Interpretation Limits

Significance of n (ages in cluster/population) and N (ages from sample)

Dealing with discordant data

Comparing age distributions from different samples

Grain complexities & portrayal of ages

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Significance of n (analyses in a cluster) and N (analyses from a sample)

Depends on objective of study:

- Provenance of clastic detritus
- Correlation of units
- Characterization of source area(s)

➔ Generate age distribution that accurately reflects ages in sample

- Recognition of specific age

➔ Identify specific age with greatest confidence

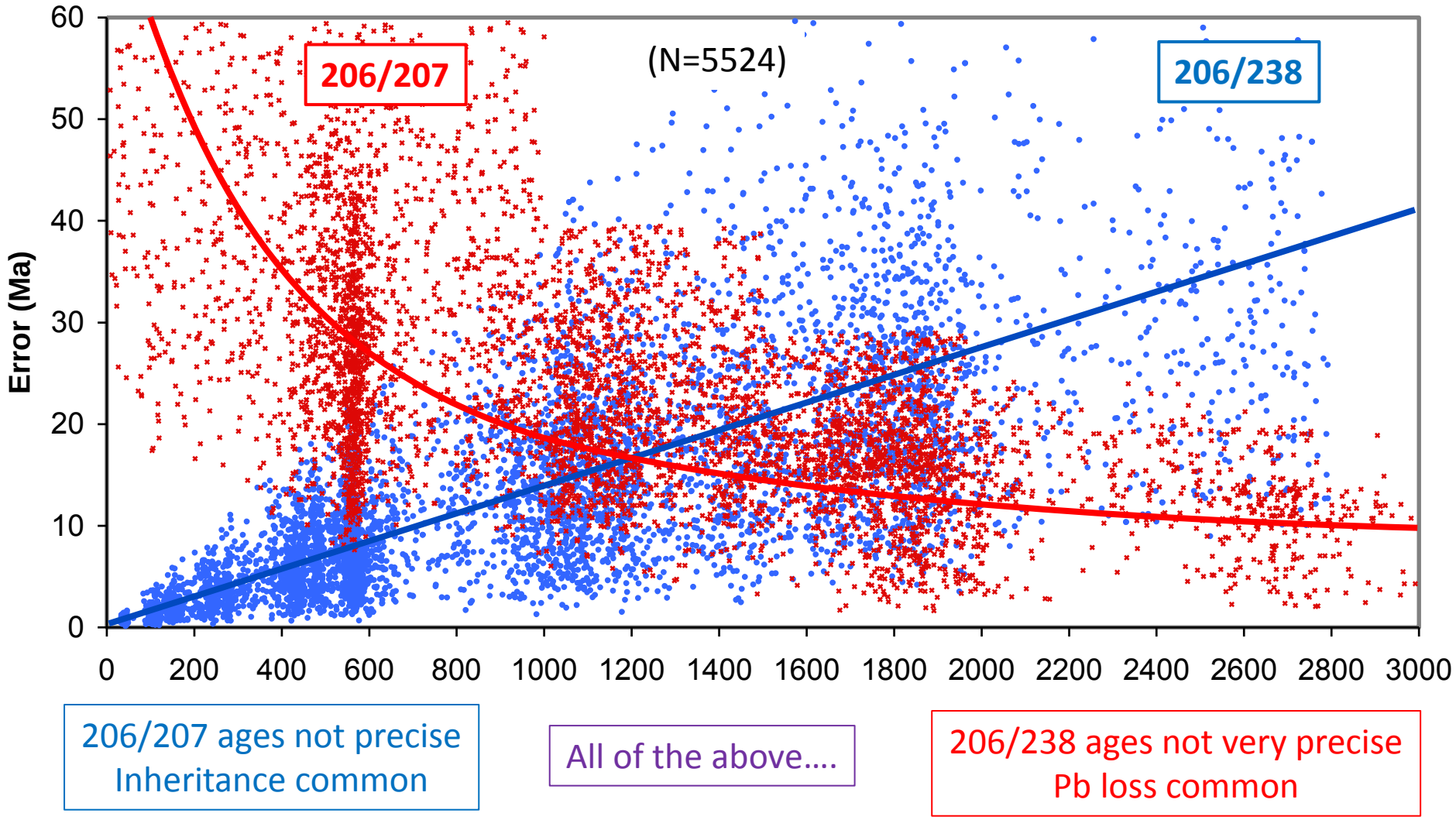
- Maximum Depositional Age

➔ Identify youngest age with greatest confidence

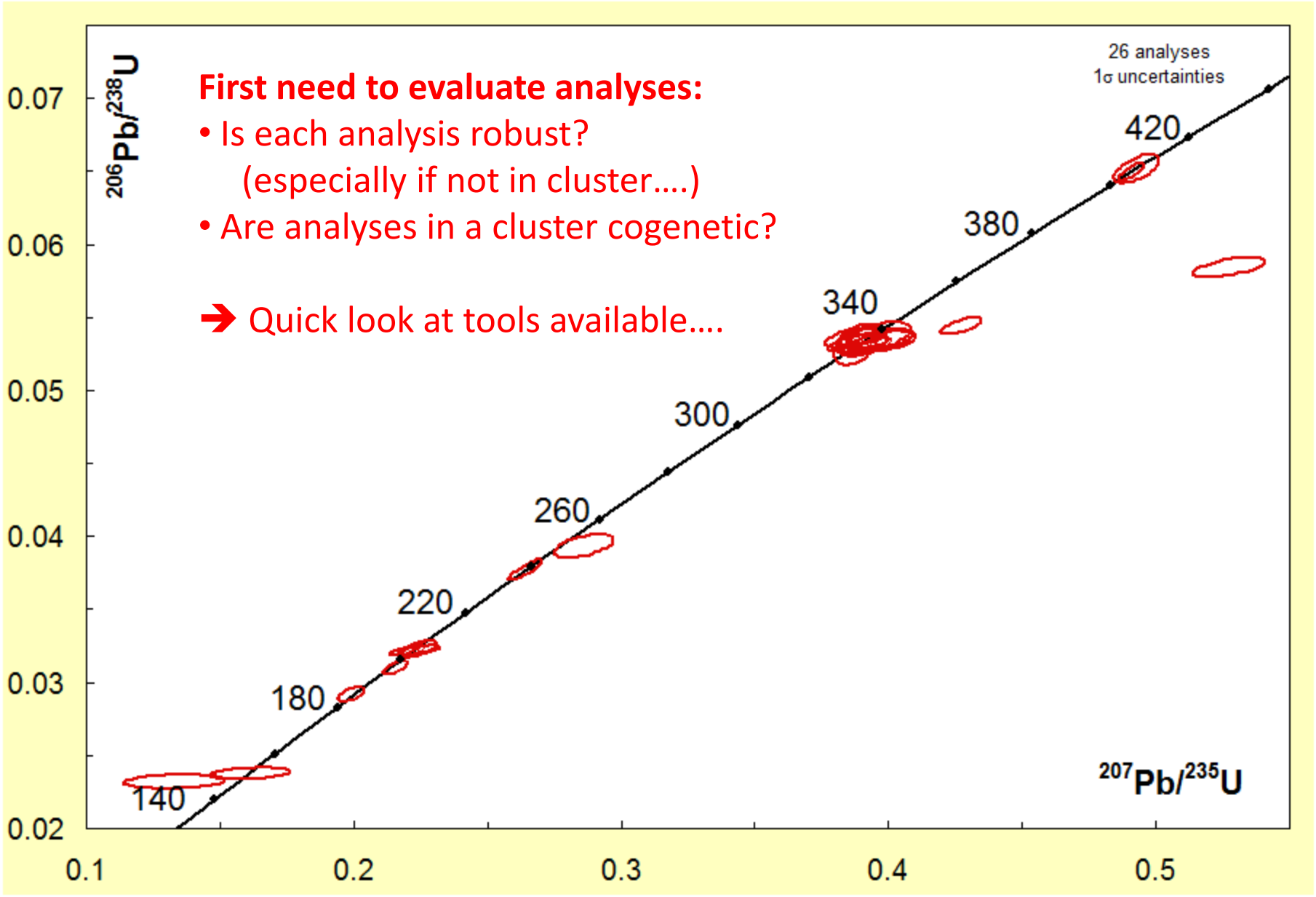
For all, Larger N ➔ larger n ➔ more robust conclusions

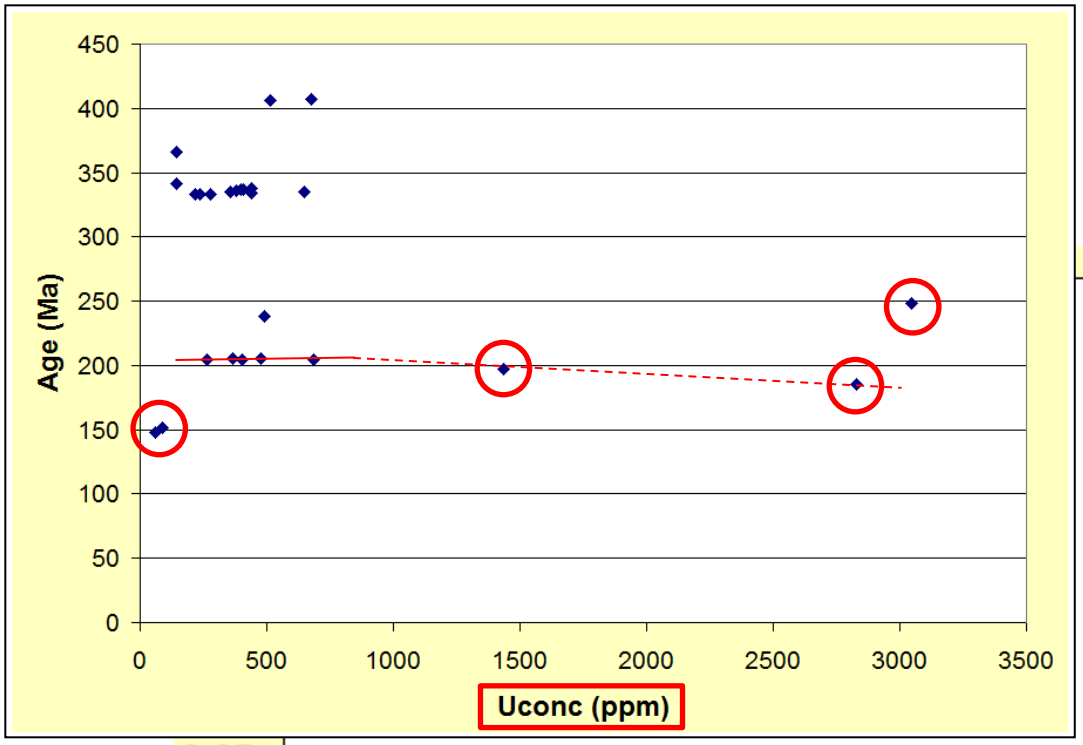
Depends on geological diversity of source areas and analytical complexities

Challenges and Strategies depend on age!


206/207
(N=5524)
206/238
Error (Ma)
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
206/207 ages not precise
Inheritance common
All of the above….
206/238 ages not very precise
Pb loss common

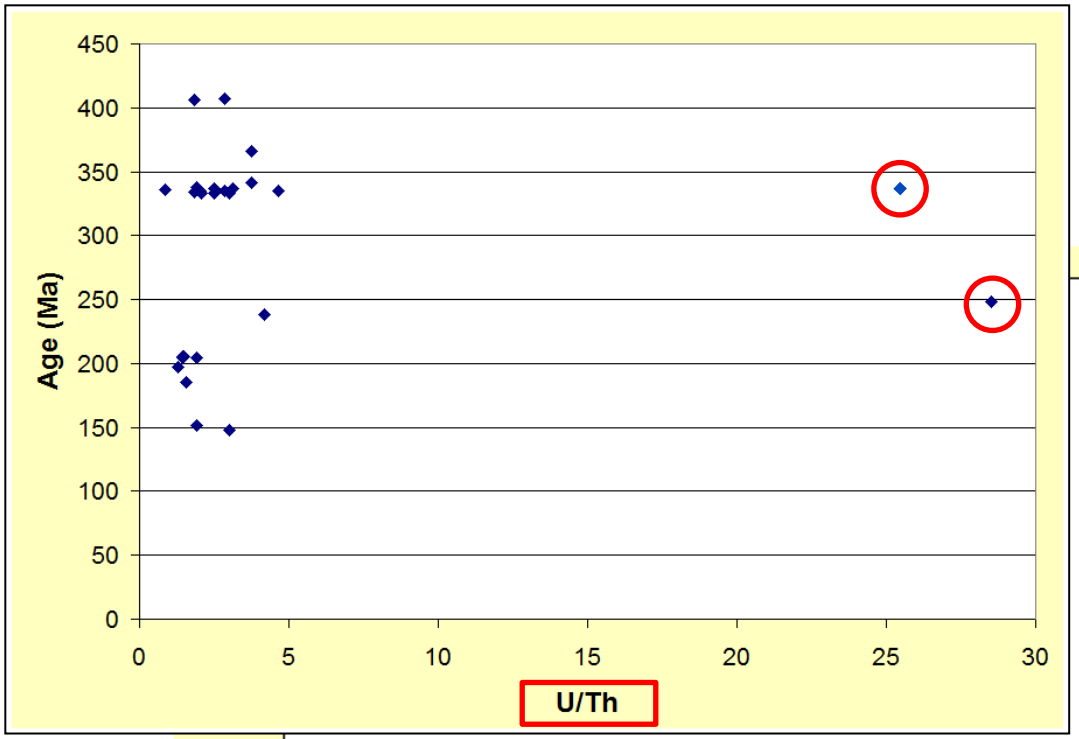
A young example…..





Uconc:

- Pb loss?
- Non-zircon?

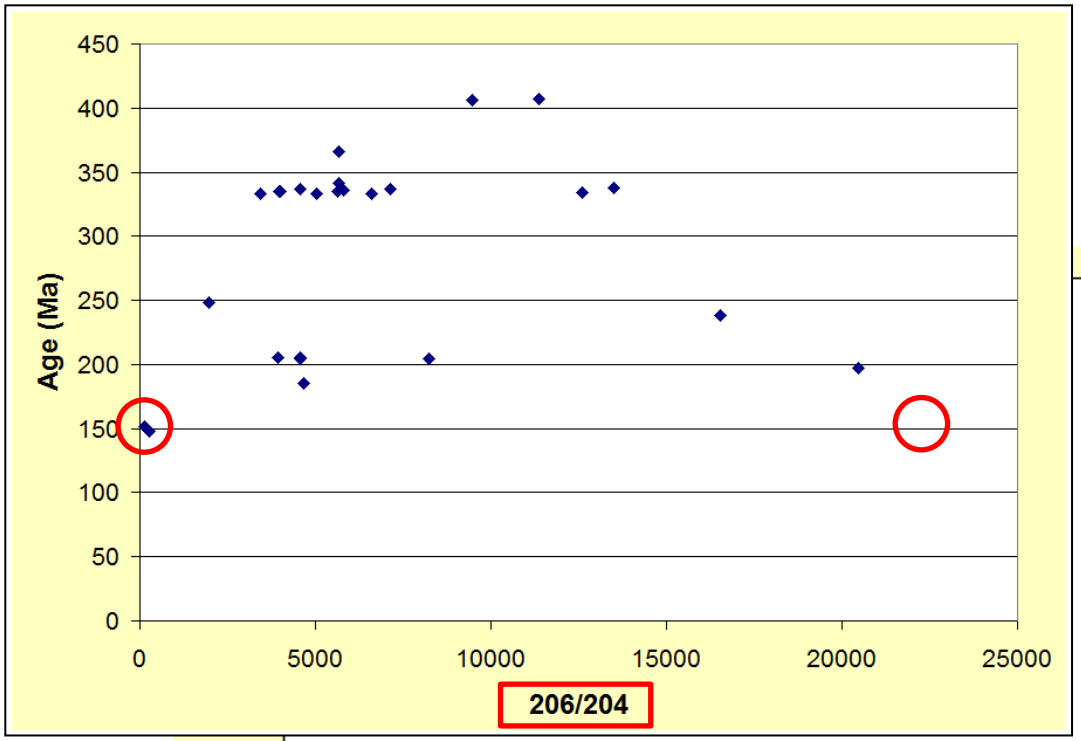


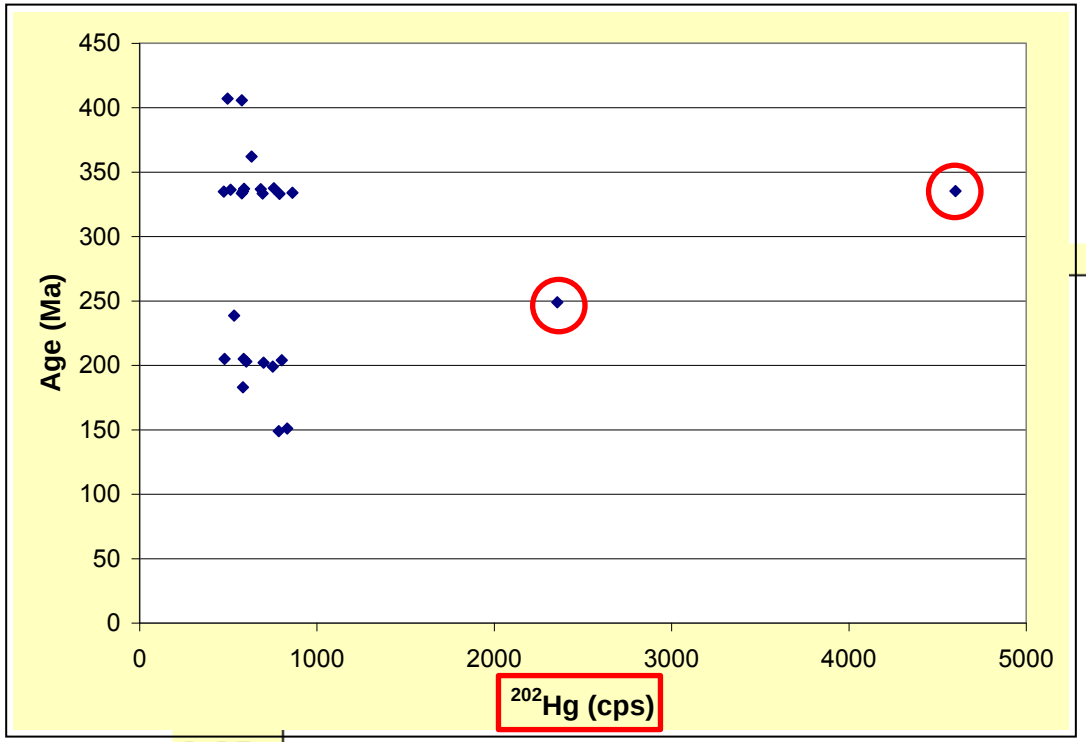
U/Th:

Petrogenesis?

Cogenetic?

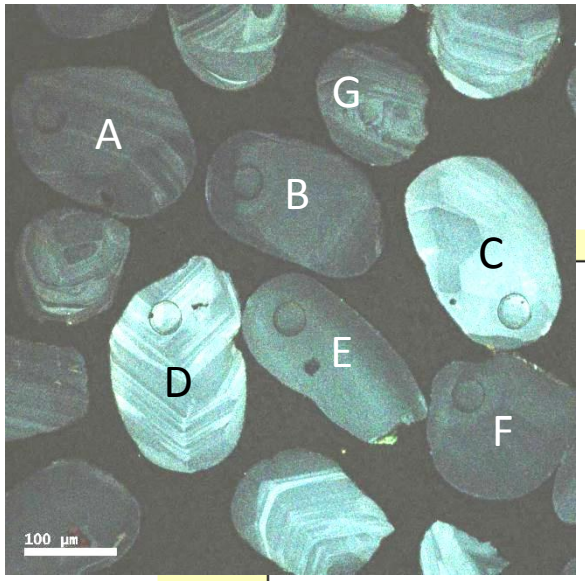
206/204:
Non-zircon?
Metamict?

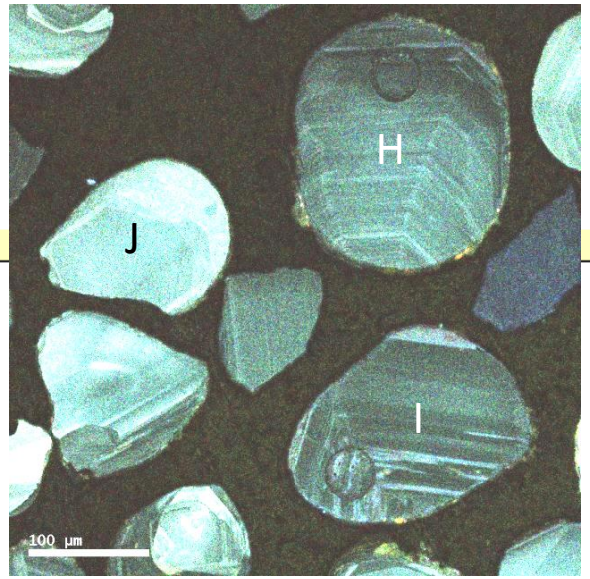




Hg abundance:

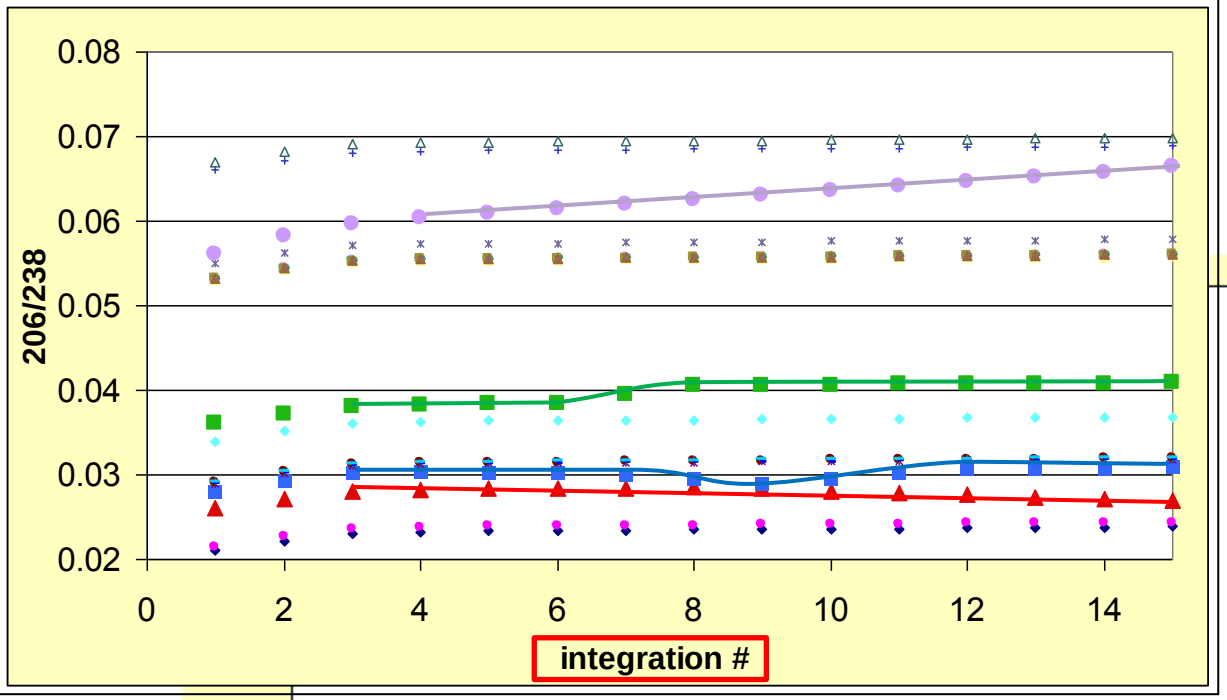
- Non-zircon?
- Analytical Issue?





CL Images:

Zonation → complexity

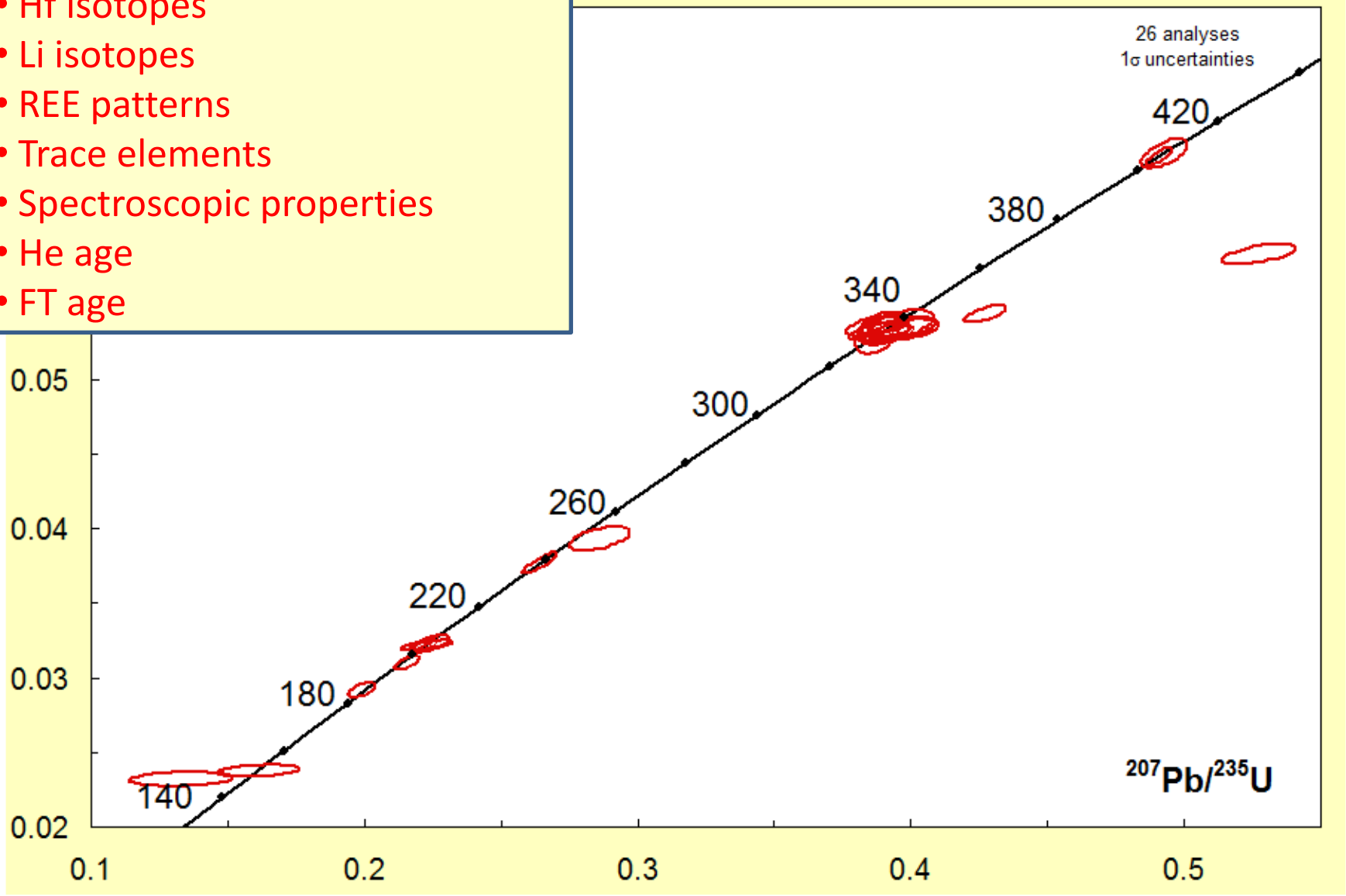


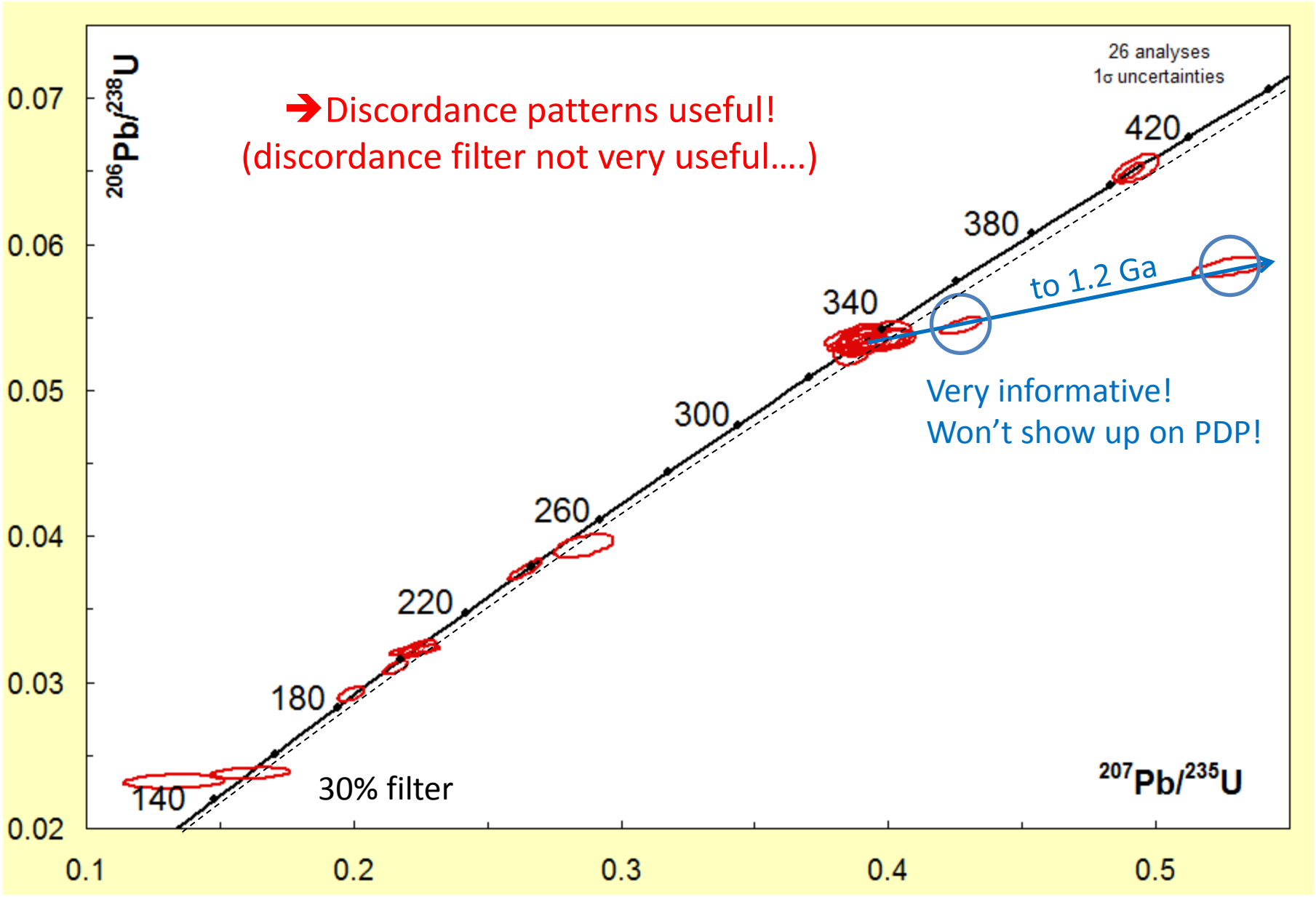
206/238 profile:

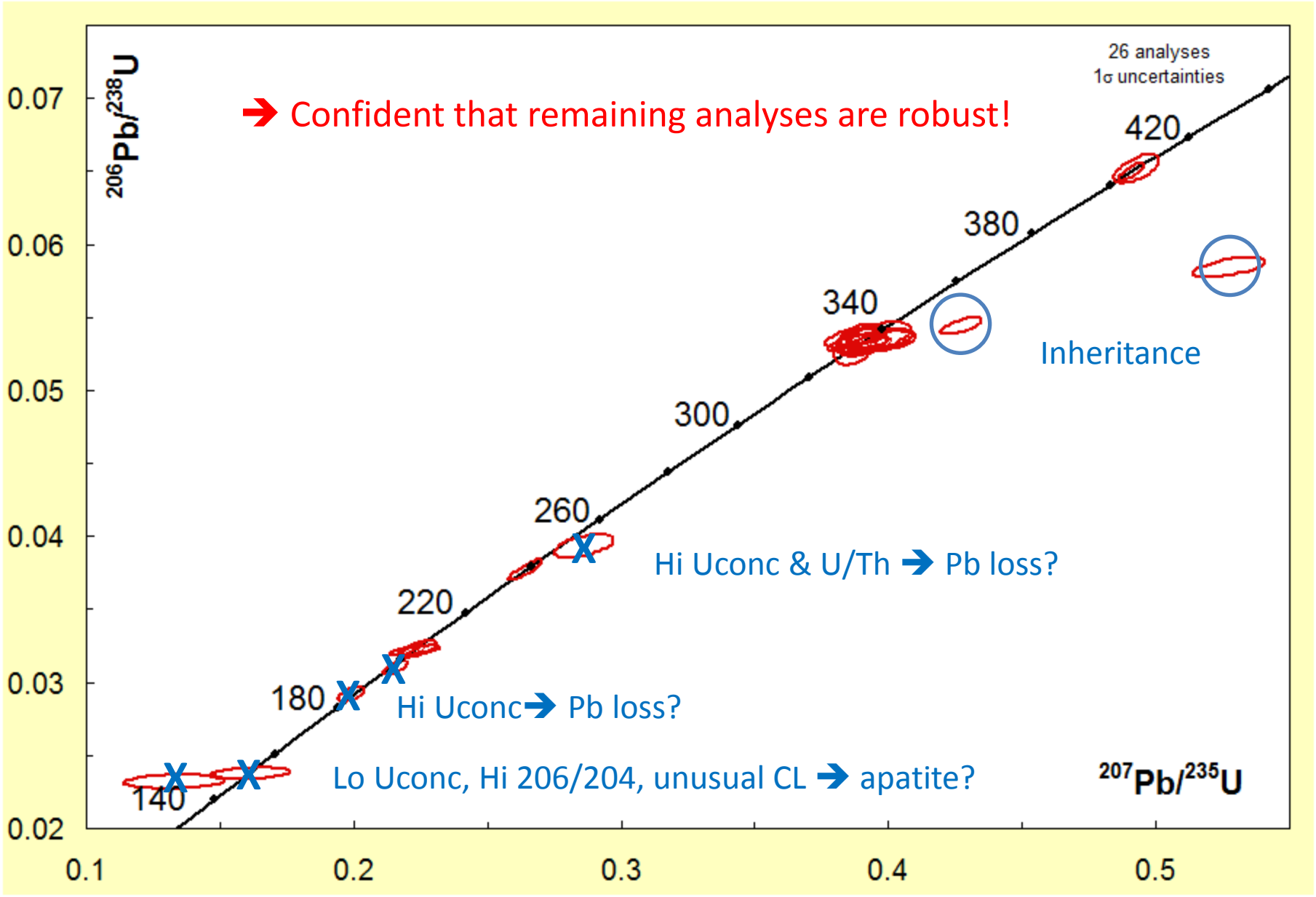
- Zonation?
- Fractures?
- Inclusions?

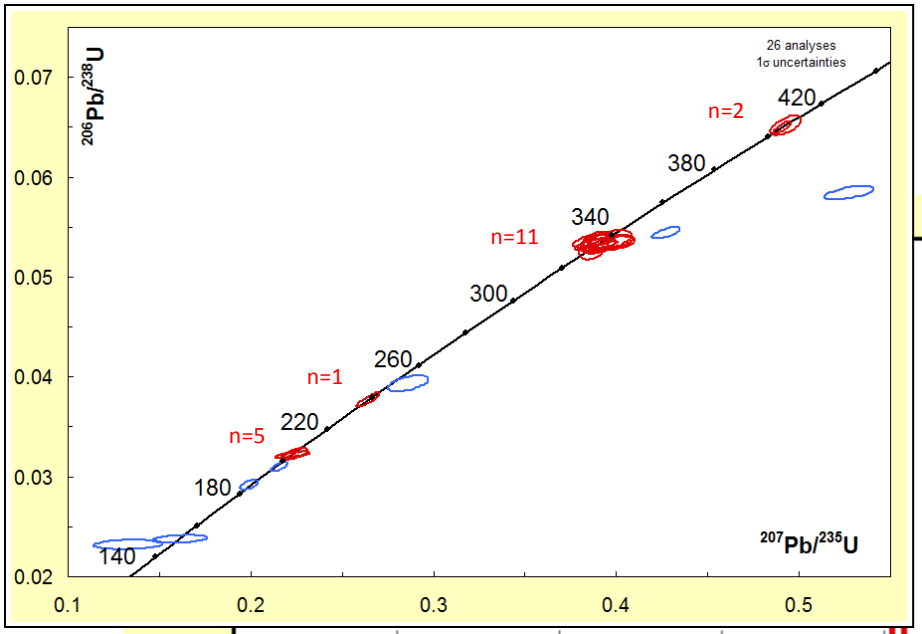
A multi-dimensional future:

- Multiple analyses on each grain
- Oxygen isotopes
- Hf isotopes
- Li isotopes
- REE patterns
- Trace elements
- Spectroscopic properties
- He age
- FT age




26 analyses
1σ uncertainties
➔Discordance patterns useful!
(discordance filter not very useful….)
420
380
340
300
260
220
180
140
to 1.2 Ga
Very informative!
Won't show up on PDP!
30% filter
$^{206}Pb/^{238}U$
$^{207}Pb/^{235}U$
0.07
0.06
0.05
0.04
0.03
0.02
0.1
0.2
0.3
0.4
0.5


26 analyses
1σ uncertainties
➔ Confident that remaining analyses are robust!
420
380
340
300
260
220
180
140
Inheritance
Hi Uconc & U/Th ➔ Pb loss?
Hi Uconc➔ Pb loss?
Lo Uconc, Hi 206/204, unusual CL ➔ apatite?
$^{206}Pb/^{238}U$
$^{207}Pb/^{235}U$
0.07
0.06
0.05
0.04
0.03
0.02
0.1
0.2
0.3
0.4
0.5



N=26 analyses

Retain small n
if analyses are robust,
tight clusters,
and N is small…

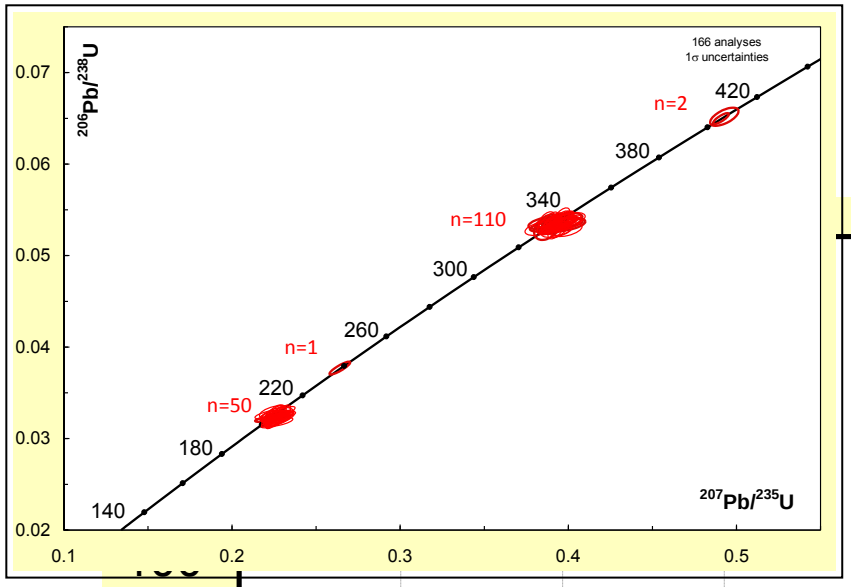
n=1

n=2

0
2
4
6
8

0
50
100
150
200
250
300
350
400
450
500

How 'bout bigger N (simple systematics)



N=166 analyses

Retain small n
if analyses robust
& tight clusters,
even with large N

certainly not very significant……

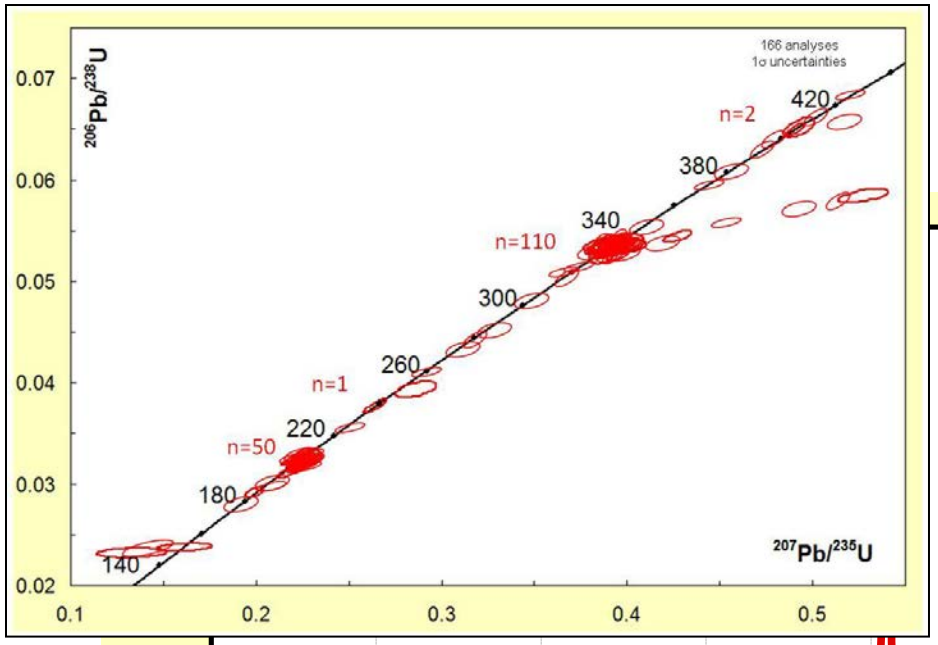
n=1

n=2

0
20
40
60
80

0
50
100
150
200
250
300
350
400
450
500

How 'bout bigger N (more complex systematics)



N=166 analyses

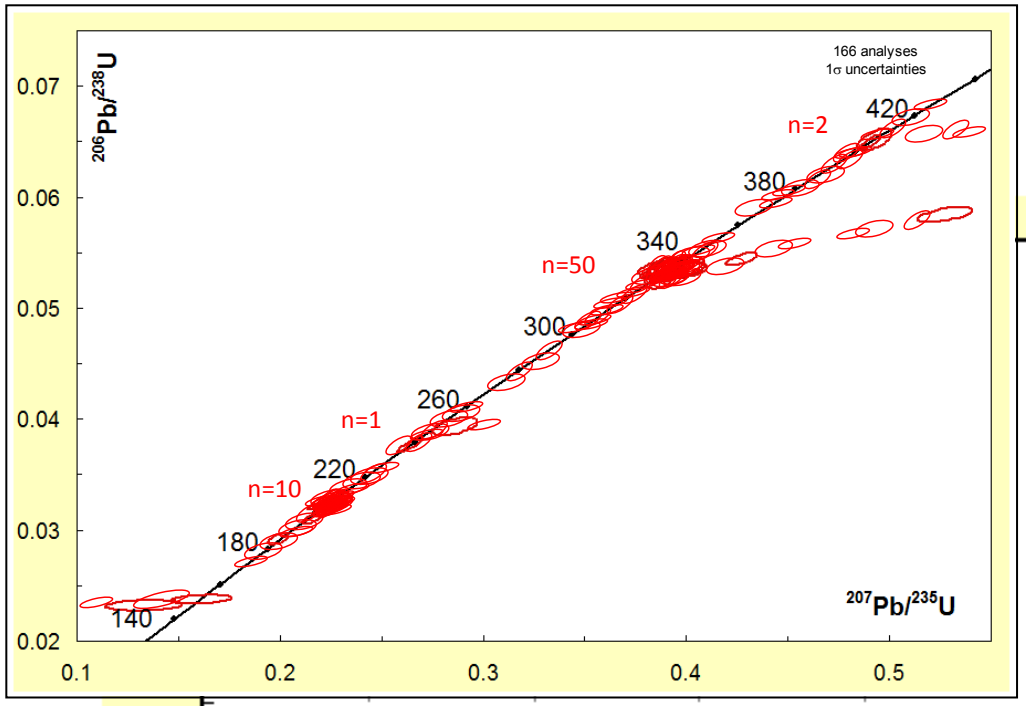
Disregard small n
if poor clusters,
even if N is large?

n=1

n=2

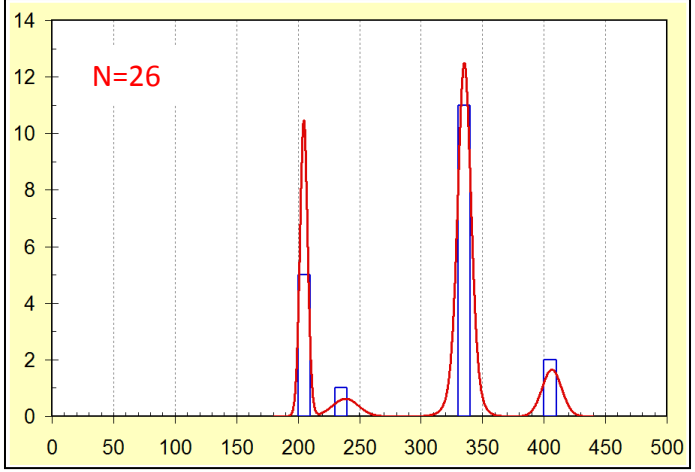
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500

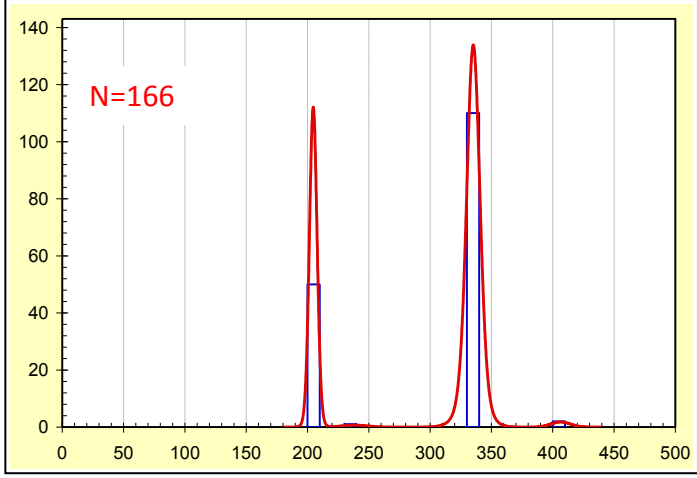
How 'bout bigger N (very complex systematics)



N=166 analyses

Disregard even moderate n
if clusters are poor!
(systematics are complex)





Significance of clusters with small n?

➔Depends on total N!

➔Depends on geological diversity

➔Depends on analytical complexity!

In practice:

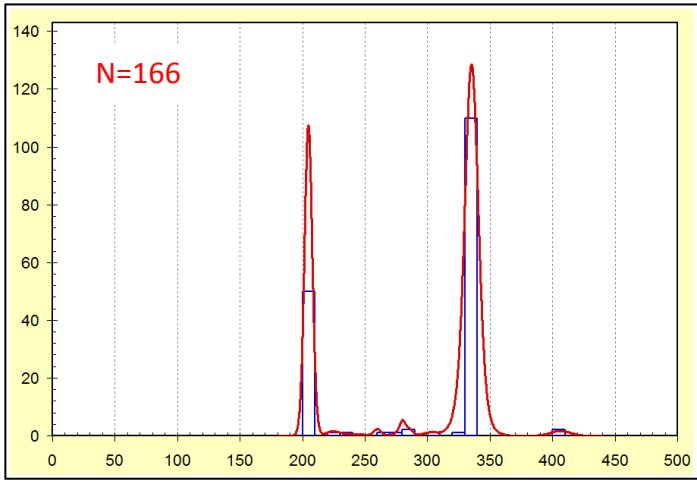
Ages clustered ➔ simple systematics

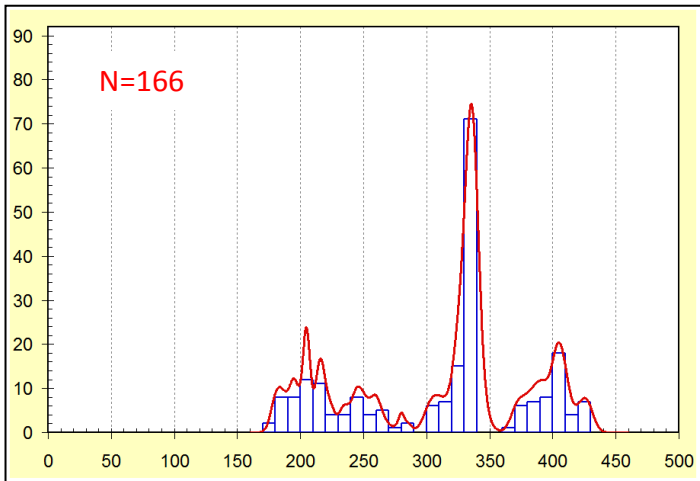
Small n has significance!

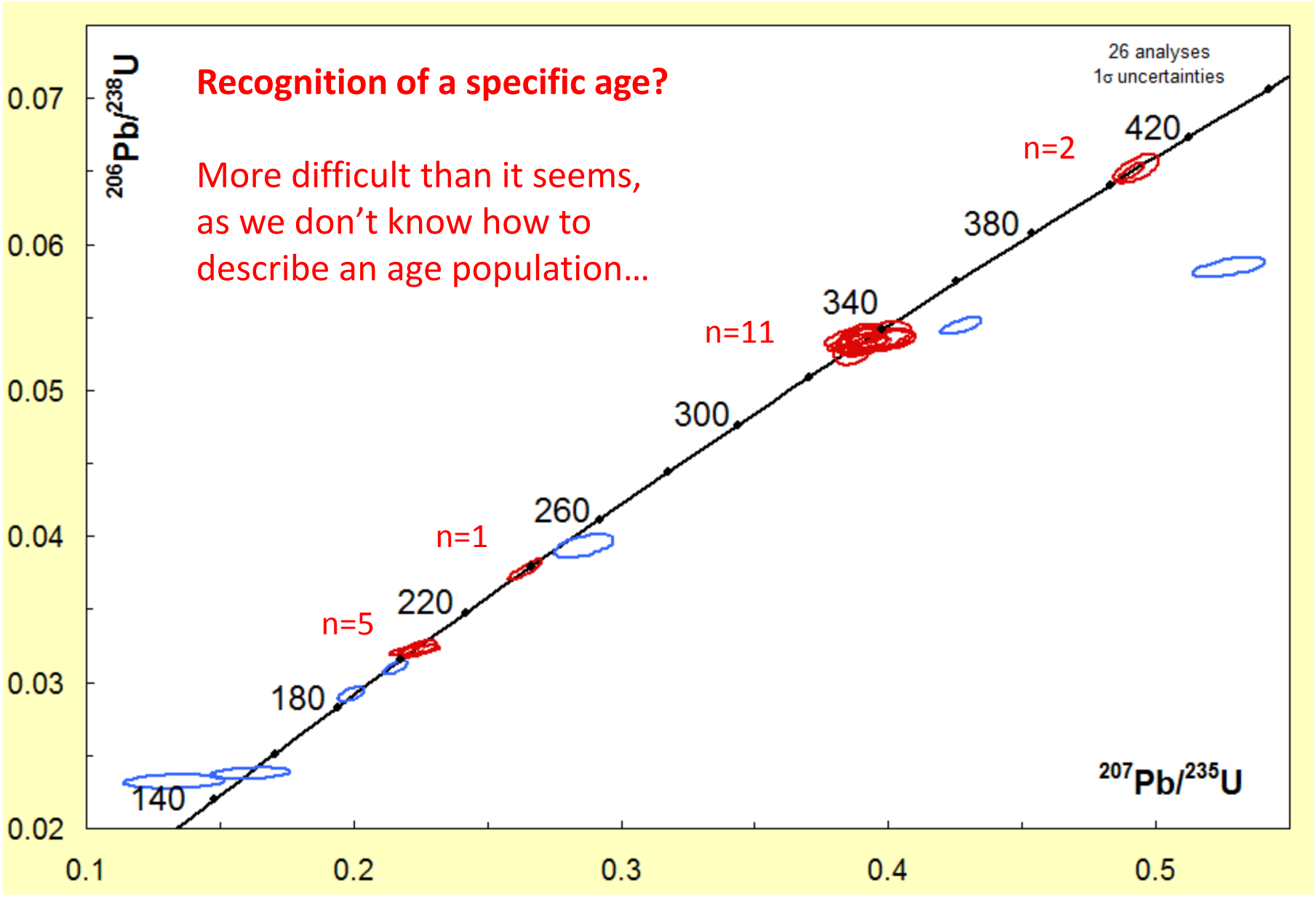
Ages scattered ➔ complex systematics

Beware small/moderate n!

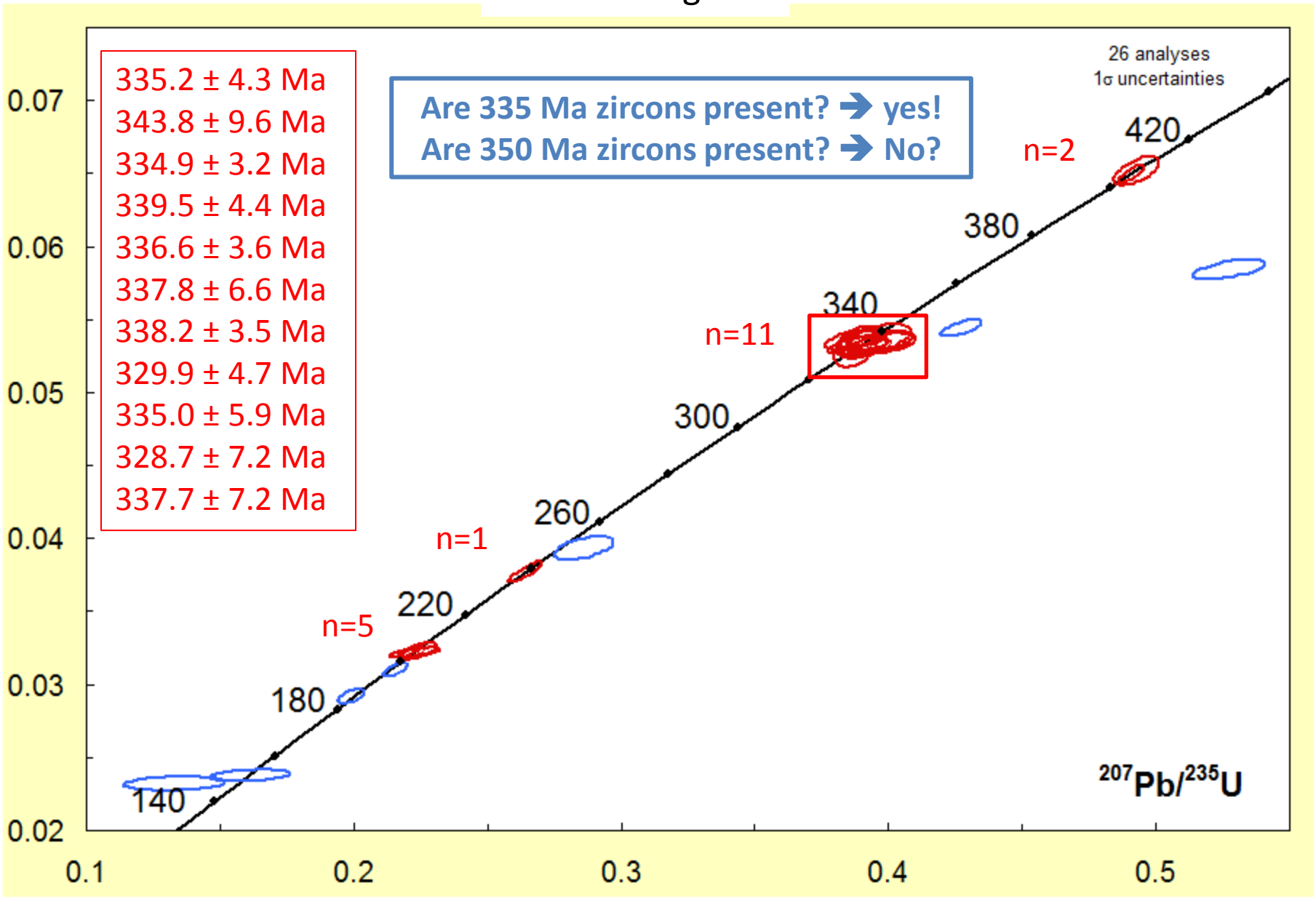
Sorry, no cookbook available…..



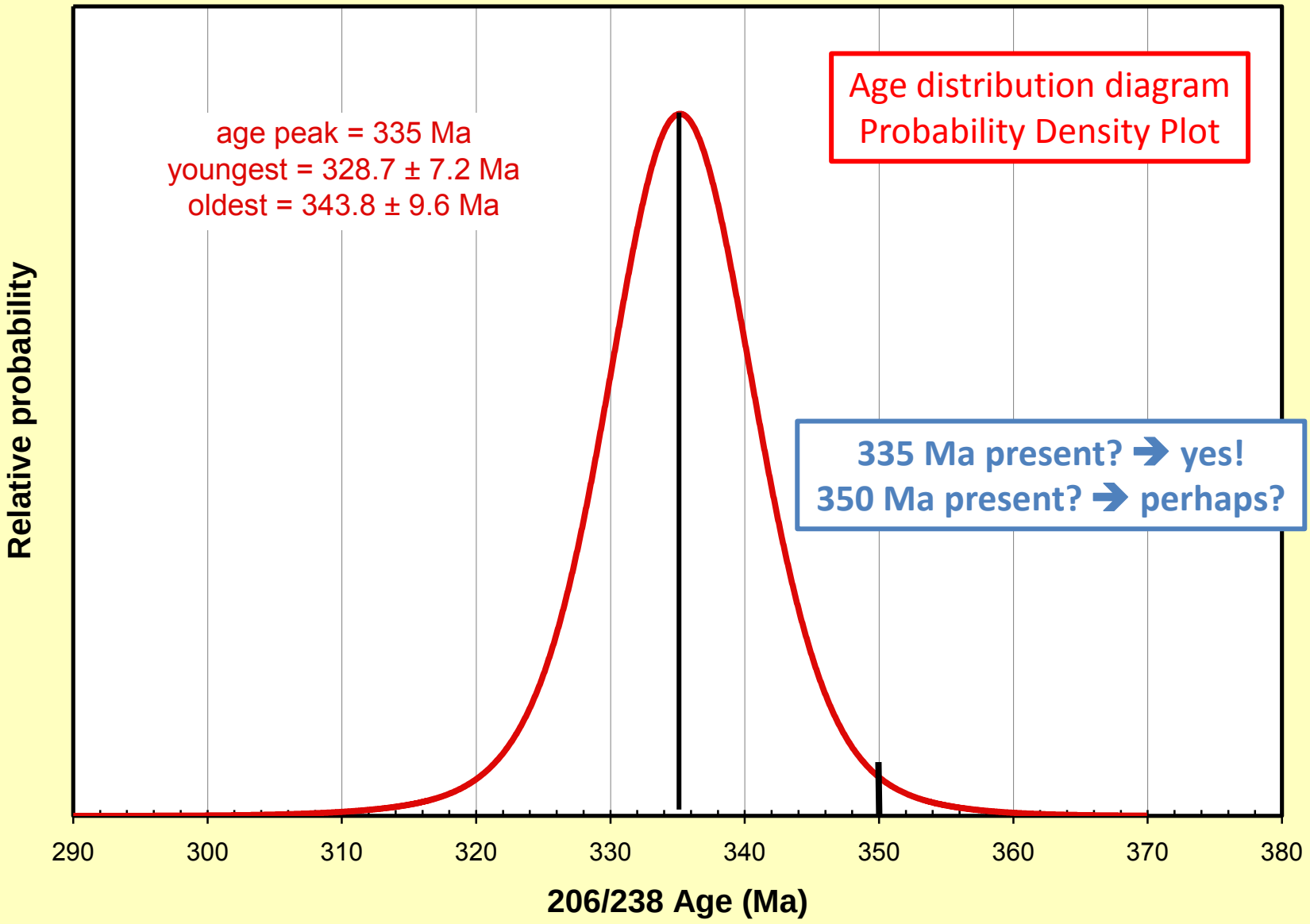


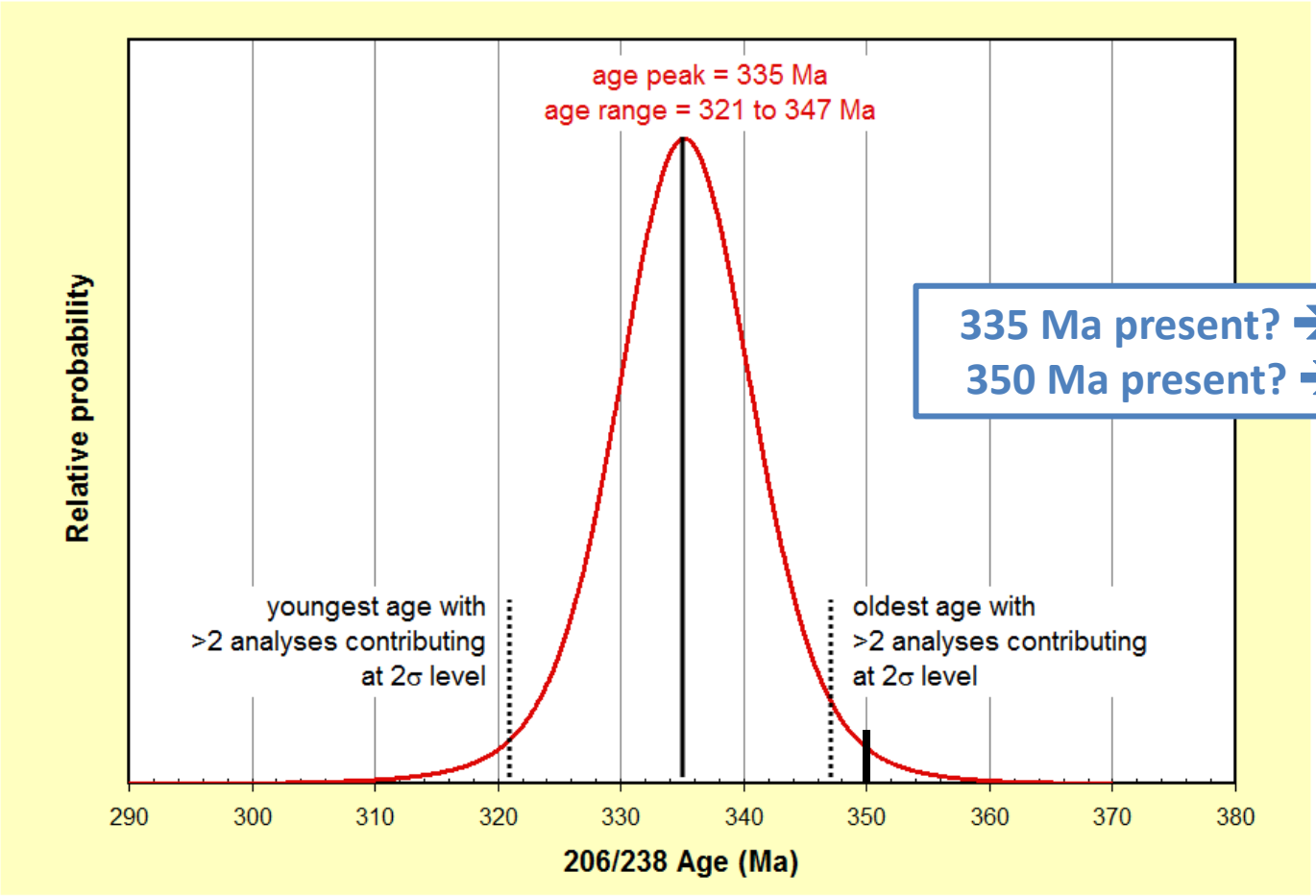

Recognition of a specific age?
More difficult than it seems,
as we don't know how to
describe an age population…
26 analyses
1σ uncertainties
$^{206}Pb/^{238}U$
$^{207}Pb/^{235}U$
0.07
0.06
0.05
0.04
0.03
0.02
0.1
0.2
0.3
0.4
0.5
140
180
220
260
300
340
380
420
n=1
n=2
n=5
n=11

List all the ages!!!



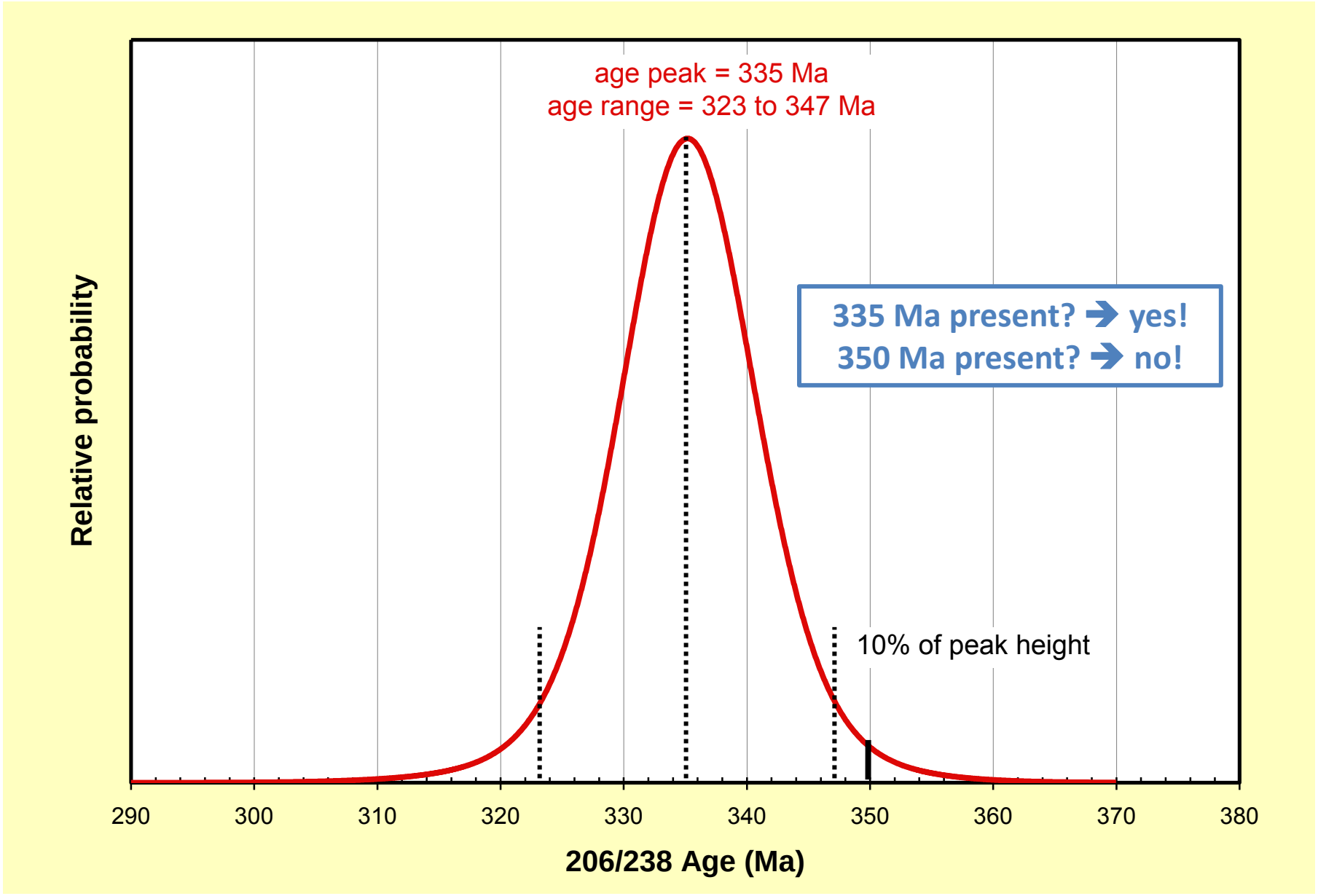
Probability Density Plot





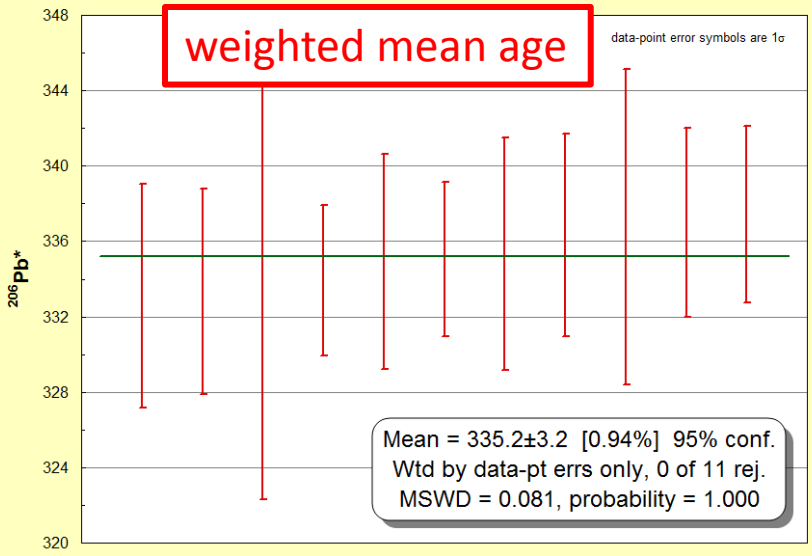
DZ AGES				
MIN AGE	MAX AGE	# GRAINS	PEAK AGE	# GRAINS
195	212	6	203	6
321	347	11	335	11

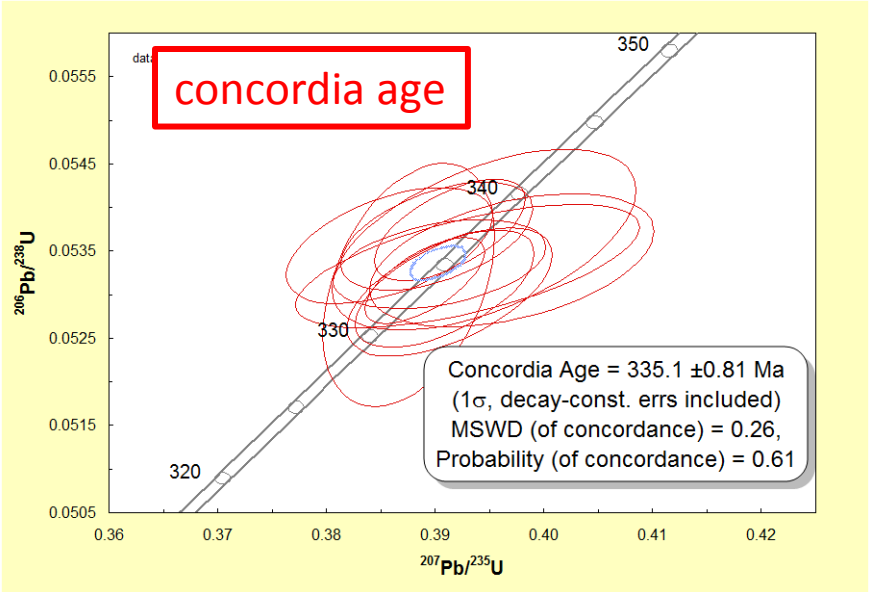
"Age Pick" program (Gehrels et al., 2006; www.laserchron.org)

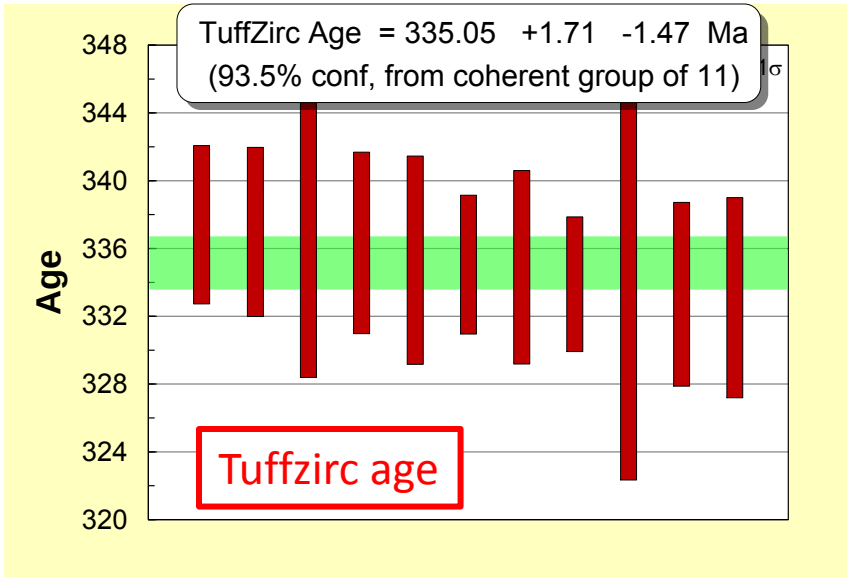

age peak = 335 Ma
age range = 323 to 347 Ma
335 Ma present? ➔ yes!
350 Ma present? ➔ no!
10% of peak height
Relative probability
290
300
310
320
330
340
350
360
370
380
206/238 Age (Ma)

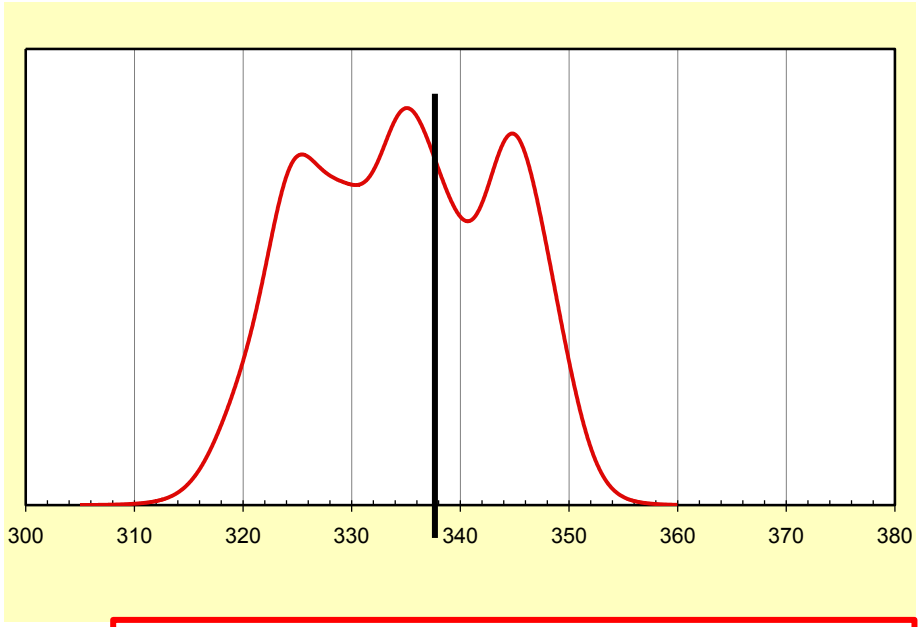
If you assume that grains are cogenetic….

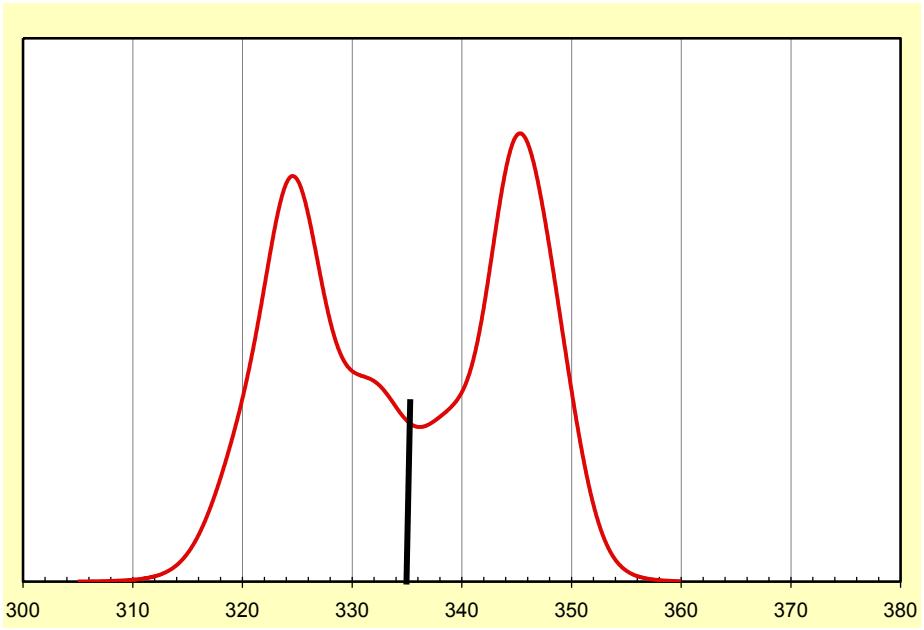
335 Ma present? ➔ yes!
350 Ma present? ➔ no!





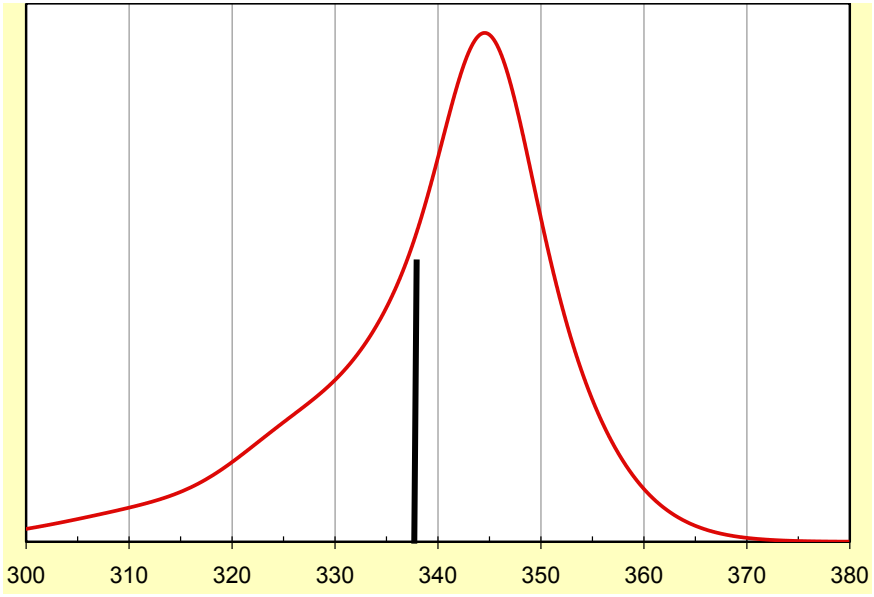


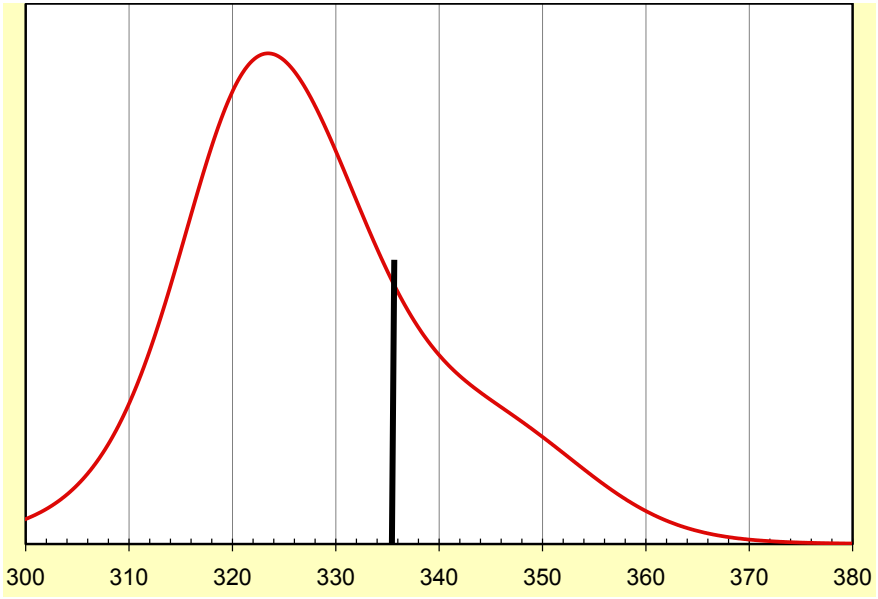


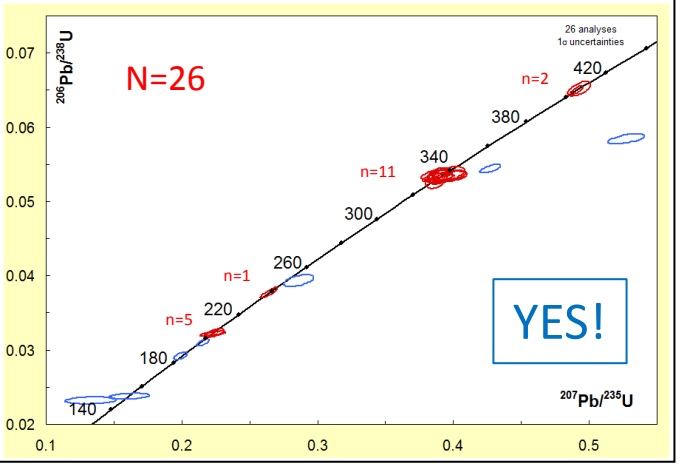


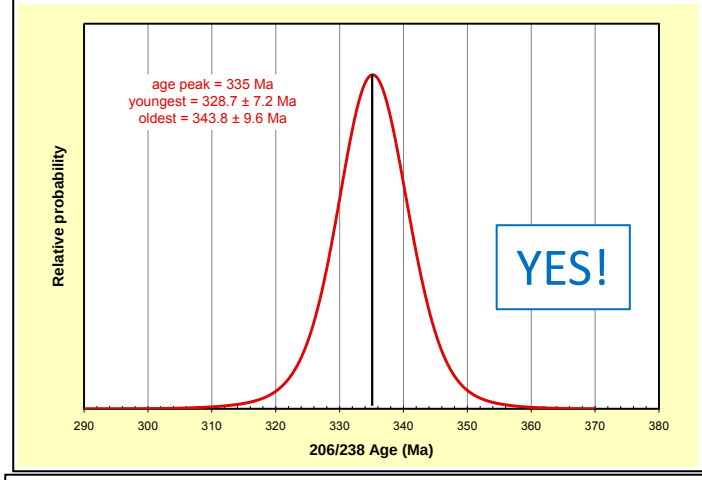
Other reasonable age distributions…..

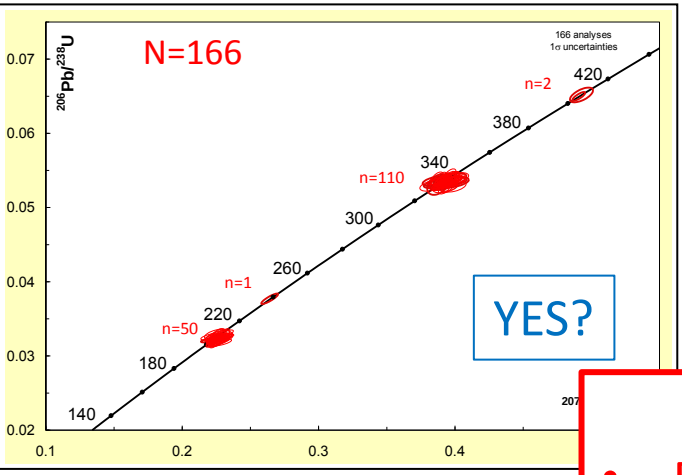
335 Ma present?

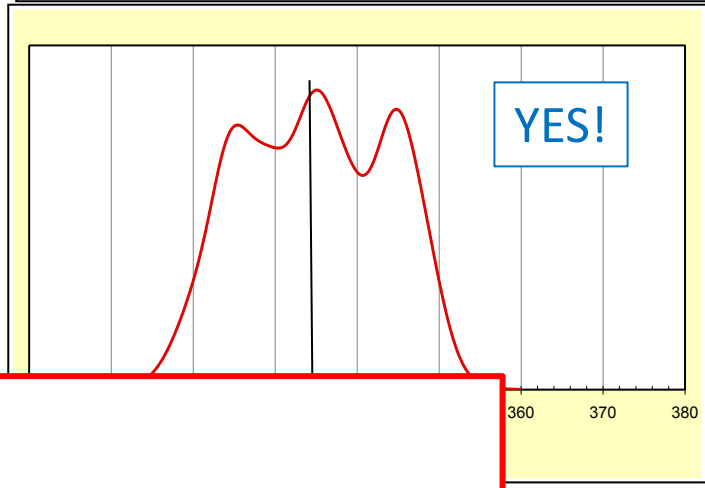








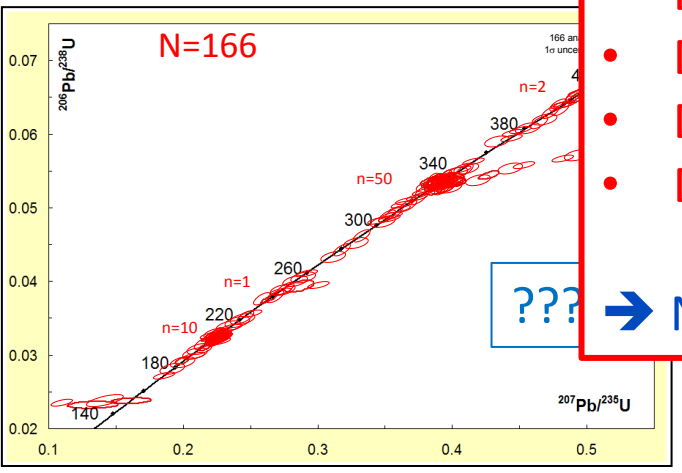


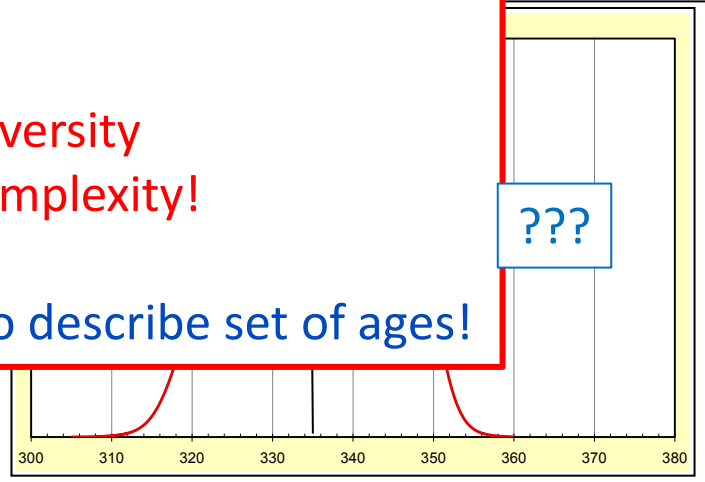


Specific Ages:

- Depends on n
- Depends on N
- Depends on geological diversity
- Depends on analytical complexity!

➔ Need to figure out how to describe set of ages!

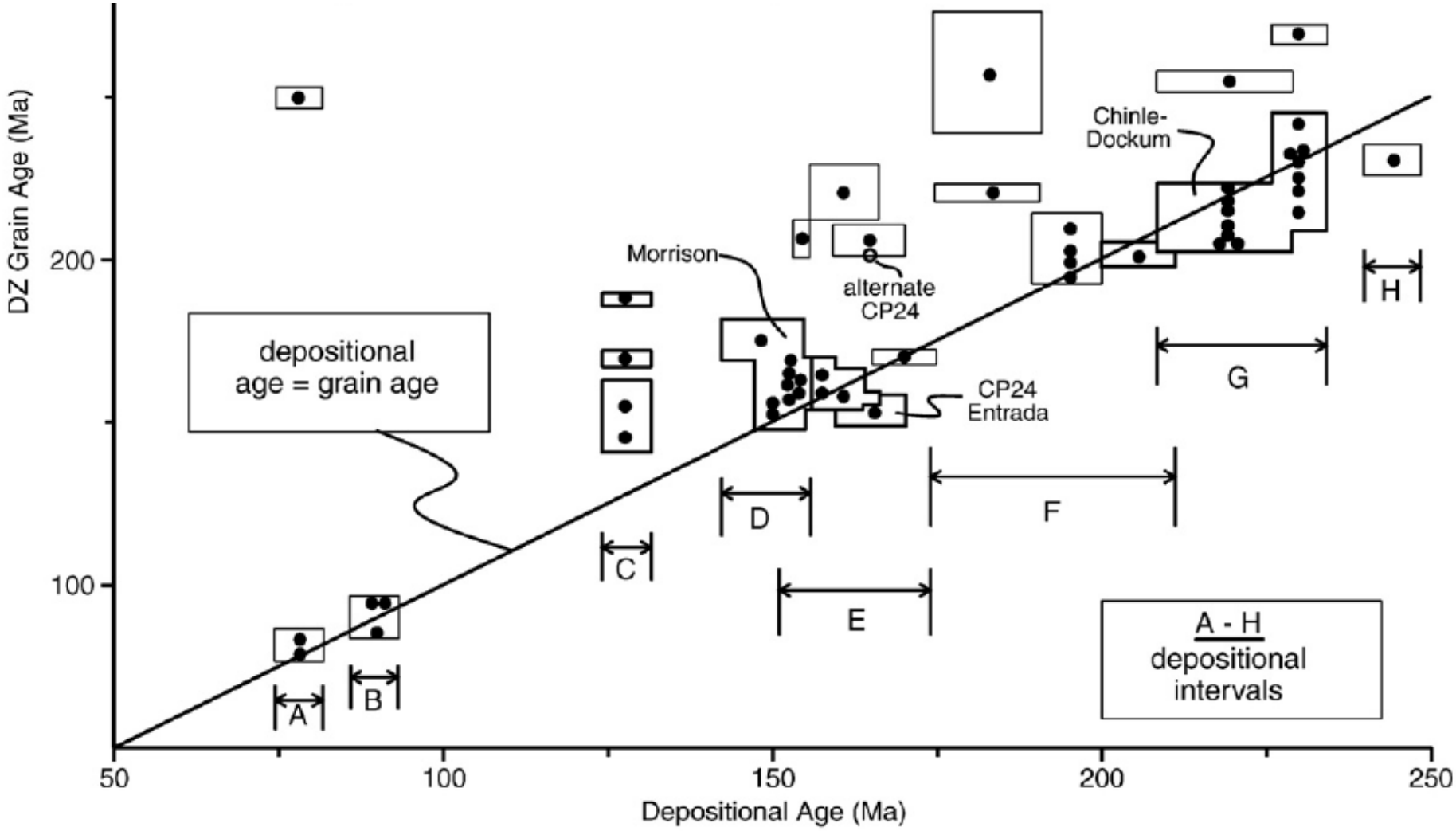




Max Depositional Age

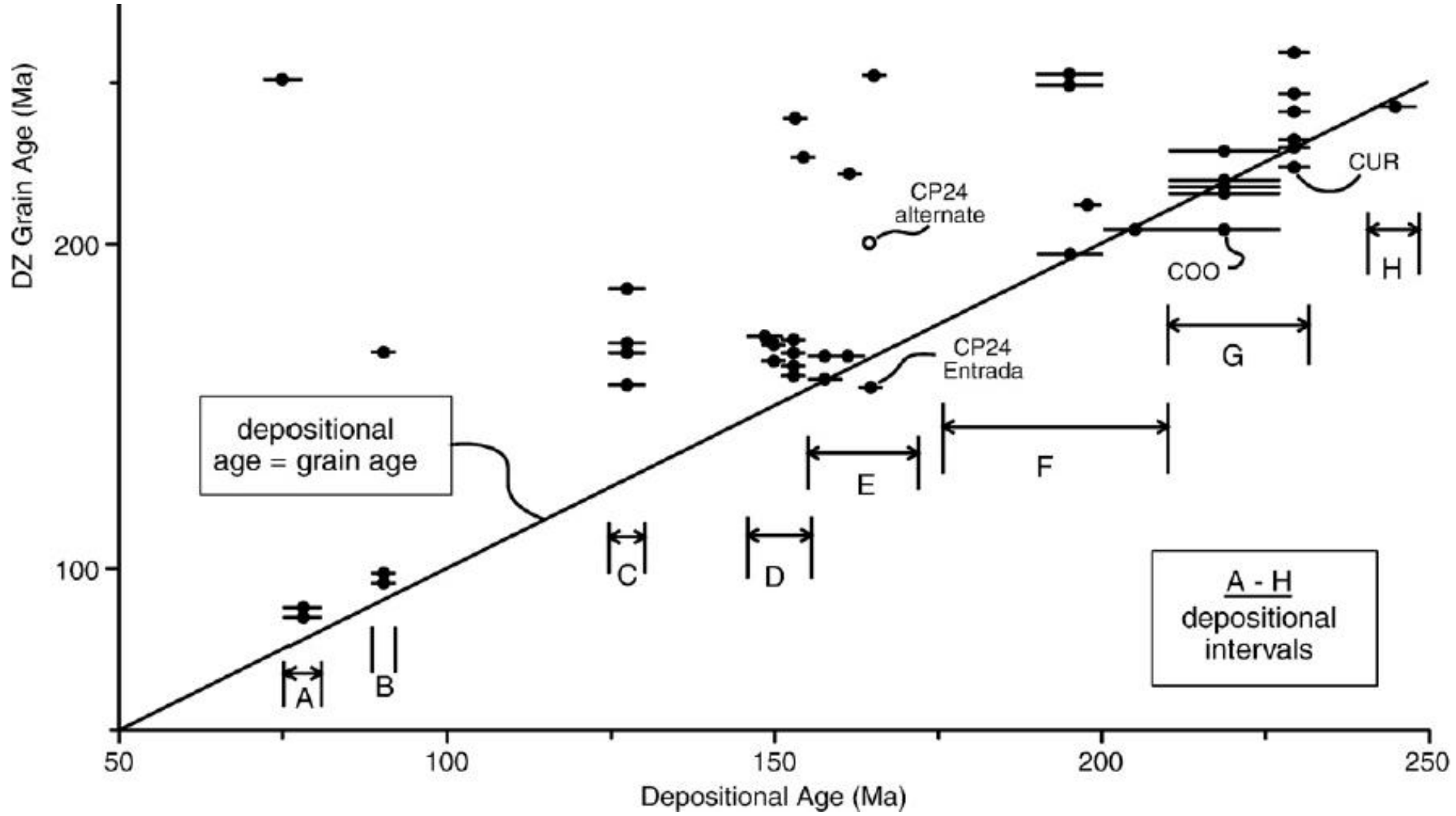
58 samples of known depositional age
(Dickinson & Gehrels, 2009, EPSL)

YOUNGEST SINGLE GRAIN
16 of 58 too young!

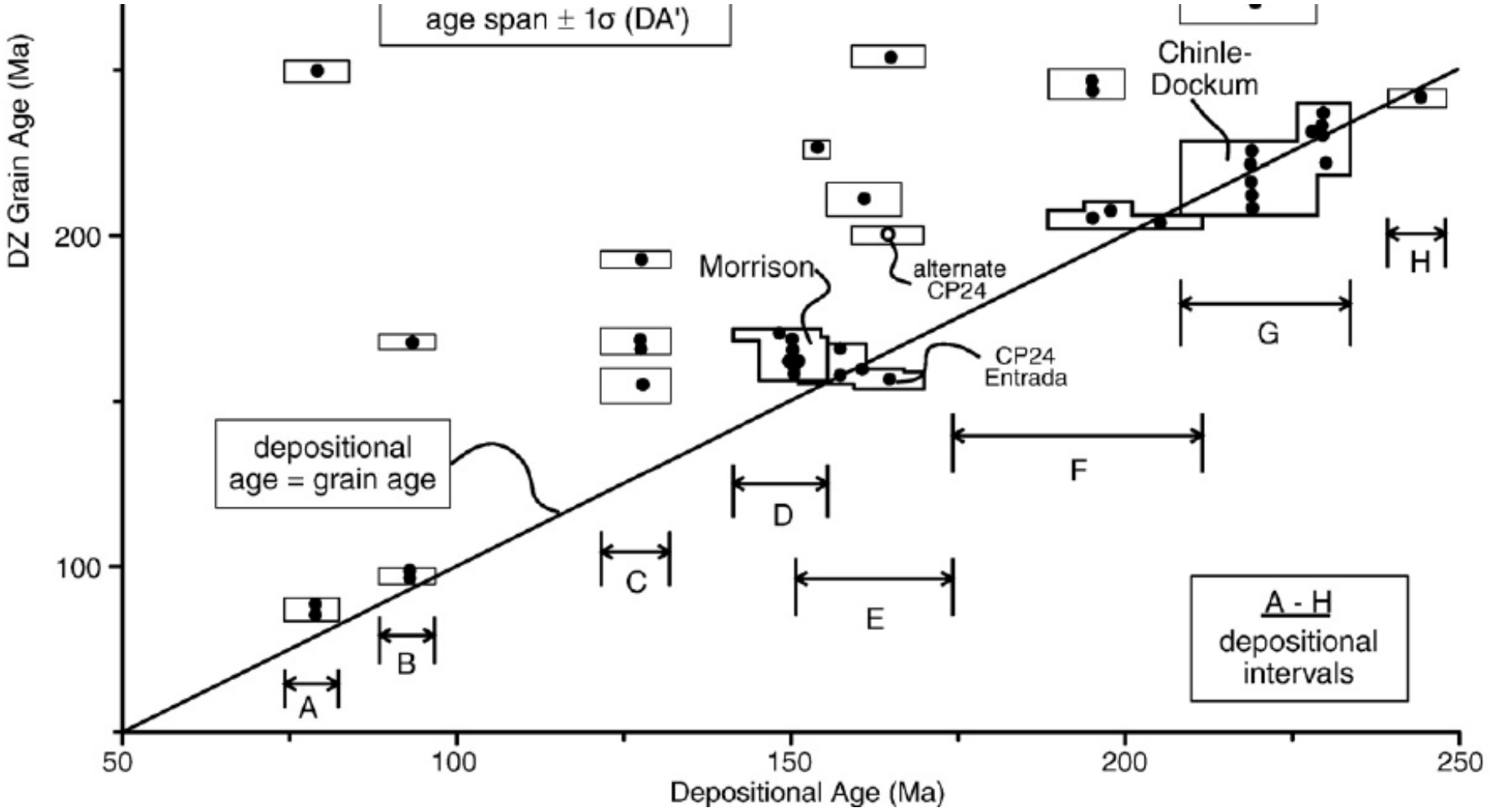


YOUNGEST PROBABILITY PEAK OF YOUNGEST 2 (OR MORE)

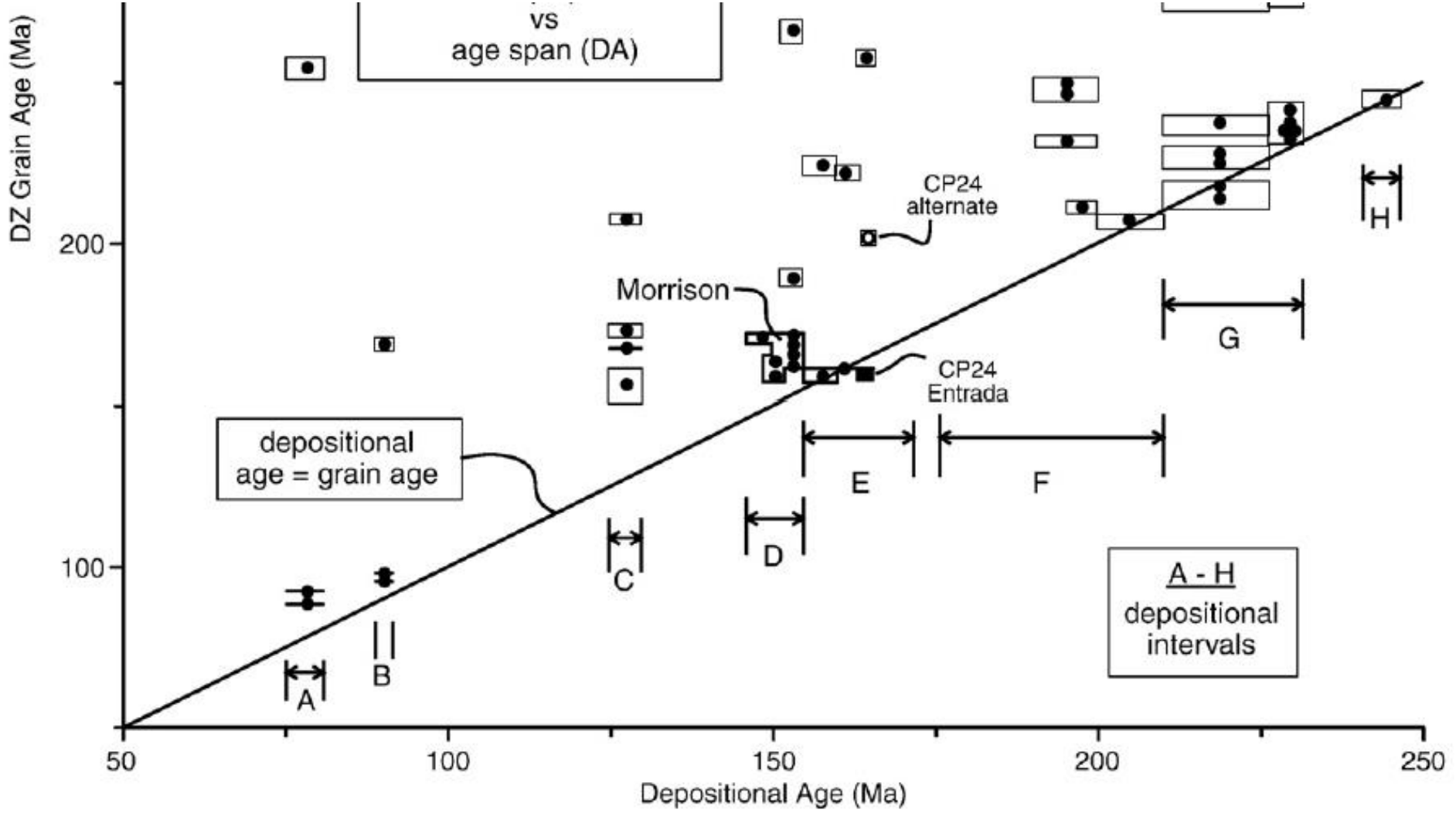
6 of 58 too young!



WEIGHTED MEAN AGE
OF YOUNGEST 2 (OR MORE)
5 of 58 too young



WEIGHTED MEAN AGE
OF YOUNGEST 3 (OR MORE)
2 of 58 too young!



Max Depositional Age

58 samples of known depositional age

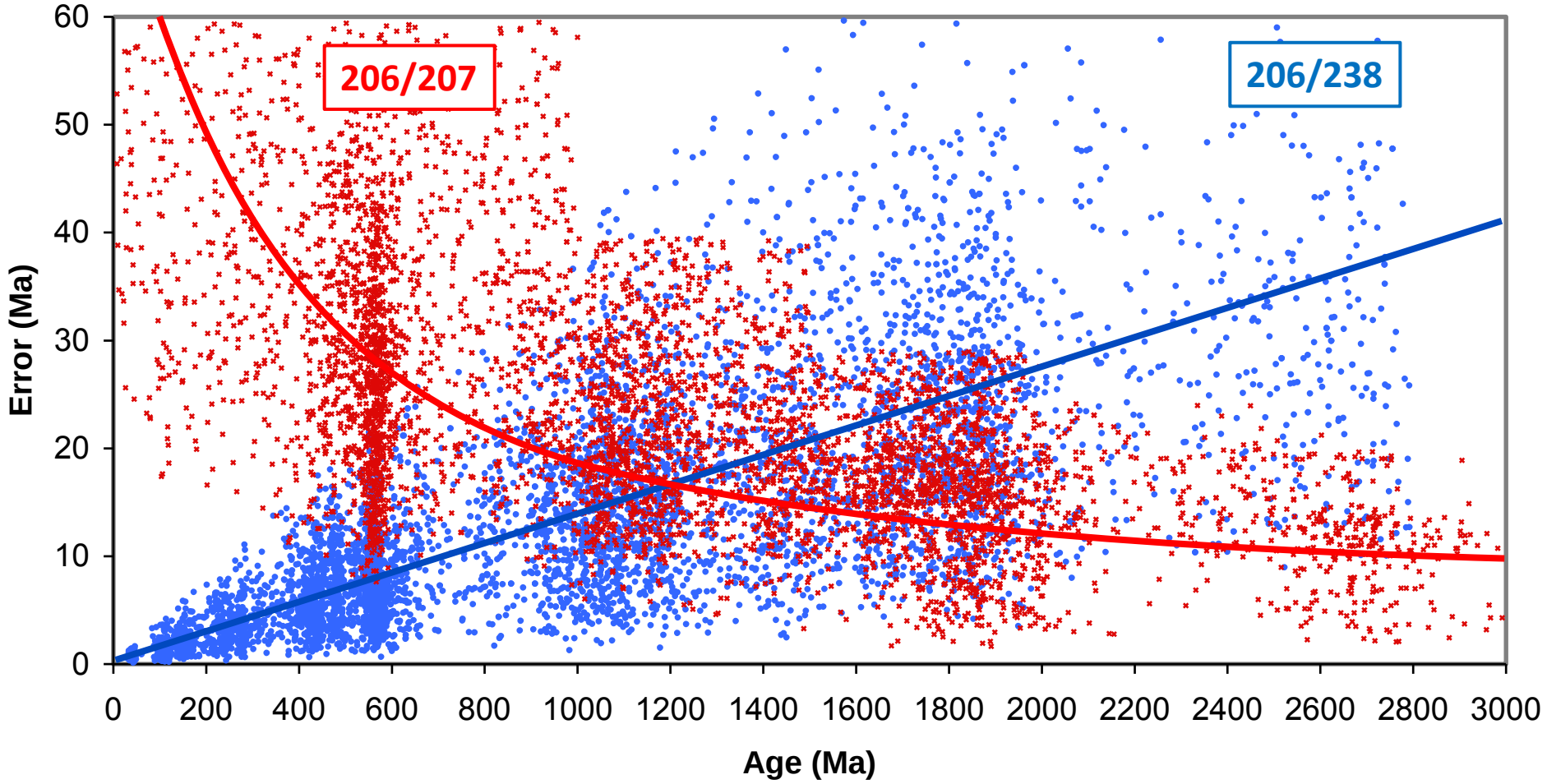
(Dickinson & Gehrels, 2009, EPSL)

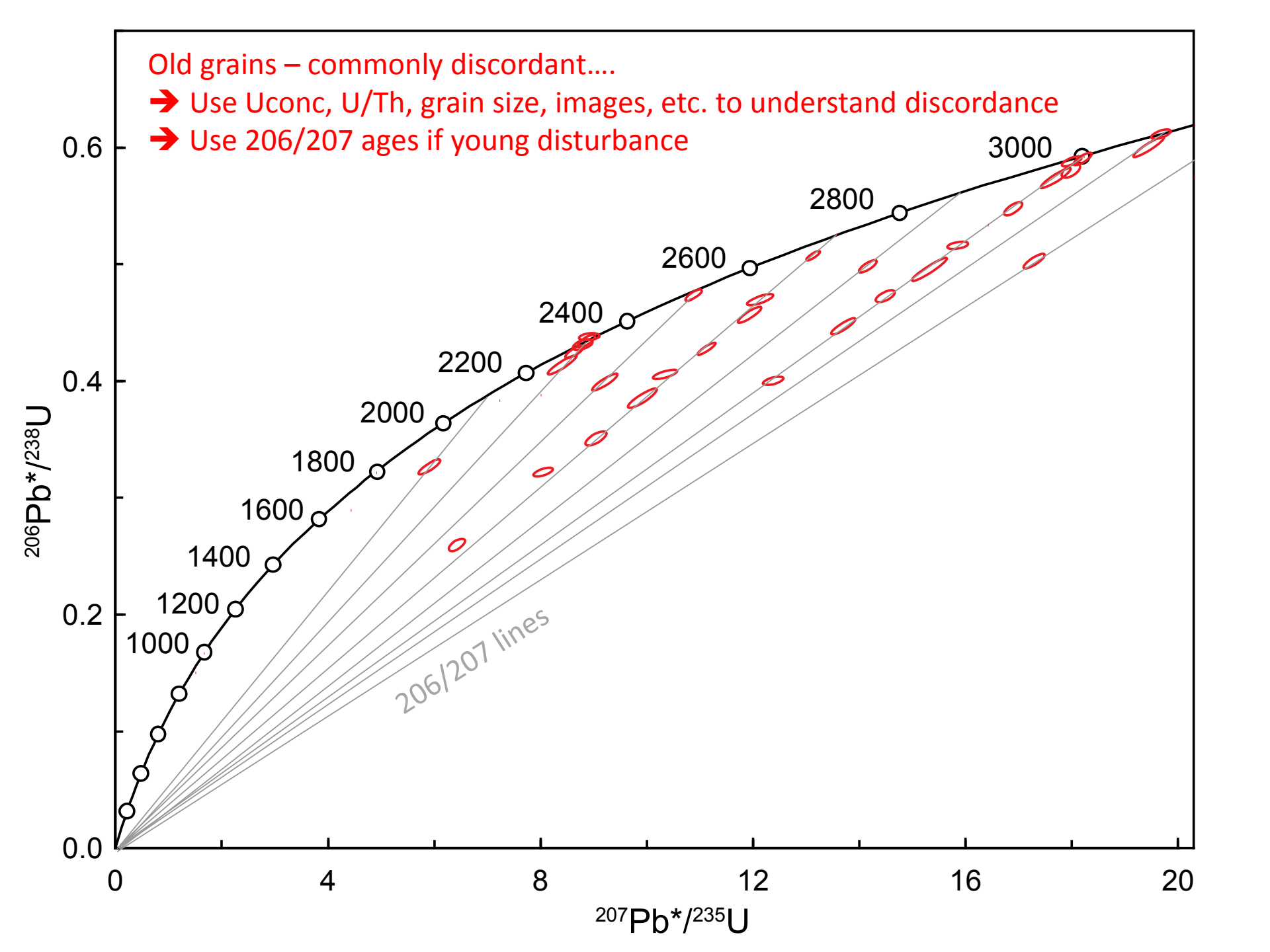
METHOD	TOO YOUNG	USEFUL (WITHIN 5 Ma)
Youngest Single Grain:	**16 of 58**	**26 of 58**
Youngest Prob Peak (2 or more):	**6 of 58**	**21 of 58**
Weighted Mean (2 or more):	**5 of 58**	**22 of 58**
Weighted Mean (3 or more):	**2 of 58**	**16 of 58**

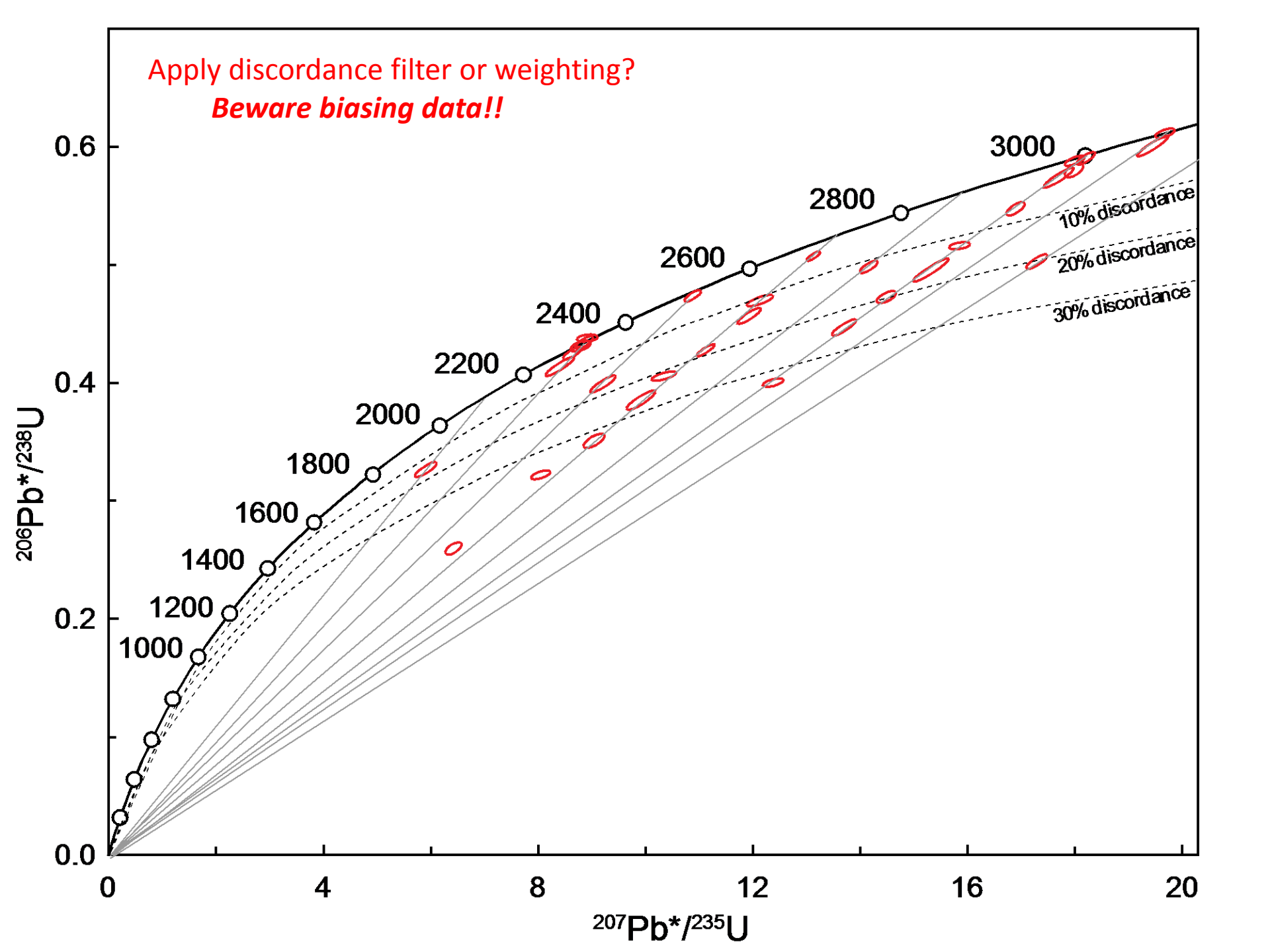
➔ **Use variety of methods, depending on samples?**

➔ **Develop better tools for identifying first-cycle grains?**

Dealing with discordant data -- an old example…..

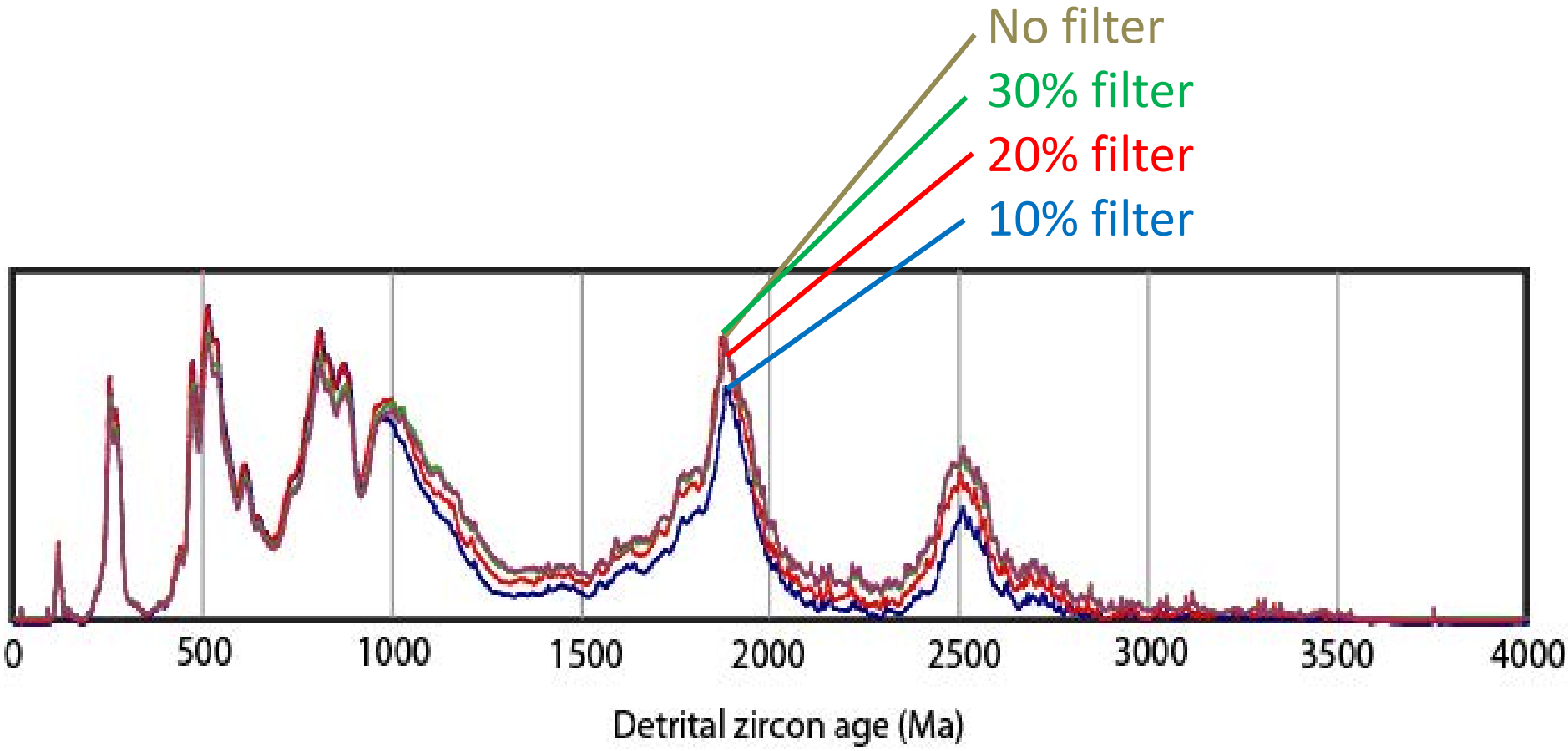


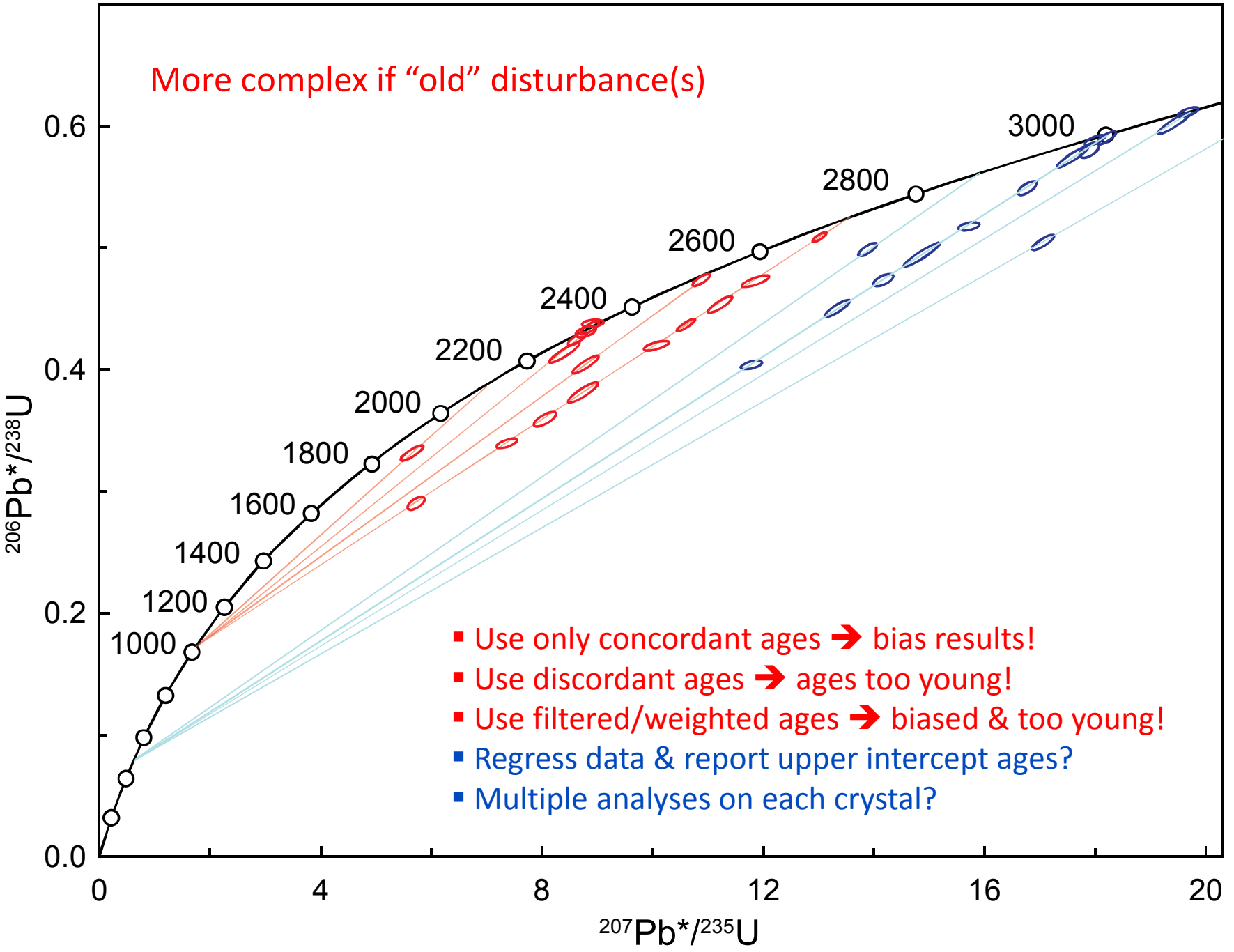

Old grains – commonly discordant….
➔ Use Uconc, U/Th, grain size, images, etc. to understand discordance
➔ Use 206/207 ages if young disturbance
0.6
0.4
0.2
0.0
$^{206}Pb^*/^{238}U$
0
4
8
12
16
20
$^{207}Pb^*/^{235}U$
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
206/207 lines


Apply discordance filter or weighting?
Beware biasing data!!
0.6
0.4
0.2
0.0
0
4
8
12
16
20
$^{206}Pb^*/^{238}U$
$^{207}Pb^*/^{235}U$
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
10% discordance
20% discordance
30% discordance

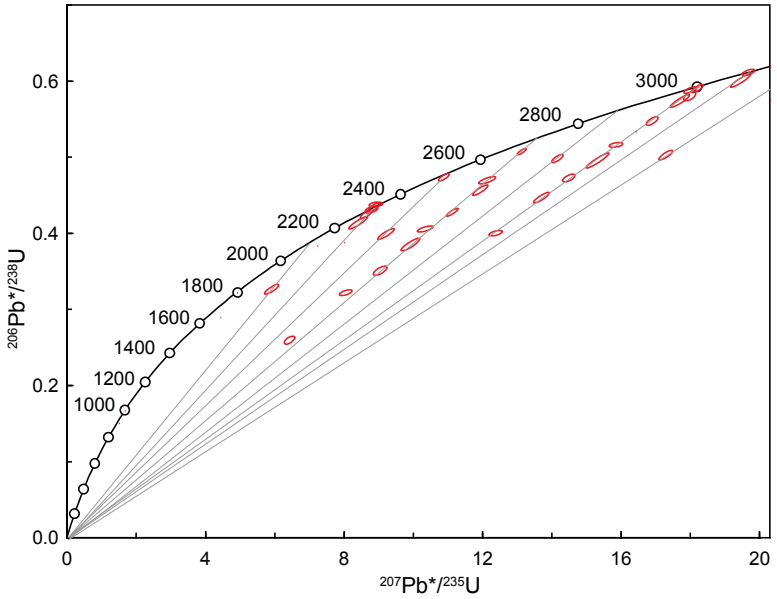
An example of impact of discordia filtering

(~11K analyses from Tibet)




More complex if “old” disturbance(s)
0.6
0.4
0.2
0.0
$^{206}Pb^*/^{238}U$
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
0
4
8
12
16
20
$^{207}Pb^*/^{235}U$
Use only concordant ages ➔ bias results!
Use discordant ages ➔ ages too young!
Use filtered/weighted ages ➔ biased & too young!
Regress data & report upper intercept ages?
Multiple analyses on each crystal?

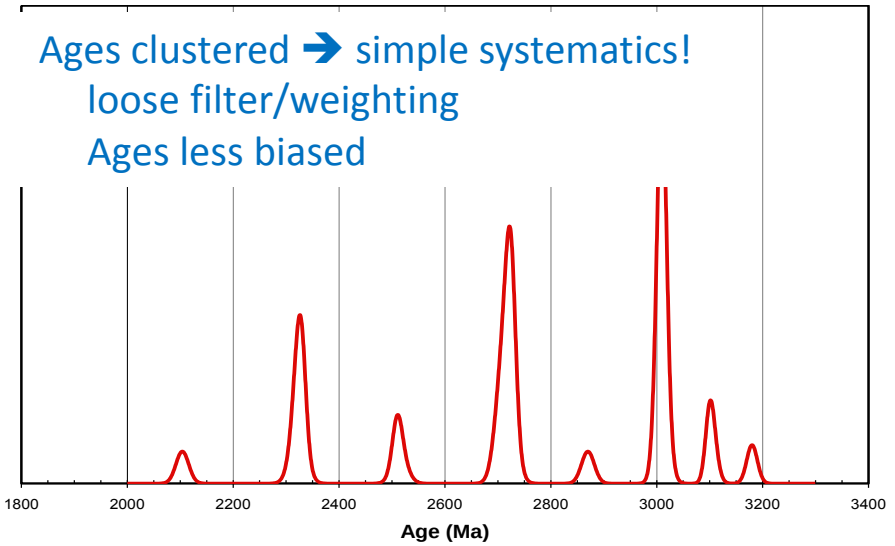
In practice, for now….

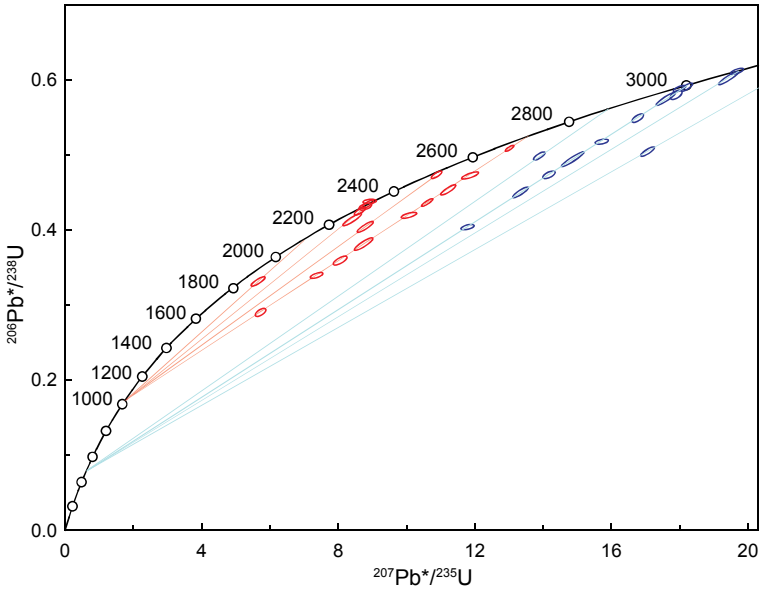


Ages clustered ➔ simple systematics!

loose filter/weighting

Ages less biased

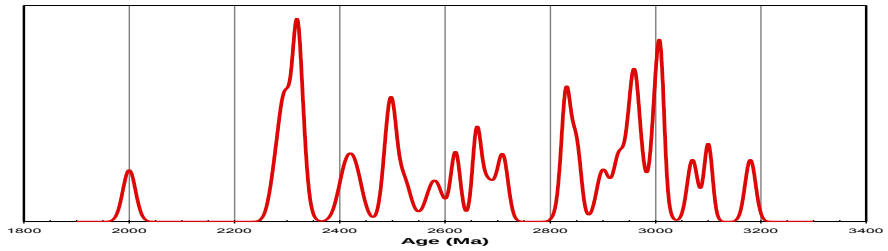




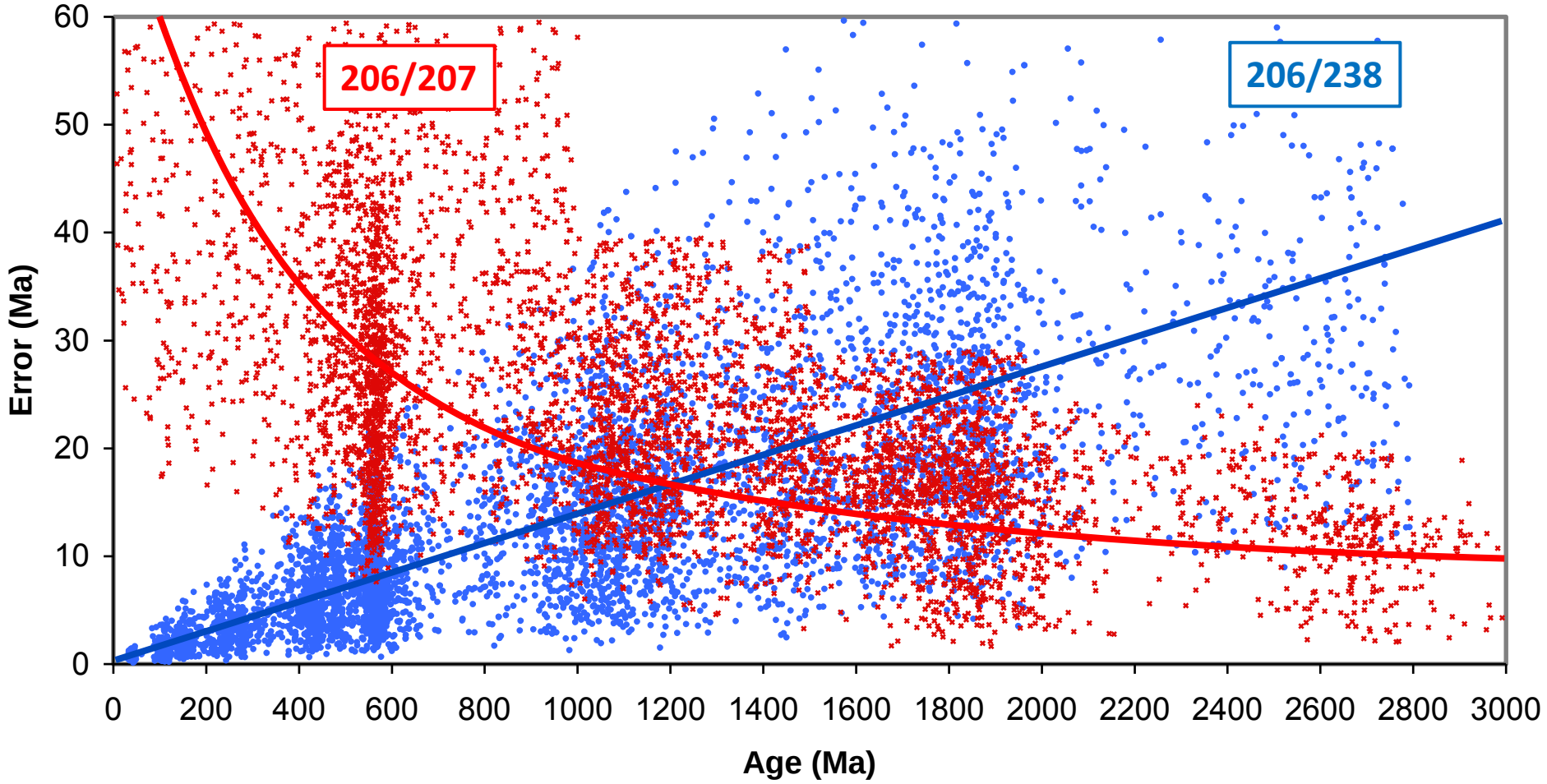
Ages scattered ➔ complex systematics!

tight filter/weighting

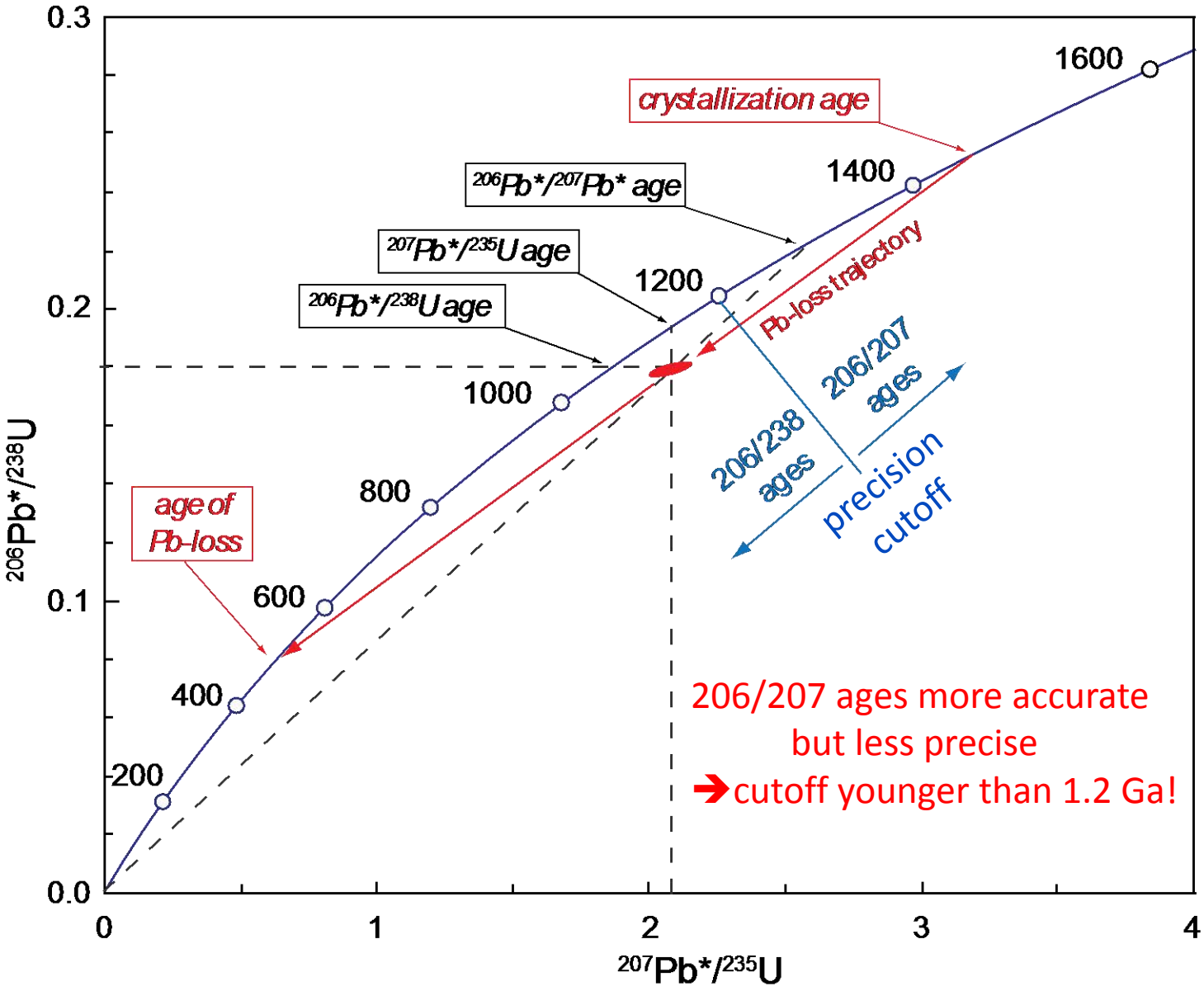
Ages highly biased

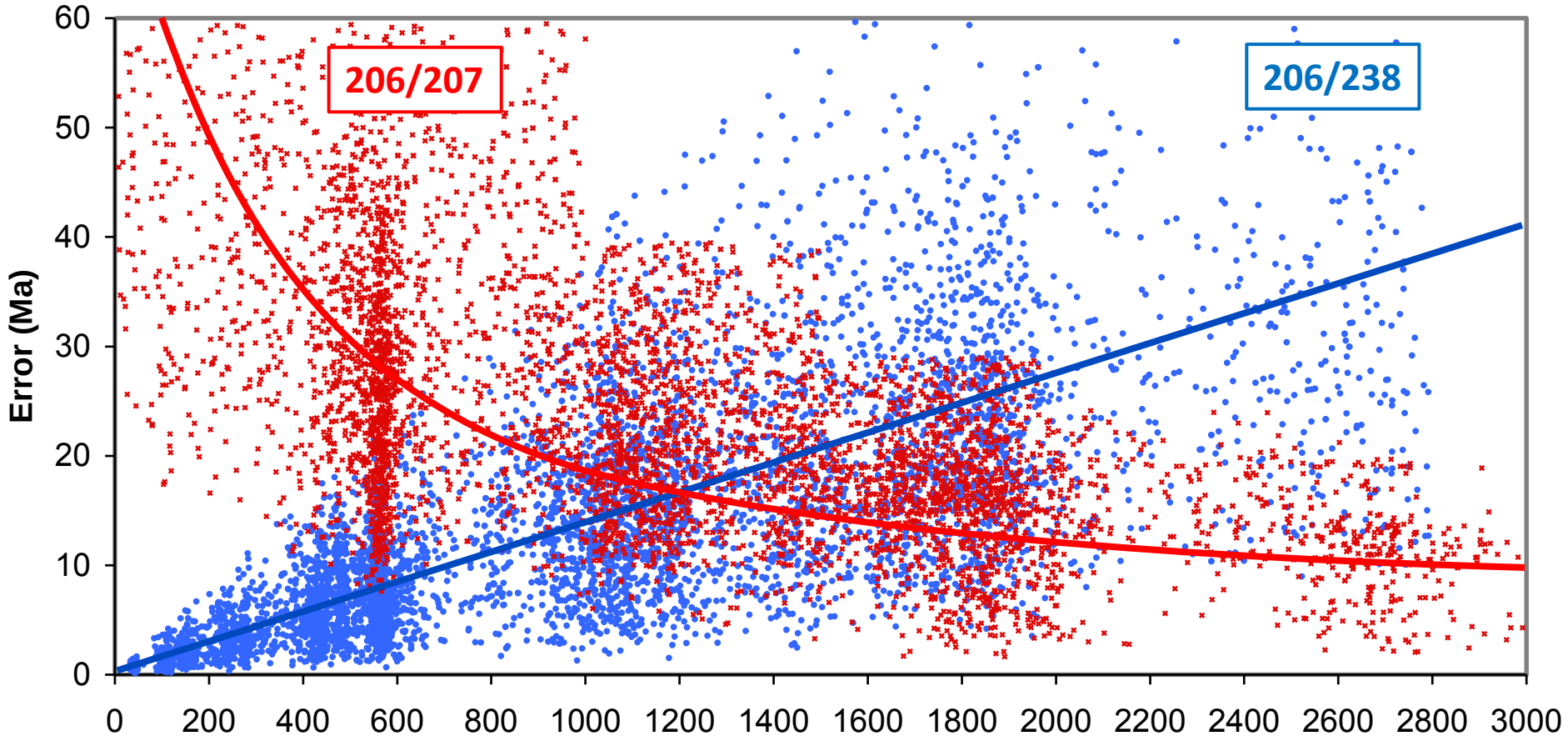


Dealing with discordant data -- An example of intermediate age…..



Ages less precise, Pb loss & inheritance common ➔ use discordant ages with caution!





no discordance filter! — **tight discordance filter?** —— **loose discordance filter?**

206/238 → | ← **206/207**

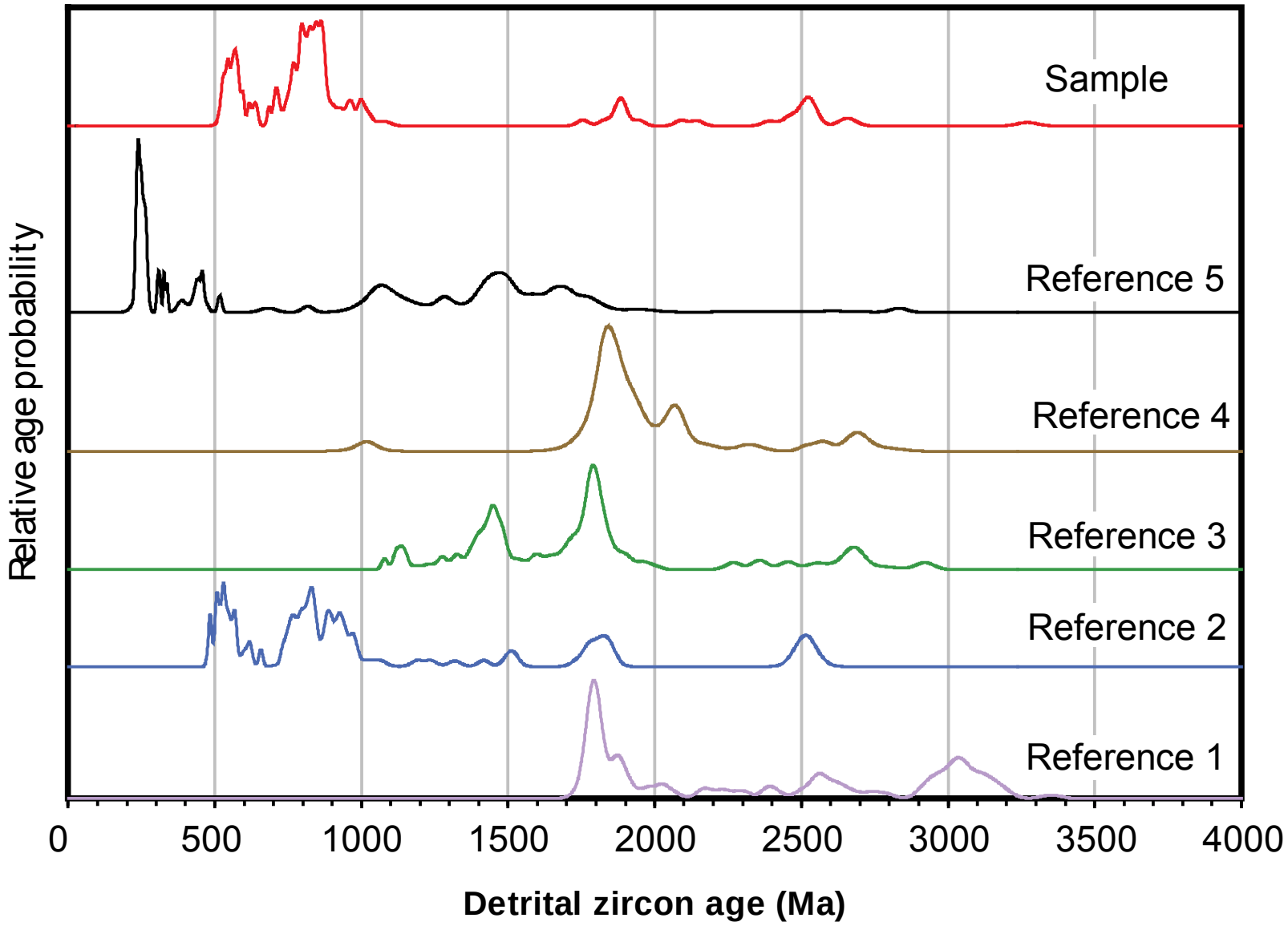
Sorry, no cookbook available….

Make sure operators understand complexities….

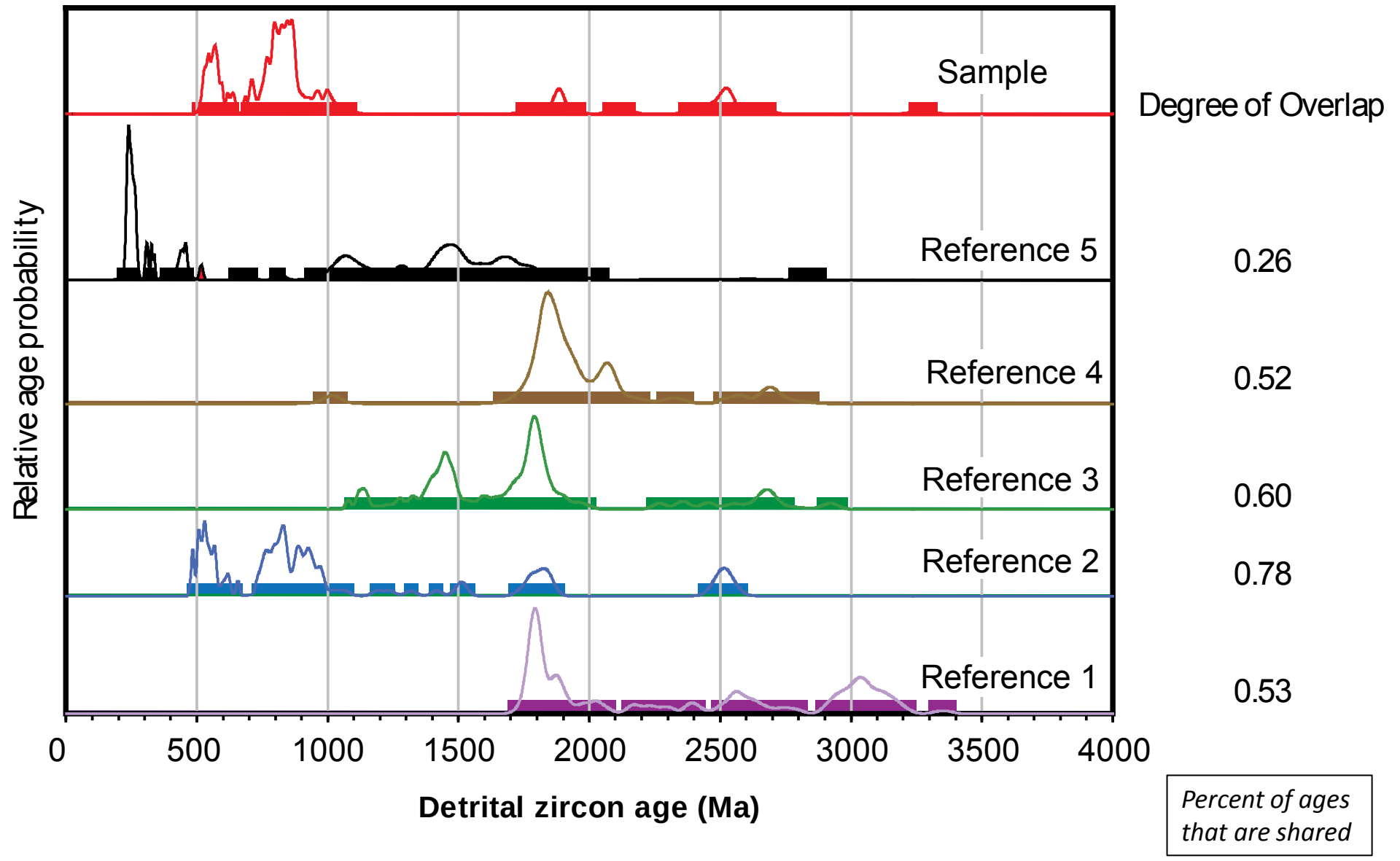
Avoid biasing results!

Avoid dividing clusters!

Comparing age distributions: Presence/Absence vs proportions?

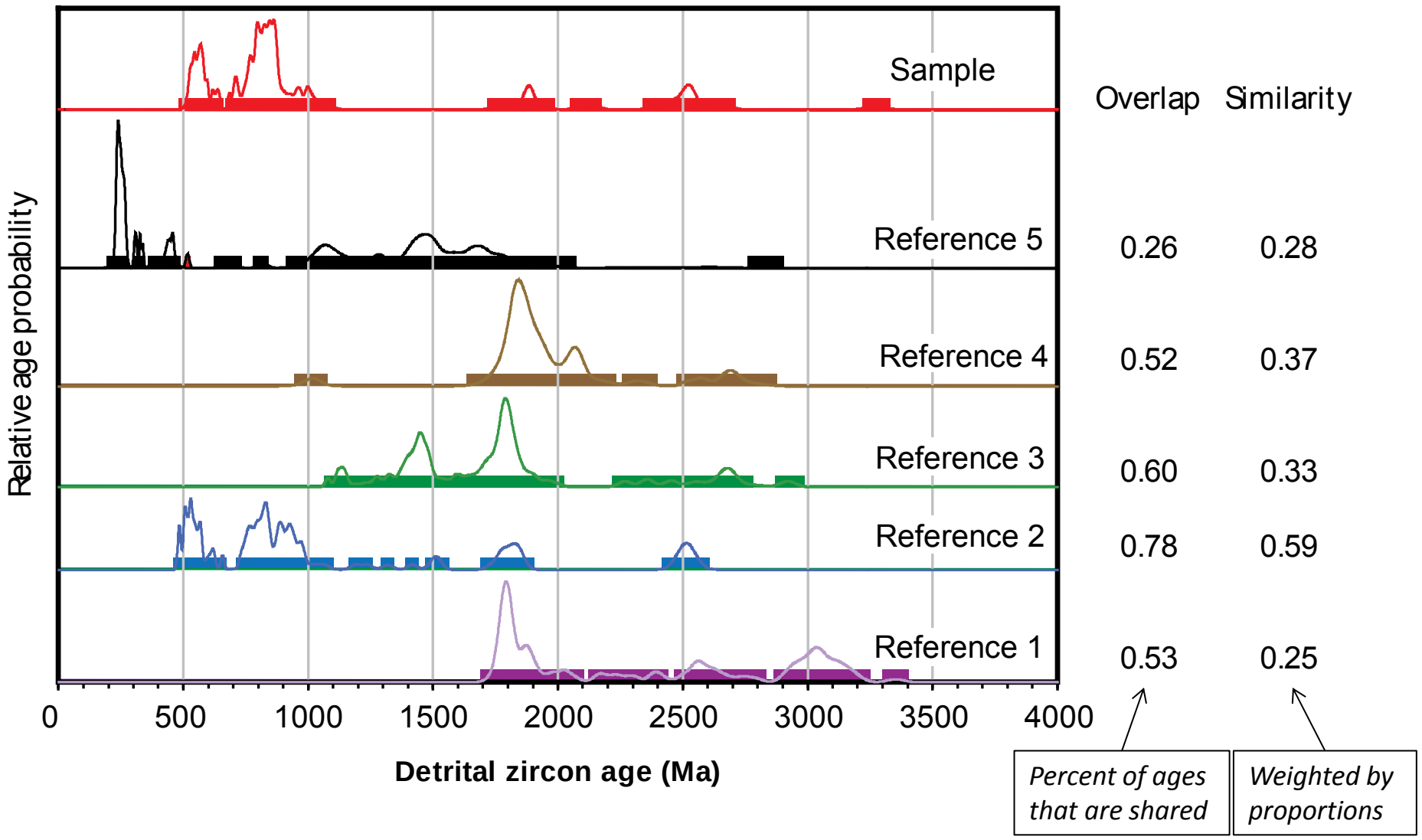


"Normalized Prob Plot" program (Gehrels, 2000; www.laserchron.org)



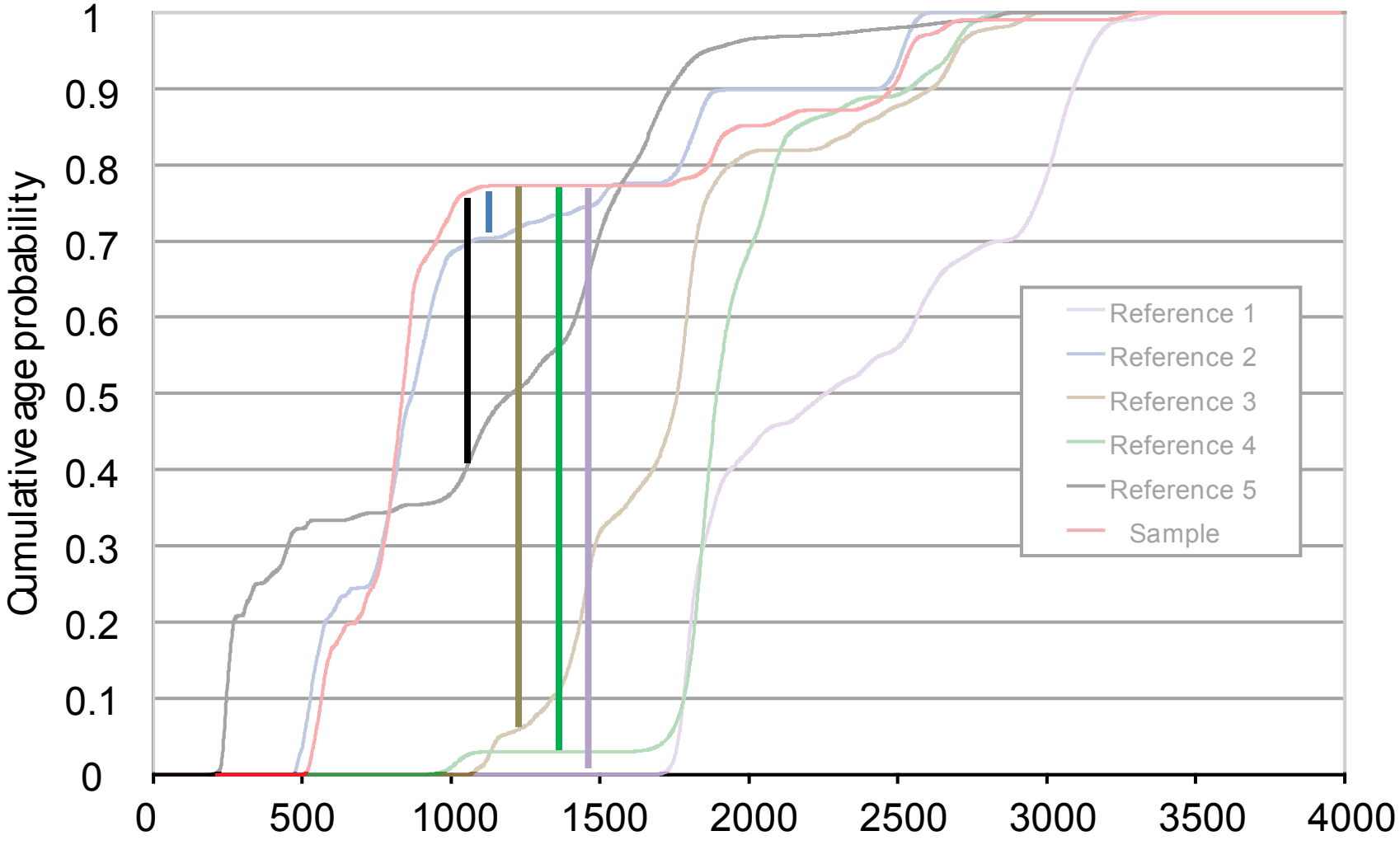
"Degree of Overlap" program (Gehrels, 2000; www.laserchron.org)

Also look at proportions of overlapping ages….



"Degree of Similarity" program (Gehrels, 2000; www.laserchron.org)

Most common comparison tool = K-S statistic

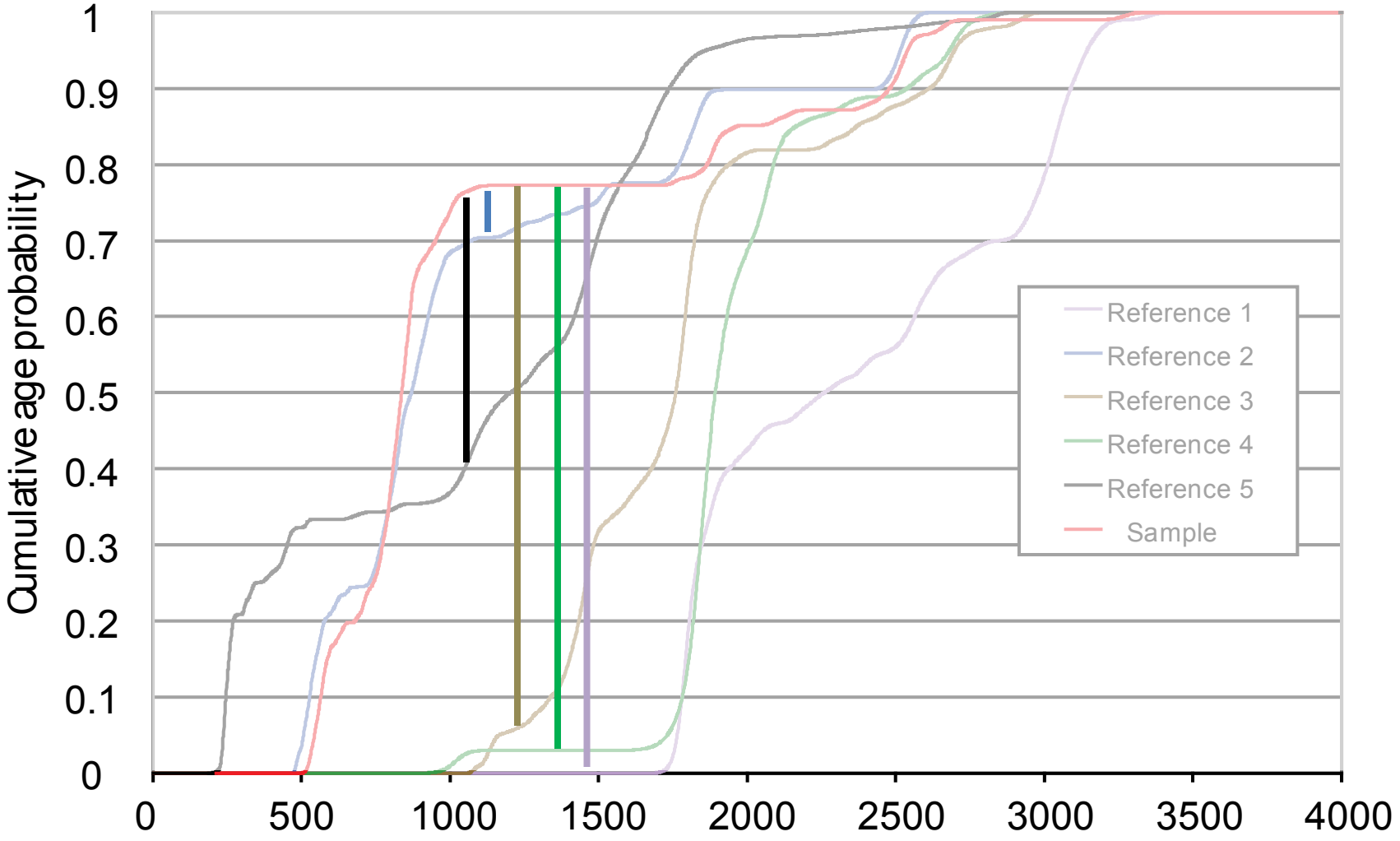


D = max difference in cumulative probability

P = probability that D results from non-representative sampling

P depends on n because larger n ➔ more representative sample

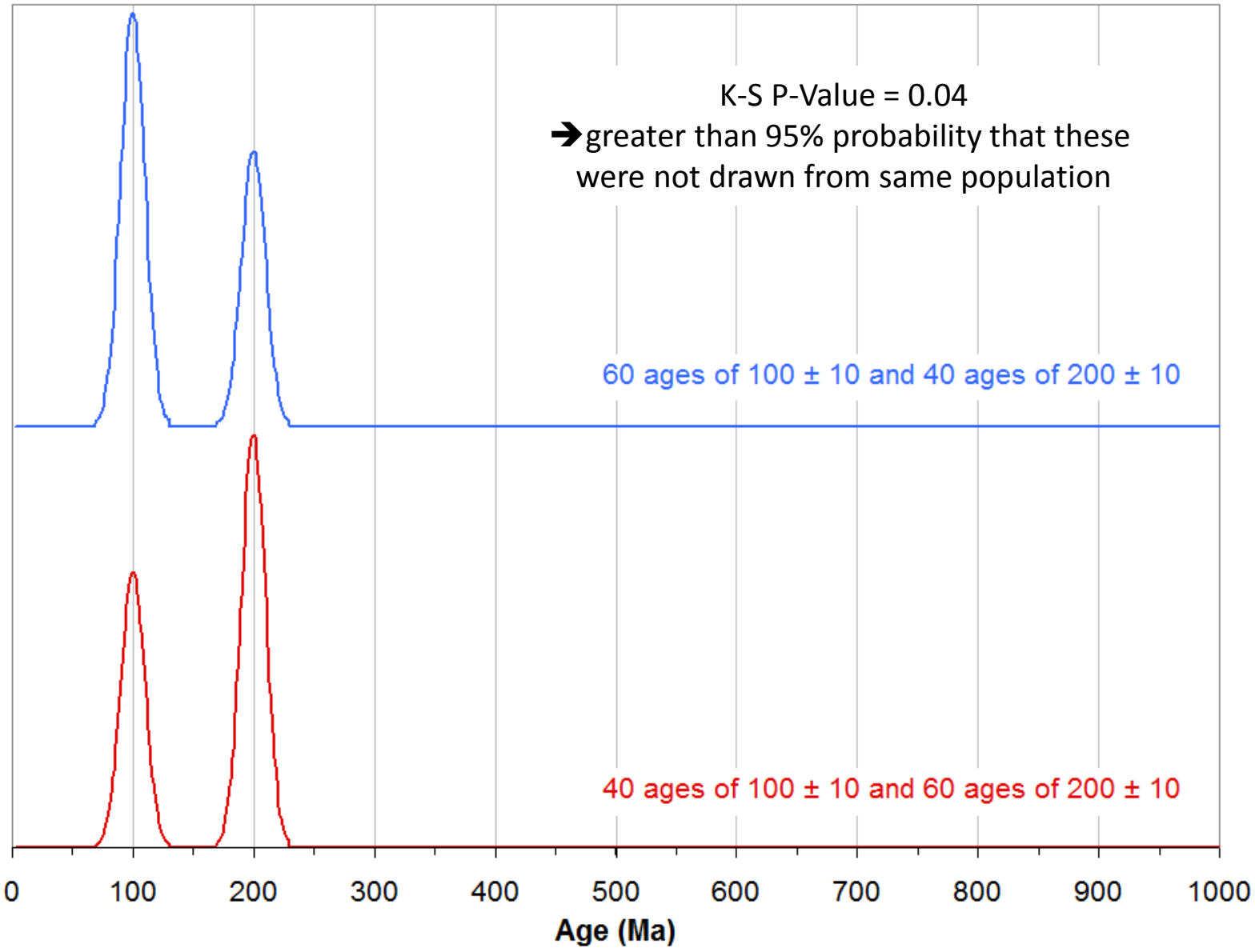
K-S statistic



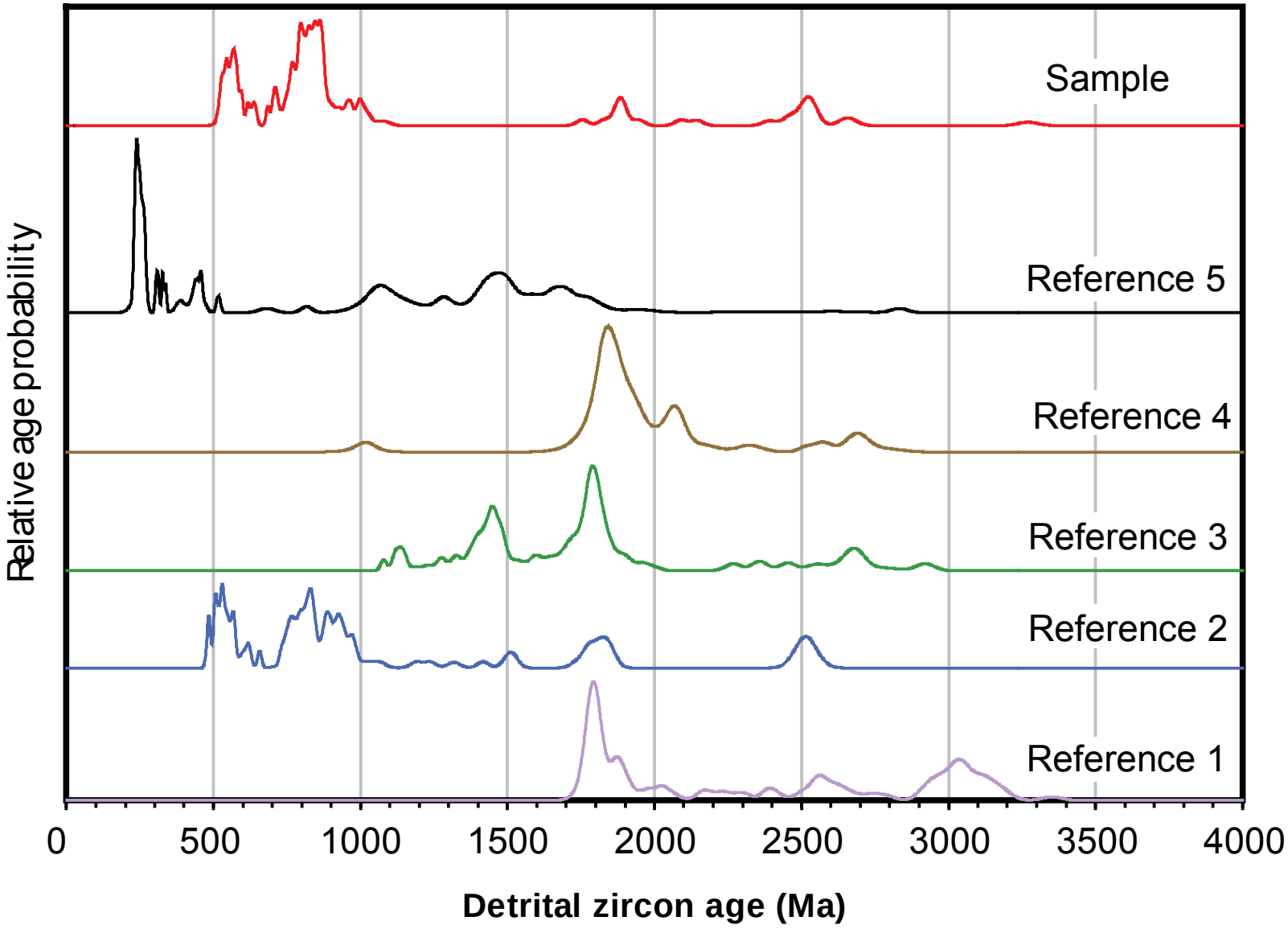
P = 0.00 for Ref 1 & 3-5 ➔ high probability that sample is significantly different from others

P = 0.38 for Ref 2 ➔ low probability that sample is significantly different from Ref 2

K-S Test: very sensitive to proportions!



➔ Need better tools for comparing presence/absence!!



Grain complexities & portrayal of ages

The ability to determine multiple ages on the same crystal presents:

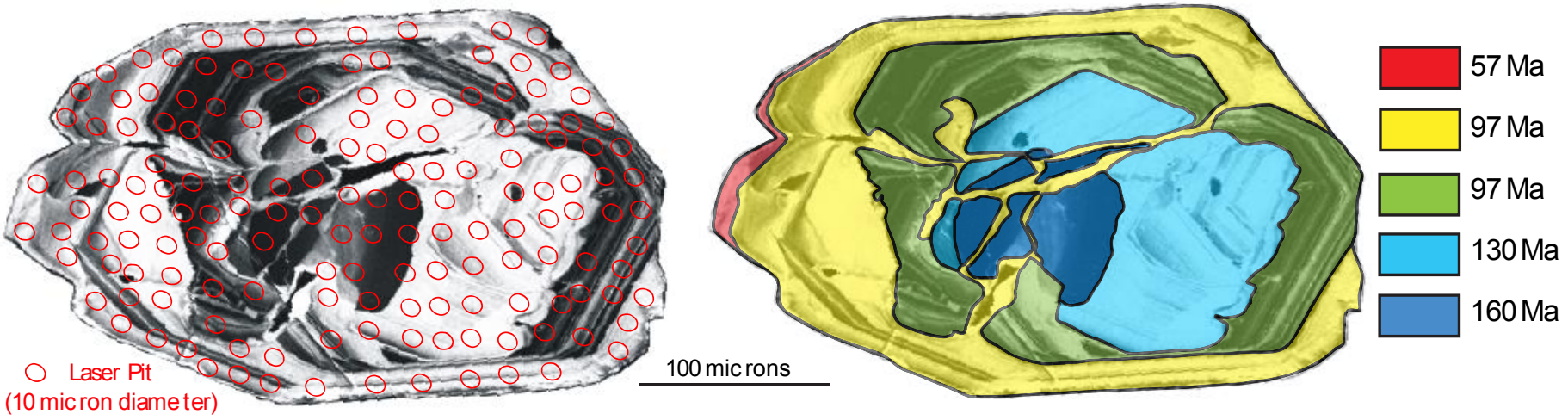
Opportunities:

- ➔ Determining more robust ages
- ➔ Using crystallization history (rather than events) as a provenance tool
- ➔ Reconstructing igneous/thermal history of known source area

Challenges:

- ➔ Which zone(s) to analyze? (all!)
- ➔ Should ages from rims, mantles, and cores be combined on a PDP? (yes!)
- ➔ Should each analysis be included on a PDP, or just the mean of each domain? (all!)

But cannot base comparisons on proportions of ages!



When is a population geologically meaningful (n=1)?

- ➔ Requires analysis of data to ensure robustness & understand complexities
- ➔ Depends on diversity of source area & complexity of data
- ➔ Depends on objectives of analysis & confidence needed in result
- ➔ No “cookbook” available…..
- ➔ *Need better methods of describing age population*

Describing youngest age component and the maximum depositional age?

- ➔ Youngest grain commonly informative, but commonly too young
- ➔ Youngest multigrain peak is more robust, but less commonly useful
- ➔ Use method(s) appropriate for study!?
- ➔ *Need better methods of identifying first-cycle grains*

Dealing with discordant data (clustering versus concordancy)

- ➔ Need to understand origin of discordance
- ➔ Rejecting discordant data or applying discordance filter/weighting will bias results
- ➔ Retaining discordant data will commonly yield ages that are too young
- ➔ Upper intercepts may be most accurate (only if grains are cogenetic!)
- ➔ Issues are most challenging for intermediate (Proterozoic) ages
- ➔ Clustering is a useful indicator of complexity
- ➔ No “cookbook” available – need to treat each sample differently!
- ➔ *Need to make sure operators understand complexities…..*

Comparing age distributions from different samples

- ➔ Probability Density Plot is useful, especially if normalized
- ➔ Presence vs absence is objective means of comparison
- ➔ All comparison methods that factor in proportions of ages are risky because of geological, analytical, and interpretive biases
- ➔ *Need better tools that are not/less sensitive to proportions of ages*

Grain complexities & portrayal of ages

- ➔ Ability to generate multiple ages from each grain presents great opportunities!
- ➔ Most powerful if complementary data available
- ➔ PDP may not be best method of capturing histories and processes recorded by these data
- ➔ *Multidimensional analysis tools are needed…..*