Depth dependent element ratios in fluid inclusion analysis by laser ablation ICP-MS

Marcel Guillong,*^{*a*} and Thomas Pettke^{*b*} Instrumentation parameters:

Table ESI 1: Instrument parameters

Laser Ablation System	Resonetics M50 HR							
Laser and wavelength	193 nm ArF excimer (Compex pro 110)							
Energy density	$0-30 \mathrm{J}\mathrm{cm}^{-2}(\sim 15 \mathrm{J}\mathrm{cm}^{-2})$							
Demagnification	15x, 20x, 25x, 30x, 35x							
Crater size (35x demagnification)	5, 7, 9, 14, 19, 29, 34, 47, 64, 89 , 120, 163 ≅m							
Beam	non-homogenized							
Ablation Cell	Laurin Technic two-volume cell							
Aerosol mixing device	Squid							
He flow	0.6 l min ⁻¹							
Software	Geostar 6.20							
ICP-MS	Agilent 7500 cs/ce							
Lens system	cs (nov.30)	ce (ja. 20)						
RF Power	1380 W	1550 W						
Make up gas flow (Ar)	0.86 l min ⁻¹	0.88 l min ⁻¹						
sampling depth	3.9 mm	3.8 mm						
Extraction lens 1 voltage	4.9 V	0 V						
extraction lens 2 voltage	- 30 V	- 100 V						
Omega bias -cs	-38 V	-22 V						
Omega lens -cs	7.8 V	-2.4V						
Cell entrance	-32 V	-36 V						
QP focus	4 V	2 V						
Cell Exit	-32 V	-50 V						
QP Bias	-3 V	-3.5 V						
Background mass 220	~ 3 cps	~ 0.7 cps						
Background mass 23	~ 7000 cps	~ 75000 cps						
Sensitivity U 238 [*]	~ 100000 cps	~ 48000 cps						
Sensitivity Li 7 [*]	~ 20000 cps	~ 15000 cps						
Oxides (ThO/Th) [*]	0.254%	0.228%						
Doubely charged (22/44) *	0.048%	0.275%						
U/Th [*]	1.16	1.21						
cooling gas flow	15 l min ⁻¹							
plasma gas flow	1.01 min ⁻¹							
reaction cell mode	no gas							
Octopole RF	200 V							
Octopole Bias	-17 V							
[*] NIST 612, 47 ≅m, 10 Hz, 3.5 J cm ⁻²	, 3 ≅m s ⁻¹ scan							

Images of Fluid Inclusion assamblages:

Sample 208-37

Figures ESI 1 to ESI 4 show the fluid inclusion assemblage in sample 208-37: Figure ESI 1 shows an overview of a free standing quartz crystal with well visible growth zones with a magnification of the analysed assemblage that is on an inclined plane relative to the surface of the thick section. This represents a typical late pseudosecondary or secondary fluid inclusion assemblage located on a healed fracture. The inclination of the plane is well suited to explore depth-dependent features of inclusion analysis. Figure ESI 2 and ESI 3 show a series of microscope pictures of the assemblage at different focal planes. Figure ESI-4 shows an image taken with the CCD camera of the laser ablation system after ablation of the inclusions. Due to surface contamination inclusions remain hardly visible.



Figure ESI 1. Microscope pictures of sample 208-37 with the analysed inclusion assemblage.



Figure ESI 2. Microscope pictures of inclusion assemblage sample 208-37 at different focal planes.



Figure ESI-3. Microscope pictures of inclusion assemblage sample 208-37 at different focal planes.



Figure ESI-4. CCD pictures of analysed inclusion assemblage sample 208-37 from the laser ablation system. Note the extensive surface contamination (deposited material) from the ablations, visible as relief texture around the craters.

Sample Loww9

Figure ESI 5 shows the inclusion assemblage of the Loww9 sample. The sample hosts pseudosecondary inclusion trails with 30-50 micron sized, well separated brine inclusions. Figure ESI 5 shows a comparison between an optical microscope and the Resonetics M50 visualization employing identical scales. The overview consists of merged individual images. The magnified areas show that the resolution is sufficient with M50 system to clearly identify and separate individual inclusions. Note that the depth of view is few tens of micrometers with the optical microscope and hundreds of micrometers with the M50 system. This can be problematic for visualization when many features are within and on the sample such as multiple inclusions or surface contamination (Figure ESI 4).



Figure ESI 5. Microscope (left) and ablation system CCD camera (right) pictures of the inclusion assemblage selected for analysis in sample Loww9. The enlarged views compare the same detail image for the two visualization systems.

Description of depth measurements:

Method 1: Microscopy prior to ablation

On an optical microscope (20 x magnifications) the surface above the inclusion was focused, and the value on the fine focusing knob was noted. After focusing on the circumference of the inclusion, the value of the fine focusing knob was noted again, the difference was calculated. The refractive index of this quartz sample was calculated based on the thickness of the quartz chip, measured with a Digital calliper to be 680 micrometer (Loww9). The optical microscope was then focused again on the surface of the chip and on the plane between the quartz chip and the microscope slide. This measurement resulted in 440 μ m. The ratio is 1.545, close to the literature value for fused silica of 1.556 as calculated for 532nm on http://refractiveindex.info, respectively, while the values for quartz vary from 1.5442 to 1.5533, depending on crystal orientation. The measured differences of the microscope were then multiplied with the refractive index to get the real mean depth of the fluid inclusions.

Method 2: After laser ablation

The ablation rate was calculated based on the thickness of the quartz chip (Loww9) and an ablation through the quartz chip. 252 seconds at 10 Hz repetition rate and ~15 J/cm² energy density where necessary to drill through which corresponds to an ablation rate of 2.7 μ m per second or 270 nm per pulse, in good agreement with previously published ablation rates for fused silica (e.g. 0.3 μ m/pulse at 12 J/cm²)^{1, 2}. From the recorded transient signal of the fluid inclusion excavation it is possible to calculate the ablation time until the inclusion signal starts. Based on the ablation rate and the time until the inclusion signal starts, the minimal inclusion depth can be calculated.

Comparison of the two methods to calculate the depth of an inclusion:

Figure ESI 6 shows the correlation between the two measured depths: There is an acceptable correlation, with two obvious effects: Nominally, the difference between the two measurements is approximately $\frac{1}{2}$ of the fluid inclusion size as the method 2 returns the minimal depth of the inclusion compared to a mean depth by method 1. Therefore, the trend of measurements cuts the x axis (method 1) at about 30 μ m. Additionally, towards deeper inclusions, method 2 overestimates the depth. This might be due to a non linear ablation rate (decrease for craters deeper 300 microns)



Figure ESI 6. Correlation between different depth measurements of fluid inclusions.

Description of measurement strategy for fluid inclusion analysis using a Resonetics M50 laser Ablation system equipped with the Geostar software:

1. Sample holder scan:

A High resolution scan of the whole sample holder is coordinated with the stage for easy orientation of the laser within the cell and samples. Figure ESI 7 shows an example with the thin section (sample 208-37 on the left and a SRM mount on the bottom right, including NIST 610, NIST 612, Sca_17, BCR-2 G, GSD-1 G, and others). Note that the thick section has to be flat and the surface needs to be at a specific height in the sample holder.

2. Keep images from the M50 CCD camera

Move the stage to the inclusions and keep images from the CCD camera, when the inclusions of interest are visible (transmitted light) and can be allocated with sample preparation figures. Figure ESI 8 shows a magnified part of ESI 7 within the Geostar software (saved display) with the kept images, as well as the yellow square indicating the actual location of the stage, visible on the live screen. With Geostar software it is possible to load and coordinate images from other sources like optical microscopes or electron microscope. This could be a possibility to locate inclusions that are poorly visible with the M50 optics. However this possibility was not explored in detail as it was possible in these samples to easily locate the inclusions.

3. Mark all inclusions of interest

In figure ESI 9, all inclusions are marked at their locations for later reference, representing a sequence of single spots in the Geostar software. Although this feature of the software is not used for fluid inclusion analysis it is very helpful at a later stage, when the inclusions are not visible anymore due to surface contamination of previous ablations (see figure ESI 4). With Geostar software it is possible to import sample locations from other sources (e.g., computerized microscope stage or electron microscope) and coordinate them. However this possibility was not explored in this study.

4. Analysis of SRM and inclusions

Now the system is ready for inclusion analysis. For the analysis we used the system manually. For a rapid crater change, the beam stop (shutter) can be opened and closed by a keyboard short cut, while the crater size is changed from the software graphical interface. Care has to be taken to not open the beam stop before the aperture wheel stopped rotating. If the surface contamination is too excessive (either for the recorded signal or visualisation) the sample can be taken out of the cell, repolished and put back, as shown in figure ESI 10.



Figure ESI 7. Scanned image of sample holder with fluid inclusion sample 208-37 and SRM block.



Figure ESI 8. Overlaid CCD camera images over the coordinated scan (Figure ESI 7) from the Geostar screen.



Figure ESI 9. Marked inclusions on CCD camera images on sample Loww9 from the Geostar software, each tagged with the analysis number.



Figure ESI 10. Overlaid images after ablation and polishing to remove surface contamination (deposited material) from sample 208-37. The sample is now ready for the next series of inclusion analysis.





Table ESI 2: Element concentration ratios relative to Na for all analysed inclusions (normalized to 45 wt-% NaCl equivalent), without obvious outliers due to incomplete sampling.

					E	lement .	Го Na со	ncentrat	ion ratio	s for indiv	idual flu	uid inclu	sions sorte	d by aspe	ct ratio		
		Aspect															
analysis name	Inclusion nam	ratio	B11	CI 35	K39	Mn55	Fe57	Cu65	Zn66	As 75	Rb85	Sr88	Mo95	Cs 133	Ba 137	Pb208	Bi 209
nv30b09.csv	208-37_FI-7	1.32	0.0005	1.6	0.47	0.019	0.42	0.014	0.016	0.00017	0.17	0.12	0.0007	0.00024	0.0008	0.018	0.00001
nv30b13.csv	208-37_FI-16	1.32	0.0007	1.8	0.61	0.024	0.50	0.004	0.020	0.00029	0.21	0.05	0.0004	0.00034	0.0012	0.023	0.00001
nv30a06.csv	208-37_FI-3	1.34	0.0006	1.7	0.34	0.024	0.40	0.047	0.033	0.00027	0.15	0.10	0.0008	0.00023	0.0004	0.025	0.00004
nv30b12.csv	208-37 FI-13	1.54	0.0012	1.9	0.56	0.030	0.66	0.002	0.026	0.00043	0.26	0.08	0.0003	0.00038	0.0009	0.025	0.00002
nv30b08.csv	208-37_FI-4	1.97	0.0004	1.5	0.41	0.019	0.36	0.023	0.020	0.00020	0.15	0.08	0.0008	0.00021	0.0005	0.025	0.00005
nv30a11.csv	208-37_FI-15	1.99	0.0006	1.8	0.38	0.022	0.36	0.005	0.019	0.00022	0.17	0.07	0.0002	0.00025	0.0000	0.017	0.00001
nv30a10.csv	208-37_FI-12	2.02	0.0002	1.8	0.42	0.022	0.32	0.055	0.025	0.00019	0.17	0.11	0.0009	0.00023	0.0008	0.028	0.00005
nv30b11.csv	208-37_FI-11	2.02	0.0011	1.3	0.37	0.016	0.29	0.006	0.012	0.00018	0.14	0.05	0.0003	0.00021	0.0012	0.016	0.00001
nv30a12.csv	208-37_FI-17	2.31	0.0007	2.0	0.66	0.031	0.62	0.059	0.033	0.00010	0.17	0.15	0.0011	0.00028	0.0006	0.035	0.00006
nv30a09 csv	208-37_FI-21 208-37_FI-10	2.57	bdl	1.7	0.38	0.022	0.42	0.057	0.023	0.00019	0.00	0.07	0.0011	0.00019	0.0006	0.020	0.00004
nv30a08.csv	208-37 FI-8	2.68	bdl	1.7	0.36	0.018	0.36	0.052	0.018	bdl	0.12	0.08	0.0009	0.00016	0.0005	0.024	0.00005
nv30b10.csv	208-37_FI-9	2.76	bdl	1.3	0.34	0.022	0.40	0.049	0.022	0.00016	0.13	0.11	0.0007	0.00019	0.0009	0.026	0.00005
nv30b15.csv	208-37_FI-20	2.76	bdl	1.8	0.74	0.037	0.77	0.107	0.046	bdl	0.18	0.16	0.0015	0.00037	0.0016	0.039	0.00013
nv30a21.csv	208-37_FI-41	2.81	0.0008	2.0	0.43	0.027	0.58	0.016	0.025	0.00036	0.23	0.10	0.0004	0.00033	0.0014	0.022	0.00002
nv30a15.csv	208-37_FI-23	2.88	bdl	2.3	0.44	0.029	0.49	0.010	0.042	bdl	0.19	0.11	0.0002	0.00028	0.0007	0.040	0.00005
nv30a16.csv	208-37_FI-25	2.88	bdl	1./	0.39	0.024	0.46	0.056	0.029	0.00022	0.16	0.11	0.0012	0.00020	0.0006	0.030	0.00005
nv30b16.csv	208-37_FI-18	2.00	bdl	1.7	0.09	0.030	0.49	0.060	0.040	0.00032	0.20	0.10	0.0008	0.00032	0.0007	0.043	0.00008
nv30b25.csv	208-37_11-22 208-37_FI-40	3.19	0.0007	2.3	0.59	0.023	0.40	0.000	0.025	0.00030	0.21	0.10	bdl	0.00023	0.0012	0.029	0.00002
nv30b21.csv	208-37_FI-34	3.75	0.0008	2.3	0.45	0.028	0.49	0.077	0.043	0.00048	0.11	0.08	0.0012	0.00027	0.0007	0.042	0.00009
nv30b20.csv	208-37_FI-33	3.97	0.0011	3.6	0.51	0.033	0.70	0.122	0.073	0.00052	0.20	0.12	0.0025	0.00033	0.0010	0.071	0.00017
nv30a17.csv	208-37_FI-27	4.04	0.0010	2.5	0.48	0.025	0.48	0.005	0.026	0.00033	0.21	0.06	0.0017	0.00030	0.0007	0.026	0.00003
nv30b24.csv	208-37_FI-39	4.19	bdl	3.6	0.45	0.025	0.53	0.006	0.038	0.00047	0.16	0.06	0.0005	0.00033	0.0009	0.039	0.00002
nv30b17.csv	208-37_FI-28	4.33	0.0006	2.1	0.43	0.019	0.37	0.012	0.023	0.00030	0.20	0.07	0.0004	0.00031	0.0002	0.027	0.00003
nv30b19.csv	208-37_FI-30	4.33	0.0007	2.4	0.47	0.025	0.50	0.086	0.040	0.00030	0.20	0.08	0.0017	0.00029	0.0010	0.046	0.00009
nv30b22.csv	208-37_FI-30	4.41	0.0005	2.2	0.34	0.021	0.42	0.052	0.038	0.00018	0.13	0.09	0.0014	0.00023	0.0000	0.041	0.00008
nv30b18.csv	208-37_FI-29	4.62	0.0005	2.0	0.39	0.024	0.52	0.053	0.037	0.00023	0.18	0.10	0.0013	0.00025	0.0008	0.036	0.00006
nv30b26.csv	208-37_FI-42	4.63	0.0006	2.2	0.25	0.024	0.48	0.068	0.039	0.00014	0.17	0.11	0.0014	0.00022	0.0007	0.040	0.00007
n v30a 19.cs v	208-37_FI-35	4.90	bdl	2.9	0.51	0.026	0.46	0.094	0.047	0.00045	0.07	0.07	0.0018	0.00031	0.0010	0.050	0.00010
nv30a27.csv	208-37_FI-52	5.11	0.0010	4.7	0.52	0.033	0.53	0.240	0.091	0.00055	0.30	0.09	0.0025	0.00040	0.0006	0.091	0.00017
nv30b27.csv	208-37_FI-44	5.74	0.0006	3.9	0.43	0.028	0.50	0.095	0.074	0.00040	0.20	0.10	0.0017	0.00032	0.0007	0.070	0.00013
nv30b28.csv	208-37_FI-46	5.96	bdl	5.1	0.51	0.032	0.55	0.140	0.083	0.00037	0.25	0.08	0.0020	0.00039	0.0007	0.087	0.00019
nv30b29.csv	208-37_FI-49	6.18	0.0017	2.2	0.50	0.035	0.64	0.095	0.089	bdl	0.16	0.05	0.0001	0.00044	0.0001	0.084	0.00017
nv30a 20.cs v	208-37_FI-38	6.35	bdl	2.9	0.39	0.017	0.29	0.061	0.034	0.00030	0.18	0.06	0.0010	0.00027	0.0003	0.045	0.00009
nv30b31.csv	208-37 FI-51	6.62	0.0009	4.2	0.60	0.037	0.84	0.146	0.099	0.00024	0.24	0.16	0.0025	0.00040	0.0013	0.000	0.00019
		0.02	0.0005		0.00											0.050	0.00015
	_	0.02	0.0005		0.00											0.050	0.00015
		aspect	0.0005		0.00											0.050	0.00015
		aspect ratio	B11	CI 35	к39	Mn55	Fe57	Cu65	Zn66	As 75	Rb85	Sr88	Mo95	Cs 133	Ba 137	Pb208	Bi209
ja 20a 06.cs v	Loww9 - FI 1	aspect ratio 1.12	B11 0.015	CI 35 3.4	КЗ9 0.58	Mn55 0.25	Fe57 1.01	Cu65 bdl	Zn 66 0.08	As 75 0.0001	Rb85 0.027	Sr88 0.034	Mo95 0.0000024	Cs 133 0.034	Ba 137 0.00067	Pb208 0.040	Bi209 0.00013
ja 20a 06.cs v ja 20a 09.cs v	Loww9 - FI 1 Loww9 - FI 4	aspect ratio 1.12 1.28	B11 0.015 0.014	CI 35 3.4 3.1	K39 0.58 0.63	Mn55 0.25 0.25	Fe57 1.01 1.02	Cu65 bdl 0.0016	Zn 66 0.08 0.08	As 75 0.0001 0.0015	Rb85 0.027 0.021	Sr88 0.034 0.038	Mo95 0.0000024 bdl	Cs 133 0.034 0.031	Ba 137 0.00067 0.00064	Pb208 0.040 0.049	Bi209 0.00013 0.00019
ja 20a 06.csv ja 20a 09.csv ja 20a 10.csv	Loww9 - FI 1 Loww9 - FI 4 Loww9 - FI 5	aspect ratio 1.12 1.28 1.44	B11 0.015 0.014 0.012	CI 35 3.4 3.1 2.9	K39 0.58 0.63 0.42	Mn55 0.25 0.25 0.19	Fe57 1.01 1.02 0.75	Cu65 bdl 0.0016 0.0029	Zn 66 0.08 0.08 0.06	As 75 0.0001 0.0015 0.0013	Rb85 0.027 0.021 0.019	Sr88 0.034 0.038 0.026	Mo95 0.0000024 bdl bdl	Cs 133 0.034 0.031 0.026	Ba 137 0.00067 0.00064 0.00039	Pb208 0.040 0.049 0.026	Bi209 0.00013 0.00019 0.00015
ja 20a06.csv ja 20a09.csv ja 20a 10.csv ja 20a 10.csv ja 20a 07.csv	Loww9 - FI 1 Loww9 - FI 4 Loww9 - FI 5 Loww9 - FI 2 Loww9 - FI 2	aspect ratio 1.12 1.28 1.44 1.54	B11 0.015 0.014 0.012 0.012	CI 35 3.4 3.1 2.9 3.2	K39 0.58 0.63 0.42 0.60	Mn55 0.25 0.25 0.19 0.23	Fe 57 1.01 1.02 0.75 0.88	Cu65 bdl 0.0016 0.0029 0.0017	Zn 66 0.08 0.08 0.06 0.07	As 75 0.0001 0.0015 0.0013 0.0012	Rb85 0.027 0.021 0.019 0.024	Sr88 0.034 0.038 0.026 0.033	Mo95 0.0000024 bdl bdl bdl	Cs 133 0.034 0.031 0.026 0.030	Ba 137 0.00067 0.00064 0.00039 0.00058	Pb208 0.040 0.049 0.026 0.040	Bi209 0.00013 0.00019 0.00015 0.00015
ja 20a06.csv ja 20a09.csv ja 20a 10.csv ja 20a 10.csv ja 20a 12.csv ja 20a 12.csv	Loww9 - FI 1 Loww9 - FI 4 Loww9 - FI 5 Loww9 - FI 5 Loww9 - FI 6.2 Loww9 - FI 6.2	aspect ratio 1.12 1.28 1.44 1.54 1.64 1.76	B11 0.015 0.014 0.012 0.012 0.012 0.012	CI 35 3.4 3.1 2.9 3.2 2.8 3.4	K39 0.58 0.63 0.42 0.60 0.54 0.83	Mn55 0.25 0.25 0.19 0.23 0.19 0.29	Fe57 1.01 1.02 0.75 0.88 0.72 1.10	Cu65 bdl 0.0016 0.0029 0.0017 0.0024	Zn 66 0.08 0.08 0.06 0.07 0.06 0.08	As 75 0.0001 0.0015 0.0013 0.0012 0.0010 0.0015	Rb85 0.027 0.021 0.019 0.024 0.020 0.031	Sr88 0.034 0.038 0.026 0.033 0.025 0.039	Mo95 0.0000024 bdl bdl bdl bdl	Cs 133 0.034 0.031 0.026 0.030 0.025 0.039	Ba 137 0.00067 0.00064 0.00039 0.00058 0.00045 0.00070	Pb208 0.040 0.049 0.026 0.040 0.037 0.053	Bi209 0.00013 0.00019 0.00015 0.00015 0.00014 0.00014
ja 20a06.csv ja 20a09.csv ja 20a07.csv ja 20a07.csv ja 20a12.csv ja 20a14.csv ja 20a14.csv	Loww9 - FI 1 Loww9 - FI 4 Loww9 - FI 5 Loww9 - FI 5 Loww9 - FI 6.2 Loww9 - FI7 Loww9 - FI9	aspect ratio 1.12 1.28 1.44 1.54 1.64 1.76 1.76	B11 0.015 0.014 0.012 0.012 0.012 0.012 0.017 0.018	Cl 35 3.4 3.1 2.9 3.2 2.8 3.4 3.4 3.8	K39 0.58 0.63 0.42 0.60 0.54 0.83 0.90	Mn55 0.25 0.25 0.19 0.23 0.19 0.29 0.31	Fe 57 1.01 1.02 0.75 0.88 0.72 1.10 1.22	Cu65 bdl 0.0016 0.0029 0.0017 0.0024 0.0027 0.0025	Zn 66 0.08 0.08 0.06 0.07 0.06 0.08 0.10	As 75 0.0001 0.0015 0.0013 0.0012 0.0010 0.0015 0.0017	Rb85 0.027 0.021 0.019 0.024 0.020 0.031 0.034	Sr88 0.034 0.038 0.026 0.033 0.025 0.039 0.040	Mo95 0.0000024 bdl bdl bdl bdl bdl 0.000015	Cs 133 0.034 0.031 0.026 0.030 0.025 0.039 0.044	Ba 137 0.00067 0.00064 0.00039 0.00058 0.00045 0.00070 0.00073	Pb208 0.040 0.049 0.026 0.040 0.037 0.053 0.061	Bi 209 0.00013 0.00019 0.00015 0.00015 0.00015 0.00014 0.00018 0.00023
ja 20a 06.csv ja 20a 09.csv ja 20a 09.csv ja 20a 10.csv ja 20a 12.csv ja 20a 14.csv ja 20a 14.csv ja 20a 16.csv ja 20a 17.csv	Loww9 - FI 1 Loww9 - FI 4 Loww9 - FI 5 Loww9 - FI 5 Loww9 - FI 6.2 Loww9 - FI 7 Loww9 - FI 10	aspect ratio 1.12 1.28 1.44 1.54 1.64 1.76 1.76	B11 0.015 0.014 0.012 0.012 0.012 0.012 0.017 0.018 0.014	Cl 35 3.4 3.1 2.9 3.2 2.8 3.4 3.8 3.1	K39 0.58 0.63 0.42 0.60 0.54 0.83 0.90 0.65	Mn55 0.25 0.25 0.19 0.23 0.19 0.29 0.31 0.23	Fe57 1.01 1.02 0.75 0.88 0.72 1.10 1.22 0.94	Cu65 bdl 0.0016 0.0029 0.0017 0.0024 0.0027 0.0025 0.0028	Zn 66 0.08 0.08 0.06 0.07 0.06 0.08 0.10 0.07	As 75 0.0001 0.0015 0.0013 0.0012 0.0010 0.0015 0.0017 0.0013	Rb85 0.027 0.021 0.019 0.024 0.020 0.031 0.034 0.024	Sr88 0.034 0.038 0.026 0.033 0.025 0.039 0.040 0.028	Mo95 0.0000024 bdl bdl bdl bdl bdl 0.0000015 0.000002	Cs 133 0.034 0.031 0.026 0.030 0.025 0.039 0.044 0.031	Ba 137 0.00067 0.00064 0.00039 0.00058 0.00045 0.00070 0.00073 0.00055	Pb208 0.040 0.049 0.026 0.040 0.037 0.053 0.061 0.042	Bi209 0.00013 0.00019 0.00015 0.00015 0.00014 0.00018 0.00023 0.00016
ja 20a 06.csv ja 20a 09.csv ja 20a 10.csv ja 20a 10.csv ja 20a 12.csv ja 20a 14.csv ja 20a 16.csv ja 20a 16.csv ja 20a 18.csv	Loww9 - Fl 1 Loww9 - Fl 4 Loww9 - Fl 5 Loww9 - Fl 2 Loww9 - Fl 7 Loww9 - Fl7 Loww9 - Fl10 Loww9 - Fl10	aspect ratio 1.12 1.28 1.44 1.54 1.64 1.76 1.76 1.76 1.91	B11 0.015 0.014 0.012 0.012 0.012 0.017 0.018 0.014 0.011	Cl 35 3.4 3.1 2.9 3.2 2.8 3.4 3.8 3.1 2.7	K39 0.58 0.63 0.42 0.60 0.54 0.83 0.90 0.65 0.54	Mn55 0.25 0.25 0.19 0.23 0.19 0.29 0.31 0.23 0.18	Fe57 1.01 1.02 0.75 0.88 0.72 1.10 1.22 0.94 0.68	Cu65 bdl 0.0016 0.0029 0.0017 0.0024 0.0027 0.0025 0.0028 0.0014	Zn 66 0.08 0.08 0.06 0.07 0.06 0.08 0.10 0.07 0.06	As 75 0.0001 0.0015 0.0013 0.0012 0.0010 0.0015 0.0017 0.0013 0.0006	Rb85 0.027 0.021 0.019 0.024 0.020 0.031 0.034 0.024 0.020	Sr88 0.034 0.038 0.026 0.033 0.025 0.039 0.040 0.028 0.023	Mo 95 0.000024 bdl bdl bdl bdl bdl 0.000015 0.000002 bdl	Cs 133 0.034 0.031 0.026 0.030 0.025 0.039 0.044 0.031 0.026	Ba 137 0.00067 0.00064 0.00039 0.00058 0.00045 0.00070 0.00073 0.00055 0.00044	Pb208 0.040 0.049 0.026 0.040 0.037 0.053 0.061 0.042 0.037	Bi209 0.00013 0.00019 0.00015 0.00015 0.00014 0.00018 0.00023 0.00016 0.00013
ja 20a 06.csv ja 20a 09.csv ja 20a 10.csv ja 20a 12.csv ja 20a 12.csv ja 20a 14.csv ja 20a 15.csv ja 20a 15.csv	Loww9 - Fl 1 Loww9 - Fl 4 Loww9 - Fl 4 Loww9 - Fl 5 Loww9 - Fl 7 Loww9 - Fl 7 Loww9 - Fl 10 Loww9 - Fl 11 Loww9 - Fl 11 Loww9 - Fl 8	aspect ratio 1.12 1.28 1.44 1.54 1.64 1.76 1.76 1.76 1.91 2.07	B11 0.015 0.014 0.012 0.012 0.012 0.012 0.017 0.018 0.014 0.011 0.017	Cl 35 3.4 3.1 2.9 3.2 2.8 3.4 3.8 3.1 2.7 3.2	K39 0.58 0.63 0.42 0.60 0.54 0.83 0.90 0.65 0.54 0.60	Mn55 0.25 0.25 0.19 0.23 0.19 0.29 0.31 0.23 0.18 0.27	Fe57 1.01 1.02 0.75 0.88 0.72 1.10 1.22 0.94 0.68 1.05	Cu65 bdl 0.0016 0.0029 0.0017 0.0024 0.0027 0.0025 0.0028 0.0014 0.0030	Zn 66 0.08 0.08 0.06 0.07 0.06 0.08 0.10 0.07 0.06 0.08	As 75 0.001 0.0015 0.0013 0.0012 0.0010 0.0015 0.0017 0.0013 0.0006 0.0014	Rb85 0.027 0.021 0.019 0.024 0.020 0.031 0.034 0.024 0.020 0.026	Sr88 0.034 0.038 0.026 0.033 0.025 0.039 0.040 0.028 0.023 0.036	Mo 95 0.000024 bdl bdl bdl bdl bdl 0.000015 0.000002 bdl bdl	Cs 133 0.034 0.031 0.026 0.030 0.025 0.039 0.044 0.031 0.026 0.034	Ba 137 0.00067 0.00064 0.00039 0.00058 0.00045 0.00070 0.00073 0.00055 0.00044 0.00072	Pb208 0.040 0.049 0.026 0.040 0.037 0.053 0.061 0.042 0.037 0.050	Bi209 0.00013 0.00019 0.00015 0.00015 0.00014 0.00013 0.00016 0.00013 0.00019
ja 20a 06.csv ja 20a 09.csv ja 20a 10.csv ja 20a 12.csv ja 20a 12.csv ja 20a 12.csv ja 20a 14.csv ja 20a 14.csv ja 20a 15.csv ja 20a 15.csv ja 20a 15.csv ja 20a 15.csv	Loww9 - FI 1 Loww9 - FI 4 Loww9 - FI 4 Loww9 - FI 5 Loww9 - FI 2 Loww9 - FI 2 Loww9 - FI 10 Loww9 - F110 Loww9 - F111 Loww9 - F12	aspect ratio 1.12 1.28 1.44 1.54 1.64 1.76 1.76 1.76 1.76 1.91 2.07 2.07	B11 0.015 0.014 0.012 0.012 0.012 0.012 0.017 0.018 0.014 0.011 0.017 0.020	Cl 35 3.4 3.1 2.9 3.2 2.8 3.4 3.8 3.1 2.7 3.2 4.0	K39 0.58 0.63 0.42 0.60 0.54 0.83 0.90 0.65 0.54 0.60 0.88	Mn55 0.25 0.25 0.19 0.23 0.19 0.29 0.31 0.23 0.18 0.27 0.33	Fe57 1.01 1.02 0.75 0.88 0.72 1.10 1.22 0.94 0.68 1.05 1.25	Cu65 bdl 0.0016 0.0029 0.0017 0.0024 0.0027 0.0025 0.0028 0.0014 0.0030 0.0036	Zn66 0.08 0.08 0.06 0.07 0.06 0.08 0.10 0.07 0.06 0.08 0.10	As 75 0.0001 0.0015 0.0013 0.0012 0.0012 0.0010 0.0015 0.0017 0.0013 0.0006 0.0014 0.0003	Rb85 0.027 0.021 0.019 0.024 0.020 0.031 0.034 0.024 0.020 0.026 0.031	Sr88 0.034 0.038 0.026 0.033 0.025 0.039 0.040 0.028 0.023 0.036 0.042	Mo95 0.0000024 bdl bdl bdl bdl 0.000015 0.000002 bdl bdl bdl bdl	Cs 133 0.034 0.031 0.026 0.025 0.039 0.044 0.031 0.026 0.034 0.039	Ba 137 0.00067 0.00064 0.00039 0.00058 0.00075 0.00073 0.00075 0.00072 0.00075	Pb208 0.040 0.049 0.026 0.040 0.037 0.053 0.061 0.042 0.037 0.050 0.063	Bi209 0.00013 0.00019 0.00015 0.00015 0.00014 0.00018 0.00018 0.00013 0.00013 0.00019 0.00023
ja 20a 06.csv ja 20a 09.csv ja 20a 10.csv ja 20a 11.csv ja 20a 12.csv ja 20a 21.csv ja 20a 23.csv ja 20a 23.csv	Loww9 - Fl 1 Loww9 - Fl 4 Loww9 - Fl 5 Loww9 - Fl 5 Loww9 - Fl 2 Loww9 - Fl 7 Loww9 - Fl 7 Loww9 - Fl 10 Loww9 - Fl 10 Loww9 - Fl 12 Loww9 - Fl 12 Loww9 - Fl 12	aspect ratio 1.12 1.28 1.44 1.54 1.64 1.76 1.76 1.76 1.91 2.07 2.07 2.07 2.12	B11 0.015 0.014 0.012 0.012 0.012 0.012 0.017 0.018 0.014 0.011 0.017 0.020 0.001	Cl 35 3.4 3.1 2.9 3.2 2.8 3.4 3.8 3.1 2.7 3.2 4.0 3.7 2.4	K39 0.58 0.63 0.42 0.60 0.54 0.83 0.90 0.65 0.54 0.60 0.88 0.60	Mn55 0.25 0.25 0.19 0.23 0.19 0.29 0.31 0.23 0.18 0.27 0.33 0.23	Fe57 1.01 1.02 0.75 0.88 0.72 1.10 1.22 0.94 0.68 1.05 1.25 0.95	Cu65 bdl 0.0016 0.0029 0.0017 0.0024 0.0025 0.0025 0.0028 0.0014 0.0030 0.0036 0.0031	Zn66 0.08 0.08 0.06 0.07 0.06 0.08 0.10 0.07 0.06 0.08 0.10 0.09	As 75 0.0001 0.0013 0.0013 0.0012 0.0010 0.0015 0.0017 0.0013 0.0006 0.0014 0.0003 0.0016	Rb85 0.027 0.021 0.019 0.024 0.020 0.031 0.034 0.024 0.020 0.026 0.031 0.026	Sr88 0.034 0.038 0.026 0.033 0.025 0.039 0.040 0.028 0.023 0.036 0.042 0.028	Mo95 0.000024 bdl bdl bdl bdl 0.000015 0.000002 bdl bdl bdl bdl bdl bdl	Cs133 0.034 0.031 0.026 0.030 0.025 0.039 0.044 0.031 0.026 0.034 0.039 0.034	Ba 137 0.00067 0.00064 0.00039 0.00058 0.00075 0.00073 0.00073 0.00075 0.00044 0.00072 0.00075	Pb208 0.040 0.049 0.026 0.040 0.037 0.053 0.061 0.042 0.037 0.050 0.063 0.054	Bi209 0.00013 0.00019 0.00015 0.00015 0.00015 0.00015 0.00018 0.00013 0.00010 0.00013 0.00013 0.00023 0.00021
ja 20a 06.csv ja 20a 09.csv ja 20a 10.csv ja 20a 10.csv ja 20a 11.csv ja 20a 11.csv ja 20a 11.csv ja 20a 11.csv ja 20a 15.csv ja 20a 13.csv ja 20a 23.csv ja 20a 32.csv ja 20a 32.csv ja 20a 32.csv	Loww9 - Fl 1 Loww9 - Fl 4 Loww9 - Fl 5 Loww9 - Fl 5 Loww9 - Fl 2 Loww9 - Fl 7 Loww9 - Fl 7 Loww9 - Fl 10 Loww9 - Fl 11 Loww9 - Fl 12 Loww9 - Fl 12 Loww9 - Fl 12 Loww9 - Fl 12	aspect ratio 1.12 1.28 1.44 1.54 1.76 1.76 1.76 1.76 1.76 1.76 1.91 2.07 2.07 2.07 2.11 2.23	B11 0.015 0.014 0.012 0.012 0.012 0.012 0.012 0.012 0.013 0.014 0.011 0.017 0.020 0.001 0.015 0.015	Cl 35 3.4 3.1 2.9 3.2 2.8 3.4 3.4 3.8 3.1 2.7 3.2 4.0 3.7 3.2 4.0 3.7 3.4 3.0	 K39 0.58 0.63 0.42 0.60 0.54 0.83 0.90 0.65 0.54 0.60 0.88 0.63 0.69 0.62 	Mn55 0.25 0.25 0.19 0.23 0.19 0.29 0.31 0.23 0.18 0.27 0.33 0.23 0.23 0.25	Fe57 1.01 1.02 0.75 0.88 0.72 1.10 1.22 0.94 0.68 1.05 1.25 0.95 1.00 0.81	Cu65 bdl 0.0016 0.0029 0.0017 0.0024 0.0025 0.0025 0.0028 0.0014 0.0030 0.0036 0.0021 0.0023	Zn66 0.08 0.08 0.06 0.07 0.06 0.08 0.10 0.07 0.06 0.08 0.10 0.09 0.09	As 75 0.0001 0.0013 0.0013 0.0012 0.0010 0.0015 0.0017 0.0016 0.0014 0.0003 0.0016 0.0015 0.0015	Rb85 0.027 0.021 0.019 0.024 0.020 0.031 0.034 0.024 0.020 0.026 0.026 0.026 0.026	Sr88 0.034 0.038 0.026 0.033 0.025 0.039 0.040 0.028 0.023 0.036 0.042 0.028 0.028 0.024	No95 0.000024 bdl bdl bdl bdl 0.0000025 bdl bdl bdl bdl bdl bdl bdl 0.000014	Cs 133 0.034 0.031 0.026 0.030 0.025 0.039 0.044 0.031 0.026 0.034 0.039 0.034 0.033	Ba 137 0.00067 0.00064 0.00039 0.00058 0.00045 0.00070 0.00073 0.00045 0.00044 0.00072 0.0004 0.00063 0.00063	Pb208 0.040 0.049 0.026 0.040 0.037 0.053 0.061 0.042 0.037 0.050 0.063 0.054 0.051 0.061	Bi 209 0.00013 0.00019 0.00015 0.00015 0.00015 0.00015 0.00018 0.00013 0.00010 0.00013 0.00019 0.00023
ja 20a 06.csv ja 20a 09.csv ja 20a 10.csv ja 20a 10.csv ja 20a 12.csv ja 20a 12.csv ja 20a 12.csv ja 20a 18.csv ja 20a 18.csv ja 20a 15.csv ja 20a 23.csv ja 20a 23.csv ja 20a 24.csv ja 20a 23.csv	Loww9 - Fl 1 Loww9 - Fl 4 Loww9 - Fl 5 Loww9 - Fl 5 Loww9 - Fl 2 Loww9 - Fl 6.2 Loww9 - Fl 6.2 Loww9 - Fl 10 Loww9 - Fl 10 Loww9 - Fl 11 Loww9 - Fl 12 Loww9 - Fl 12 Loww9 - Fl 13 Loww9 - Fl 20 Loww9 - Fl 20	aspect ratio 1.12 1.28 1.44 1.54 1.76 1.76 1.76 1.76 1.76 1.77 2.07 2.07 2.11 2.23 2.23 2.28	B11 0.015 0.014 0.012 0.012 0.012 0.012 0.017 0.018 0.014 0.011 0.017 0.020 0.001 0.015 0.011 0.011	Cl 35 3.4 3.1 2.9 3.2 2.8 3.4 3.8 3.1 2.7 3.2 4.0 3.7 3.4 3.0 3.1	 K39 0.58 0.63 0.42 0.60 0.54 0.83 0.90 0.65 0.54 0.60 0.88 0.63 0.69 0.62 0.57 	Mn55 0.25 0.19 0.23 0.19 0.31 0.23 0.18 0.23 0.18 0.27 0.33 0.23 0.23 0.25 0.20	Fe57 1.01 1.02 0.75 0.88 0.72 1.10 1.22 0.94 0.68 1.05 1.25 0.95 1.00 0.87	Cu65 bdl 0.0016 0.0029 0.0017 0.0024 0.0025 0.0028 0.0014 0.0030 0.0036 0.0021 0.0023 0.0003	Zn66 0.08 0.06 0.07 0.06 0.08 0.10 0.07 0.06 0.08 0.10 0.09 0.09 0.06 0.07	As 75 0.0001 0.0015 0.0013 0.0012 0.0010 0.0015 0.0017 0.0013 0.0006 0.0014 0.0003 0.00016 0.0015 0.0015 0.0012	Rb85 0.027 0.021 0.029 0.024 0.020 0.031 0.034 0.024 0.020 0.026 0.031 0.026 0.026 0.022	Sr88 0.034 0.038 0.026 0.033 0.025 0.039 0.040 0.028 0.023 0.036 0.042 0.028 0.034 0.028	No95 0.000024 bdl bdl bdl bdl 0.000015 0.000002 bdl bdl bdl bdl 0.000014 0.000014 0.000013 bdl	Cs 133 0.034 0.031 0.026 0.030 0.025 0.039 0.044 0.031 0.026 0.034 0.039 0.034 0.033 0.028 0.029	Ba 137 0.00067 0.00064 0.00039 0.00058 0.00045 0.00073 0.00073 0.00075 0.00075 0.00075 0.00060 0.00063 0.00064 0.00064	Pb208 0.040 0.049 0.026 0.040 0.037 0.053 0.061 0.042 0.037 0.050 0.063 0.054 0.051 0.041	Bi209 0.00013 0.00013 0.00015 0.00015 0.00014 0.00018 0.00013 0.00013 0.00019 0.00021 0.00021
ja 20a 06.csv ja 20a 09.csv ja 20a 10.csv ja 20a 10.csv ja 20a 12.csv ja 20a 12.csv ja 20a 14.csv ja 20a 14.csv ja 20a 14.csv ja 20a 15.csv ja 20a 23.csv ja 20a 23.csv ja 20a 24.csv ja 20a 33.csv ja 20a 34.csv	Loww9 - FI 1 Loww9 - FI 4 Loww9 - FI 5 Loww9 - FI 5 Loww9 - FI 6.2 Loww9 - FI 6.2 Loww9 - FI 10 Loww9 - FI 10 Loww9 - FI 10 Loww9 - FI 11 Loww9 - FI 12 Loww9 - FI 13 Loww9 - FI 6.1 Loww9 - FI 27	aspect ratio 1.12 1.28 1.44 1.54 1.64 1.76 1.76 1.76 1.91 2.07 2.07 2.07 2.11 2.23 2.23 2.23 2.87	B11 0.015 0.014 0.012 0.012 0.012 0.012 0.014 0.014 0.012 0.014 0.014 0.014 0.014 0.011 0.017 0.020 0.001 0.015 0.011 0.015	Cl 35 3.4 3.1 2.9 3.2 2.8 3.4 3.8 3.1 2.7 3.2 4.0 3.7 3.2 4.0 3.7 3.4 3.0 3.1 3.5	K39 0.58 0.63 0.42 0.60 0.54 0.83 0.90 0.65 0.54 0.60 0.88 0.63 0.69 0.62 0.57 0.66	Mn55 0.25 0.25 0.19 0.23 0.19 0.29 0.31 0.23 0.23 0.27 0.33 0.25 0.20 0.22 0.22	Fe57 1.01 1.02 0.75 0.88 0.72 1.10 1.22 0.94 0.68 1.05 1.25 0.95 1.00 0.87 0.92	Cu65 bdl 0.0016 0.0029 0.0027 0.0024 0.0025 0.0028 0.0014 0.0030 0.0036 0.0021 0.0023 0.0003	Zn66 0.08 0.06 0.07 0.06 0.08 0.10 0.07 0.06 0.08 0.10 0.09 0.09 0.09 0.07 0.07	As 75 0.0001 0.0015 0.0015 0.0012 0.0010 0.0017 0.0017 0.0013 0.0006 0.0013 0.0006 0.0014 0.0003 0.0016 0.0012 0.0012 0.0012	Rb85 0.027 0.021 0.024 0.020 0.031 0.034 0.024 0.020 0.026 0.026 0.026 0.022 0.023 0.025	Sr88 0.034 0.038 0.026 0.033 0.025 0.039 0.040 0.028 0.023 0.036 0.042 0.028 0.034 0.024 0.024 0.022	Mo95 0.000024 bdl bdl bdl 0.000015 0.000002 bdl bdl bdl 0.0000014 0.0000013 bdl bdl bdl bdl bdl bdl bdl bdl bdl bdl	Cs 133 0.034 0.031 0.026 0.030 0.025 0.039 0.044 0.031 0.026 0.039 0.034 0.033 0.033 0.028 0.029	Ba 137 0.00067 0.00064 0.00039 0.00058 0.00045 0.00070 0.00073 0.00055 0.00044 0.00072 0.00060 0.00063 0.00044 0.00051 0.00051	Pb208 0.040 0.049 0.026 0.040 0.037 0.053 0.061 0.042 0.037 0.050 0.063 0.054 0.051 0.041 0.041 0.042	Bi209 0.00013 0.00019 0.00015 0.00015 0.00015 0.00014 0.00013 0.00013 0.00013 0.00013 0.00019 0.00023 0.00019 0.00009 0.00016 0.00021
ja 20a06.csv ja 20a09.csv ja 20a10.csv ja 20a12.csv ja 20a12.csv ja 20a12.csv ja 20a14.csv ja 20a14.csv ja 20a15.csv ja 20a15.csv ja 20a23.csv ja 20a23.csv ja 20a24.csv ja 20a14.csv ja 20a3.csv	Loww9 - Fl 1 Loww9 - Fl 4 Loww9 - Fl 4 Loww9 - Fl 5 Loww9 - Fl 2 Loww9 - Fl 2 Loww9 - Fl 7 Loww9 - Fl 7 Loww9 - Fl 10 Loww9 - Fl 11 Loww9 - Fl 12 Loww9 - Fl 12 Loww9 - Fl 20 Loww9 - Fl 20 Loww9 - Fl 20 Loww9 - Fl 20	aspect ratio 1.12 1.28 1.44 1.54 1.64 1.76 1.76 1.76 1.91 2.07 2.07 2.07 2.01 2.11 2.23 2.23 2.23 2.28 2.87 2.93	B11 0.015 0.014 0.012 0.012 0.017 0.018 0.014 0.011 0.017 0.020 0.001 0.015 0.011 0.013 0.014	Cl 35 3.4 3.1 2.9 3.2 2.8 3.4 3.4 3.8 3.1 2.7 3.2 4.0 3.7 3.4 3.0 3.1 3.5 3.7	K39 0.58 0.63 0.42 0.60 0.54 0.83 0.90 0.65 0.54 0.60 0.88 0.63 0.63 0.69 0.62 0.57 0.66 0.73	Mn55 0.25 0.25 0.19 0.23 0.19 0.23 0.31 0.23 0.23 0.27 0.33 0.25 0.20 0.22 0.23 0.23	Fe 57 1.01 1.02 0.75 0.88 0.72 1.10 1.22 0.94 0.68 1.05 1.25 0.95 1.00 0.81 0.81 0.92 1.12	Cu65 bdl 0.0016 0.0029 0.0017 0.0025 0.0025 0.0028 0.0014 0.0030 0.0030 0.0031 0.0023 0.0003 0.0014 0.0038 0.0014	Zn66 0.08 0.06 0.07 0.06 0.08 0.10 0.07 0.06 0.08 0.10 0.09 0.09 0.09 0.07 0.06 0.07	As 75 0.0001 0.0015 0.0013 0.0012 0.0010 0.0015 0.0017 0.0013 0.0006 0.0014 0.0016 0.0015 0.0012 0.0012 0.0012 0.0014	Rb85 0.027 0.021 0.029 0.024 0.020 0.031 0.024 0.020 0.026 0.026 0.026 0.022 0.023 0.025 0.022	Sr88 0.034 0.038 0.026 0.033 0.025 0.039 0.040 0.028 0.023 0.036 0.042 0.028 0.034 0.024 0.024 0.026	Mo95 0.000024 bdl bdl bdl bdl 0.000015 0.000002 bdl bdl bdl 0.000014 0.000013 bdl 0.000013 bdl 0.000013	Cs 133 0.034 0.031 0.026 0.030 0.025 0.039 0.044 0.031 0.026 0.034 0.034 0.039 0.034 0.033 0.028 0.033 0.028 0.036	Ba 137 0.00067 0.00064 0.00039 0.00058 0.00045 0.00070 0.00072 0.00075 0.00044 0.00072 0.00063 0.00063 0.00065	Pb208 0.040 0.049 0.026 0.040 0.037 0.053 0.061 0.042 0.037 0.050 0.063 0.054	Bi 209 0.00013 0.00013 0.00015 0.00015 0.00015 0.00014 0.00013 0.00013 0.00013 0.00013 0.00013 0.00013 0.00013 0.00013 0.00014 0.00013 0.00014 0.00013
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