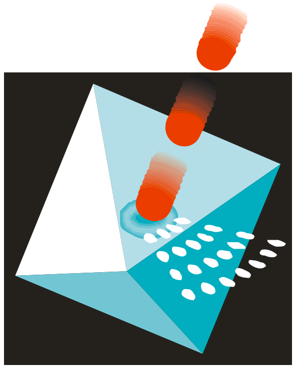
Agecalc:
U-Th-Pb data reduction program used at Arizona LaserChron Center



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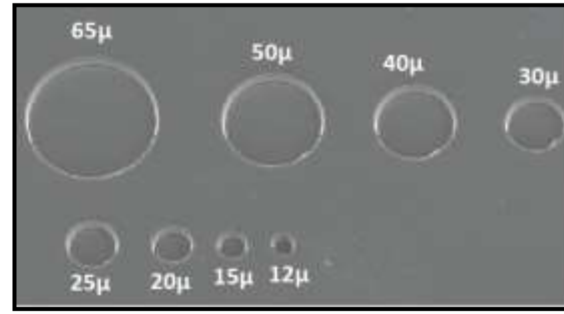
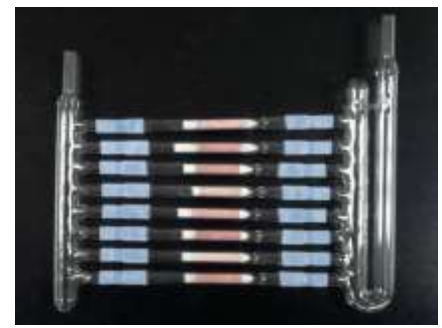
Nu HR ICPMS & Photon Machines Analyte G2 laser

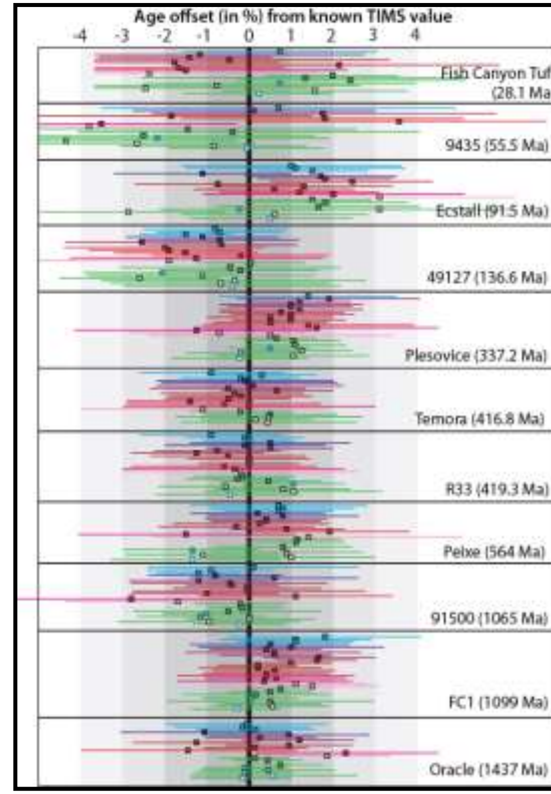


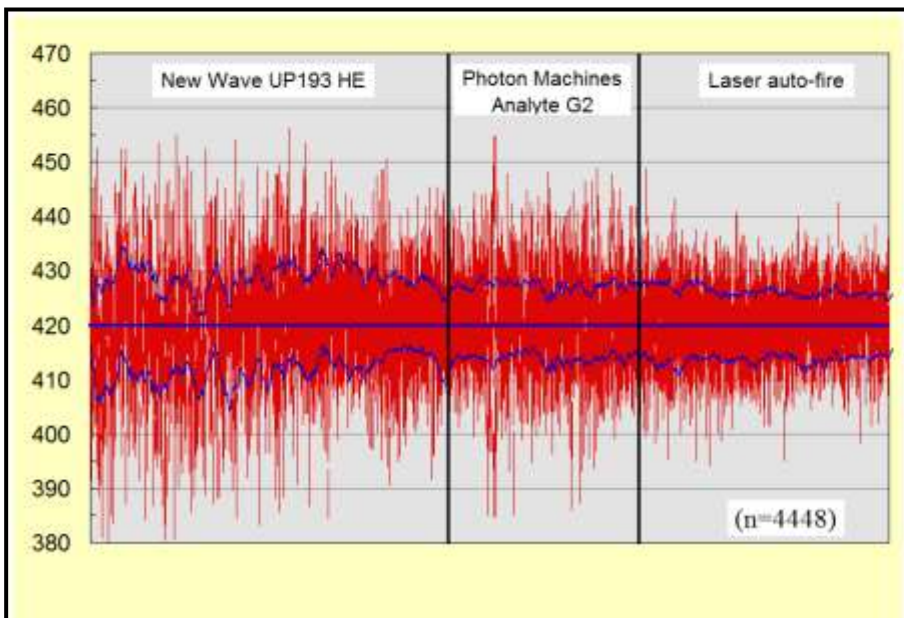


Faradays with 3x10^11 ohm resistors												Discrete dynode ion counters			
Ex-Hi	H2	H1	Ax	L1	L2	L3	L4	L5	L6	L7	L8	IC0	IC1	IC2	IC3
^{238}U	^{232}Th								^{208}Pb	^{207}Pb	^{206}Pb	^{204}Pb		^{202}Pb	
^{238}U	^{232}Th											^{208}Pb	^{207}Pb	^{206}Pb	^{204}Pb
		^{180}Hf	^{179}Hf	^{178}Hf	^{177}Hf	^{176}Hf ^{176}Lu ^{176}Yb	^{175}Lu	^{174}Hf	^{173}Yb	^{172}Yb	^{171}Yb				

Standards

Primary Standard:
Sri Lanka zircon
564 ± 4 Ma (ID-TIMS)
563.5 ± 3.2 Ma (CA-TIMS)
518 ppm U
118 ppm Th

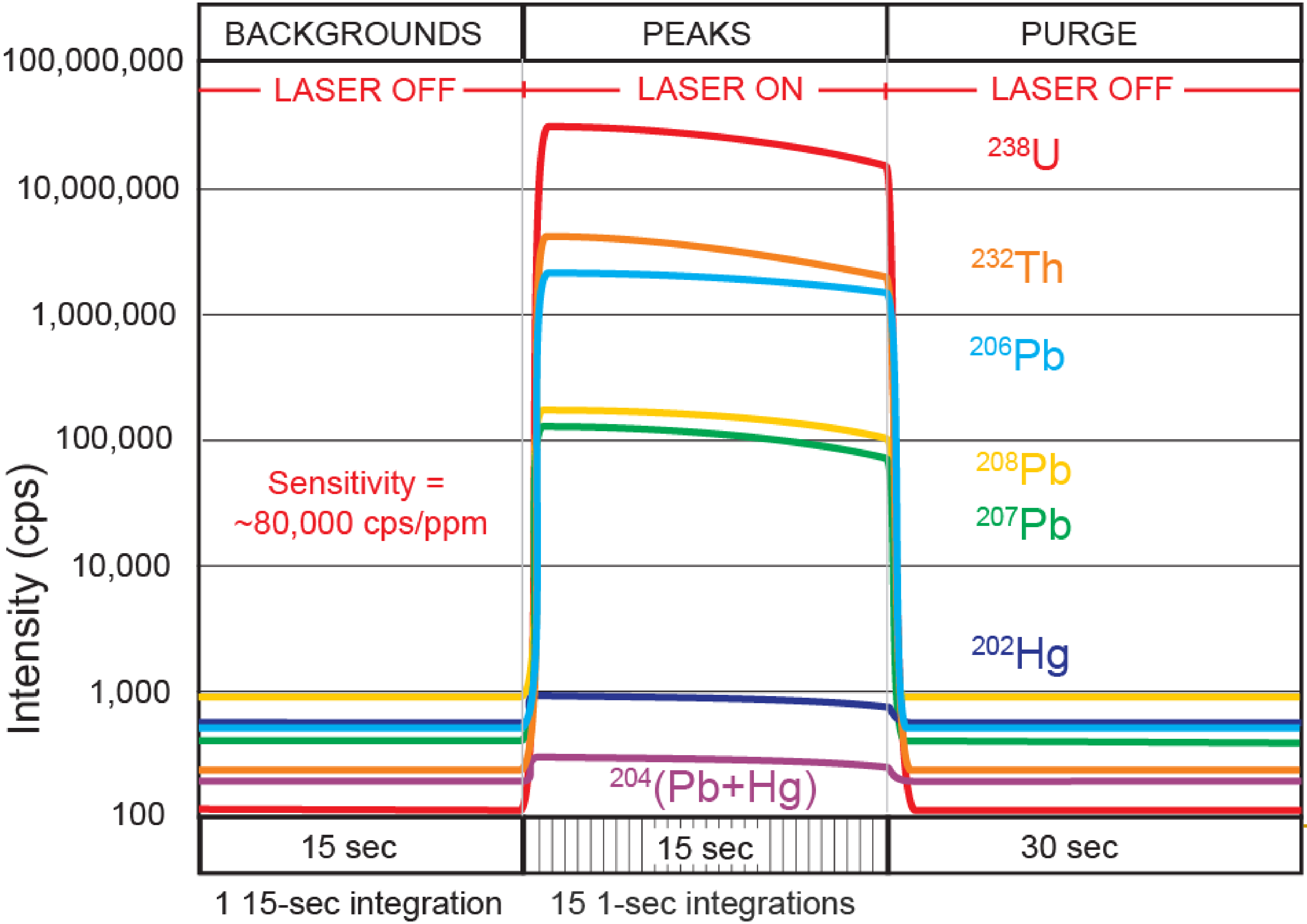




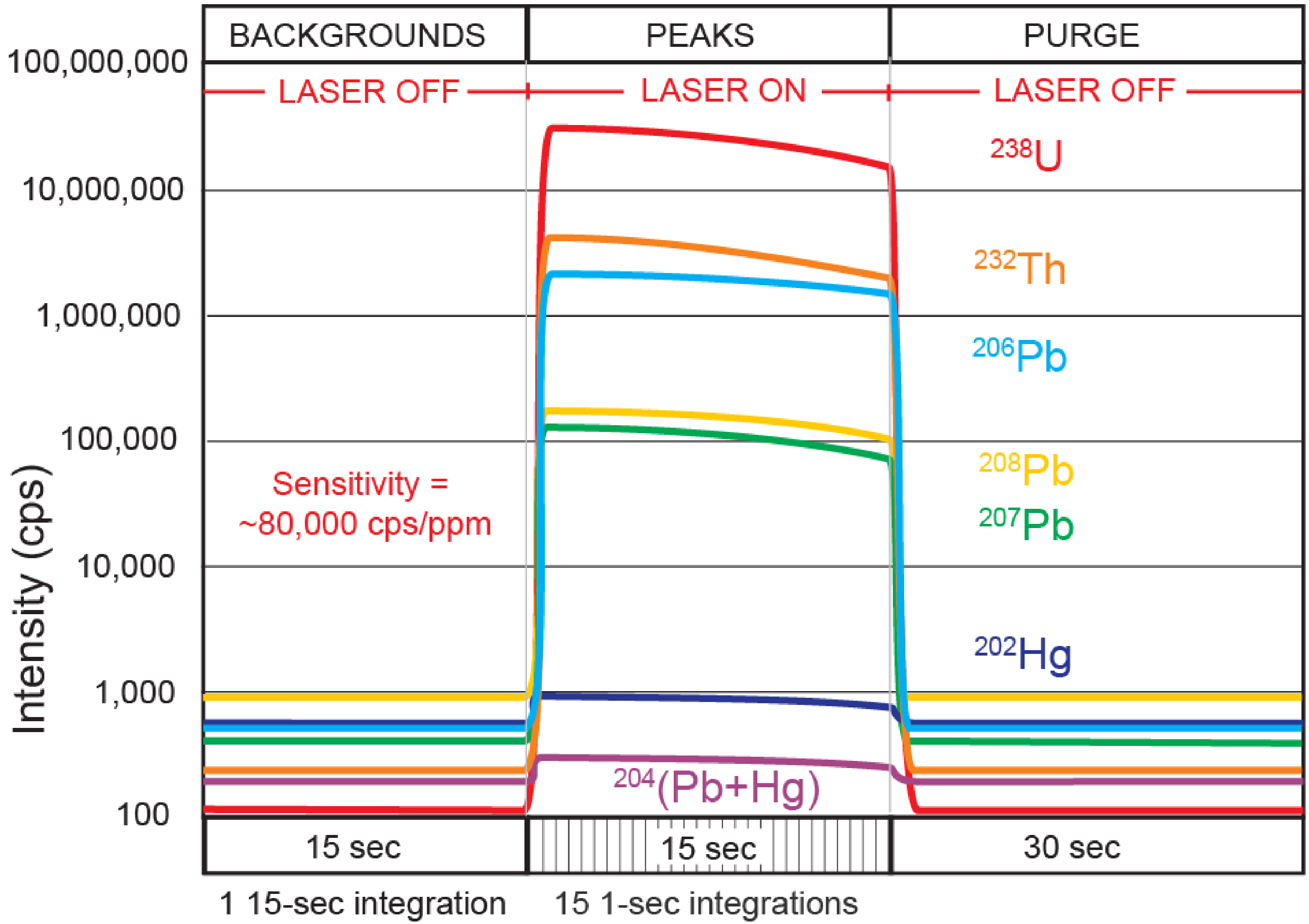
Secondary standard = R33
419.3 ± 0.4 Ma (ID-TIMS)
420.5 ± 0.2 Ma (CA-TIMS)

15 sec backgrounds
15 sec laser firing (1-sec integration)
30 sec purge

30 micron diam
15 micron depth



1. Background Subtraction



Background = a single integration, so no uncertainty propagated

2. Hg Correction:

Faradays with $3x10^{11}$ ohm resistors												Discrete dynode ion counters			
Ex-Hi	H2	H1	Ax	L1	L2	L3	L4	L5	L6	L7	L8	IC0	IC1	IC2	IC3
^{238}U	^{232}Th								^{208}Pb	^{207}Pb	^{206}Pb	^{204}Pb		^{202}Pb	

^{204}Pb (cps) = 204 (cps) – ^{202}Hg (cps) / 4.34

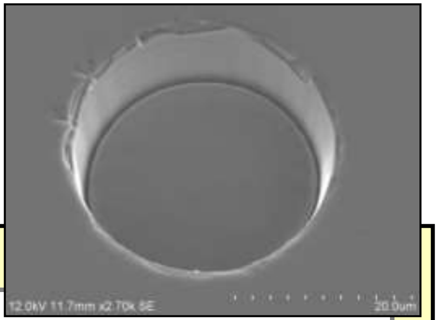
4.34 = natural 202/204

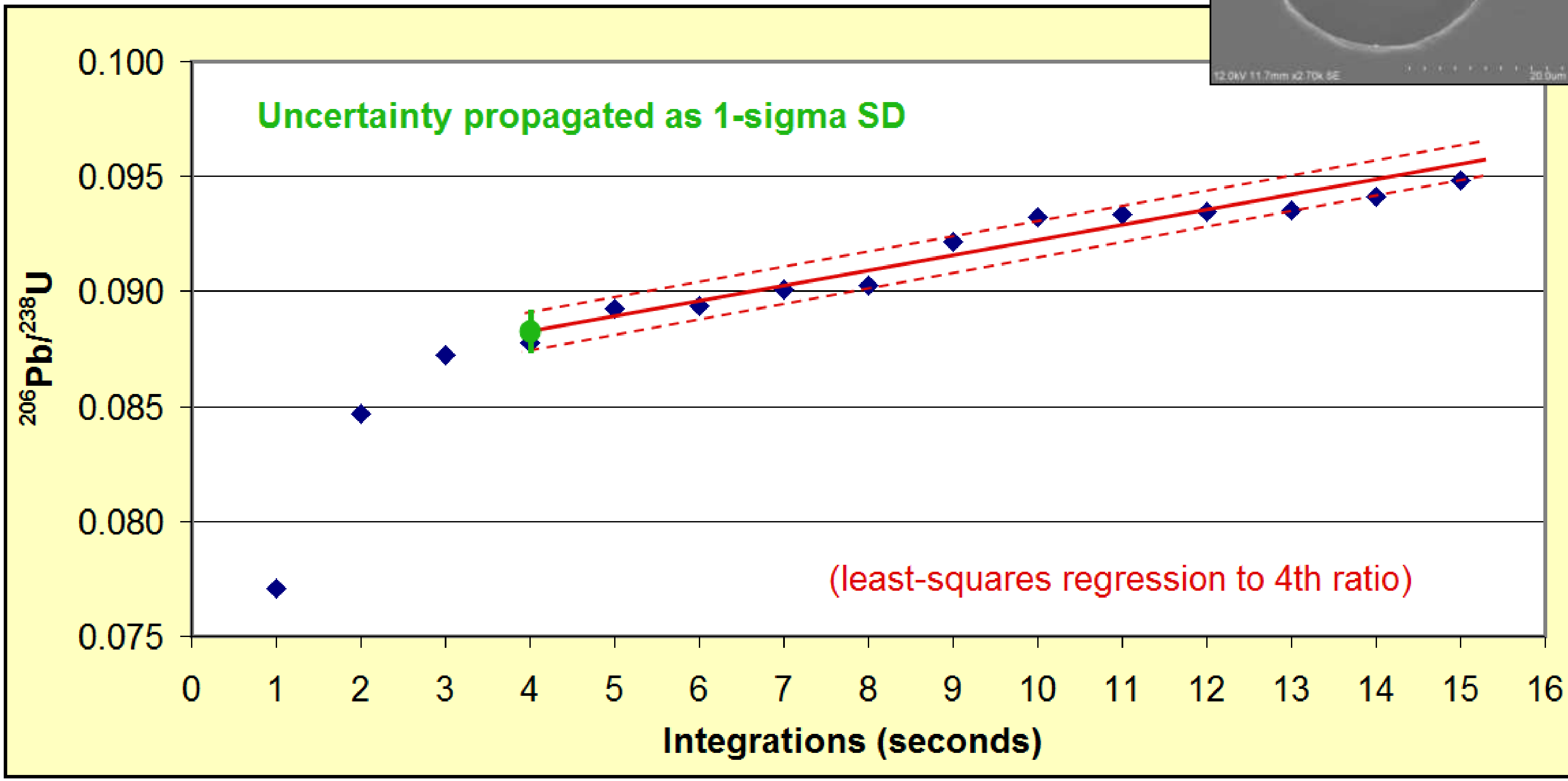
(no measurable difference in He cylinders)

(not significant so long as ^{204}Hg is low)

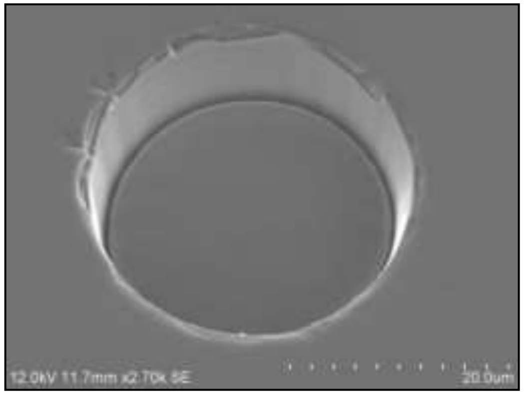
Uncertainty of 202/204 not propagated

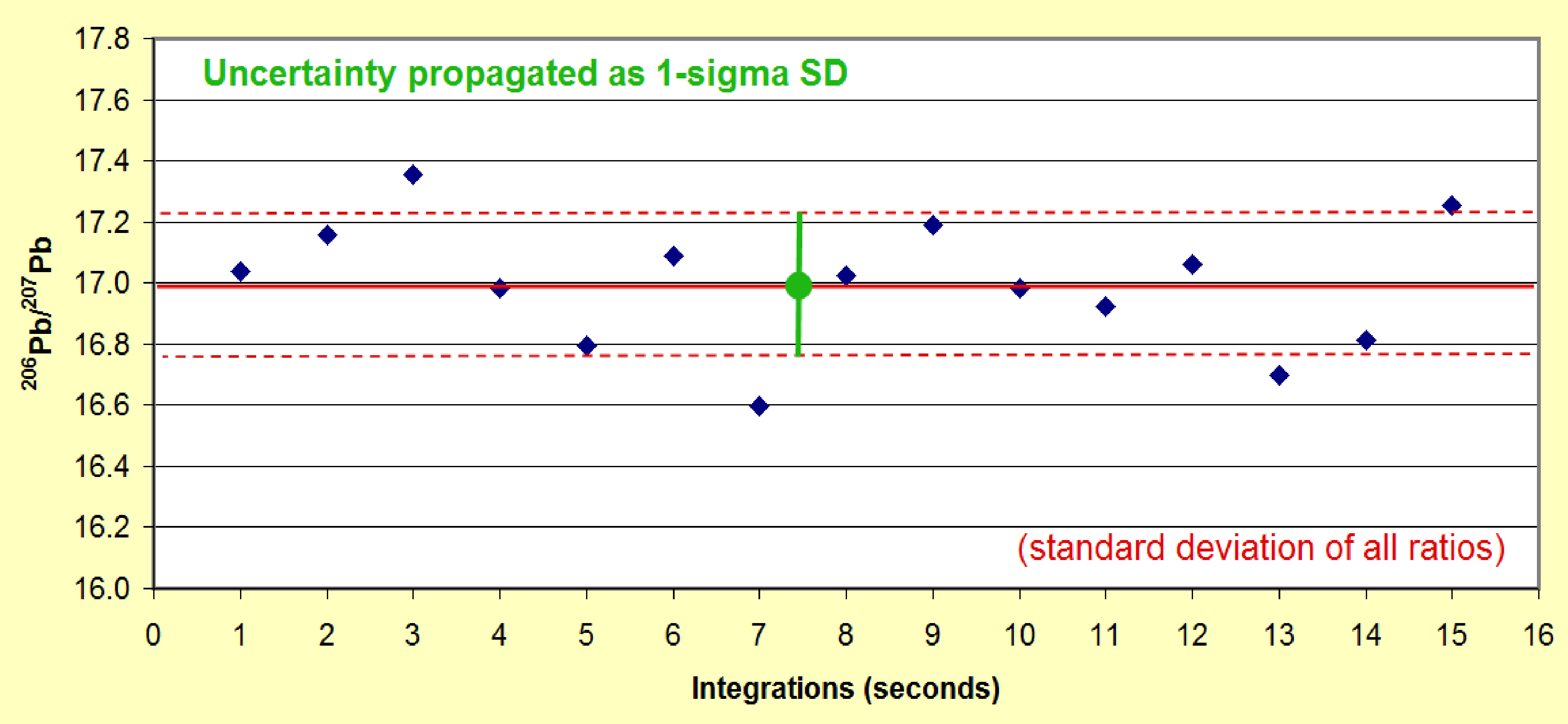
3. Mean & Std Dev of 206/238 & 208/232
➔ must correct for down-hole fractionation





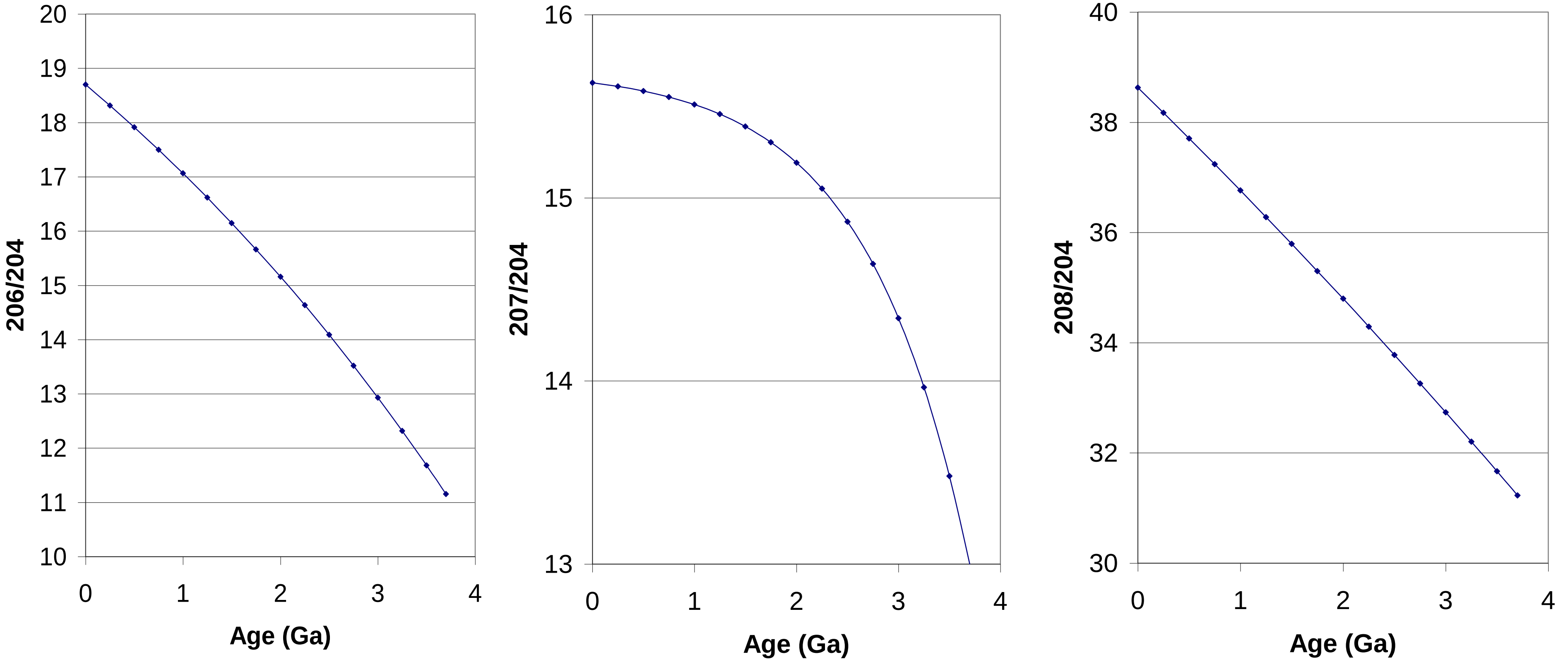
4. Mean & Std Dev of 206/207 & 206/204
➔ no down-hole fractionation





5. Common Pb Correction (using 204)

1. Calculate preliminary age from measured 206/238
2. Use age to calculate common Pb composition (Stacey-Kramers model)
3. Use common Pb composition to correct 206/238, 208/232, & 206/207



Slight improvement if age calculation is iterative
Better to use both 206/238 & 206/207 ages (if discordant)

6. Uncertainty of Common Pb Correction

1. Use variations in modern common Pb to determine ranges of S-K 206/238, 208/232, 206/207

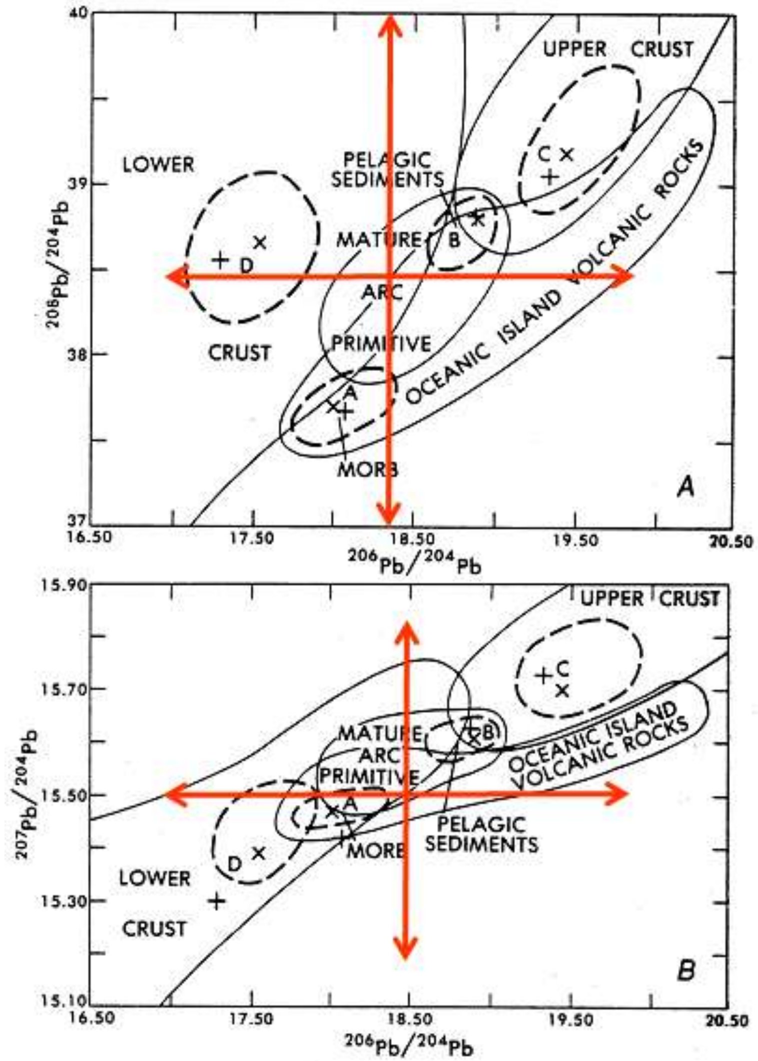
2. Propagate Hi & Lo values through age equation and monitor resulting age variation

3. Assign resulting age variation (in %) to external uncertainty

$$206_{I}/204 = 18.6 \pm 1.5$$

$$207_{I}/204 = 15.6 \pm 0.3$$

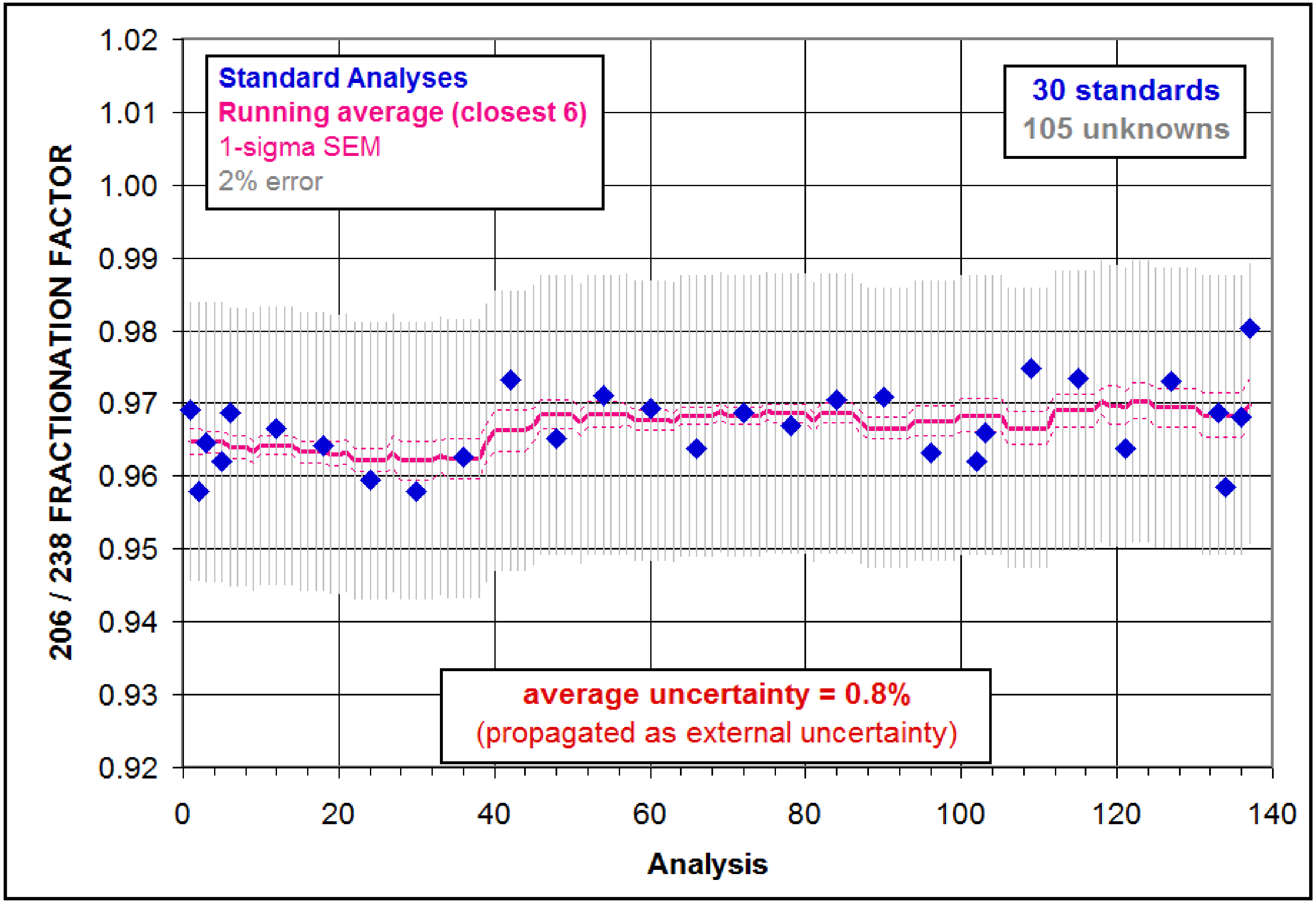
$$208_{I}/204 = 38.5 \pm 1.5$$



Zartman & Doe "plumbotectonics" (1981)

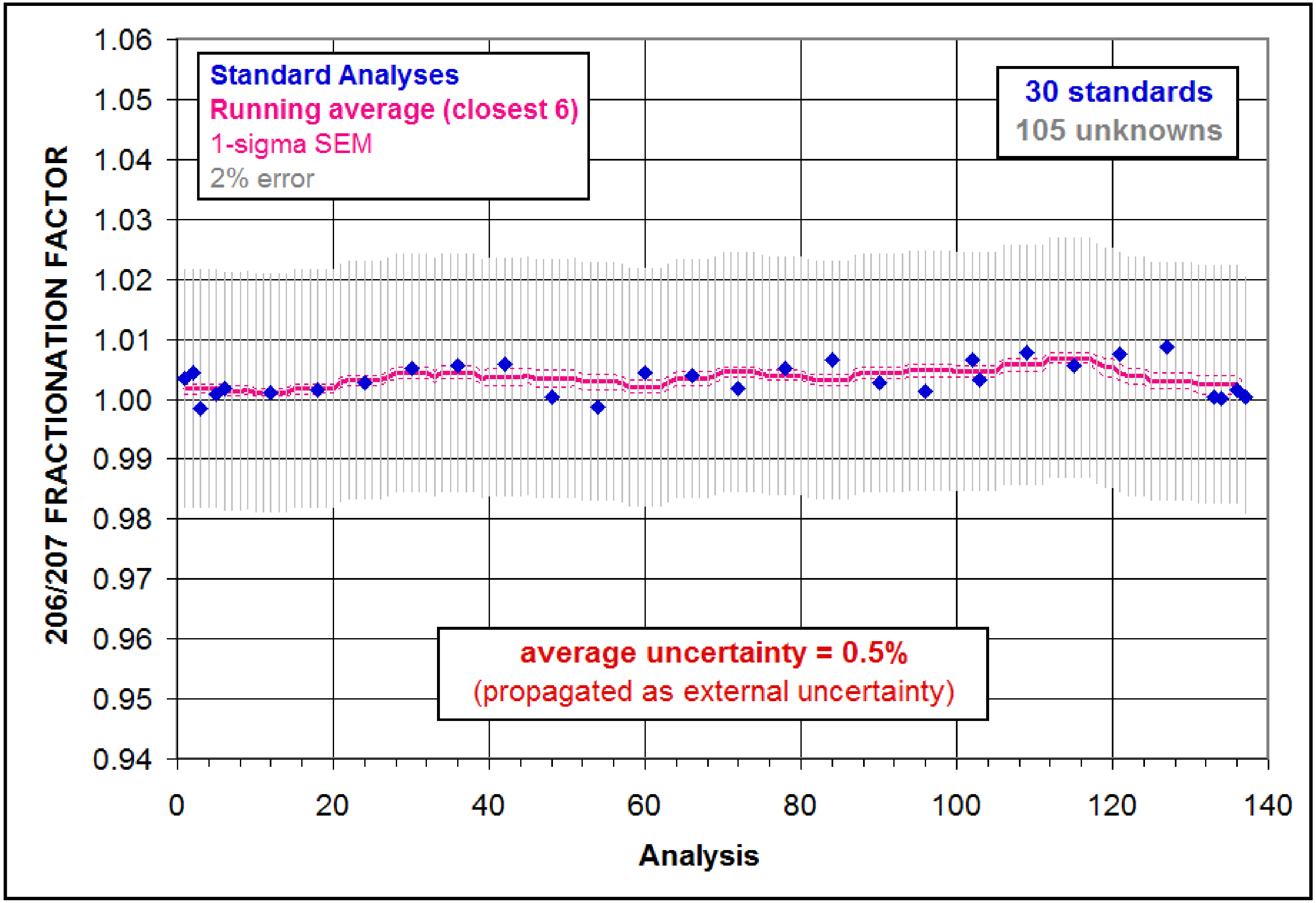
Uncertainty is not entirely external, as depends on value of measured 206/204

7. Fractionation Correction: 206/238



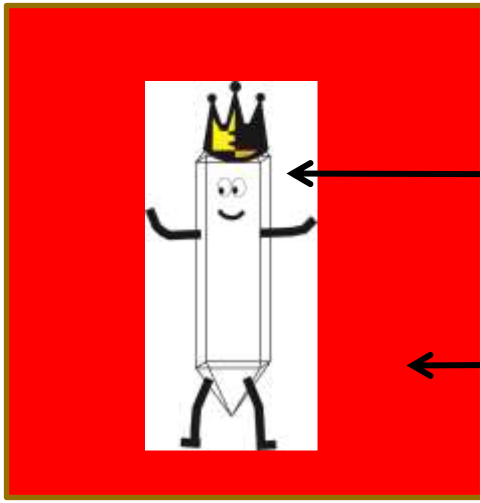
- Each unknown (gray bar) corrected for local (SW) average
- Average uncertainty = main contribution to external error

8. Fractionation Correction: 206/207



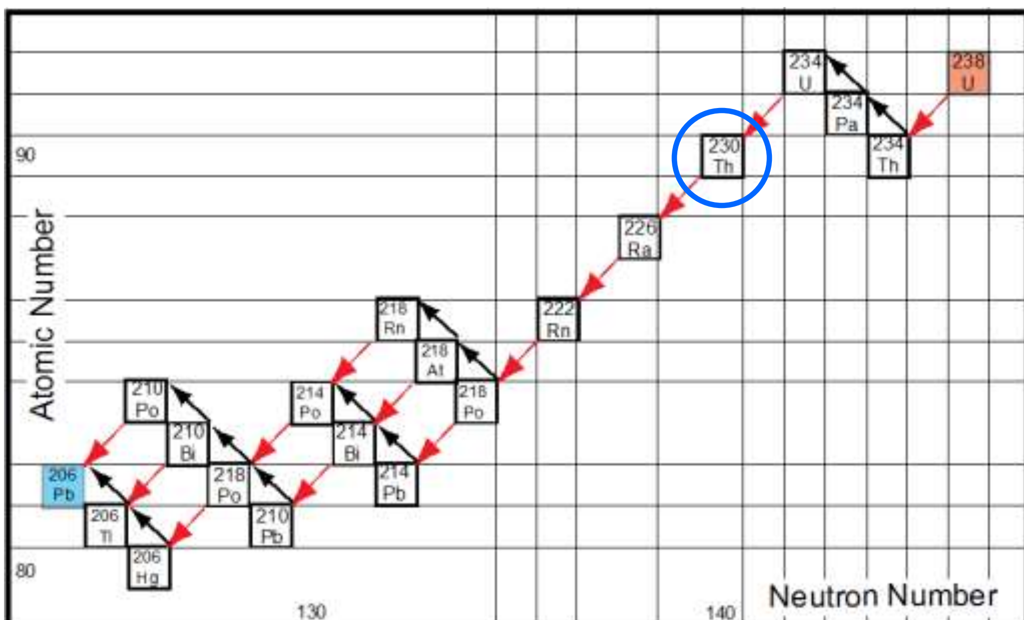
- Each unknown (gray bar) corrected for local average
- Average uncertainty = main contribution to as external error

9. Disequilibrium correction for 206/238 (excess Th in magma)



Zircon = Lo Th

Magma = Hi Th
Small amount is ^{230}Th
➔ excess 206 in zircon



$$206^*/238_{dc} = 206^*/238 - [(\lambda^{238} / \lambda^{230}) \times (Th/U)_m / 2.3 - 1]$$

assumed Th/U of magma

- Important for < 2 Ma
- Disappears > 10 Ma

Uncertainty of 2.3 not propagated

10. Calculate ages & uncertainties

INTERNAL UNCERTAINTIES (apply to single analyses)

- $^{206}Pb/^{238}U$ ages => uncertainty of measured $^{206}Pb/^{238}U$ & $^{206}Pb/^{204}Pb$
- $^{206}Pb/^{207}Pb$ ages => uncertainty of measured $^{206}Pb/^{207}Pb$ & $^{206}Pb/^{204}Pb$

(Contributions added quadratically to determine final uncertainty)

EXTERNAL UNCERTAINTIES (apply to multiple analyses)

- Uncertainty from fractionation correction of standard
- Uncertainty in age of standard
- Uncertainty from propagation of common Pb composition
- Uncertainty in decay constants for ^{238}U and ^{235}U

(Contributions added quadratically to determine final uncertainty)

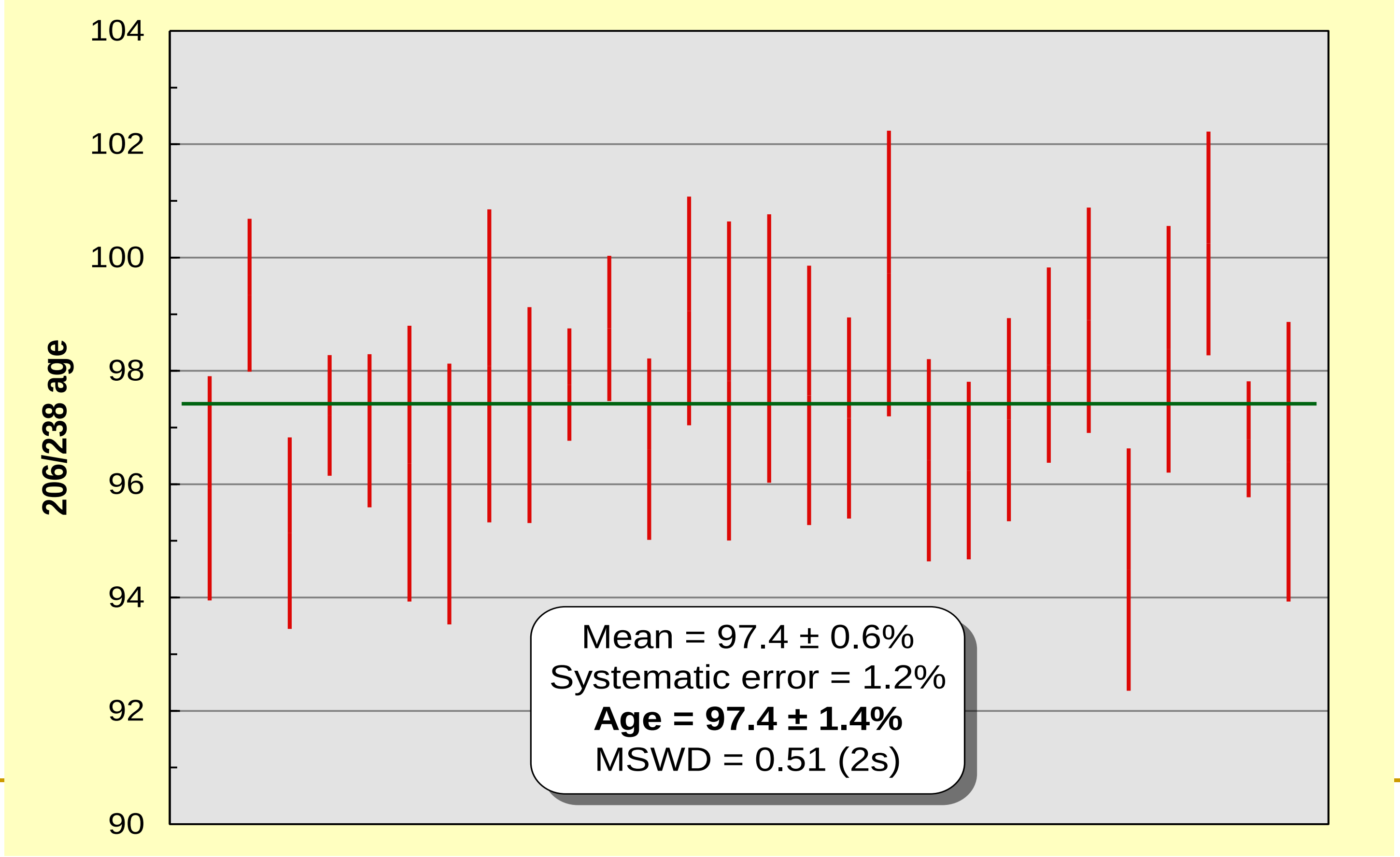
Individual analyses: assigned only internal uncertainties.

Sets of analyses (e.g., weighted mean): External uncertainty added quadratically to weighted mean uncertainty (not to individual analyses)

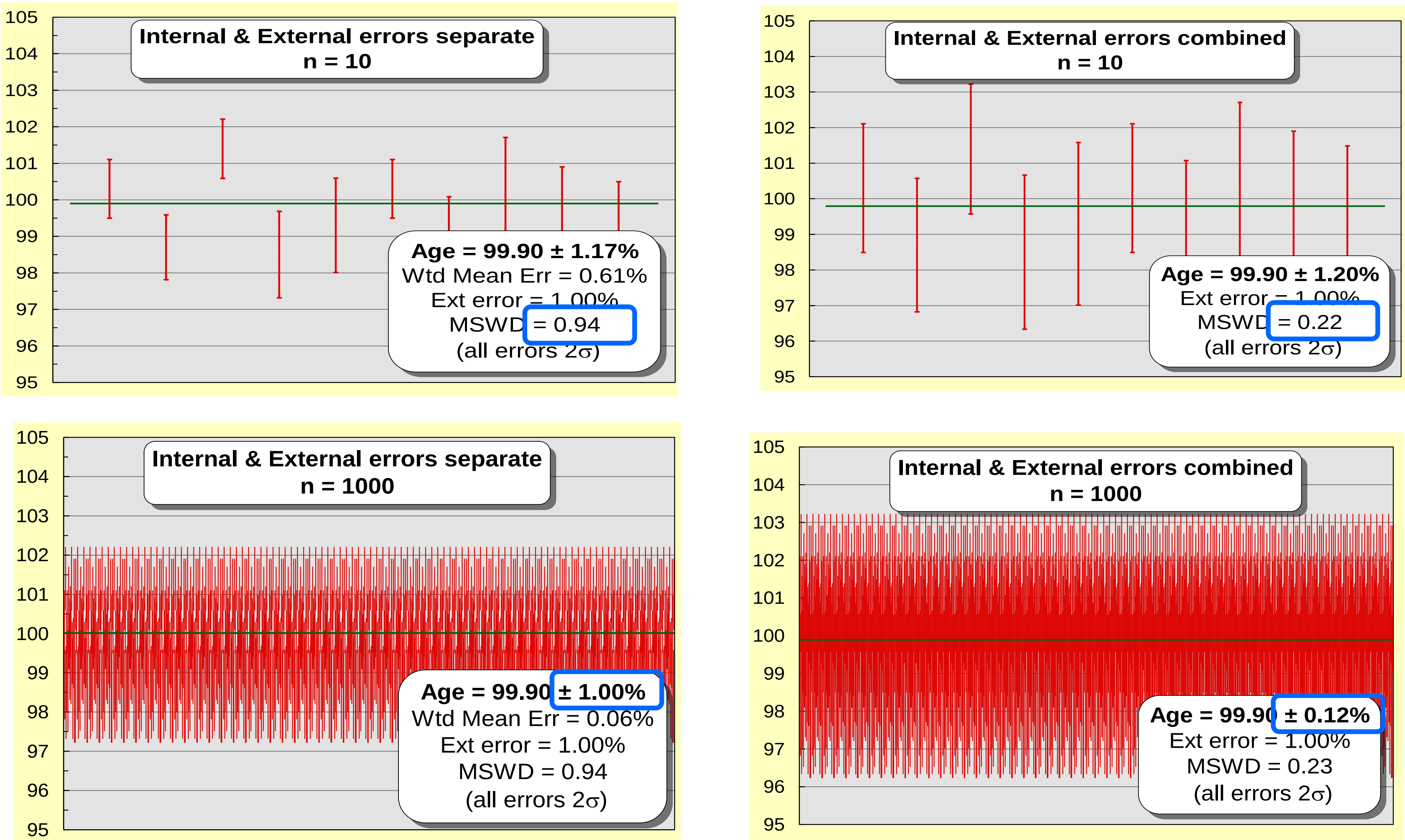
10. Calculate ages & uncertainties

Individual analyses: assigned only internal uncertainties.

Sets of analyses (e.g., weighted mean): External uncertainty added quadratically to weighted mean uncertainty (not to individual analyses)



Separation of Internal & External uncertainties – essential!



11. Filtering data

Automatic filters for:

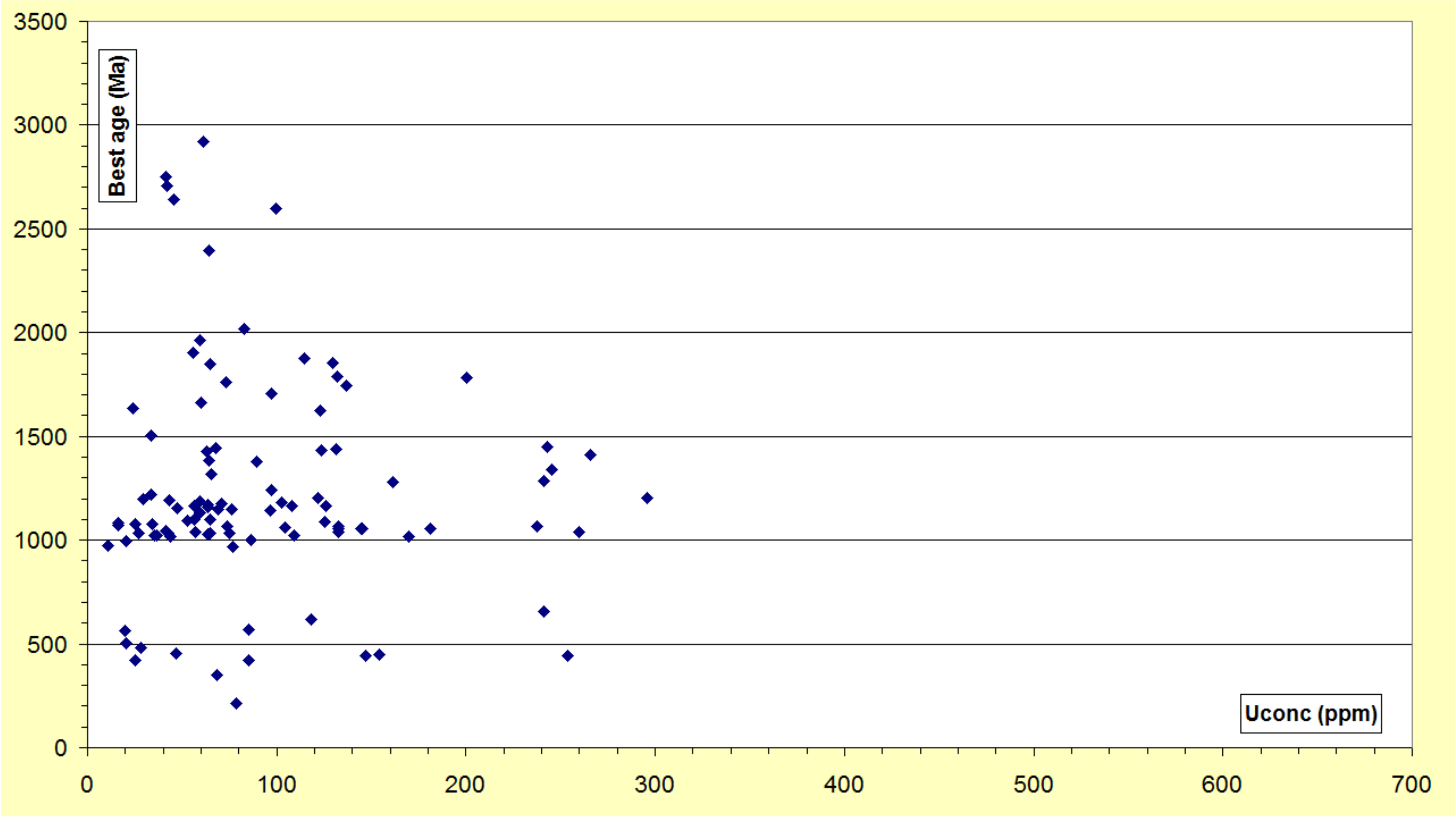
- High 204 counts (default = 500 cps)
- High 202 counts (default = 2000 cps)
- Discordance (default = 20%)
- Reverse Discordance (default = 5%)
- High 206/238 uncertainty (default = 10%)
- High 208/232 uncertainty (default = 10%)
- High 206/207 uncertainty (default = 10%)

All filter settings are adjustable

Filtered analyses rejected unless intentionally accepted

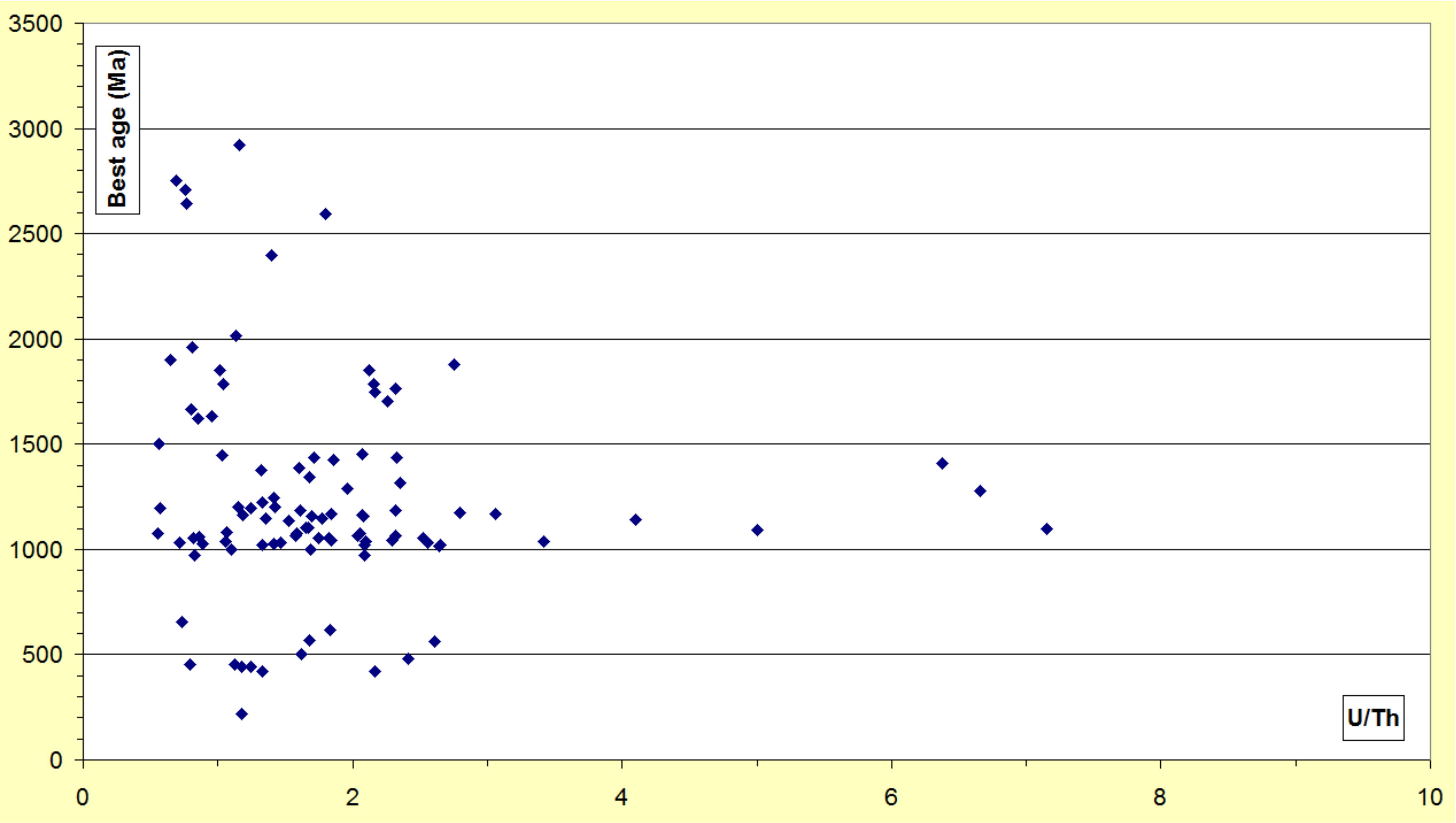
Would be nice if all filters were graphical

Tools for data interpretation – age vs Uconc



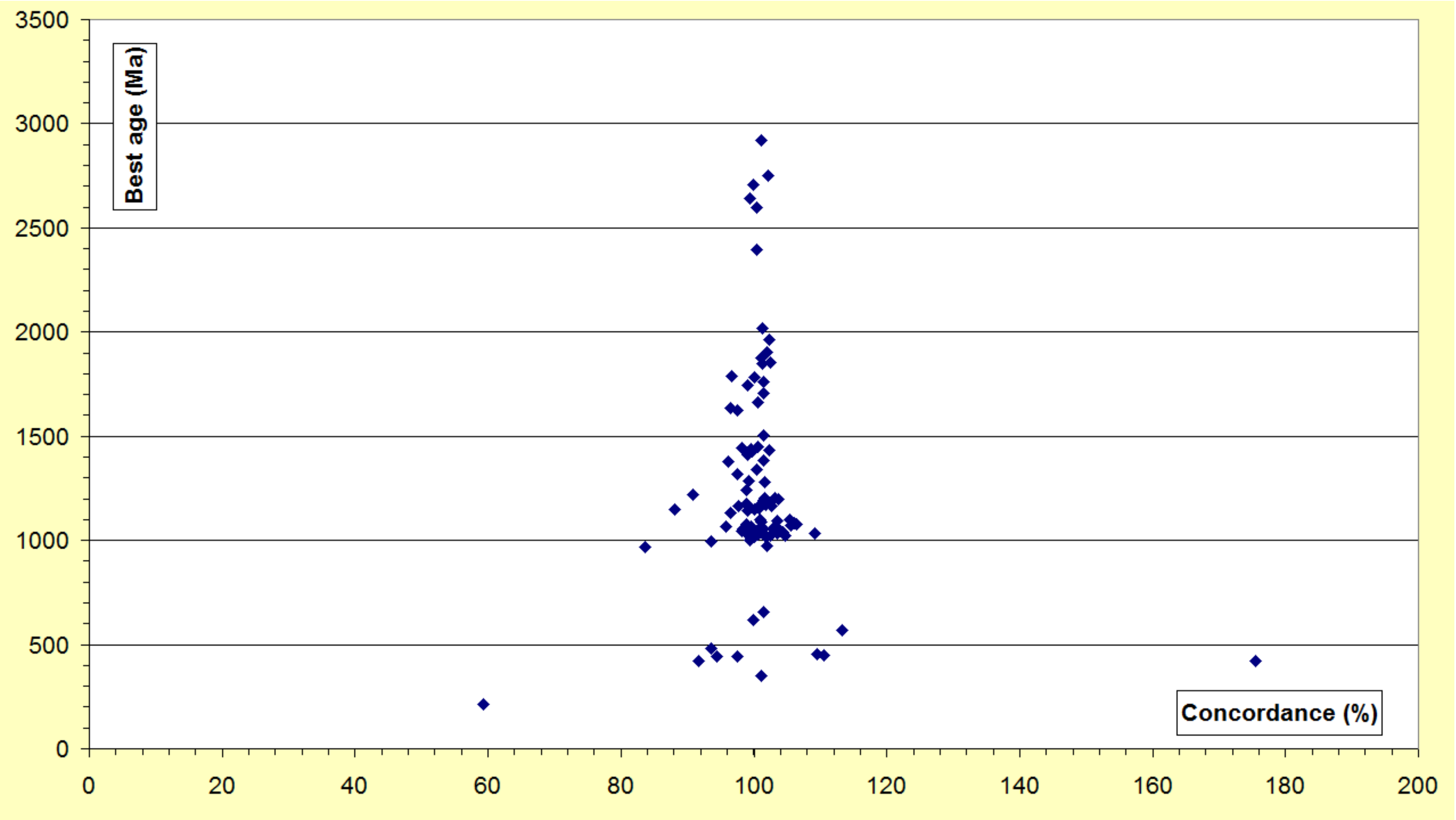
Helps identify Pb loss (common with Uconc >500 ppm)

Tools for data interpretation – age vs U/Th



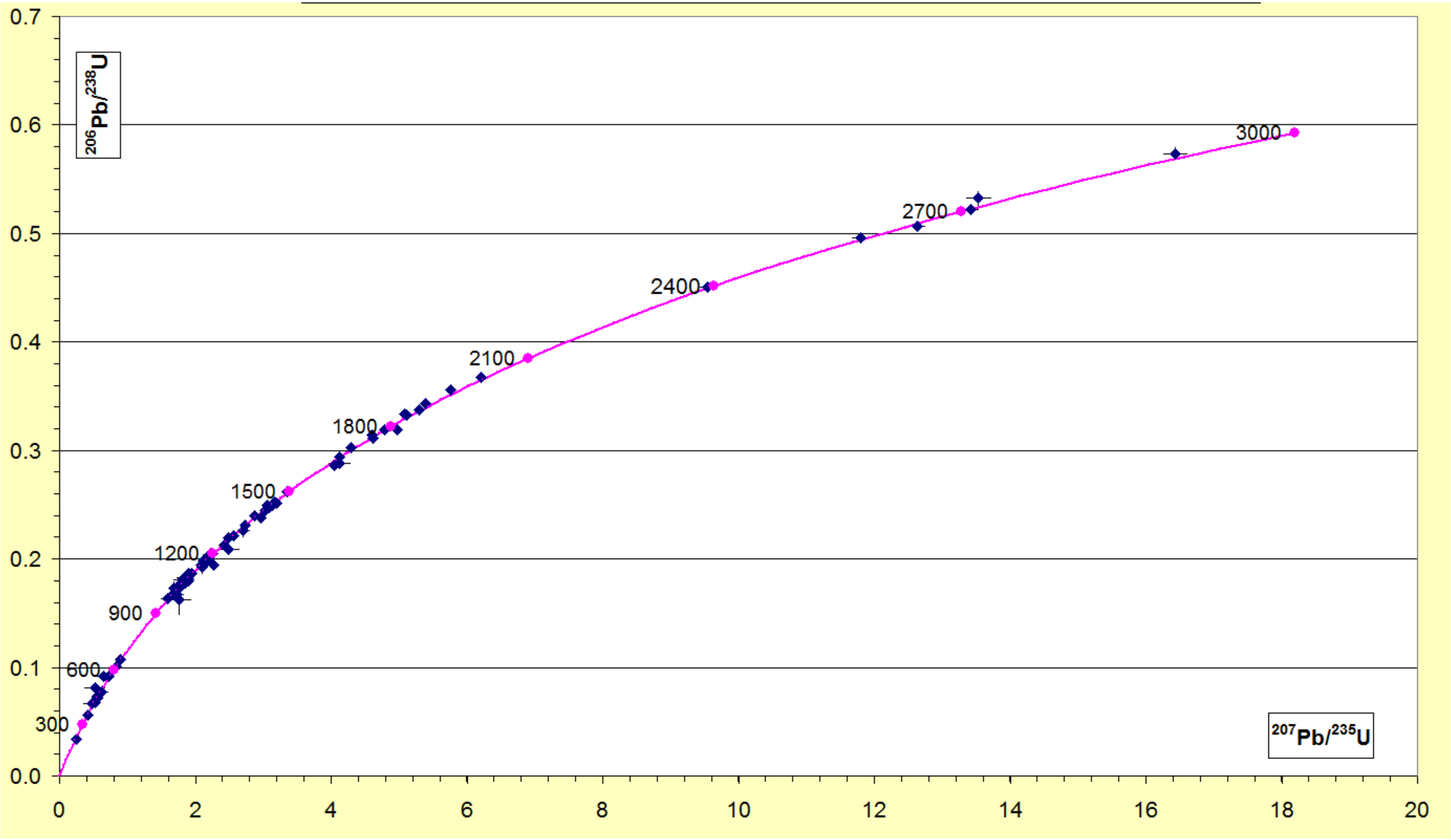
Helps identify igneous versus metamorphic zircon (igneous < ~5 > metamorphic)

Tools for data interpretation – age vs concordance



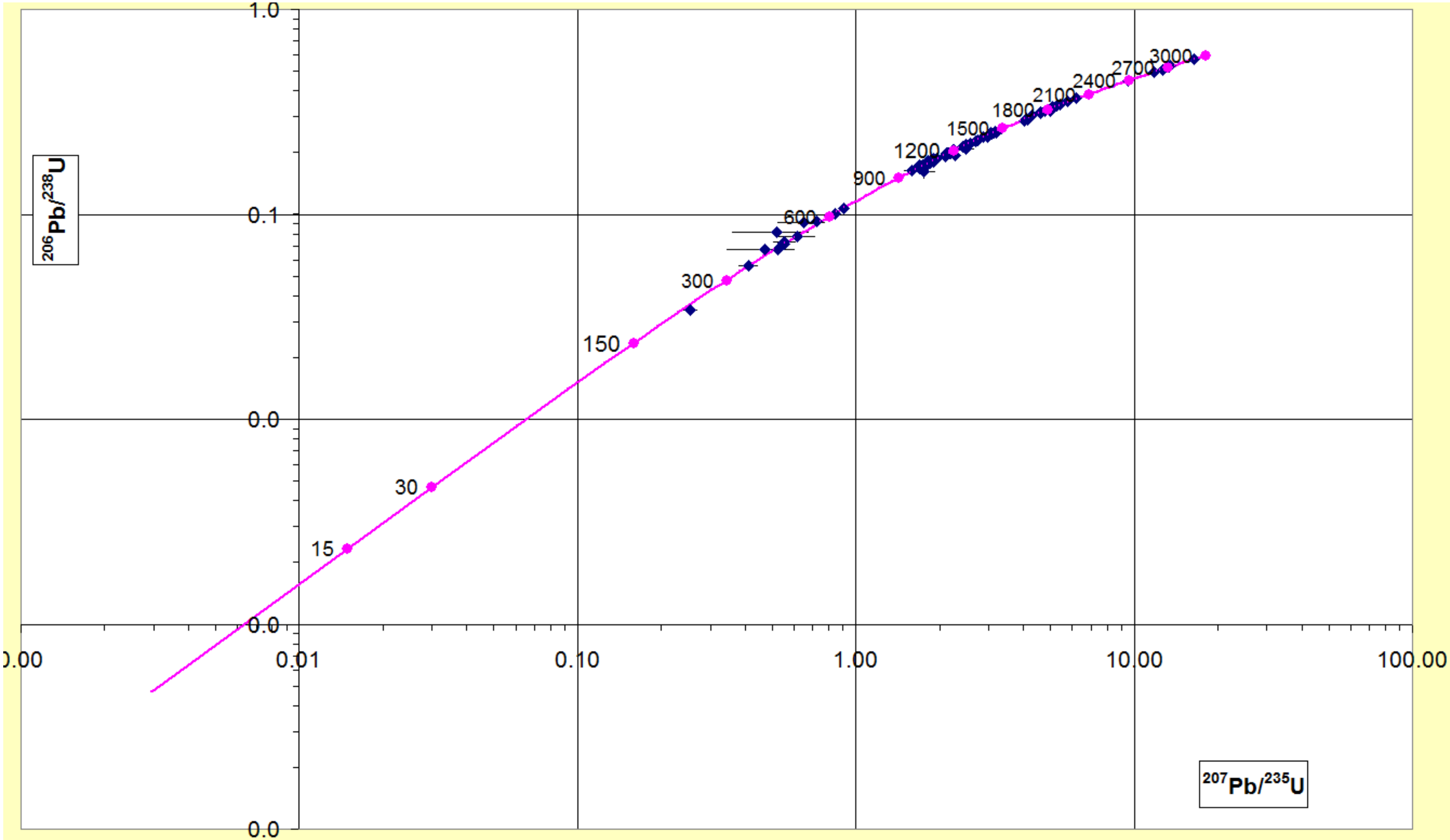
Helps identify discordance patterns

Tools for data interpretation – concordia diagram



Helps evaluate discordance & precision

Tools for data interpretation – log-scale concordia diagram



Helps evaluate young analyses

Publication-ready data table of acceptable analyses

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
4	Analysis	U	206Pb	U/Th	206Pb*	±	207Pb*	±	206Pb*	±	error	206Pb*	±	207Pb*	±	206Pb*	±	Best age	±	Conc
5		(ppm)	204Pb		207Pb*	(%)	235U*	(%)	238U	(%)	corr.	238U*	(Ma)	235U	(Ma)	207Pb*	(Ma)	(Ma)	(Ma)	(%)
7																				
8																				
9	XOMAOS25-1	68	44378	1.0	10.8528	1.2	3.1911	1.6	0.2512	1.1	0.67	1444.6	14.0	1455.0	12.5	1470.3	23.0	1470.3	23.0	98.2
10	XOMAOS25-2	89	85359	1.3	11.0847	0.7	2.9600	1.5	0.2380	1.3	0.87	1376.1	16.2	1397.4	11.4	1430.1	14.2	1430.1	14.2	96.2
11	XOMAOS25-3	131	114803	1.7	10.9960	0.7	3.1337	1.3	0.2499	1.1	0.82	1438.0	13.9	1441.0	10.0	1445.4	14.1	1445.4	14.1	99.5
12	XOMAOS25-4	41	34546	1.8	13.3667	2.1	1.8127	2.6	0.1757	1.5	0.58	1043.6	14.3	1050.0	16.7	1063.5	41.9	1063.5	41.9	98.1
13	XOMAOS25-5	20	10050	1.6	21.6498	30.8	0.5181	31.0	0.0813	3.8	0.12	504.2	18.5	423.9	107.8	7.5	756.0	504.2	18.5	67.6
14	XOMAOS25-6	45	95580	0.8	5.5313	0.5	12.6299	1.1	0.5067	0.9	0.87	2642.4	20.2	2652.4	10.0	2660.1	8.5	2660.1	8.5	99.3
15	XOMAOS25-7	126	109727	3.1	12.7471	0.8	2.1451	1.3	0.1983	1.0	0.80	1166.3	10.7	1163.5	8.7	1158.3	15.1	1158.3	15.1	100.7
16	XOMAOS25-8	59	33193	1.5	12.6419	1.8	2.0965	4.0	0.1922	3.6	0.90	1133.4	37.8	1147.7	27.8	1174.7	34.7	1174.7	34.7	96.5
17	XOMAOS25-9	74	90757	1.6	13.3186	2.3	1.8611	2.6	0.1798	1.2	0.47	1065.7	12.1	1067.4	17.2	1070.7	46.1	1070.7	46.1	99.5
18	XOMAOS25-12	181	57813	1.8	13.4089	0.7	1.8260	1.5	0.1776	1.3	0.90	1053.7	13.0	1054.8	9.8	1057.2	13.3	1057.2	13.3	99.7
19	XOMAOS25-13	76	62027	1.8	12.8344	1.7	2.0906	2.1	0.1946	1.3	0.60	1146.2	13.4	1145.7	14.6	1144.7	33.8	1144.7	33.8	100.1
20	XOMAOS25-14	35	17828	2.1	13.9582	4.0	1.6977	4.4	0.1719	1.7	0.39	1022.4	15.9	1007.7	27.9	975.8	82.0	975.8	82.0	104.8
21	XOMAOS25-16	243	363408	2.1	11.0140	0.3	3.1621	1.3	0.2526	1.3	0.98	1451.9	16.6	1448.0	10.1	1442.3	4.8	1442.3	4.8	100.7
22	XOMAOS25-17	161	72964	6.7	12.1275	1.0	2.4913	1.3	0.2191	0.9	0.65	1277.2	10.0	1269.5	9.6	1256.4	19.5	1256.4	19.5	101.7
23	XOMAOS25-18	129	143978	2.1	9.0389	0.3	5.0812	0.7	0.3331	0.7	0.91	1853.4	10.6	1833.0	6.1	1809.8	5.5	1809.8	5.5	102.4
24	XOMAOS25-19	137	52494	2.2	9.2867	0.5	4.6162	1.1	0.3109	1.1	0.92	1745.2	16.1	1752.2	9.6	1760.5	8.3	1760.5	8.3	99.1
25	XOMAOS25-20	79	8700	1.2	18.5760	6.5	0.2529	7.1	0.0341	3.0	0.41	216.0	6.3	228.9	14.6	364.0	146.6	216.0	6.3	NA
26	XOMAOS25-21	147	70304	1.2	17.7171	2.7	0.5542	3.1	0.0712	1.4	0.46	443.5	6.1	447.8	11.1	469.8	60.4	443.5	6.1	94.4
27	XOMAOS25-22	109	94015	2.7	13.6241	0.7	1.7363	1.2	0.1716	1.0	0.84	1020.7	9.8	1022.1	8.0	1025.0	13.6	1025.0	13.6	99.6
28	XOMAOS25-23	33	36695	0.6	10.7921	1.8	3.3520	2.3	0.2624	1.5	0.64	1501.9	20.2	1493.3	18.3	1480.9	34.1	1480.9	34.1	101.4
29	XOMAOS25-24	61	103877	1.2	4.8126	0.3	16.4307	1.1	0.5735	1.1	0.97	2922.2	25.9	2902.2	10.9	2888.4	4.5	2888.4	4.5	101.2
30	XOMAOS25-25	132	52447	2.0	13.4277	1.0	1.8482	2.0	0.1800	1.8	0.86	1066.9	17.3	1062.8	13.5	1054.3	21.0	1054.3	21.0	101.2
31	XOMAOS25-26	56	19201	2.1	12.5338	3.0	2.1768	3.3	0.1979	1.2	0.38	1163.9	13.0	1173.6	22.6	1191.7	59.5	1191.7	59.5	97.7
32	XOMAOS25-27	97	65803	4.1	12.7753	0.7	2.0944	2.4	0.1941	2.3	0.95	1143.3	23.8	1147.0	16.4	1153.9	14.6	1153.9	14.6	99.1