Supplementary information

Sequential separation of multi-isotopes from limited samples through a two-step column chromatography apporach

Lei Li[a], Fang Liu[a]*, Qingyao Peng[a], Zhaofeng Zhang[a], Xin Li[a], Yajun An[a]

[a] Research Center for Planetary Science, College of Earth Sciences, Chengdu University of Technology, Chengdu 610059, China

Corresponding author. E-mail address: liufang@cdut.edu.cn.

The Supplementary information includes Table S1, S2,S3 and Figure S1.

Table S1. The isotopic compositions of Ca and Sr of standards and simulated lunar soil samples.

Sample	$\delta^{44/40}Ca$	2SD	Reference	$^{87}Sr/^{86}Sr$	2SE	Reference
NOD-A-1	1.19	0.05	This Study	0.709227	0.000006	This Study
	1.14	0.11	Liu et al.[1]			
	1.02	0.15	Feng et al.[2]			
COQ-1	0.71	0.13	This Study	0.703311	0.000004	This Study
	0.71	0.11	Feng et al.[2]	0.703319	0.000015	Bellefroid et al.[3]
	0.74	0.13	Liu et al.[1]	0.703293	0.000009	Kochergina et al.[4]
AGV-2	0.76	0.04	This Study	0.704005	0.000007	This Study
	0.71	0.11	Liu et al.[1]	0.704000	0.000014	Yu et al.[5]
	0.79	0.09	Feng et al.[2]	0.704020	0.000020	Andersen et al.[6]
BHVO-2	0.81	0.04	This Study	0.703543	0.000005	This Study
	0.80	0.10	Liu et al.[1]	0.703503	0.000013	Cheng et al.[7]
	0.84	0.07	Zhu et al.[8]	0.703493	0.000011	Liu et al.[1]
GSP-2	0.28	0.06	This Study	0.764964	0.000006	This Study
	0.25	0.06	Liu et al.[1]	0.764962	0.000034	Raczek et al.[9]
	0.30	0.03	He et al.[10]	0.764996	0.000019	Sun et al.[11]
CUG-1A	0.72	0.05	This Study	0.705825	0.000004	This Study
CUG-1B	0.72	0.02	This Study	0.703344	0.000005	This Study
915a	0.03	0.09	This Study			
	0.00	0.03	Amini et al.[12]			
	0.02	0.13	Kang et al.[13]			
IAPSO	1.87	0.13	This Study			
seawater	1.82	0.12	Liu et al.[1]			
	1.83	0.01	Zhu.[14]			
NBS987				0.710234	0.000005	This Study
				0.710231	0.000013	Niu et al.[15]
				0.710234	0.000006	Zhang et al.[16]

Table S2. The isotopic compositions of Ba, Ce, and Nd for standards and simulated lunar soil samples.

Sample	$\delta^{137/134}$Ba ±2SD‰	$\delta^{138/134}$Ba ±2SD‰	Reference	$\delta^{142/140}$Ce	2SD	Reference	$\delta^{146/144}$Nd	2SE	$\delta^{148/144}$Nd	2SE	Reference	^{143}Nd/^{144}Nd	Reference
NOD-A-1	0.11±0.02	0.14±0.01	This Study	0.107	0.036	This Study	0.038	0.007	0.096	0.012	This Study	0.512130±4	This Study
				0.131	0.042	Bai et al.[17]	0.043	0.007	0.079	0.012	Liu et al.[18]	0.512128±3	Liu et al.[18]
				0.104	0.022	Liu et al.[19]	-0.015	0.028			Bai et al.[20]	0.512136±5	Bai et al.[20]
COQ-1	0.06±0.02	0.07±0.00	This Study	0.022	0.032	This Study	-0.068	0.006	-0.151	0.010	This Study	0.512827±5	This Study
	0.08±0.04	0.10[a]	Zeng et al.[21]	-0.018	0.042	Bai et al.[17]	-0.080	0.007	-0.140	0.012	Liu et al.[18]	0.512816±3	Liu et al.[18]
				0.042	0.028	Nakada et al.[22]							
AGV-2	0.00±0.01	0.01±0.00	This Study	0.004	0.031	This Study	-0.029	0.007	-0.053	0.011	This Study	0.512787±4	This Study
	0.03[a]	0.05±0.01	Deng et al.[23]	0.000	0.046	Bai et al.[17]	-0.029	0.007	-0.049	0.012	Liu et al.[18]	0.512784±3	Liu et al.[18]
				-0.009	0.028	Nakada et al.[22]	-0.014	0.030			Bai et al.[20]	0.512786±10	Bai et al.[20]
BHVO-2	0.04±0.03	0.03±0.04	This Study	-0.028	0.026	This Study	-0.041	0.005	-0.077	0.008	This Study	0.512972±4	This Study
	0.02±0.03	0.03[a]	Li et al.[24]	0.004	0.040	Nakada et al.[22]	-0.041	0.007	-0.057	0.011	Liu et al.[18]	0.512979±4	Liu et al.[18]
	0.01±0.04	0.02±0.03	An et al.[25]	-0.019	0.036	Liu et al.[19]	-0.030	0.030			Bai et al.[20]	0.512987±17	Bai et al.[20]
GSP-2	-0.04±0.02	-0.04±0.03	This Study	0.005	0.013	This Study	-0.055	0.007	-0.095	0.010	This Study	0.511386±3	This Study
	0.00±0.03	0.00[a]	Nan et al.[26]	0.022	0.035	Bai et al.[17]	-0.044	0.007	-0.067	0.012	Liu et al.[18]	0.511380±3	Liu et al.[18]
	-0.01±0.03	0.00±0.03	Deng et al.[27]				-0.063	0.031			Bai et al.[20]	0.511361±9	Bai et al.[20]
CUG-1A	0.03±0.03	0.02±0.03	This Study	0.006	0.014	This Study	-0.051	0.005	-0.082	0.008	This Study	0.512555±4	This Study
CUG-1B	0.09±0.02	0.09±0.01	This Study	0.023	0.023	This Study	-0.027	0.005	-0.052	0.009	This Study	0.512964±3	This Study
USTC-Ba		0.09±0.01	Nan et al.[26]										
ICPUS-Ba		-0.03±0.01	Nan et al.[26]										
CDUT-Ce				0.117	0.033	This Study							
				0.118	0.033	Liu et al.[19]							
				0.129	0.041	Bai et al.[17]							
JMC304				0.006	0.036	This Study							
				0.005	0.038	Liu et al.[19]							
JNdi-1							-0.002	0.016	-0.005	0.035	This Study	0.512104±7	This Study
							0.001	0.005	-0.005	0.008	Liu et al.[18]	0.512110±5	Liu et al.[18]
												0.512104±8	Bai et al.[20]

Table S3. The main and trace data of rock standard samples and simulated lunar soils. (Rock standard data are cited from http://georem.mpch-mainz.gwdg.de; The data of simulated lunar soils CUG-1A and CUG-1B were cited from Li et al. [28]; Chang'e 5 soil data are cited from Zong et al.[29])

Elements	unit	NOD-A-1	COQ-1	AGV-2	BHVO-2	GSP-2	CUG-1A	CUG-1B	CE-5
SiO_2	wt.%	3.81	3.54	59.14	49.60	66.60	49.33	47.77	41.25
MgO	wt.%	4.76	1.20	1.79	7.23	0.96	7.94	9.89	6.52
Al_2O_3	wt.%	3.87	0.37	16.91	13.44	14.90	15.34	14.21	11.55
CaO	wt.%	15.40	48.55	5.15	11.40	2.10	7.02	7.38	11.64
TiO_2	wt.%	0.53	0.15	1.05	2.73	0.66	2.12	1.75	5.12
Fe_2O_3	wt.%	15.60	2.94	6.09	12.30	4.90	11.94	11.22	22.70
Na_2O	wt.%	1.00	0.10	4.19	2.22	2.78	3.64	4.59	0.46
K_2O	wt.%	0.60	0.16	2.88	0.52	5.38	2.01	2.27	0.21
MnO	wt.%	4.76	1.20	1.79	7.23	0.96	0.17	0.16	0.28
P_2O_5	wt.%	1.37	2.58	0.48	0.27	0.29	0.49	0.75	0.27
Li	μg/g	76.0	3.4	11.0	4.5	36.0	10.1	9.0	15.4
Be	μg/g	5.6	1.2	2.3	1.1	1.5	1.6	2.6	2.8
Sc	μg/g	12.2	3.0	13.0	32.3	6.3	17.3	14.8	62.9
V	μg/g	770	110	120	317	52	144	119	93
Cr	μg/g	21	10	17	280	20	272	355	1459
Co	μg/g	3110	4	15	45	7	45	46	37
Ni	μg/g	5548	3	19	120	17	202	296	139
Cu	μg/g	1100	3	53	123	43	40	38	12
Zn	μg/g	587	87	86	101	120	96	118	14
Ga	μg/g	6.3	6.0	20.0	20.6	22.0	19.0	22.4	5.8
Rb	μg/g	10.6	14.6	68.0	9.8	245.0	58.0	38.7	5.2
Sr	μg/g	1748	12000	658	389	240	648	971	313
Y	μg/g	116	81	20	23	28	25	22	116
Zr	μg/g	328	65	232	169	550	203	241	545
Nb	μg/g	43	3900	15	18	27	50	70	36
Mo	μg/g	364.00	7.40	2.00	4.07	2.10	1.91	1.91	0.03
Cs	μg/g	0.56	0.36	1.17	0.10	1.20	0.90	0.62	0.22
Ba	μg/g	1670	1000	1140	130	1340	699	389	395
La	μg/g	112.0	750.0	38.2	15.2	180.0	40.2	44.4	35.4
Ce	μg/g	720	1700	69	38	410	77	82	99
Pr	μg/g	24.3	150.0	8.2	5.3	51.0	8.5	9.0	12.7
Nd	μg/g	93.0	412.0	30.5	24.3	200.0	32.6	35.1	59.3
Sm	μg/g	19.8	50.0	5.5	6.0	27.0	6.4	7.3	17.0
Eu	μg/g	5.20	15.00	1.55	2.04	2.30	2.05	2.36	2.77
Gd	μg/g	24.90	50.00	4.68	6.21	12.00	5.77	6.43	19.60
Tb	μg/g	3.90	3.93	0.65	0.94	1.09	0.84	0.89	3.27
Dy	μg/g	23.50	18.60	3.55	5.28	6.10	4.66	4.60	20.50

Ho	μg/g	4.90	3.29	0.68	0.99	1.00	0.86	0.76	4.07
Er	μg/g	14.07	8.07	1.83	2.51	2.20	2.35	1.85	11.30
Tm	μg/g	2.00	1.07	0.26	0.33	0.29	0.32	0.23	1.57
Yb	μg/g	13.80	5.90	1.65	1.99	1.60	1.95	1.27	9.90
Lu	μg/g	2.20	0.73	0.25	0.28	0.23	0.29	0.17	1.36
Hf	μg/g	4.0	0.2	5.1	4.5	14.0	4.6	5.2	14.0
Ta	μg/g	0.76	8.50	0.87	1.15	0.43	2.77	3.97	1.83
Pb	μg/g	846.0	4.3	13.1	1.7	42.0	6.9	3.9	0.1
Th	μg/g	23.40	10.60	6.17	1.22	105.00	6.04	5.64	0.28
U	μg/g	7.00	11.20	1.89	0.41	2.40	1.31	1.74	0.08

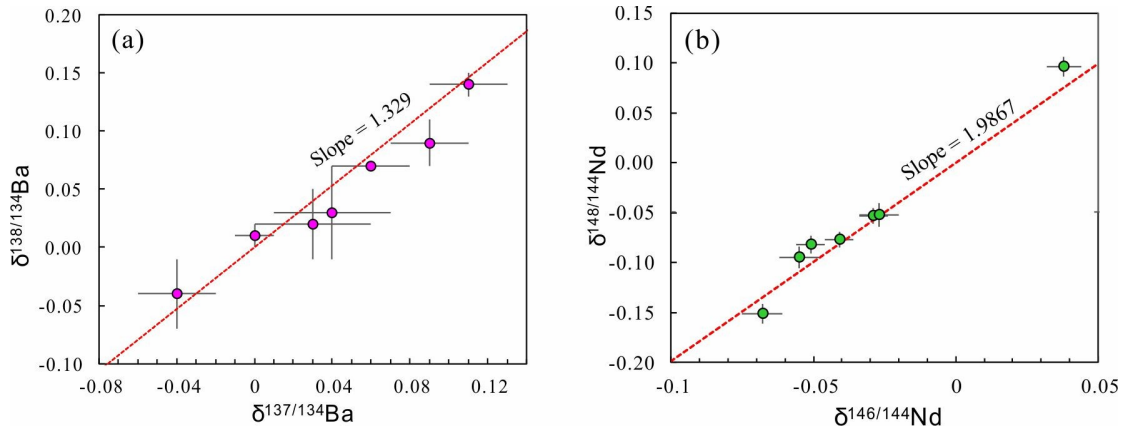

Figure S1. The three-isotope plot for Ba and Nd isotopes of all samples analyzed in this study. The graph shows the mass-dependent covariant relationship between $\delta^{138/134}$Ba–$\delta^{137/134}$Ba and $\delta^{148/144}$Nd–$\delta^{146/144}$Nd. The dashed red lines represent the theoretical mass fractionation line, with slopes of 1.33 and 1.9687, respectively.

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