High resolution pulse-by-pulse laser ablation U-Pb age dating of complex zircons and simultaneous Hf isotope analyses from petrographic thin sections

Qing-Zhu Yin

Department of Geology
University of California-Davis

College of Charleston
NSF Workshop on LA-ICP-MS
March 8, 2013

Geochemistry Geophysics Geosystems G3

Technical Brief
Volume 13, Number 3
21 March 2012
Q03017, doi:10.1029/2011GC004027
ISSN: 1525-2027

Published by AGU and the Geochemical Society

A trio of laser ablation in concert with two ICP-MSs: Simultaneous, pulse-by-pulse determination of U-Pb discordant ages and a single spot Hf isotope ratio analysis in complex zircons from petrographic thin sections

Darren L. Tollstrup
Department of Geology, University of California, One Shields Avenue, Davis, California 95616, USA

Lie-Wen Xie
State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, PO Box 9825, Beijing 100029, China

Josh B. Wimpenny
Department of Geology, University of California, One Shields Avenue, Davis, California 95616, USA

Emily Chin and Cin-Ty Lee
Department of Earth Sciences, Rice University, Houston, Texas 77005, USA

Qing-Zhu Yin
Department of Geology, University of California, One Shields Avenue, Davis, California 95616, USA (qyin@ucdavis.edu)

Earth and Planetary Science Letters 361 (2013) 120–133

Contents lists available at SciVerse ScienceDirect

Earth and Planetary Science Letters

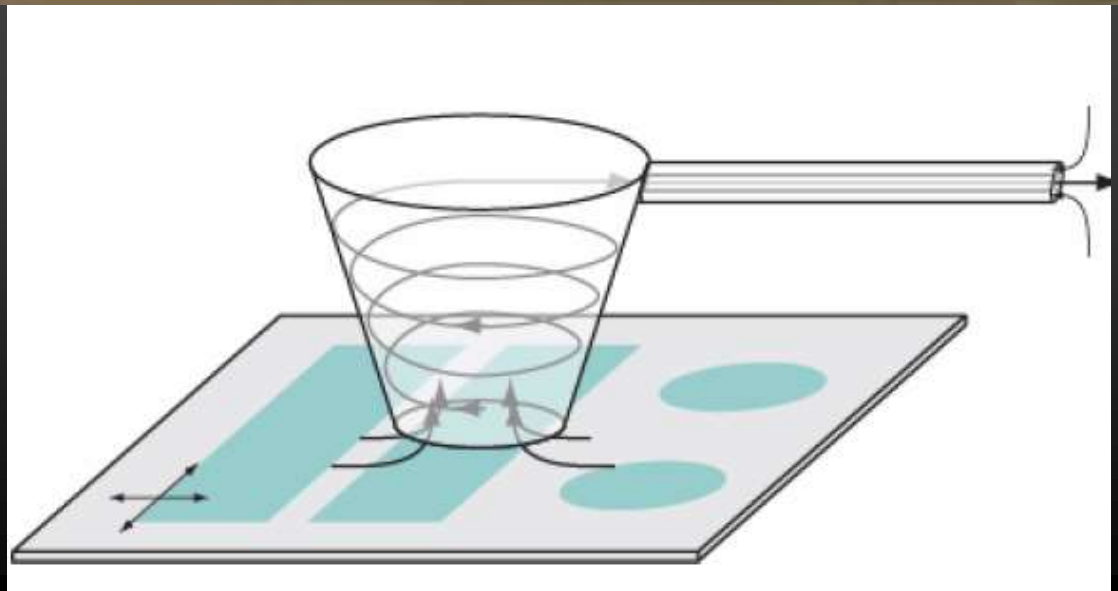
journal homepage: www.elsevier.com/locate/epsl

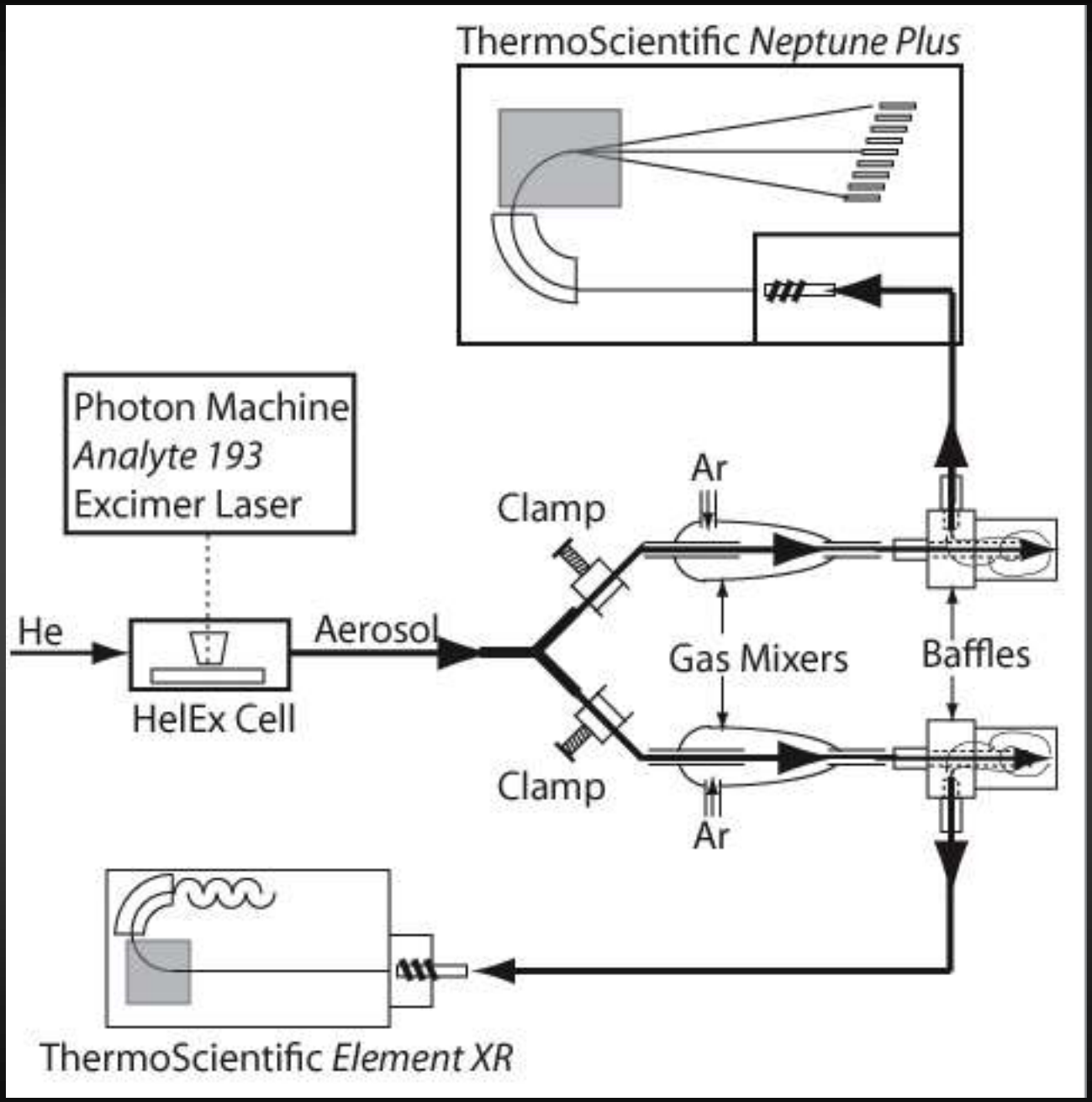
On the origin of hot metasedimentary quartzites in the lower crust of continental arcs

Emily J. Chin [a,*], Cin-Ty A. Lee [a], Darren L. Tollstrup [b], Liewen Xie [c], Josh B. Wimpenny [b], Qing-Zhu Yin [b]

[a] Department of Earth Science, Rice University, Houston, TX 77005, USA
[b] Department of Geology, University of California Davis, Davis, CA 95616, USA
[c] State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China

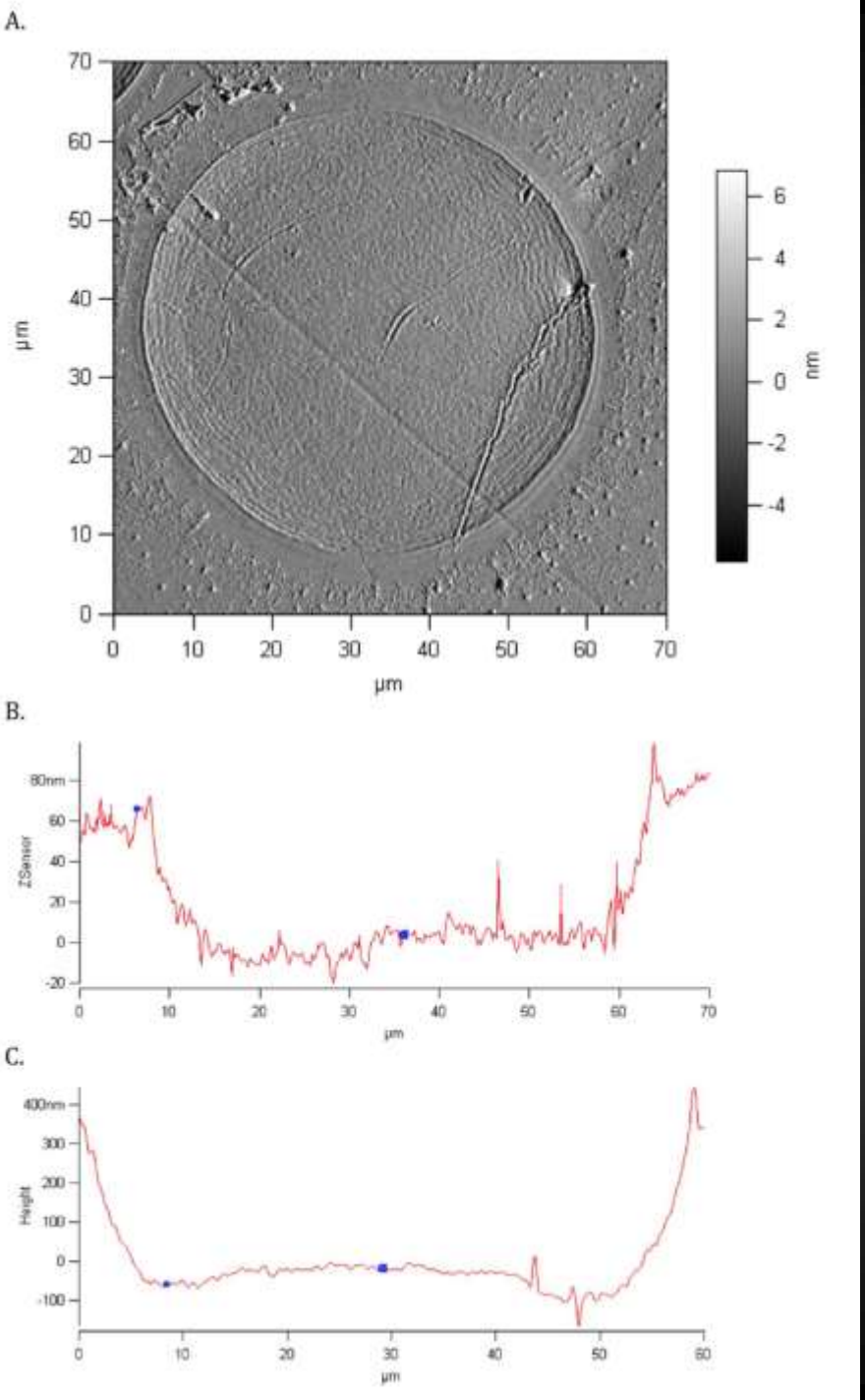

EXIT
NEPTUNE



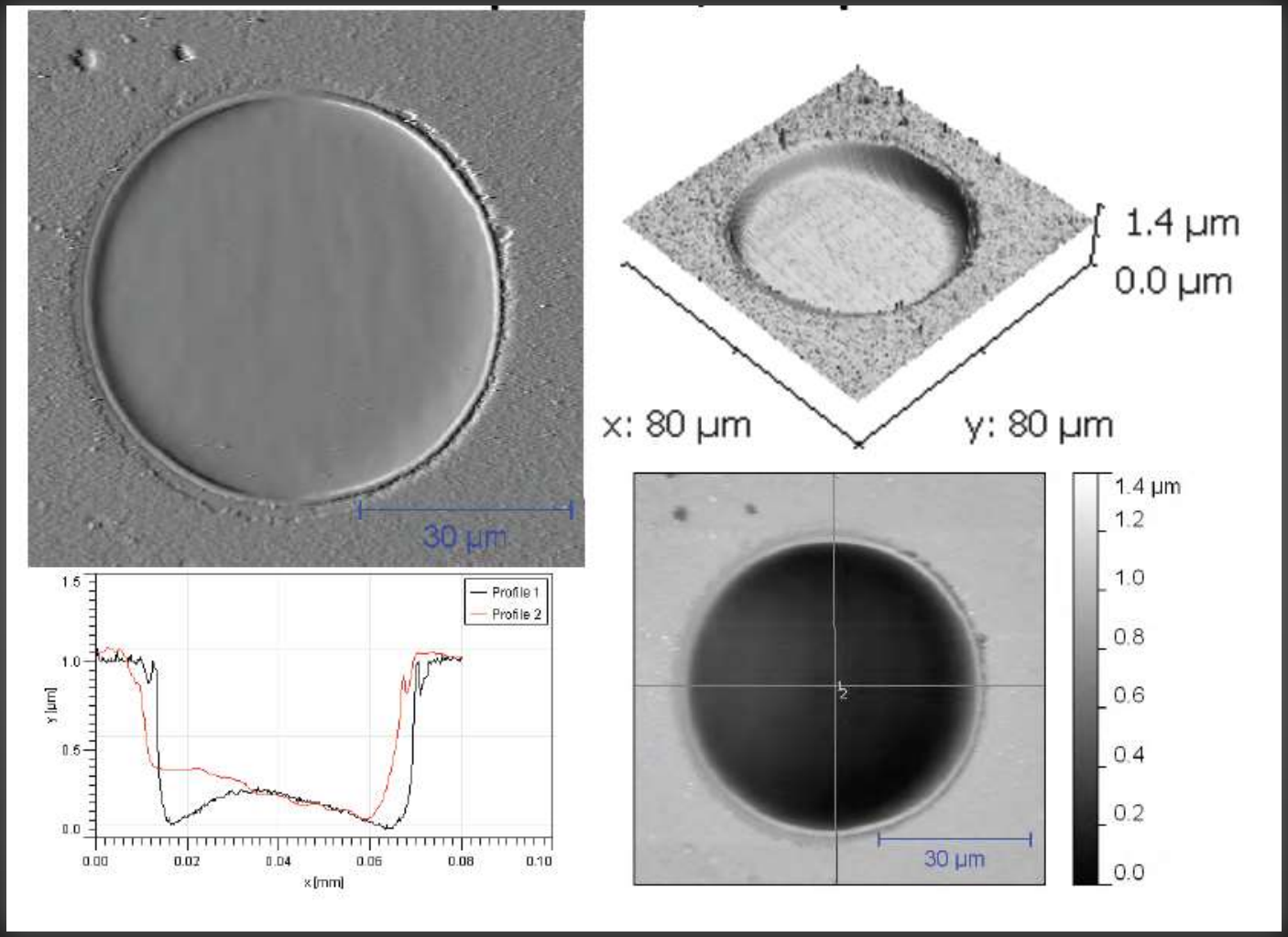

ThermoScientific *Neptune Plus*
Photon Machine
Analyte 193
Excimer Laser
Ar
Clamp
He
Aerosol
Gas Mixers
Baffles
HelEx Cell
Clamp
Ar
ThermoScientific *Element XR*

Tollstrup et al (2012)

AFM Image and Depth Profile of 91500

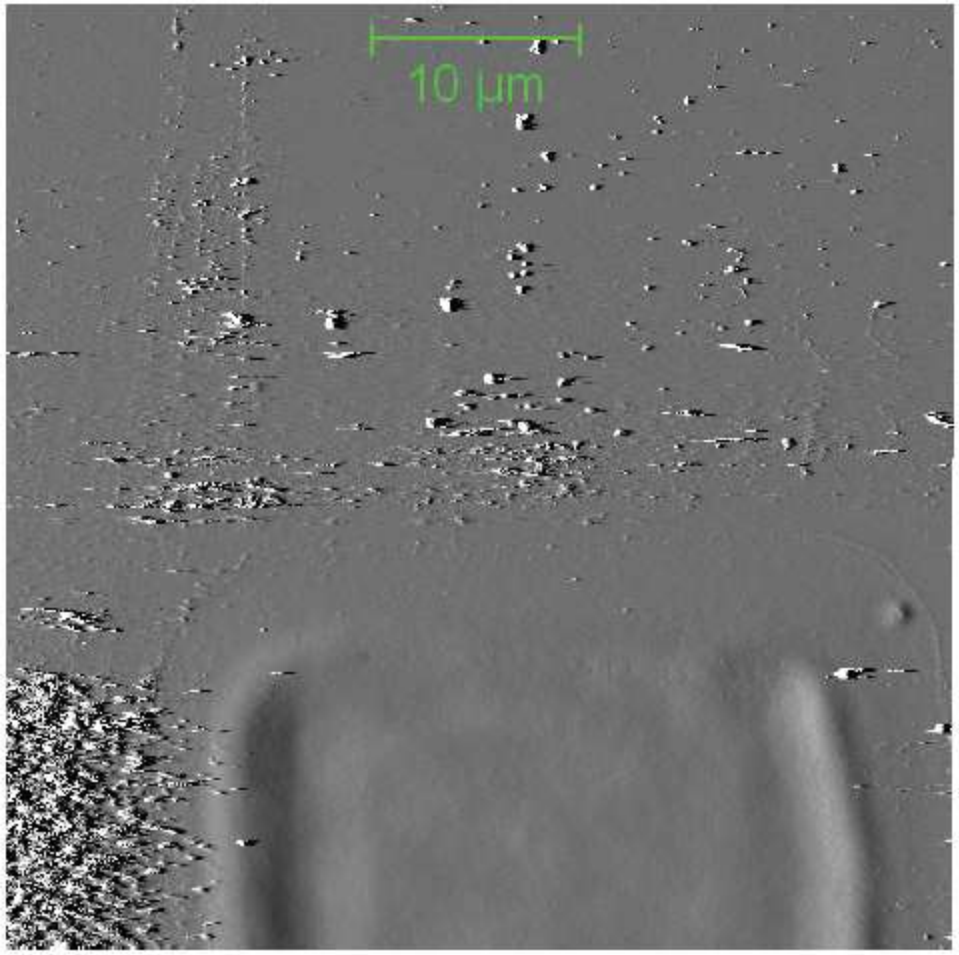


Characterising pit depth: AFM



Sapphire: 50 pulses ~ 800nm depth

Characterizing pit depth of Si with AFM



Single Pulse, 10% Laser Energy

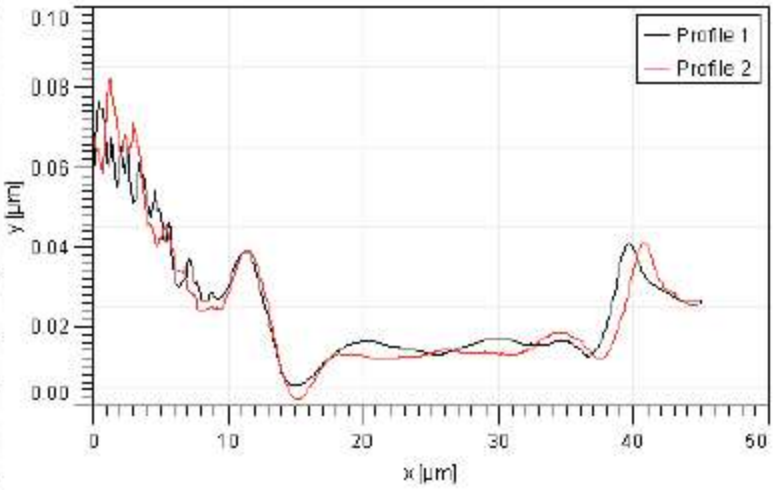
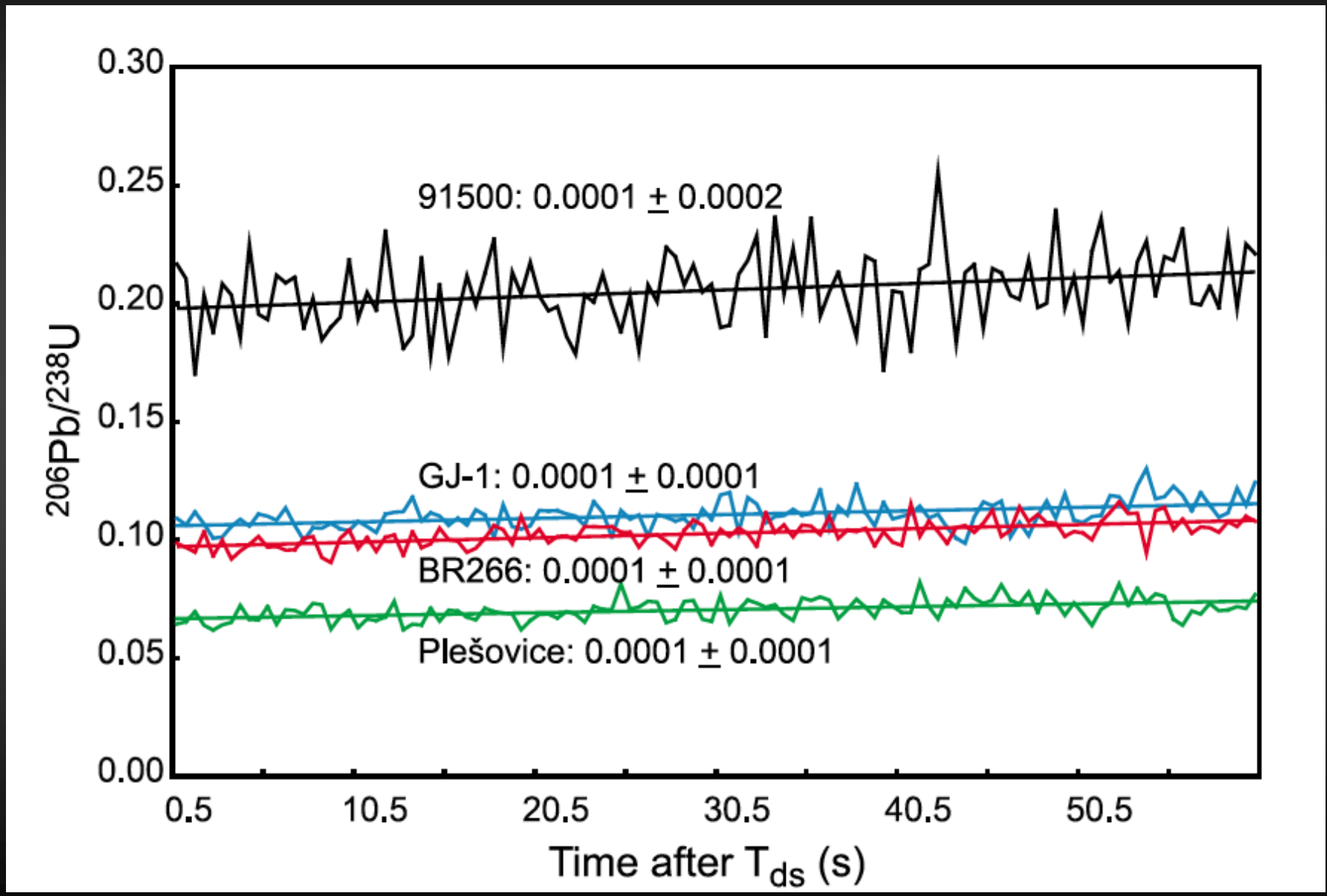


Table 2. Data Acquisition Parameters

	Description/Value
	HR-SF-ICP-MS
Isotopes measured	^{204}(Pb + Hg), ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{232}Th, ^{238}U
Settling time	1 ms
Samples per peak	100
Mass window (%)	3
Sample Time	20 ms for ^{207}Pb, 10 ms for all other isotopes
Segment duration	60 ms for ^{207}Pb, 30 ms for all other isotopes
Cycles	350
Total time	76 s
	MC-ICP-MS
Isotopes measured	^{172}Yb, ^{173}Yb, ^{175}Lu, ^{176}Hf, ^{177}Hf, ^{178}Hf, ^{179}Hf, ^{180}Hf
Integration time	0.131 s
Settling time	3 s
Baseline type	On-Peak Zeros
Baseline duration	60 s

Note the Dwell time

Four stds after every five unknowns (Tollstrup et al., 2012)
Down hole fractionation



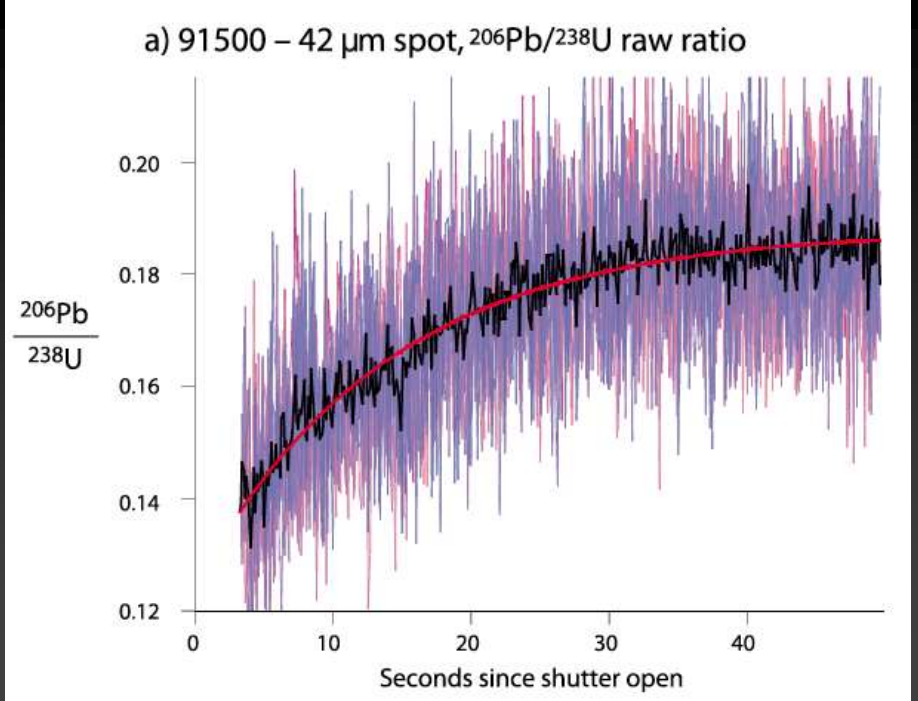
Paton et al (2010)

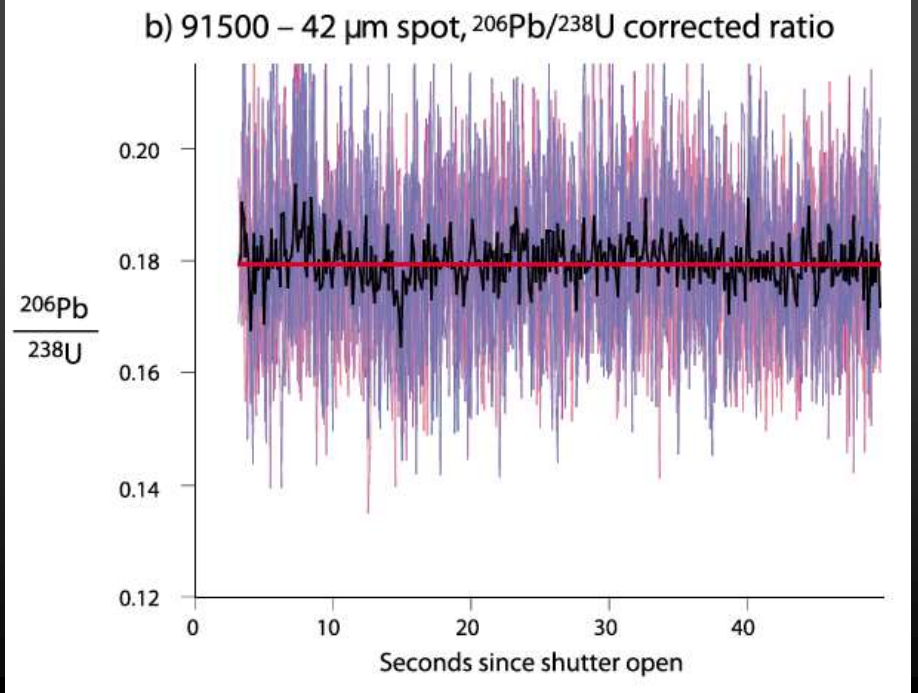
Observed correlation

(Red: exponential fit line)

“Corrected 206Pb/238U ratios show no variability with time, indicating that the fitted exponential curve is a suitable model for downhole elemental fractionation.”

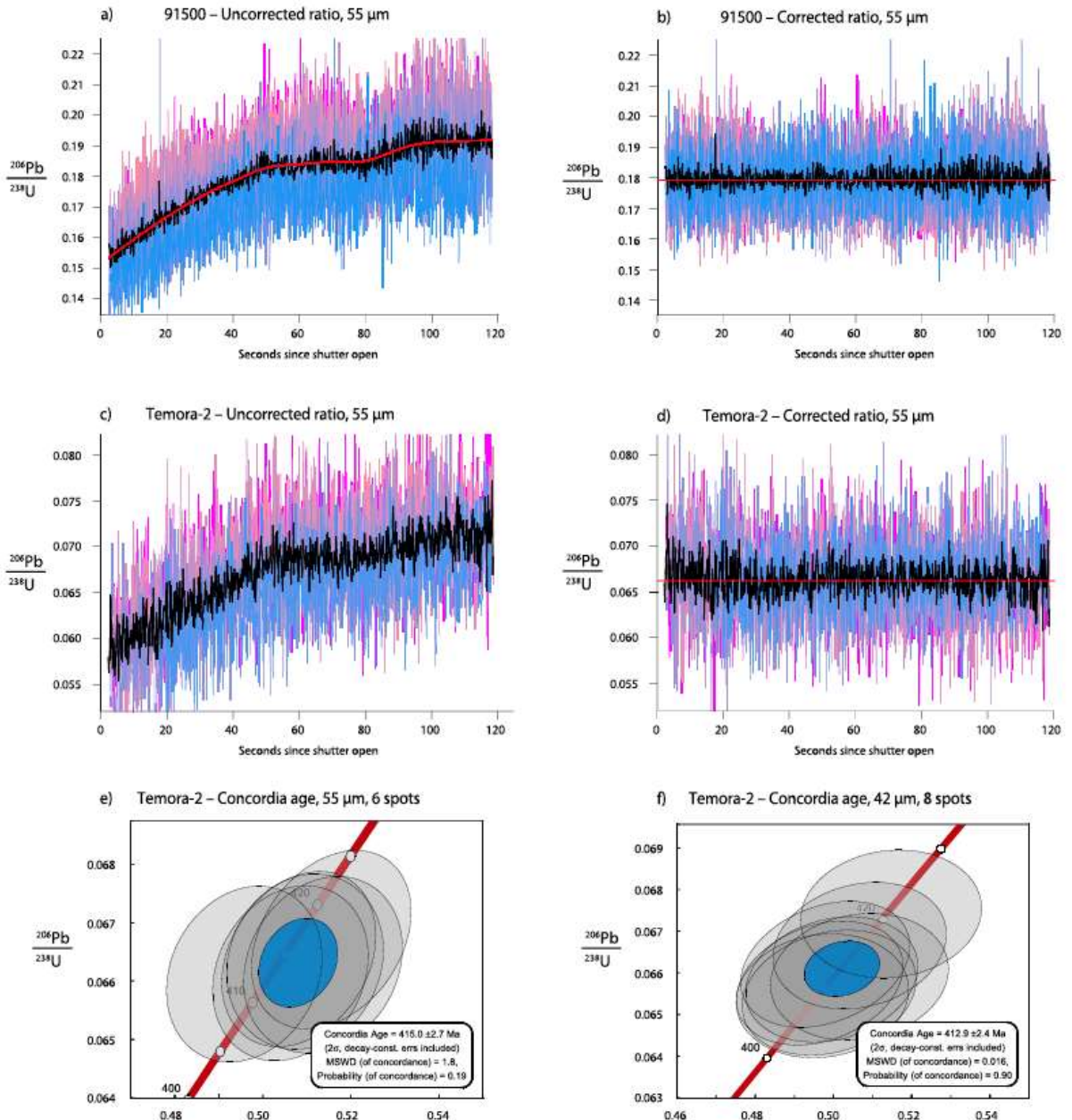
????





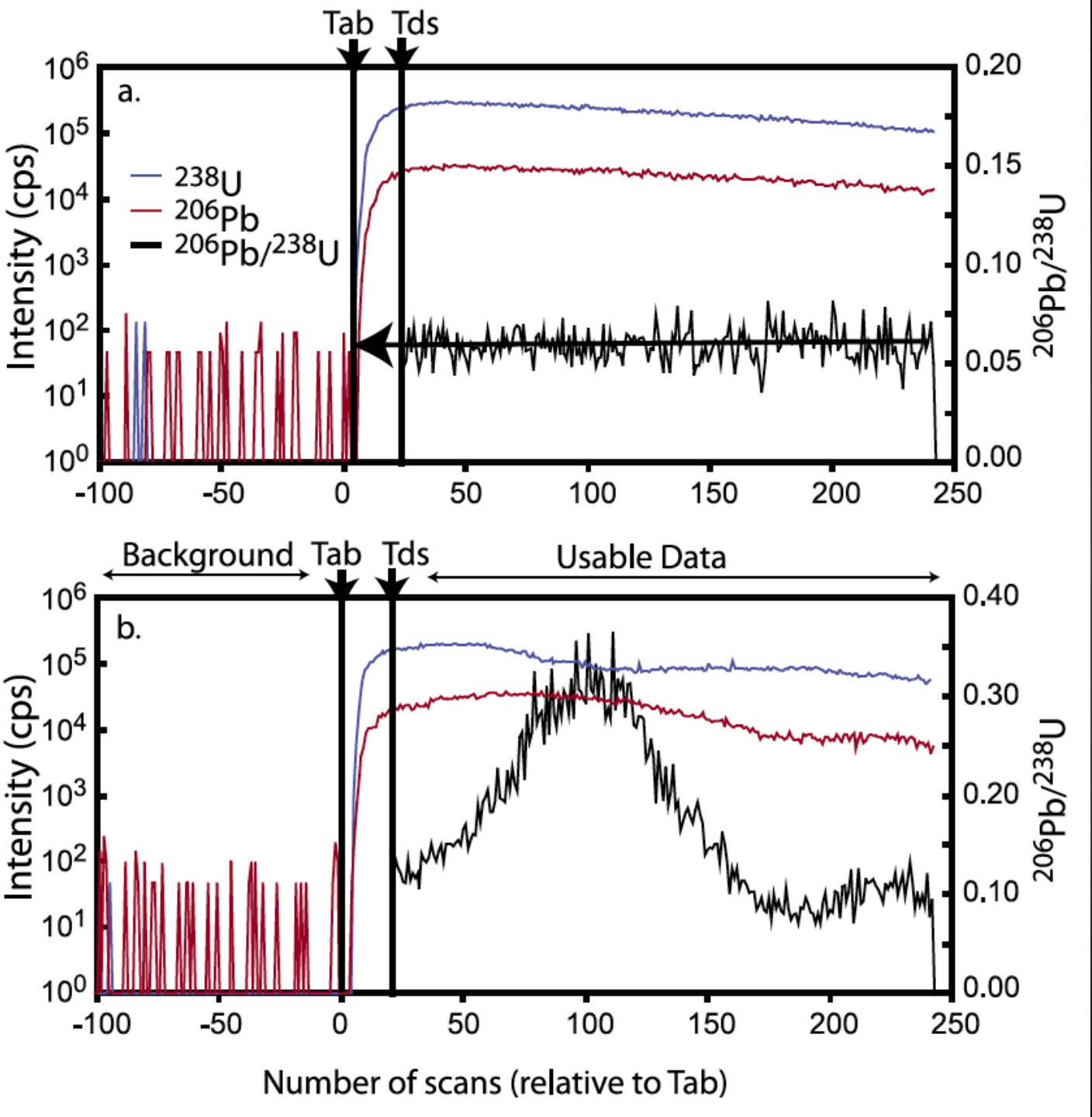
Paton et al (2010)

Cubic spline fit of Zircon 91500 applied to Temora

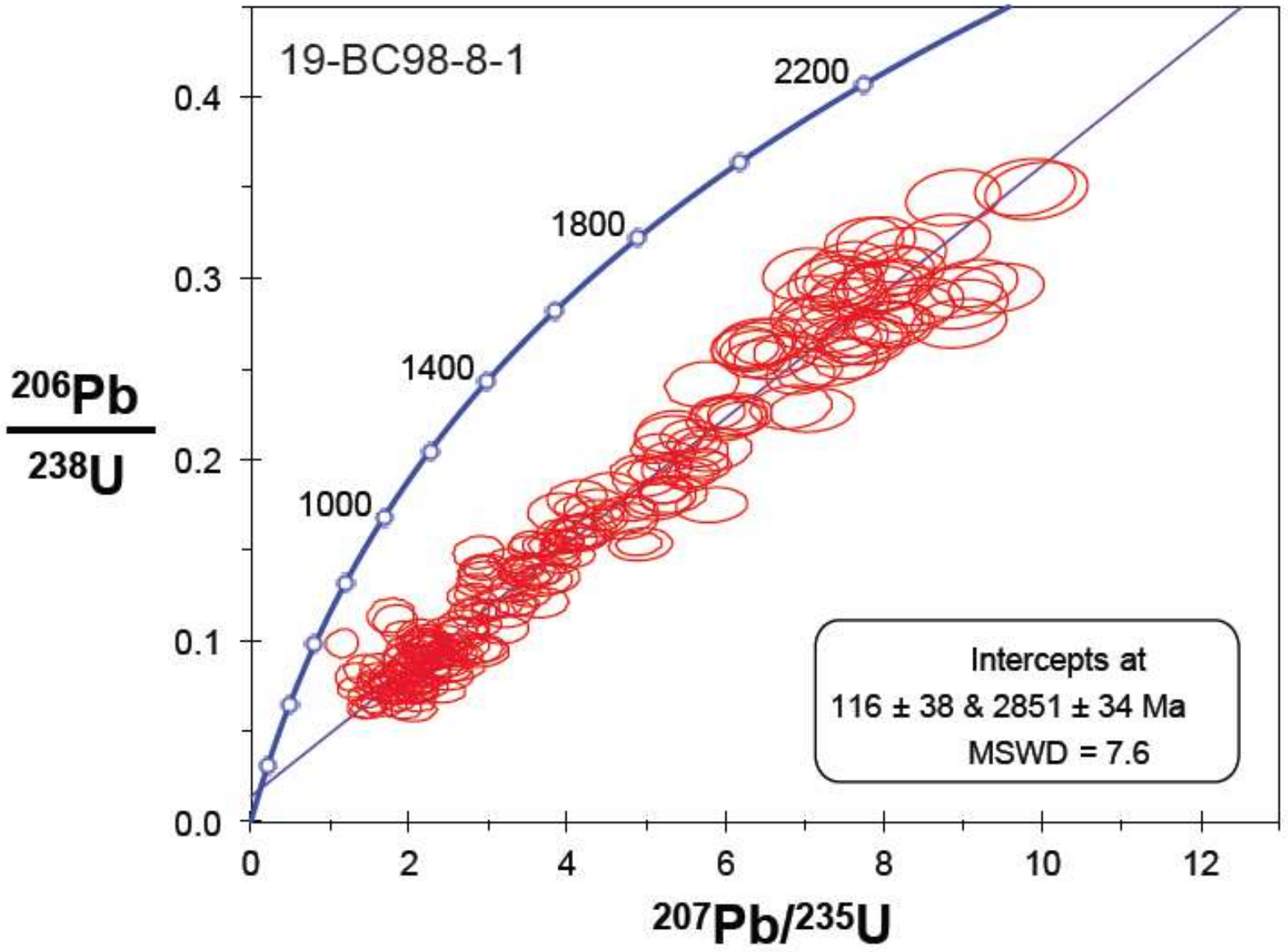


Our work

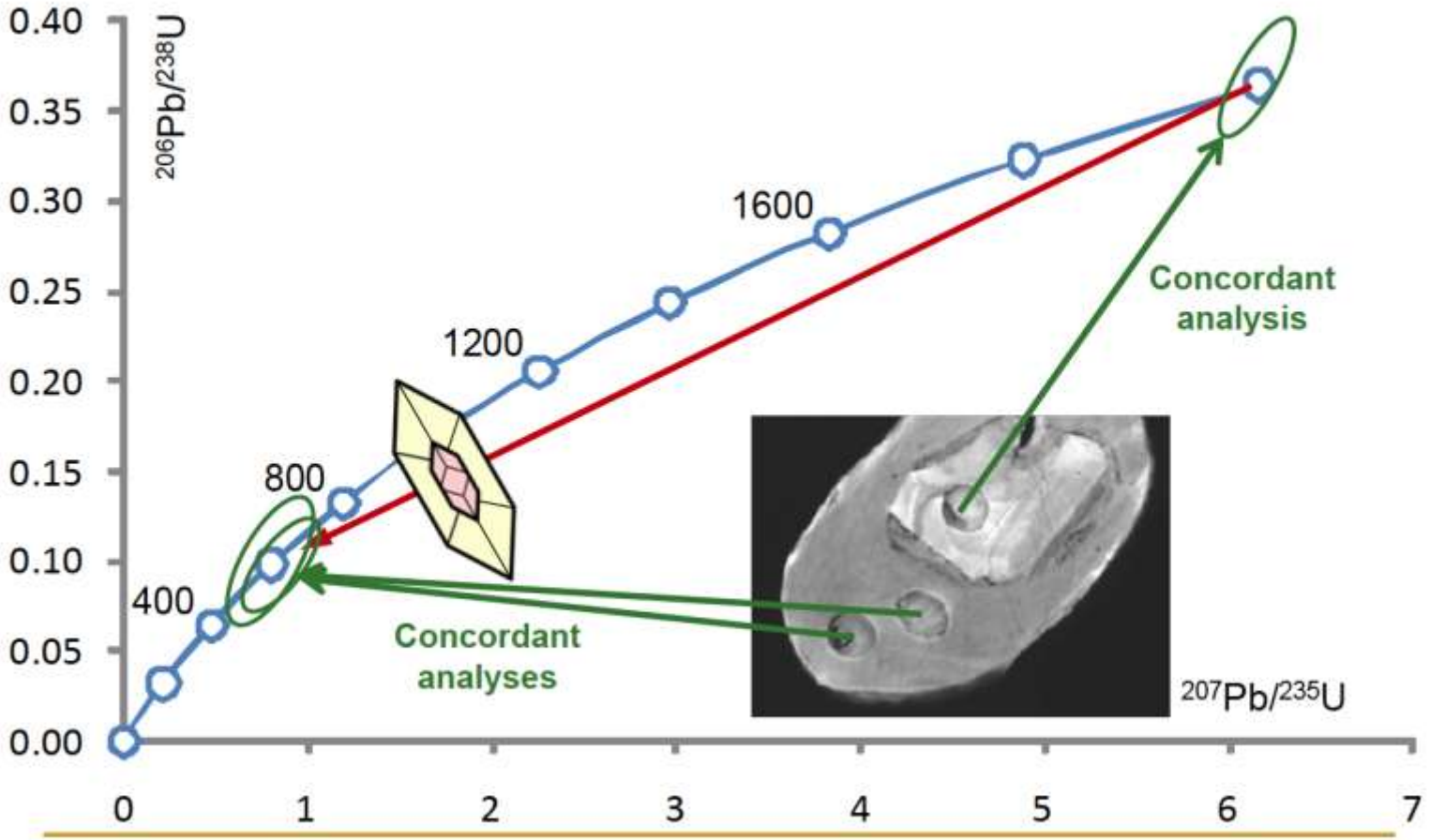
Tollstrup et al (2012)



Our work (Chin et al., 2013 EPSL)

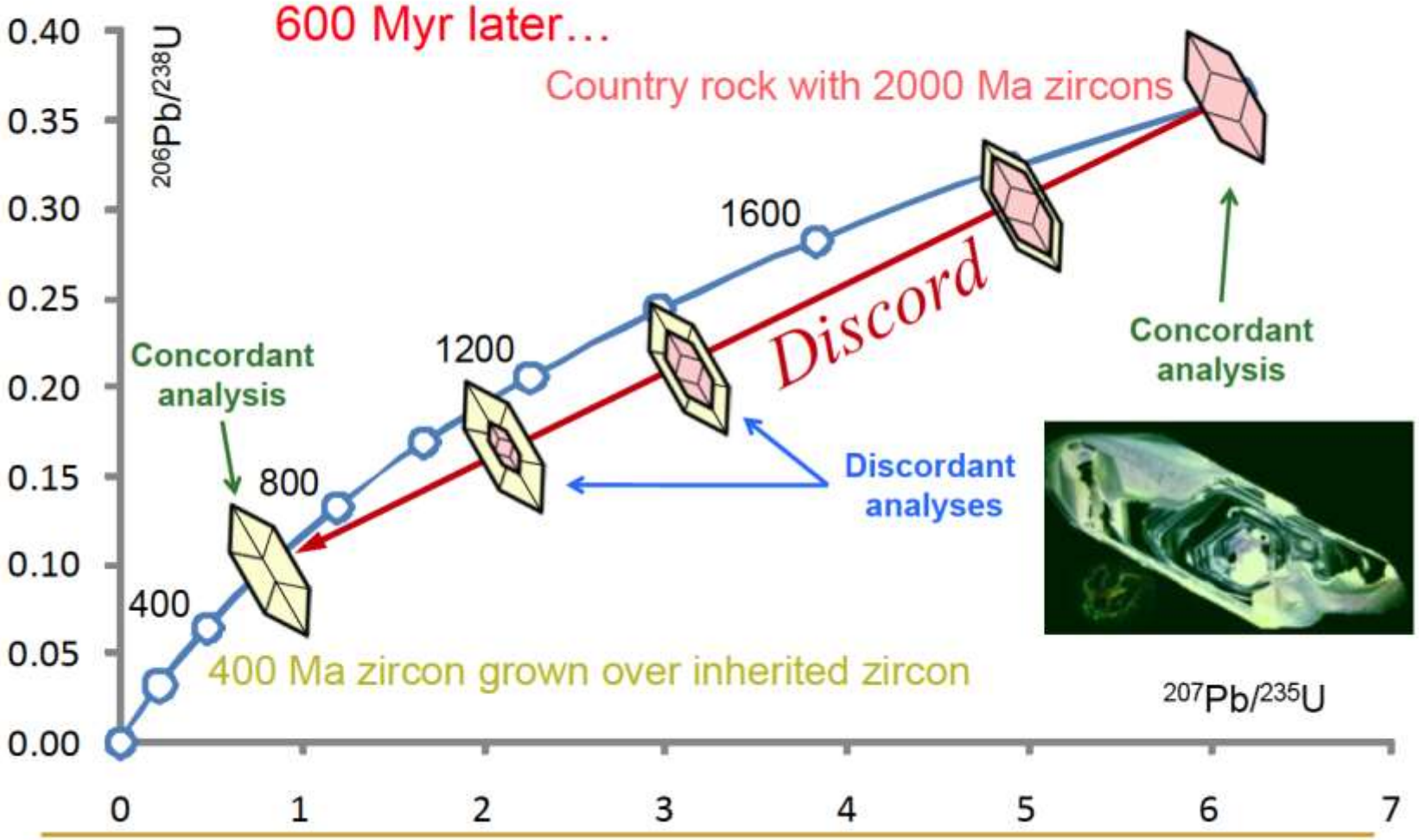


Unravel complexity through wise spot choices



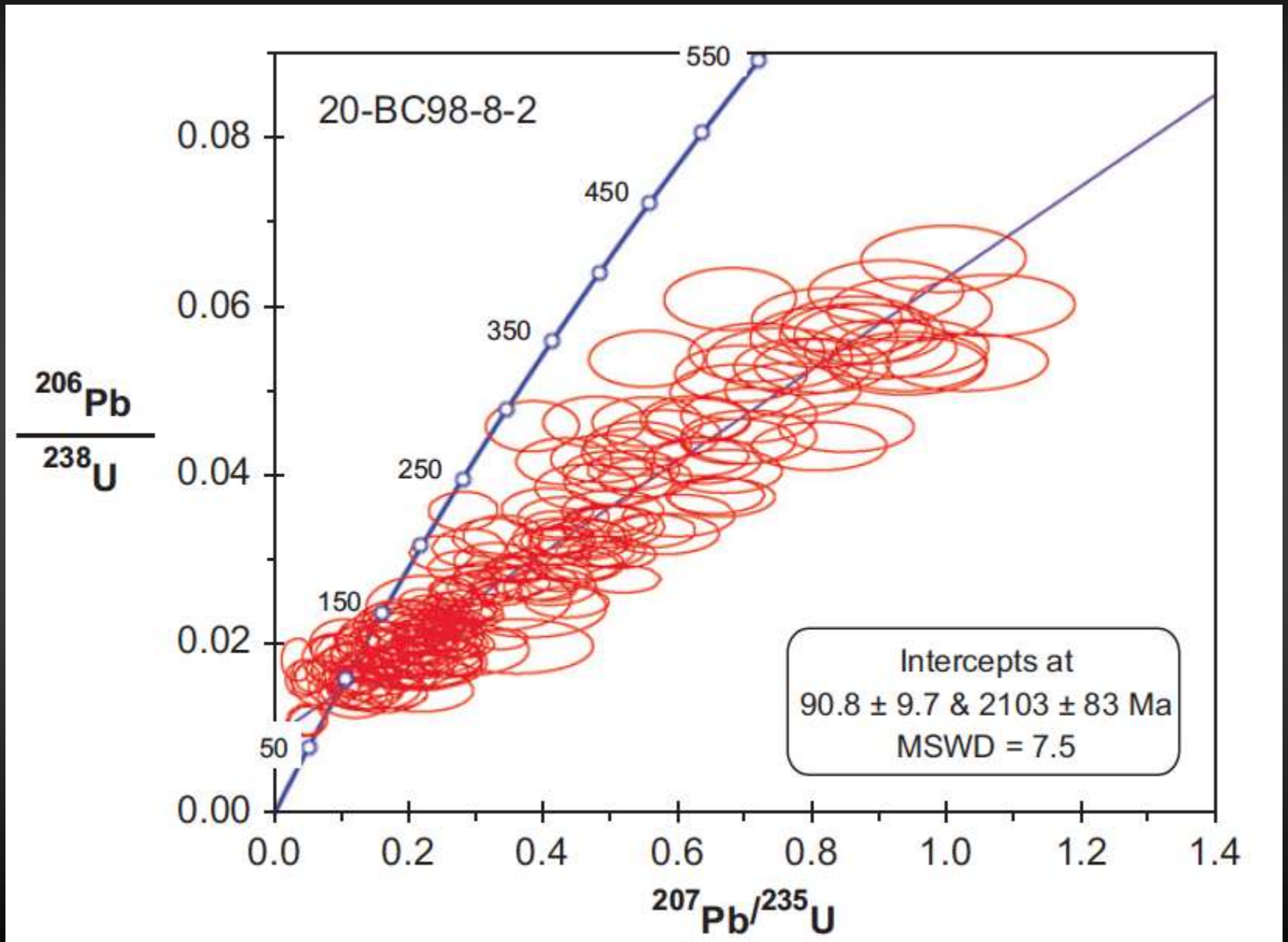
Borrowing AGU 2011 Workshop Slides from Gehrels et al

Complexity from inheritance

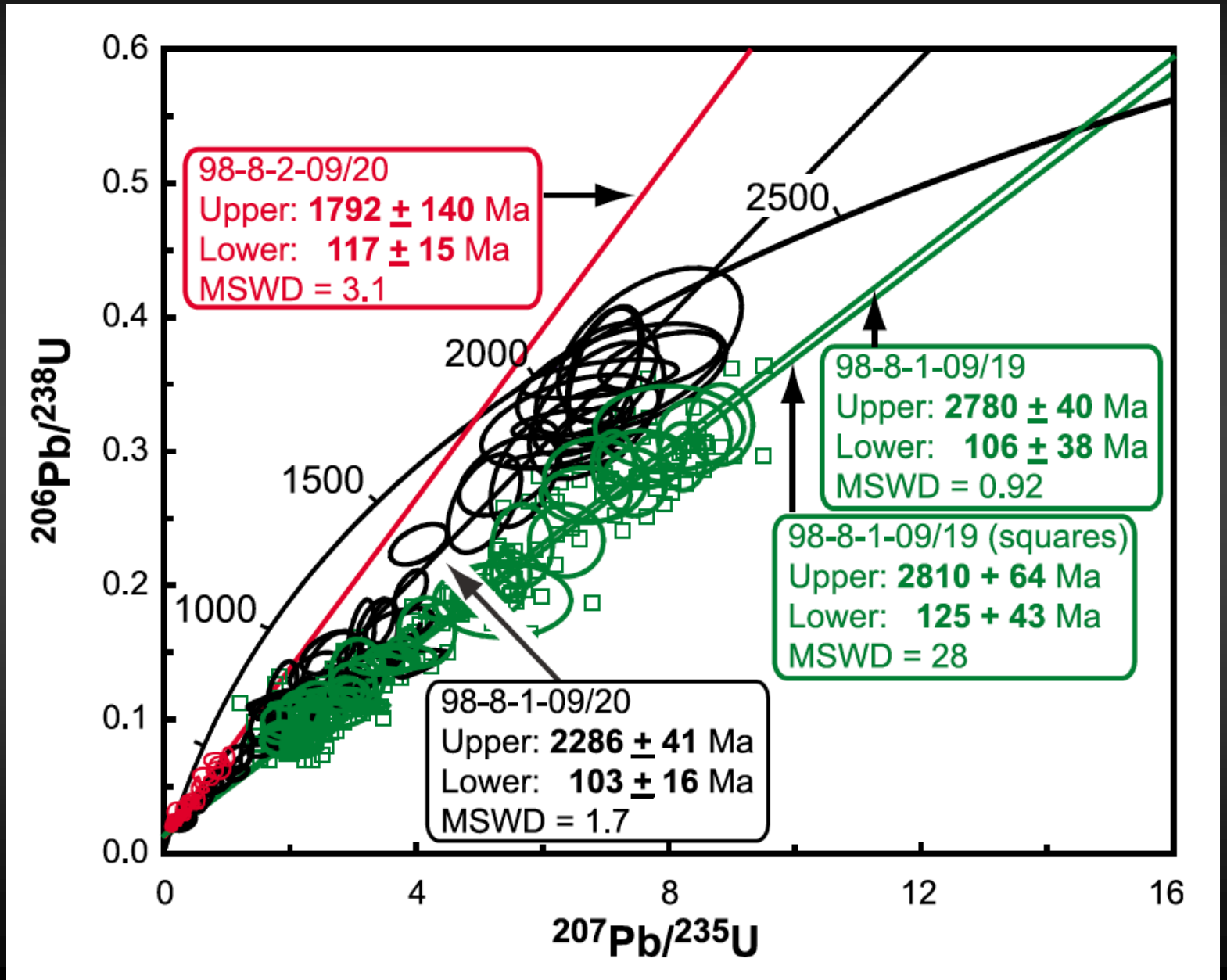


Out of single zircon, we can accomplish something very similar to this!!

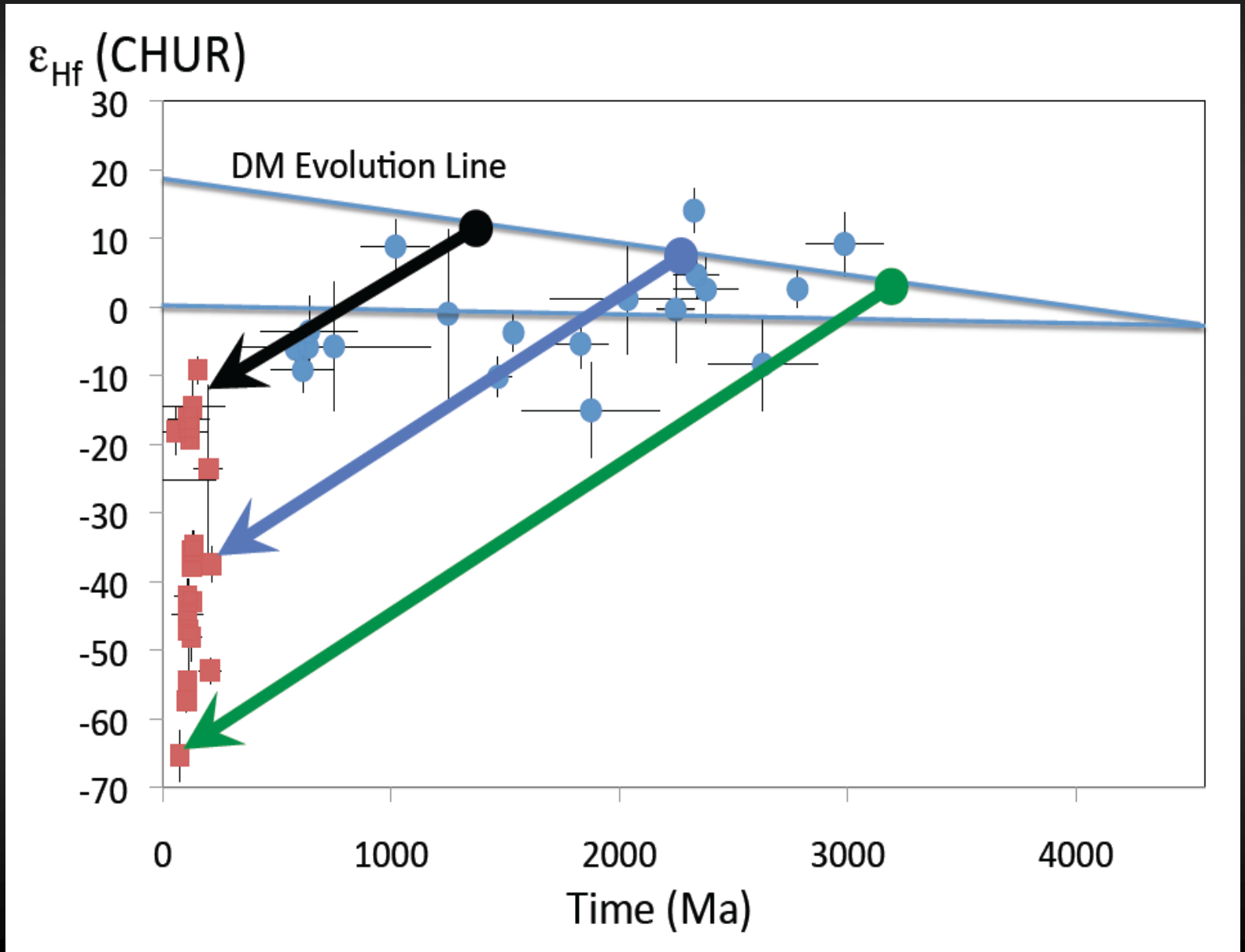
Chin et al. (2013) EPSL

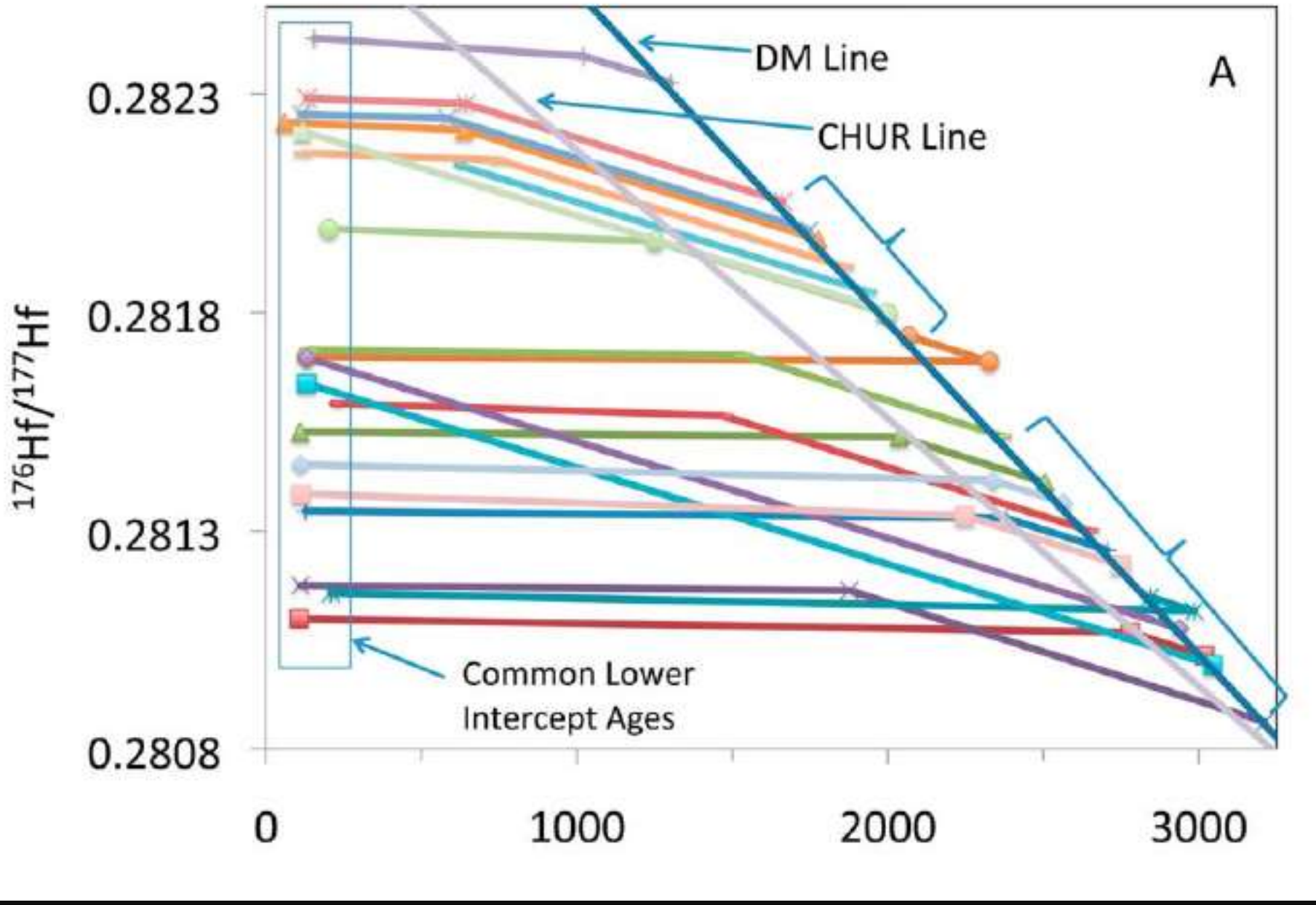


Tollstrup et al (2012 G^3)

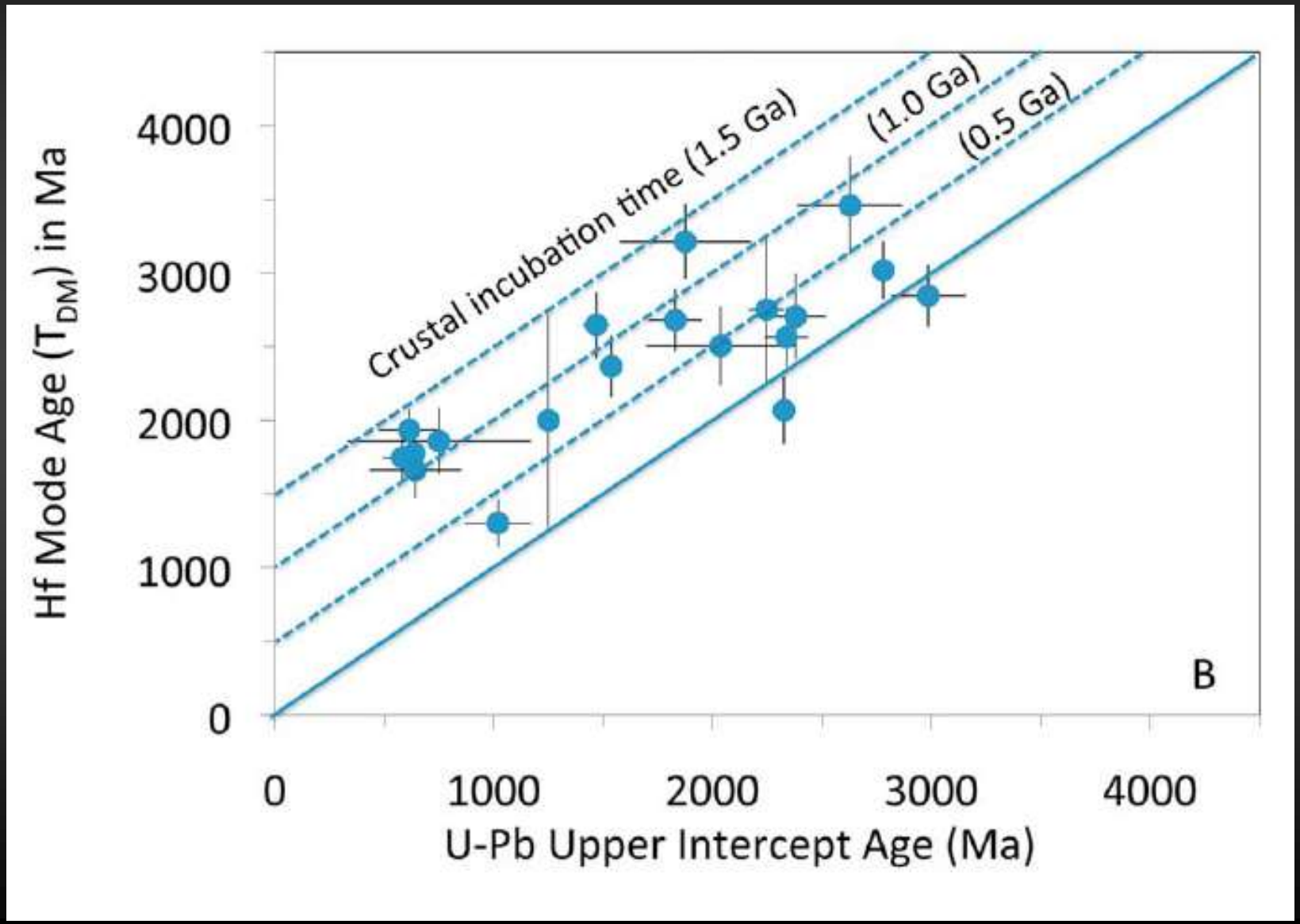


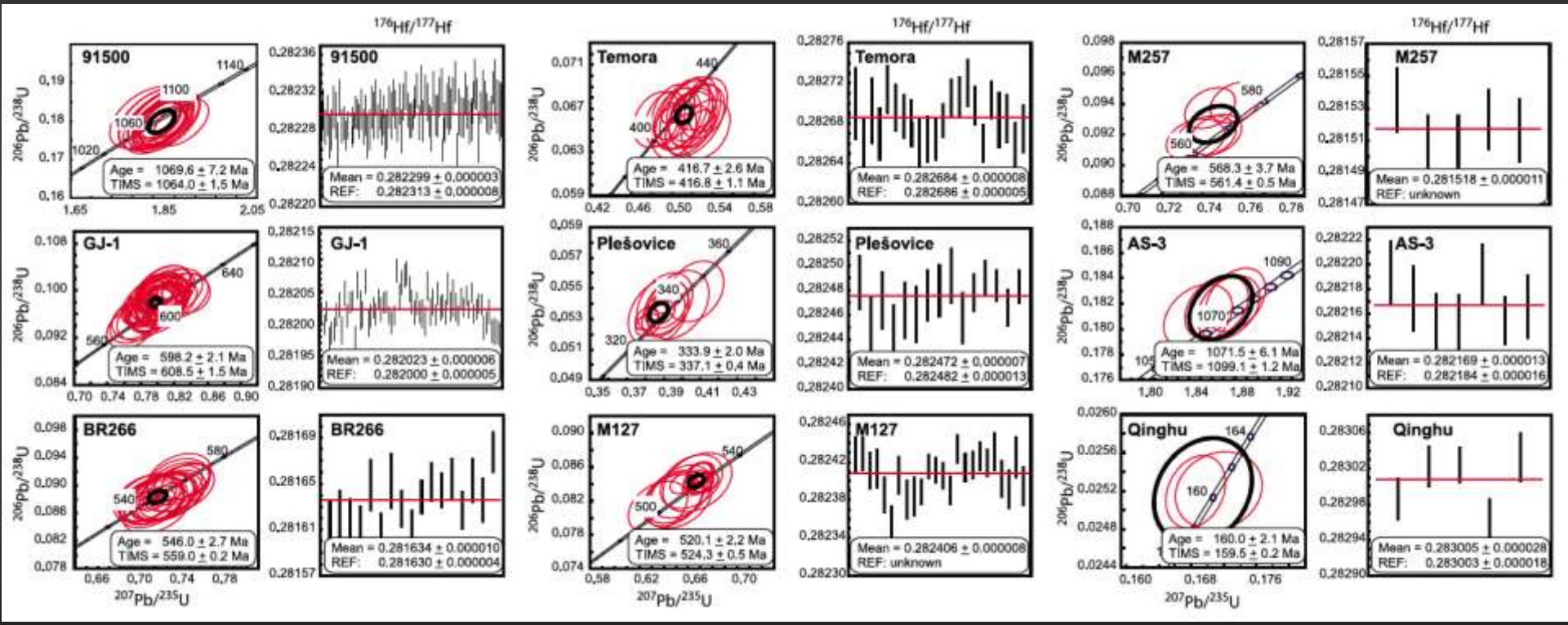
Tollstrup et al (2012 G^3)




DM Line
CHUR Line
A
0.2823
0.2818
0.2813
0.2808
$^{176}Hf/^{177}Hf$
Common Lower
Intercept Ages
0
1000
2000
3000

Tollstrup et al (2012 G^3)




91500
Age = 1069.6 ± 7.2 Ma
TIMS = 1064.0 ± 1.5 Ma
Mean = 0.282299 ± 0.000003
REF: 0.282313 ± 0.000008
GJ-1
Age = 598.2 ± 2.1 Ma
TIMS = 608.5 ± 1.5 Ma
Mean = 0.282023 ± 0.000006
REF: 0.282000 ± 0.000005
BR266
Age = 546.0 ± 2.7 Ma
TIMS = 559.0 ± 0.2 Ma
Mean = 0.281634 ± 0.000010
REF: 0.281630 ± 0.000004
Temora
Age = 416.7 ± 2.6 Ma
TIMS = 416.8 ± 1.1 Ma
Mean = 0.282684 ± 0.000008
REF: 0.282686 ± 0.000005
Plešovice
Age = 333.9 ± 2.0 Ma
TIMS = 337.1 ± 0.4 Ma
Mean = 0.282472 ± 0.000007
REF: 0.282482 ± 0.000013
M127
Age = 520.1 ± 2.2 Ma
TIMS = 524.3 ± 0.5 Ma
Mean = 0.282406 ± 0.000008
REF: unknown
M257
Age = 568.3 ± 3.7 Ma
TIMS = 561.4 ± 0.5 Ma
Mean = 0.281518 ± 0.000011
REF: unknown
AS-3
Age = 1071.5 ± 6.1 Ma
TIMS = 1099.1 ± 1.2 Ma
Mean = 0.282169 ± 0.000013
REF: 0.282184 ± 0.000016
Qinghu
Age = 160.0 ± 2.1 Ma
TIMS = 159.5 ± 0.2 Ma
Mean = 0.283005 ± 0.000028
REF: 0.283003 ± 0.000018
$^{206}Pb/^{238}U$
$^{207}Pb/^{235}U$
$^{176}Hf/^{177}Hf$

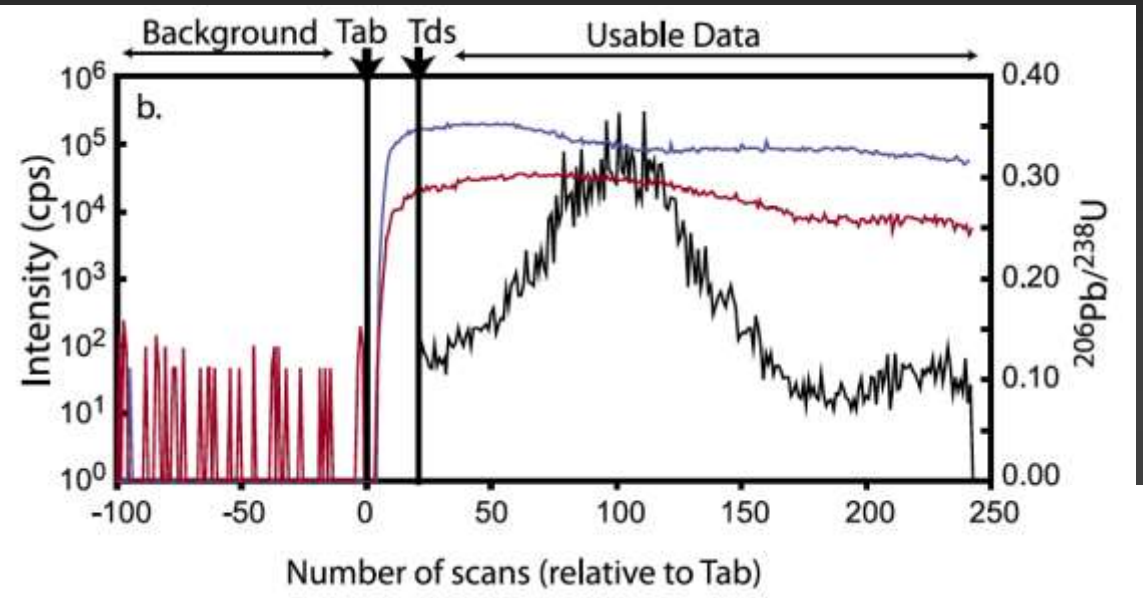
Conclusion

- We have developed a technique for the simultaneous in situ determination of U-Pb ages and Hf isotope ratios from a single spot in complex, discordant zircons by combining both a single-collector and a multicollector sector field inductively coupled plasma–mass spectrometry (ICP-MS) with a 193 nm excimer laser ablation system.
- Accurately to within 0.3–2.5% (2σ) compared to the nominal value, internal errors are better than 0.4–0.7%; hafnium isotope <0.008%.

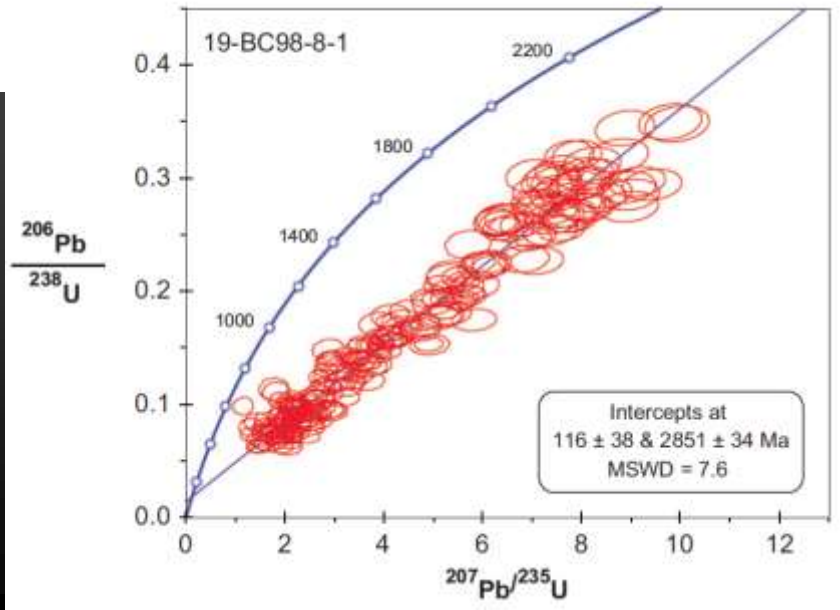
- We applied the technique to complex, discordant zircons with variable $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ ratios, commonly discarded previously as "un-reducible data," to construct a Discordia in U-Pb Concordia plot, using every scan/cycle, every laser pulse as individual data points from a single laser ablation spot (typically > 200–250 data points).
- We show that the upper and lower intercept ages from the Discordia, augmented by high precision Hf isotope data obtained on the same spot, reveal invaluable information that permit unique insight to geological processes not available by other means.

Conclusion

Someone's trash



is someone else's treasure



Conclusion

"Don't throw the baby out with the bathwater"

Need software development