508	35
	16th	0.9	0.03	10.2	0.2	10.33	0.02	0.0318	0.0001	170.3	4.4	1764	18
	17th	0.6	0.02	2.1	0.5	11.37	0.03	0.0380	0.0001	29.5	0.8	5814	59
	18th	0.9	0.03	6.9	0.2	10.64	0.02	0.0337	0.0003	125.8	3.2	2437	25
	19th	0.9	0.03	14.9	0.1	9.90	0.01	0.0303	0.0001	461.7	11.9	821	9
	20th	0.9	0.03	3.1	0.3	11.39	0.03	0.0380	0.0002	38.2	1.0	6468	65
	21st	0.8	0.03	2.3	0.4	11.86	0.03	0.0402	0.0001	32.4	0.8	7388	74
	22nd	0.9	0.03	13.2	0.1	10.23	0.02	0.0314	0.0001	211.7	5.4	1469	15
	23rd	0.8	0.03	7.2	0.2	10.50	0.02	0.0329	0.0003	106.4	2.7	2434	25
	24th	0.8	0.02	6.7	0.2	10.50	0.02	0.0327	0.0003	93.9	2.4	2502	25
	25th	0.7	0.02	4.1	0.3	10.80	0.02	0.0347	0.0003	53.2	1.4	3960	40
	26th	0.5	0.01	4.1	0.3	10.51	0.02	0.0330	0.0003	66.6	1.5	2227	23
	27th	0.9	0.03	9.2	0.2	10.45	0.02	0.0323	0.0002	149.4	3.8	1925	20
	28th	0.7	0.02	17.5	0.7	10.11	0.09	0.0300	0.0002	394.4	10.1	830	9
	29th	0.5	0.01	29.4	0.7	9.90	0.09	0.0290	0.0002	646.0	16.6	498	5
	30th	1.2	0.04	7.0	0.2	10.88	0.02	0.0349	0.0003	100.7	2.6	3605	36
	31st	0.7	0.02	7.1	0.2	10.41	0.02	0.0323	0.0003	118.0	3.0	2063	21
	32nd	0.5	0.02	7.9	0.2	10.46	0.02	0.0314	0.0002	107.3	2.7	1579	16
						^{21}Ne/^{22}Ne$_E$ = 0.0484±0.0002							

^{21}Ne/^{22}Ne$_E$ is the mantle ^{21}Ne/^{22}Ne ratio corrected for shallow level air contamination.

Sample locations (latitude and longitude) are presented in Lupton et al., 2009.

Supplemental Table 2: Xe abundance and isotopic measurements

Sample	Step	^{130}Xe	$^{129}Xe/^{130}Xe$	1σ	$^{129}Xe/^{136}Xe$	1σ	$^{130}Xe/^{132}Xe$	1σ	$^{131}Xe/^{132}Xe$	1σ	$^{134}Xe/^{132}Xe$	1σ	$^{136}Xe/^{132}Xe$	1σ
NLD- 13 I	1st	3.64	6.63	0.03	2.983	0.017	0.1508	0.0008	0.7837	0.0036	0.3888	0.0016	0.3349	0.0014
(3.19g)	2nd	6.49	6.56	0.02	2.942	0.011	0.1501	0.0006	0.7780	0.0025	0.3926	0.0010	0.3350	0.0012
	3rd	2.39	6.60	0.04	2.970	0.015	0.1508	0.0009	0.7829	0.0045	0.3911	0.0022	0.3347	0.0012
	4th	1.38	6.61	0.06	3.028	0.017	0.1505	0.0012	0.7874	0.0053	0.3874	0.0027	0.3286	0.0013
	5th	0.47	6.58	0.05	3.007	0.025	0.1492	0.0017	0.7912	0.0085	0.3881	0.0046	0.3269	0.0022
	6th	0.51	6.53	0.05	3.003	0.025	0.1516	0.0017	0.8047	0.0087	0.3884	0.0046	0.3295	0.0022
NLD- 13 II	1st	0.78	6.68	0.07	2.979	0.018	0.1505	0.0014	0.7946	0.0058	0.3967	0.0030	0.3381	0.0014
(3.13g)	2nd	1.91	6.58	0.05	3.008	0.016	0.1521	0.0011	0.7814	0.0049	0.3915	0.0024	0.3330	0.0012
	3rd	0.95	6.85	0.07	3.020	0.018	0.1502	0.0014	0.7796	0.0056	0.3962	0.0029	0.3406	0.0014
	4th	1.48	6.89	0.06	3.010	0.017	0.1494	0.0012	0.7802	0.0052	0.3986	0.0027	0.3425	0.0013
	5th	1.62	6.84	0.06	2.994	0.016	0.1497	0.0011	0.7912	0.0050	0.3964	0.0025	0.3418	0.0013
	6th	1.12	6.74	0.07	2.989	0.017	0.1498	0.0013	0.7898	0.0056	0.3908	0.0028	0.3377	0.0014
NLD- 13 III	1st	0.14	6.93	0.02										
(2.86g)	2nd	0.71	6.59	0.12										
NLD- 14 I	1st	2.78	6.63	0.03	2.985	0.015	0.1528	0.0008	0.7808	0.0042	0.3973	0.0021	0.3391	0.0012
(3.82g)	4th	14.43	6.58	0.02	3.003	0.006	0.1506	0.0004	0.7826	0.0020	0.3881	0.0008	0.3303	0.0006
	5th	10.63	6.59	0.02	2.977	0.007	0.1512	0.0005	0.7925	0.0020	0.3886	0.0009	0.3348	0.0009
	7th	8.99	6.57	0.02	3.014	0.007	0.1522	0.0005	0.7898	0.0020	0.3911	0.0010	0.3319	0.0010
	9th	3.56	6.74	0.04	2.996	0.017	0.1494	0.0008	0.7948	0.0037	0.3915	0.0016	0.3358	0.0014
	10th	4.96	6.67	0.03	2.983	0.014	0.1508	0.0007	0.7859	0.0032	0.3938	0.0013	0.3374	0.0013
	11th	4.69	6.67	0.03	2.982	0.015	0.1507	0.0007	0.7865	0.0033	0.3941	0.0014	0.3370	0.0014
	12th	3.07	6.58	0.03	2.976	0.015	0.1516	0.0008	0.7872	0.0040	0.3920	0.0019	0.3351	0.0012
	13th	4.86	6.58	0.03	2.991	0.015	0.1509	0.0007	0.7860	0.0032	0.3917	0.0014	0.3319	0.0013
	14th	1.75	6.57	0.05	3.004	0.016	0.1512	0.0011	0.7893	0.0050	0.3920	0.0025	0.3303	0.0012
	15th	1.68	6.47	0.05	2.999	0.016	0.1540	0.0011	0.7865	0.0050	0.3894	0.0025	0.3320	0.0013
NLD- 20 I	1st	4.40	6.55	0.03										
(3.78g)	2nd	0.21	6.79	0.12										
	3rd	1.86	6.51	0.05										
	4th	0.70	6.61	0.07										

Sample	Step	^{130}Xe	$^{129}Xe/^{130}Xe$	1σ	$^{129}Xe/^{136}Xe$	1σ	$^{130}Xe/^{132}Xe$	1σ	$^{131}Xe/^{132}Xe$	1σ	$^{134}Xe/^{132}Xe$	1σ	$^{136}Xe/^{132}Xe$	1σ
	5th	0.89	6.63	0.06										
NLD- 20 II	1st	0.02	6.90	0.13										
(4.24g)	2nd	0.25	6.46	0.03										
	3rd	0.18	6.50	0.04										
	4th	0.03	6.70	0.13										
	5th	0.04	6.46	0.12										
	6th	0.08	6.61	0.13										
	7th	0.06	6.54	0.13										
	8th	0.02	6.68	0.12										
NLD- 27 I	1st	11.44	6.72	0.02	3.007	0.006	0.1494	0.0004	0.7880	0.0020	0.3941	0.0008	0.3338	0.0009
(3.86g)	2nd	9.15	6.72	0.02	2.987	0.007	0.1500	0.0005	0.7897	0.0020	0.3967	0.0010	0.3372	0.0011
	4th	9.01	6.72	0.02	2.989	0.007	0.1500	0.0005	0.7822	0.0020	0.3930	0.0010	0.3373	0.0011
	5th	6.47	6.92	0.02	3.004	0.011	0.1489	0.0006	0.7755	0.0025	0.3991	0.0010	0.3434	0.0012
	6th	13.27	6.80	0.02	3.002	0.006	0.1498	0.0004	0.7794	0.0020	0.3969	0.0008	0.3396	0.0007
	7th	9.49	6.79	0.02	3.011	0.007	0.1501	0.0005	0.7782	0.0020	0.3966	0.0010	0.3387	0.0010
	8th	5.68	6.90	0.03	2.996	0.012	0.1491	0.0006	0.7773	0.0028	0.3988	0.0012	0.3434	0.0013
	9th	8.06	6.83	0.02	3.002	0.008	0.1498	0.0005	0.7798	0.0024	0.3980	0.0010	0.3410	0.0011
	10th	5.36	6.84	0.03	3.000	0.013	0.1507	0.0007	0.7834	0.0029	0.4011	0.0013	0.3439	0.0013
	11th	2.07	6.79	0.05	2.989	0.016	0.1489	0.0009	0.7783	0.0045	0.3938	0.0023	0.3382	0.0012
	12th	1.36	6.85	0.06	2.998	0.017	0.1488	0.0011	0.7669	0.0049	0.3917	0.0027	0.3401	0.0013
	13th	0.53	6.84	0.08	3.010	0.018	0.1506	0.0015	0.7838	0.0059	0.3962	0.0031	0.3414	0.0014
NLD- 27 II	2nd	7.26	6.66	0.02	2.980	0.010	0.1500	0.0005	0.7857	0.0024	0.3911	0.0009	0.3350	0.0012
(3.61g)	3rd	5.61	6.69	0.03	2.952	0.013	0.1485	0.0007	0.7813	0.0029	0.3924	0.0012	0.3362	0.0013
	4th	8.67	6.56	0.02	2.993	0.007	0.1512	0.0005	0.7865	0.0022	0.3922	0.0010	0.3315	0.0011
	5th	3.43	6.74	0.04	2.985	0.017	0.1493	0.0008	0.7883	0.0037	0.3963	0.0017	0.3372	0.0015
	6th	3.73	6.69	0.04	2.996	0.017	0.1501	0.0008	0.7852	0.0036	0.3959	0.0016	0.3352	0.0014
	7th	11.45	6.58	0.02	2.987	0.007	0.1514	0.0004	0.7855	0.0020	0.3933	0.0009	0.3333	0.0009
	8th	5.34	6.62	0.03	2.983	0.014	0.1517	0.0007	0.7853	0.0030	0.3938	0.0013	0.3366	0.0013
	9th	6.11	6.74	0.02	2.991	0.012	0.1502	0.0006	0.7870	0.0028	0.3959	0.0011	0.3383	0.0013
	10th	4.65	6.72	0.03	2.980	0.015	0.1517	0.0007	0.7823	0.0033	0.3967	0.0014	0.3419	0.0014
	12th	12.14	6.55	0.02	2.982	0.007	0.1523	0.0004	0.7909	0.0020	0.3902	0.0009	0.3339	0.0009

Sample	Step	^{130}Xe	$^{129}Xe/^{130}Xe$	1σ	$^{129}Xe/^{136}Xe$	1σ	$^{130}Xe/^{132}Xe$	1σ	$^{131}Xe/^{132}Xe$	1σ	$^{134}Xe/^{132}Xe$	1σ	$^{136}Xe/^{132}Xe$	1σ
	13th	3.20	6.63	0.04	2.988	0.018	0.1527	0.0008	0.7838	0.0038	0.3964	0.0017	0.3390	0.0014
	14th	7.53	6.54	0.02	2.981	0.010	0.1525	0.0005	0.7835	0.0023	0.3920	0.0009	0.3348	0.0012
	15th	1.88	6.70	0.05	2.983	0.016	0.1514	0.0010	0.7850	0.0049	0.3947	0.0024	0.3398	0.0013
	16th	3.91	6.64	0.03	2.984	0.017	0.1526	0.0008	0.7903	0.0036	0.3951	0.0016	0.3396	0.0014
	17th	1.17	6.66	0.07	2.995	0.017	0.1533	0.0013	0.7803	0.0055	0.4002	0.0029	0.3419	0.0014
	18th	3.65	6.63	0.04	2.992	0.017	0.1523	0.0008	0.7893	0.0037	0.3956	0.0016	0.3377	0.0014
	19th	7.14	6.52	0.02	2.975	0.010	0.1528	0.0006	0.7938	0.0024	0.3898	0.0009	0.3347	0.0012
	20st	1.98	6.79	0.05	3.008	0.016	0.1507	0.0010	0.7877	0.0048	0.3932	0.0024	0.3400	0.0013
	21nd	1.60	6.75	0.06	2.983	0.016	0.1513	0.0011	0.7924	0.0051	0.3968	0.0026	0.3422	0.0013
	22rd	4.19	6.61	0.03	3.001	0.016	0.1520	0.0008	0.7949	0.0035	0.3936	0.0015	0.3346	0.0014
	23th	3.02	6.71	0.03	3.006	0.014	0.1507	0.0007	0.7920	0.0041	0.3987	0.0020	0.3361	0.0011
	24th	2.92	6.67	0.03	2.992	0.014	0.1502	0.0007	0.7872	0.0041	0.3925	0.0020	0.3348	0.0011
	25th	1.60	6.72	0.06	2.968	0.016	0.1519	0.0011	0.7943	0.0051	0.3957	0.0026	0.3433	0.0013
	26th	1.62	6.66	0.06	2.980	0.016	0.1498	0.0011	0.7828	0.0051	0.3939	0.0026	0.3348	0.0013
	27th	3.51	6.70	0.04	3.011	0.017	0.1506	0.0008	0.7920	0.0037	0.3908	0.0016	0.3349	0.0014
	28th	8.14	6.48	0.02	2.967	0.009	0.1517	0.0005	0.7844	0.0021	0.3884	0.0008	0.3311	0.0011
	29th	9.95	6.53	0.02	2.996	0.007	0.1510	0.0005	0.7904	0.0014	0.3883	0.0009	0.3291	0.0010
	30st	3.42	6.73	0.04	2.994	0.018	0.1513	0.0008	0.7817	0.0038	0.3942	0.0017	0.3399	0.0014
	31nd	2.51	6.71	0.03	3.011	0.015	0.1506	0.0008	0.7856	0.0043	0.3927	0.0021	0.3356	0.0012
	32rd	1.52	6.78	0.06	3.020	0.016	0.1491	0.0011	0.7901	0.0051	0.3943	0.0026	0.3339	0.0013

^{130}Xe abundance is in units of 10^{-14} cc STP

Fission derived isotopes were not determined for NLD- 20 because of low obtained abundances.

Xenon abundances for six steps were higher than the largest calibrated air standard; Isotopic compositions for these steps were not determined.

Table S3: NLD-27 source and end-member compositions used in the Pu-U-I deconvolutions

Sample	$^{130}Xe/^{132}Xe$	$^{131}Xe/^{132}Xe$	$^{134}Xe/^{132}Xe$	$^{136}Xe/^{132}Xe$
NLD- 27[1]	0.1497 ±0.0002	0.7793 ±0.0010	0.4018 ±0.0005	0.3457 ±0.0005
Atm.[2]	0.15135 ±0.00012	0.7890 ±0.0011	0.3879 ±0.0006	0.3294 ±0.0004
SW[3]	0.1661 ±0.0009	0.8272 ±0.0053	0.367 ±0.015	0.299 ±0.001
AVCC[4]	0.1626 ±0.0007	0.8200 ±0.0058	0.3836 ±0.0027	0.3233 ±0.0024
U-fission[5]	0	0.144 ±0.001	1.437 ±0.002	1.737 ±0.003
Pu-fission[6]	0	0.279 ±0.012	1.048 ±0.005	1.124 ±0.014

1. NLD- 27 composition was determined by linear regression between $^{129}Xe/^{132}Xe$ and $^{130,131,134,136}Xe/^{132}Xe$ ratios forced through the atmospheric composition (y=mx) and projecting to a mantle $^{129}Xe/^{132}Xe$ value of 1.0382 (Supplemental Figure 1, see main text for details).
2. Atmospheric composition is from Basford et al. (1973).
3. SW is for solar wind, and solar wind composition is from Wieler and Baur (1994) and Pepin et al. (1995).
4. AVCC is Average Carbonaceous Chondrite, and AVCC composition is from Pepin 1991, 2000.
5. U-fission composition is the error-weighted average of the data presented by Wetherill (1953), Hebeda et al. (1987), Eikenberg et al. (1993), and Ragettli et al. (1994).
6. Pu-fission composition is the error-weighted average of the data presented by Alexander et al. (1971), Lewis et al. (1975) and Hudson et al. (1985).