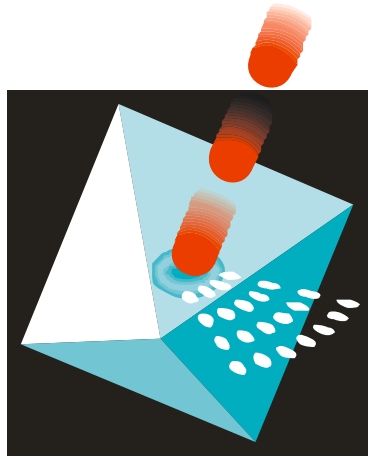
U-Th-Pb Geochronology Short Course
Part 1: Basics



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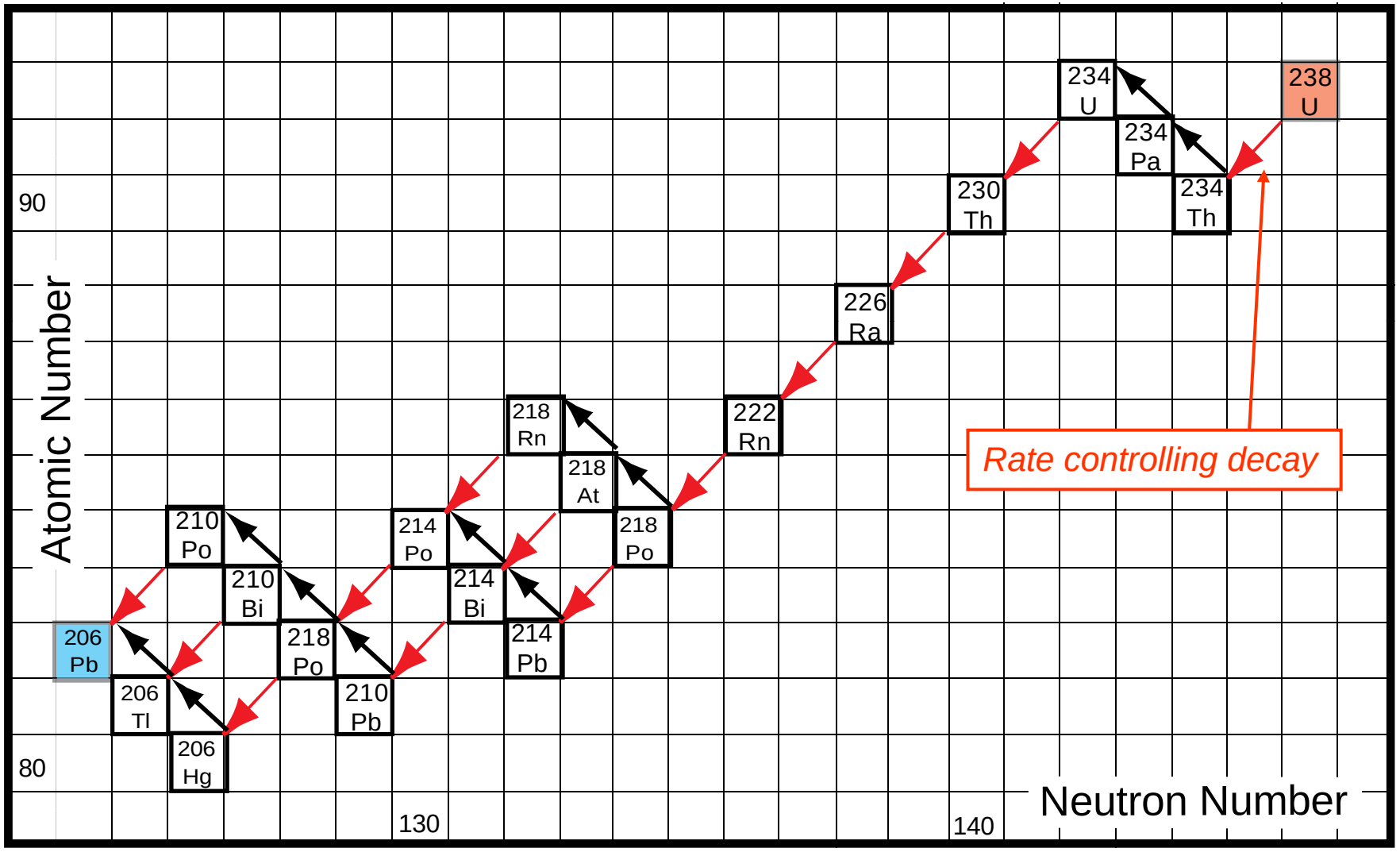
Outline

1. Basics of U-Th-Pb decay system
2. Measurement methods
3. Mineral systems & applications
4. Complexities for zircon
5. Detrital geochronology (plots & analyses)
6. Data analysis
7. Future opportunities

Decay of ^{238}U to ^{206}Pb

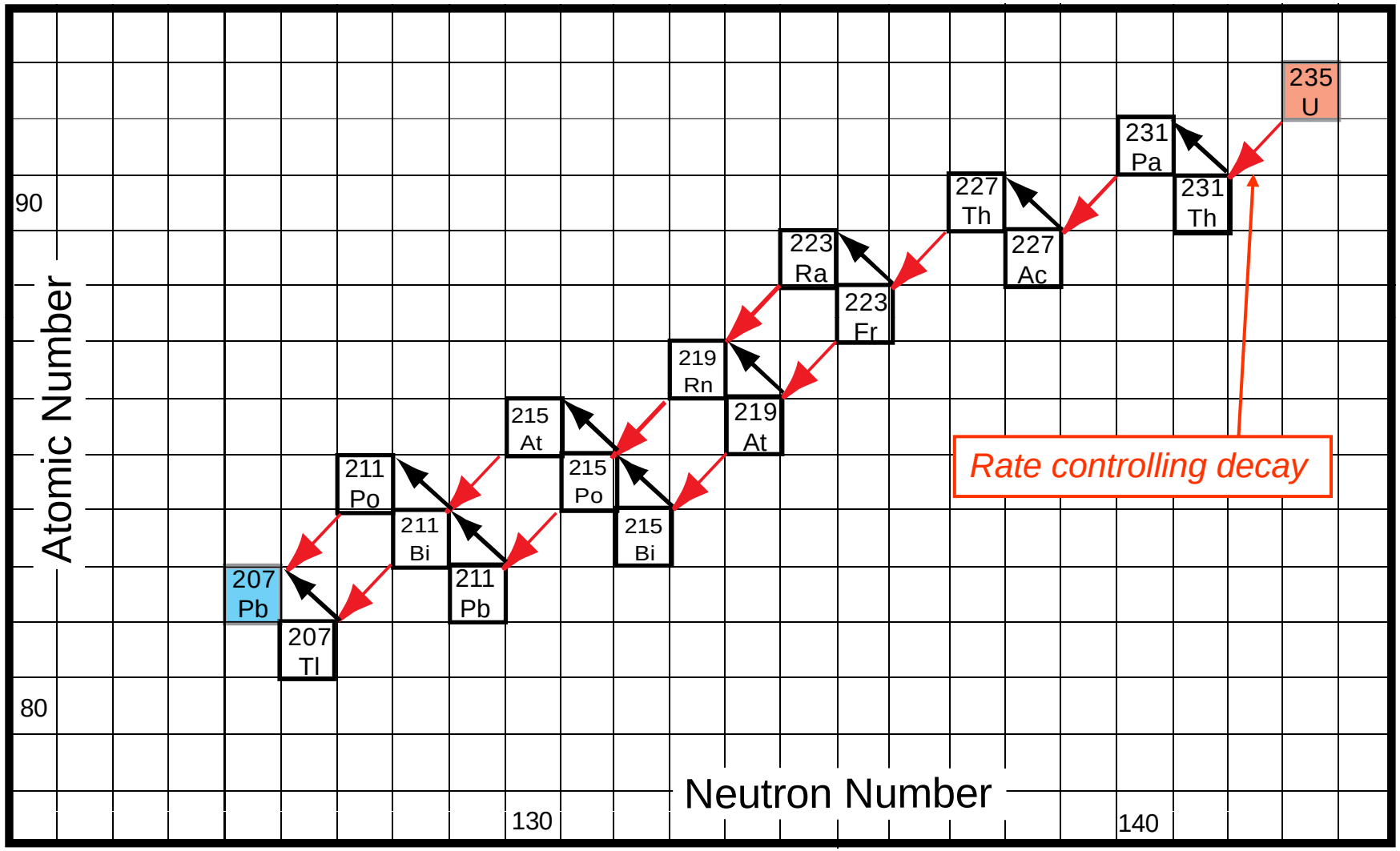
($T_{1/2}$ = 4.468 Ga)



Possible complications from ^{230}Thorium.....

Decay of ^{235}U to ^{207}Pb

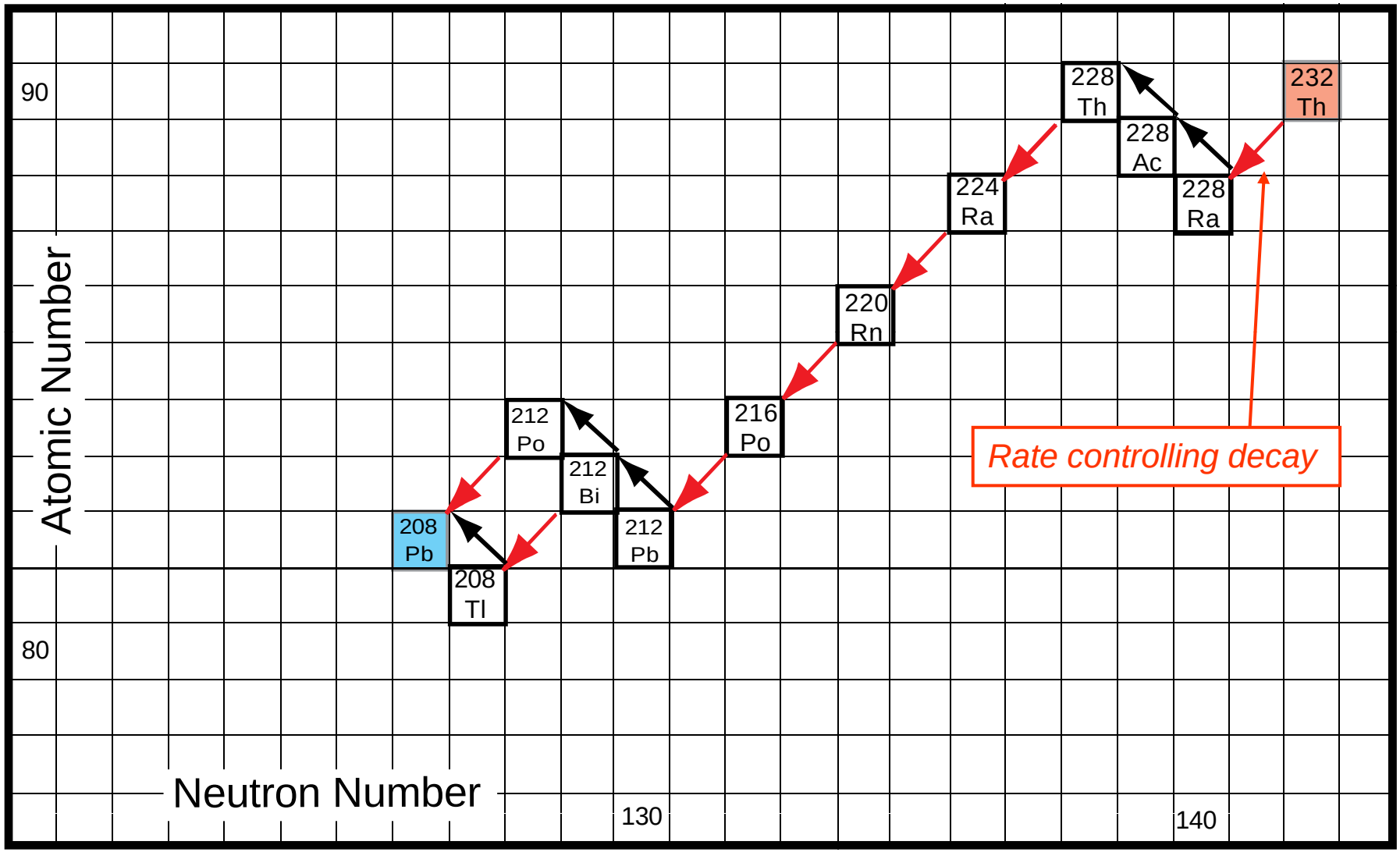
($T_{1/2}$ = 0.704 Ga)



Possible complications from ^{231}Protactinium

Decay of ^{232}Th to ^{208}Pb

($T_{1/2}$ = 14.01 Ga)



U-Th-Pb decay

dN/dt = proportional to N (process of radioactive decay)

$-dN/dt = \lambda N$ ➔ (integrate both sides) ➔ $-\ln N = \lambda t + c$

because $N = N_i$ when $t = 0$, $c = -\ln N_i$

$-\ln N = \lambda t - \ln N_i$ ➔ $N = N_i e^{-\lambda t}$

$D^* = N_i - N$ ➔ $N_i = D^* + N$

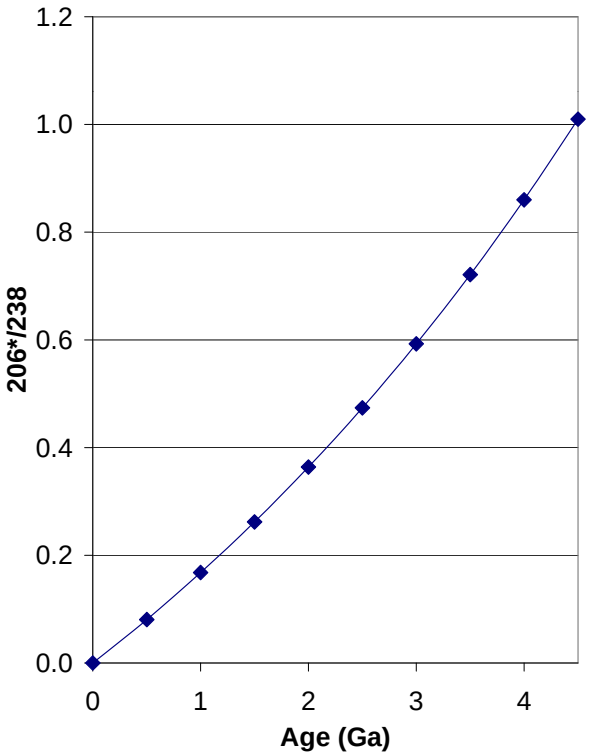
$D^* = N (e^{\lambda t} - 1)$ ➔ **$D^*/N = e^{\lambda t} - 1$ (decay equation)**

D*/N as function of age:

$^{238}U \rightarrow {}^{206}Pb^*$

$T_{1/2} = 4.468\ Ga$

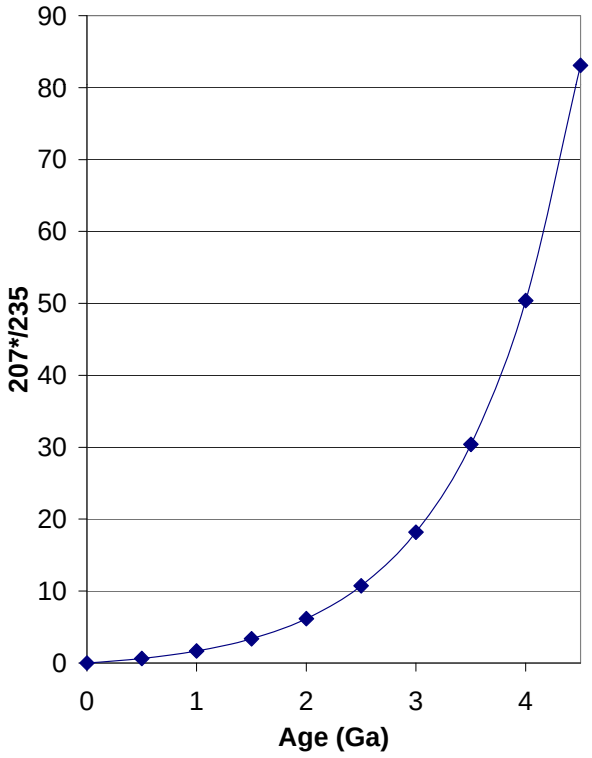
$^{206}Pb^*/^{238}U = e^{\lambda_1 t} - 1$



$^{235}U \rightarrow {}^{207}Pb^*$

$T_{1/2} = 0.704\ Ga$

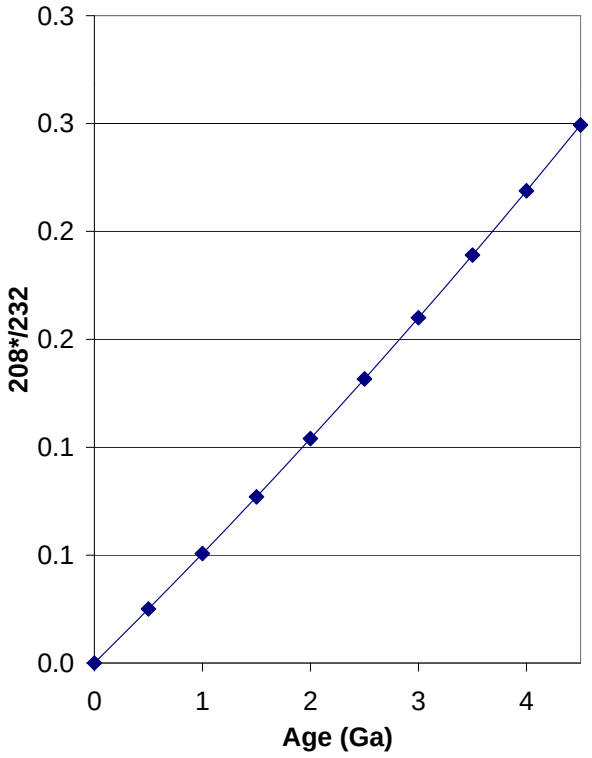
$^{207}Pb^*/^{235}U = e^{\lambda_2 t} - 1$



$^{232}Th \rightarrow {}^{208}Pb^*$

$T_{1/2} = 14.01\ Ga$

$^{208}Pb^*/^{232}Th = e^{\lambda_3 t} - 1$



** = radiogenic*

U-Th-Pb age equations

$D^*/N = e^{\lambda t} - 1$ (decay equation)

solve for t

$t = \ln (D^*/N + 1) / \lambda$ (age equation)

$Age_{(206/238)} = \ln (206^*/238 + 1) / {}^{238}\lambda$

$Age_{(207/235)} = \ln (207^*/235 + 1) / {}^{235}\lambda$

$Age_{(208/232)} = \ln (208^*/232 + 1) / {}^{232}\lambda$

Can also determine age from 206/207 because 238/235 = 137.88 in nearly all rocks:

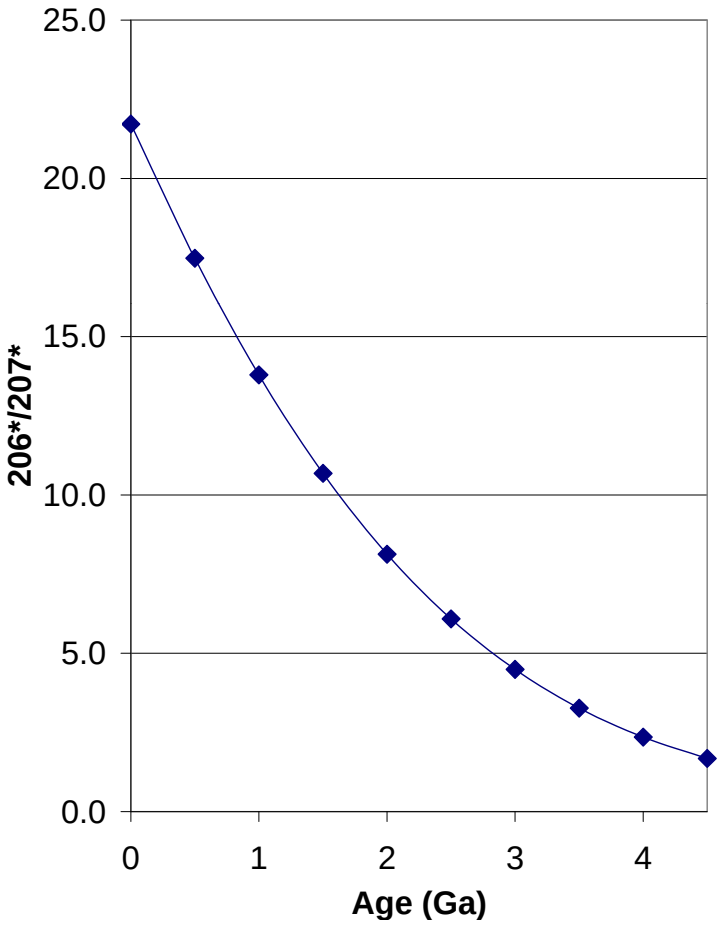
$^{206}Pb^* = {}^{238}U (e^{\lambda_1 t} - 1)$

$^{207}Pb^* = {}^{235}U (e^{\lambda_2 t} - 1)$

$$^{206}Pb^* / {}^{207}Pb^* = [{}^{238}U (e^{\lambda 1t} - 1)] / [{}^{235}U (e^{\lambda 2t} - 1)]$$

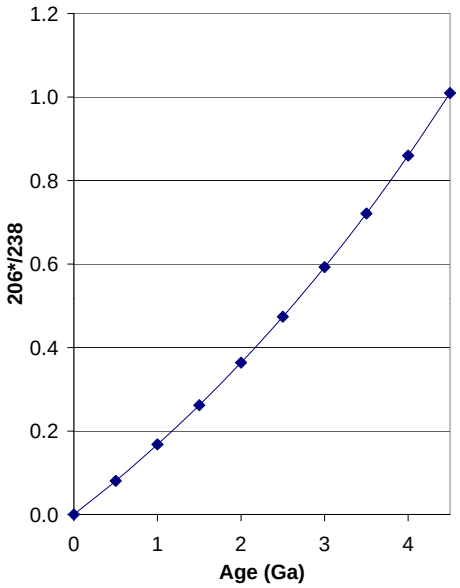
$$= 137.88 [(e^{\lambda 1t} - 1) / (e^{\lambda 2t} - 1)]$$

(have to iterate or use a table…..)

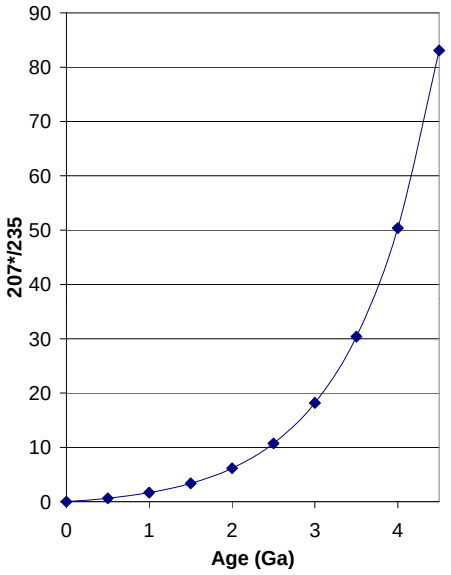


U-Th-Pb chronometers:

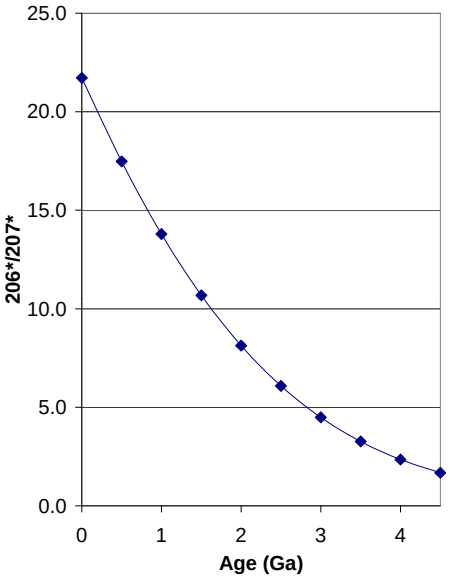
206/238



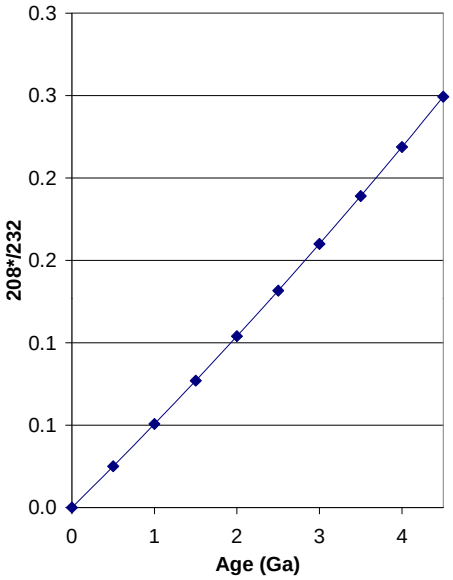
207/235



206/207



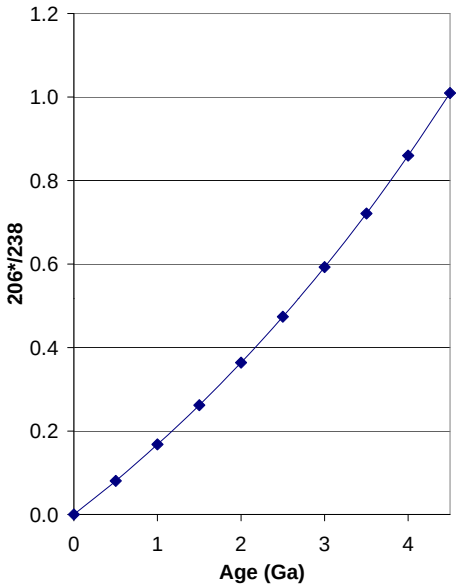
208/232



U-Th-Pb chronometers:

Low Th in most minerals
➔ Tough to measure!

206/238



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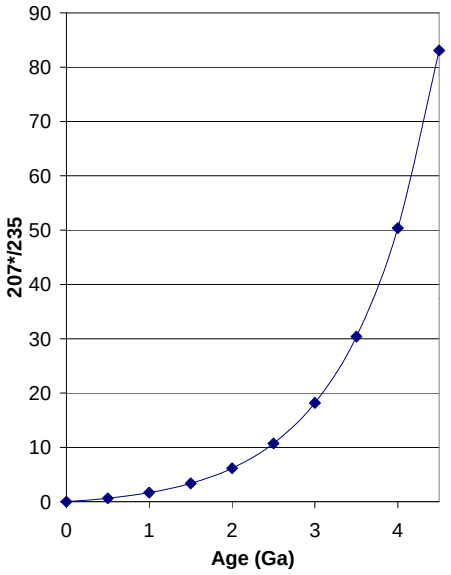
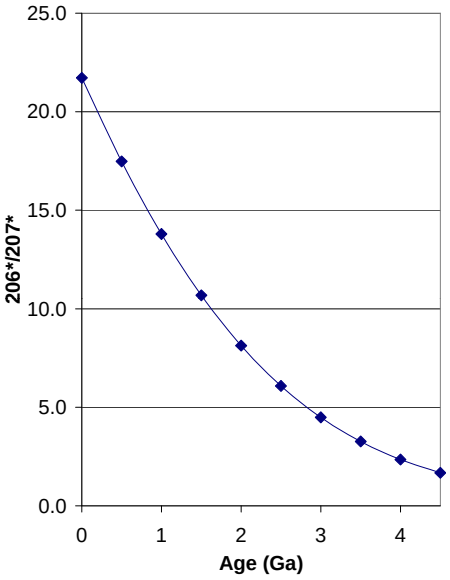
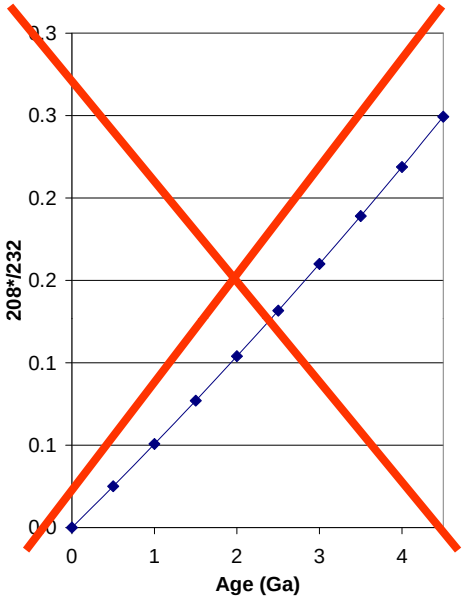


206/207



208/232



What about Pb in crystal when it formed?

Measured Pb = radiogenic Pb + common Pb (present when crystal formed):

$204_M = 204_C$

$206_M = 206_C + 206_R$

$207_M = 207_C + 207_R$

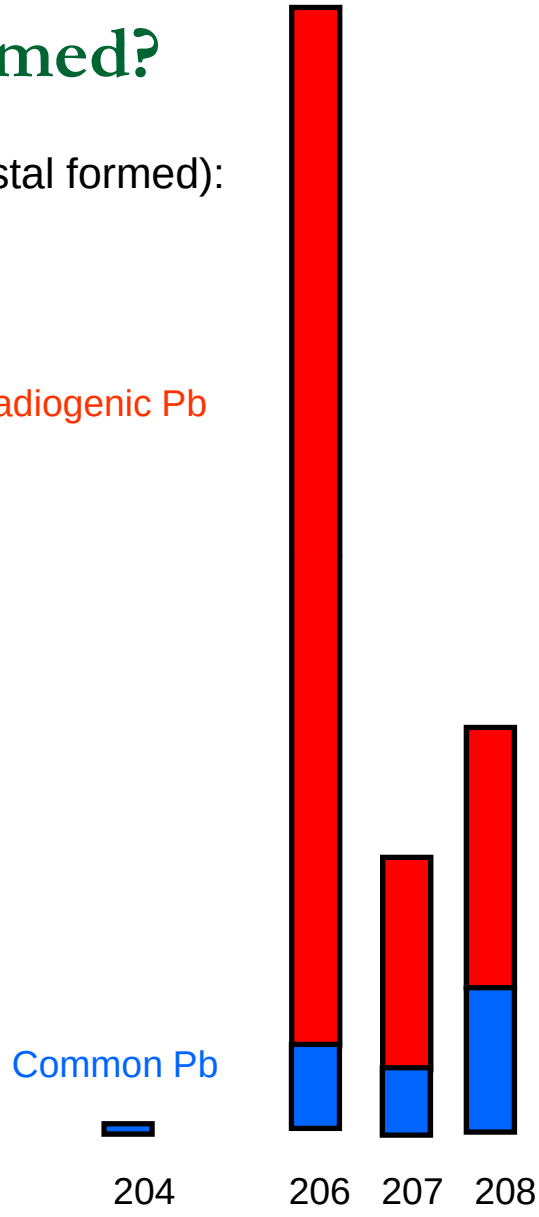
$208_M = 208_C + 208_R$

$(206/204)_M = (206/204)_R + (206/204)_C$

➔ $(206/204)_R = (206/204)_M - (206/204)_C$

➔ $206^* = 204\ [(206/204)_M - (206/204)_C]$
➔ $207^* = 204\ [(207/204)_M - (207/204)_C]$
➔ $208^* = 204\ [(208/204)_M - (208/204)_C]$

How determine common Pb composition when Crystal formed??

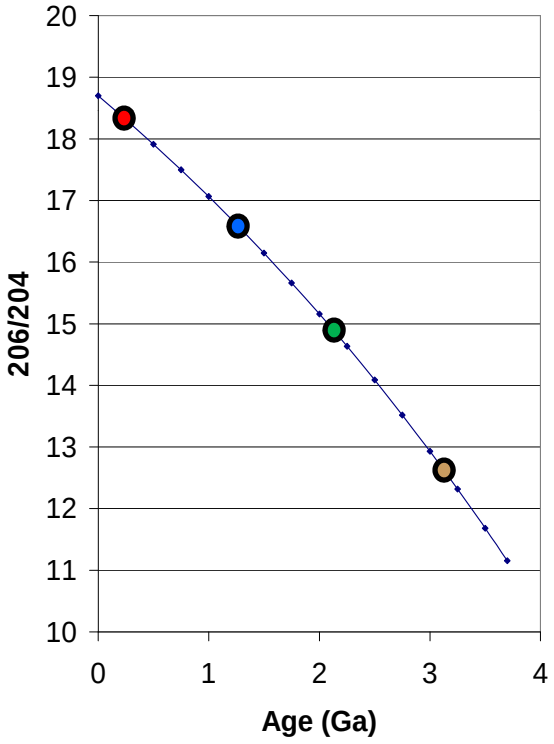


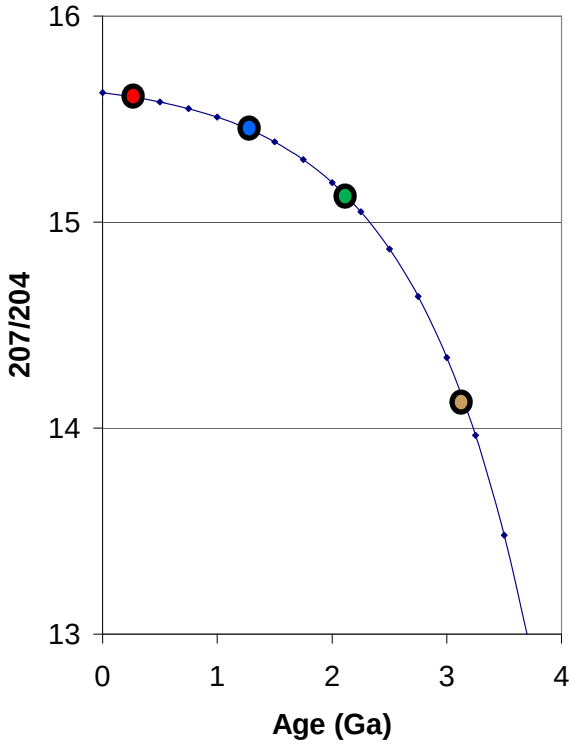
Common Pb composition

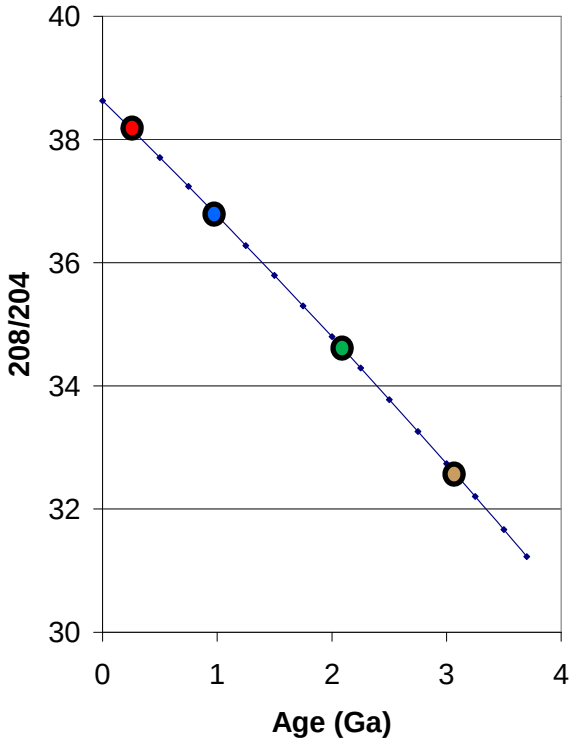
➔ Ore minerals (e.g. galena) have such high Pb contents that they do not change over time

➔ Measure Pb in ore minerals of various ages to determine evolution of Pb in the crust

= Stacey-Kramers (1975) model for evolution of crustal Pb

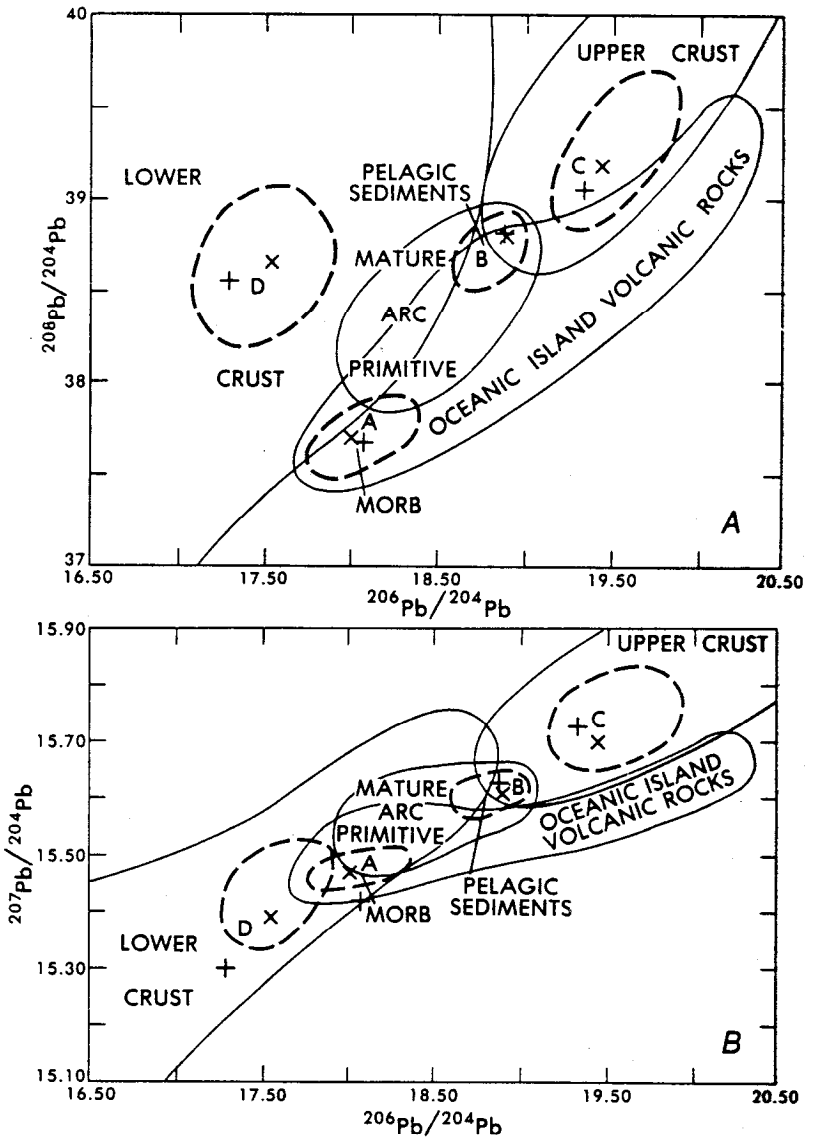






Common Pb composition

But there is variation in modern common Pb composition:

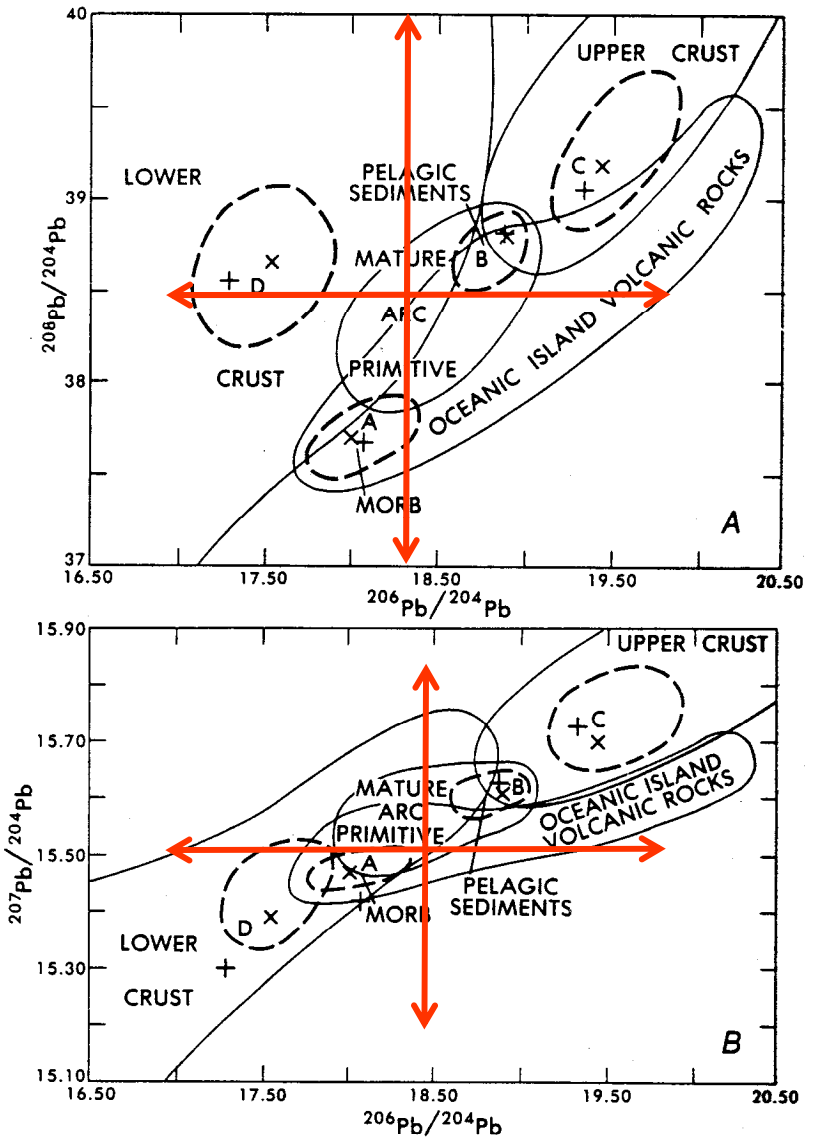


Common Pb composition

But there is variation in common Pb composition today:

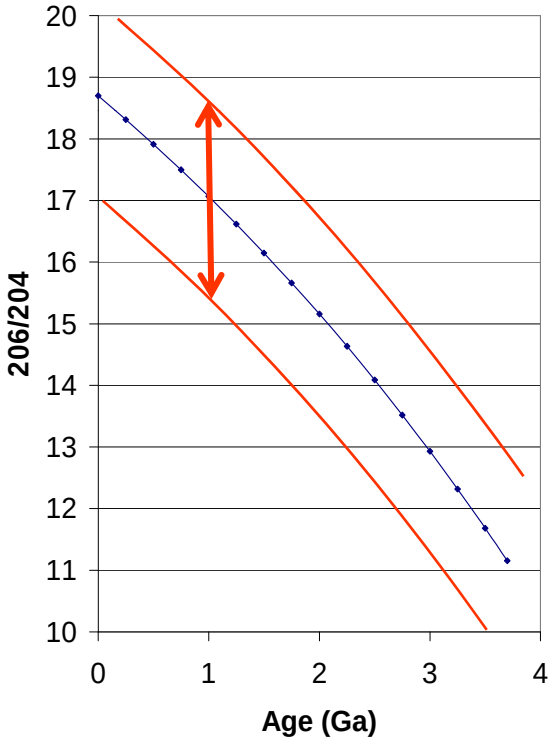
So need to apply an uncertainty to Stacey-Kramers Pb compositions…..

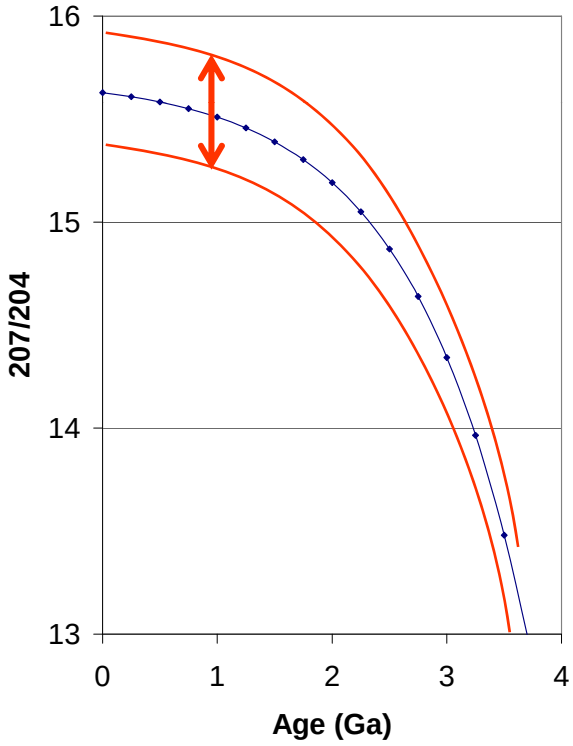
± 1.5 to $^{206}Pb/^{204}Pb$
± 0.3 to $^{207}Pb/^{204}Pb$
± 1.5 to $^{208}Pb/^{204}Pb$

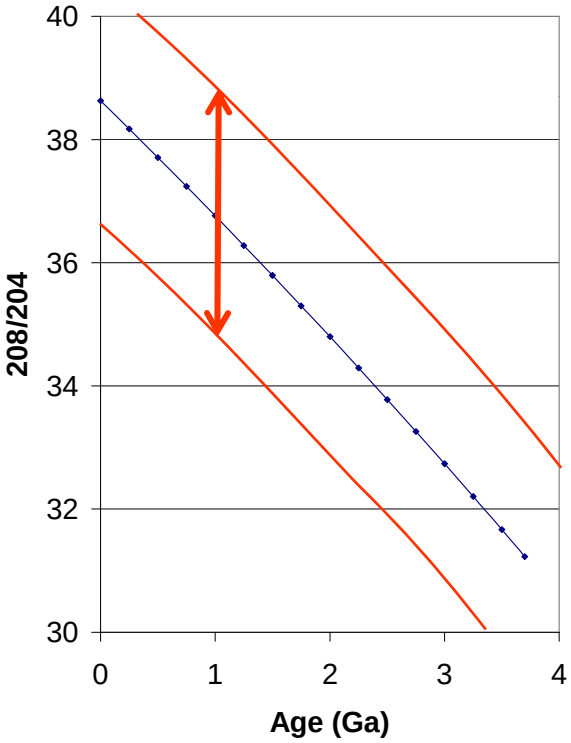


Common Pb correction

➔Apply Stacey-Kramers (1975) composition with uncertainties
(for age of crystallization = slightly circular…..)

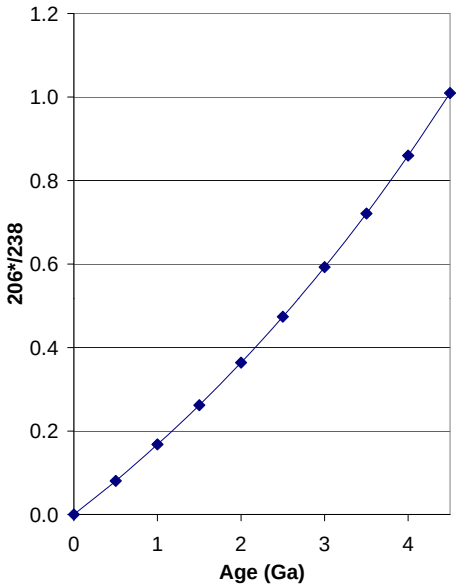




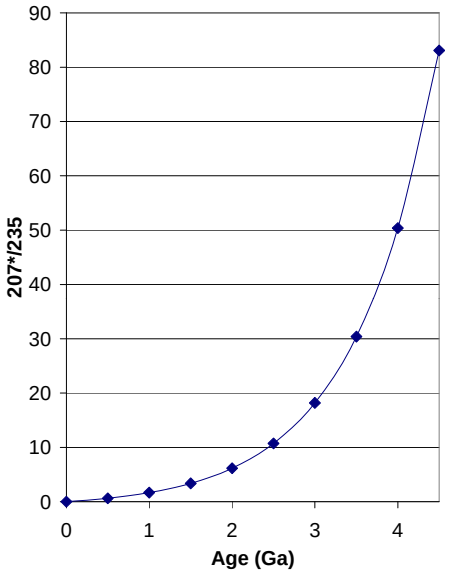


Plot U-Pb chronometers on a single diagram:

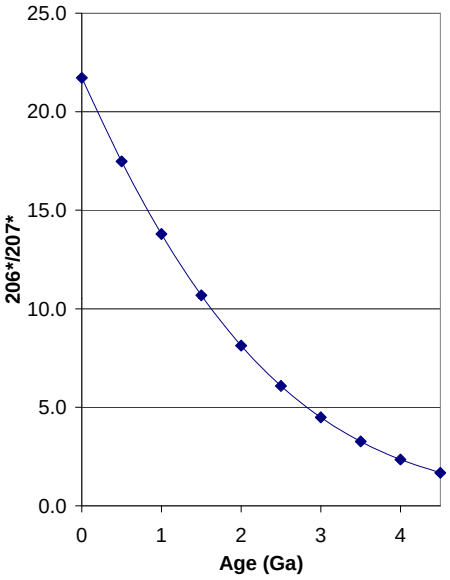
206/238



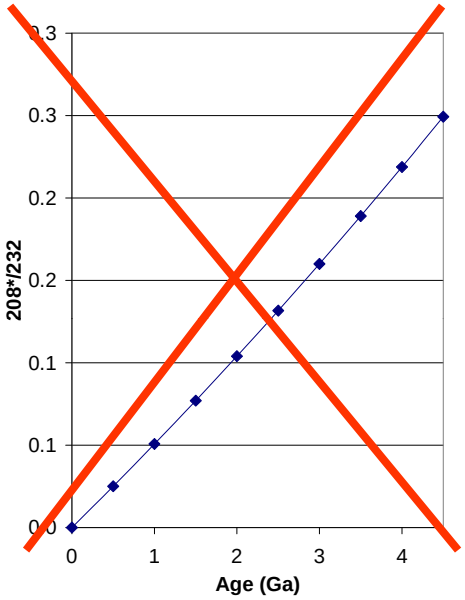
207/235



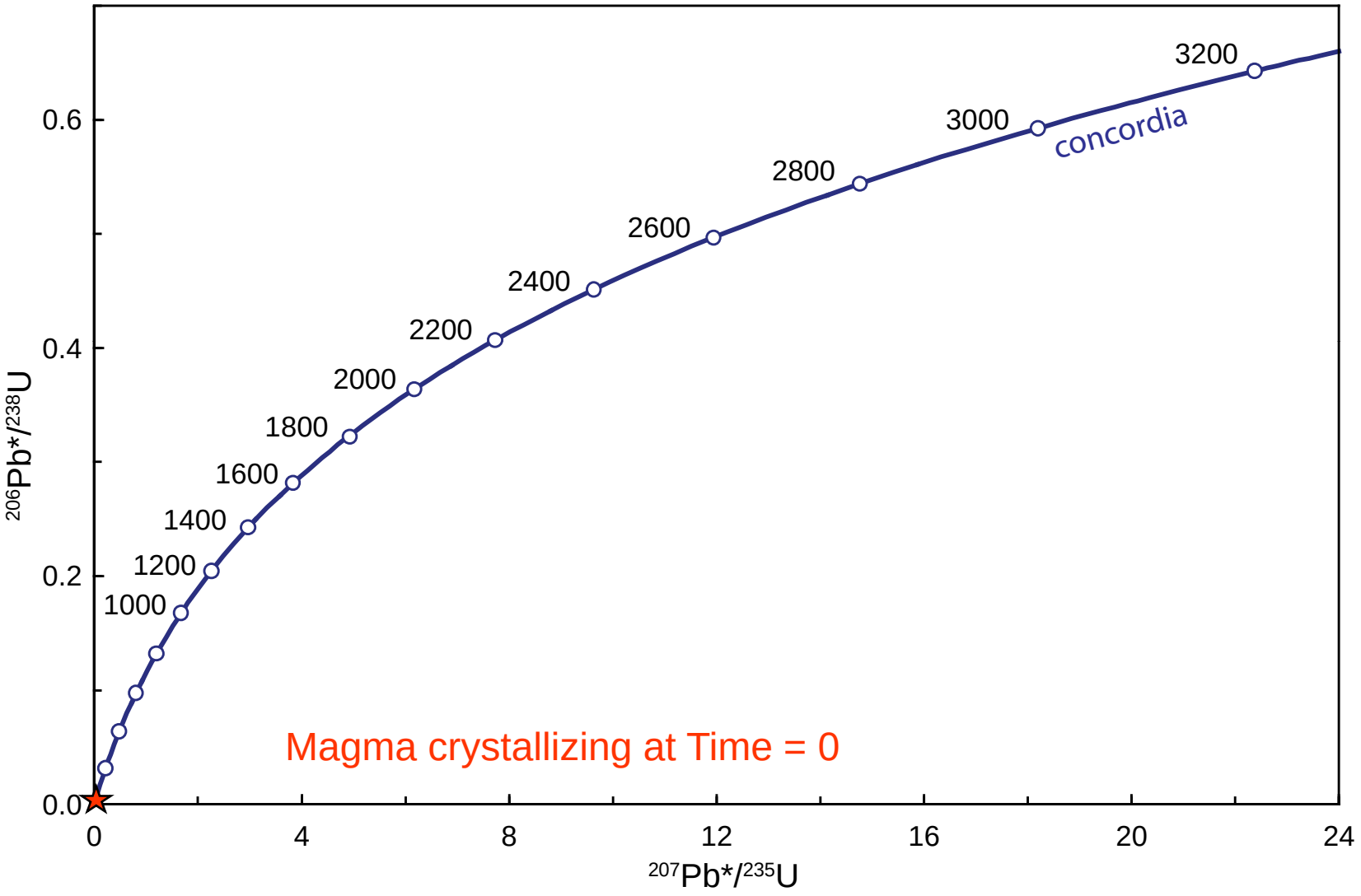
206/207



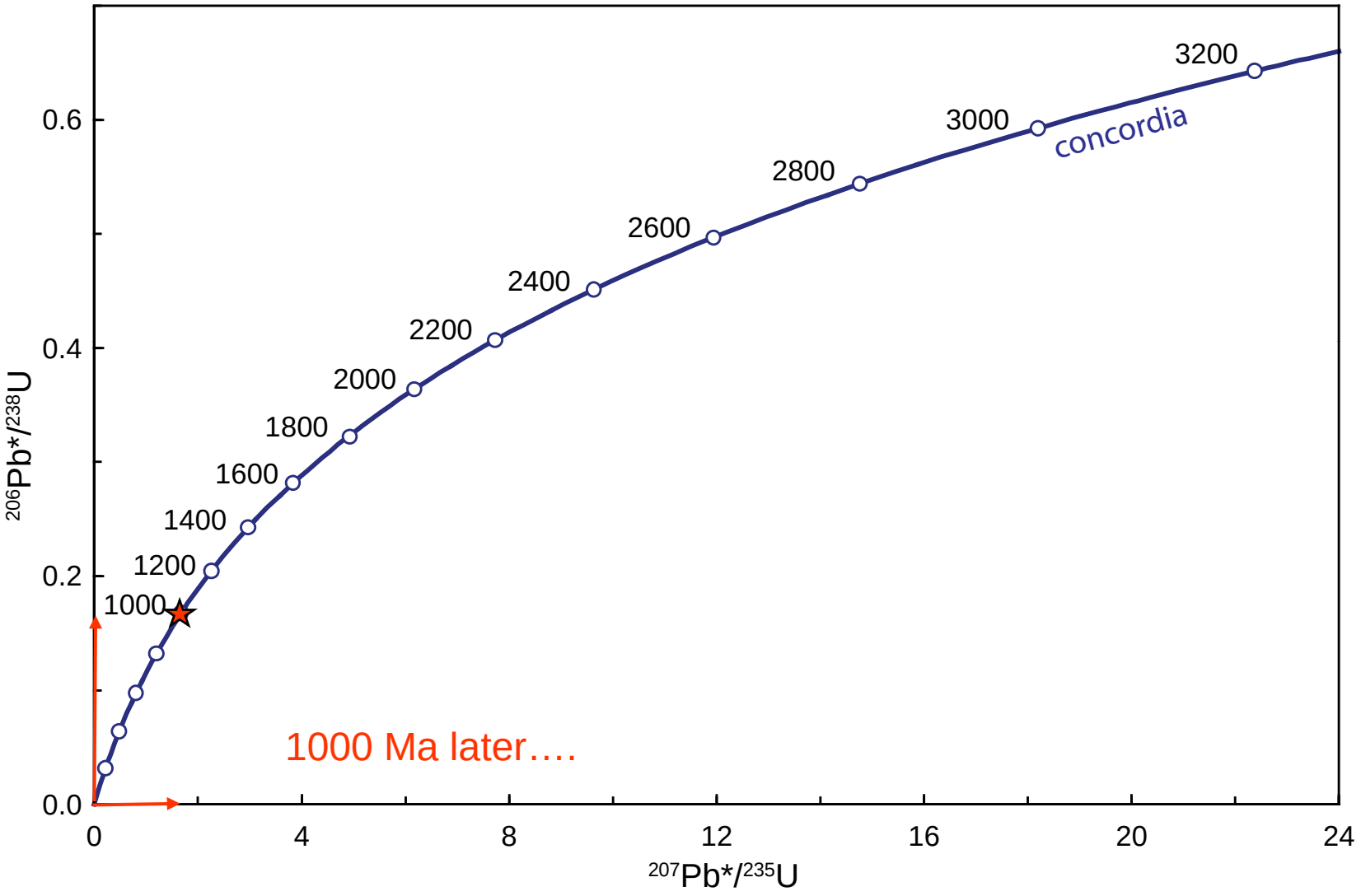
208/232



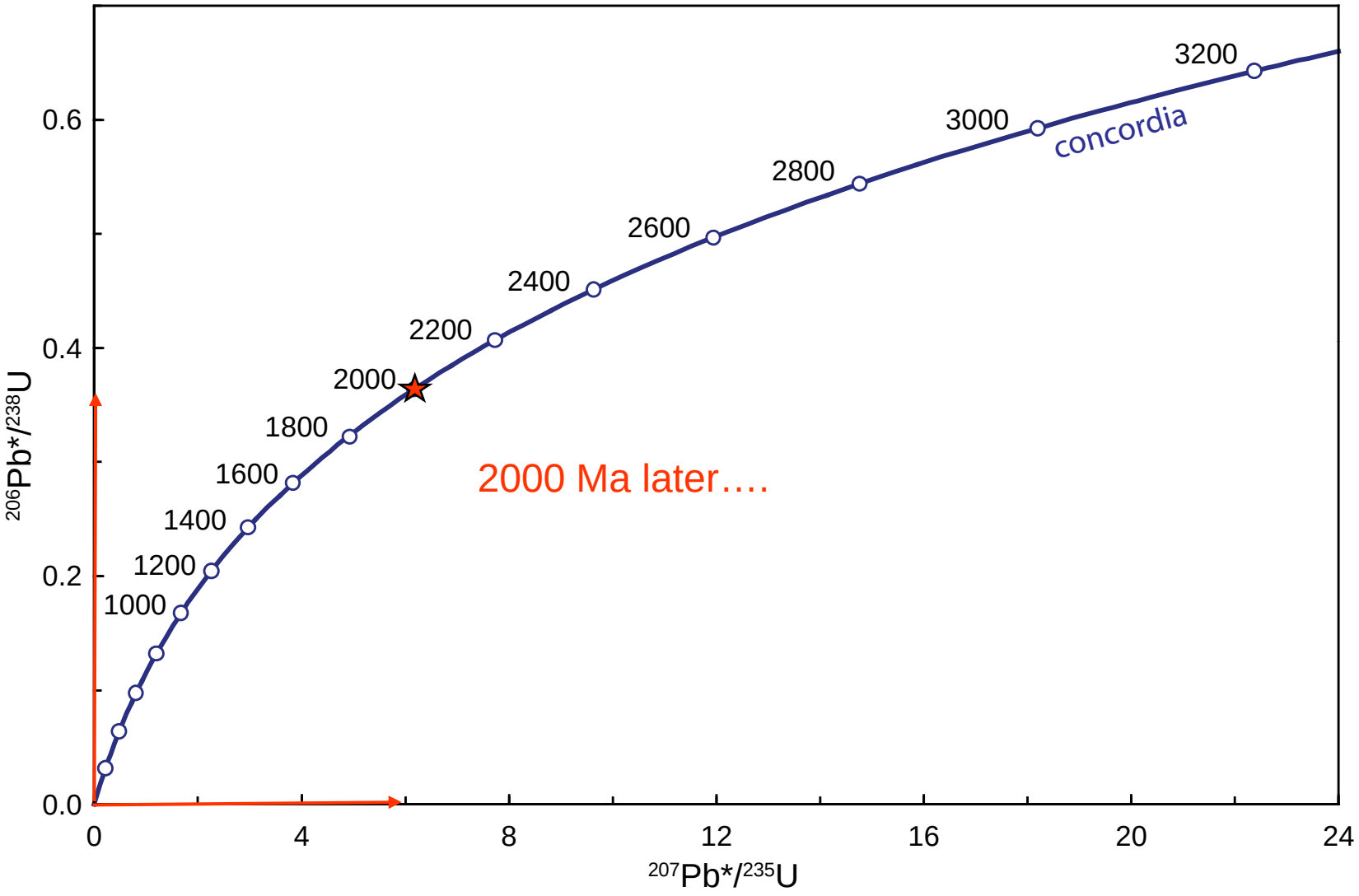
U-Pb concordia diagram *(Wetherill, 1956)*



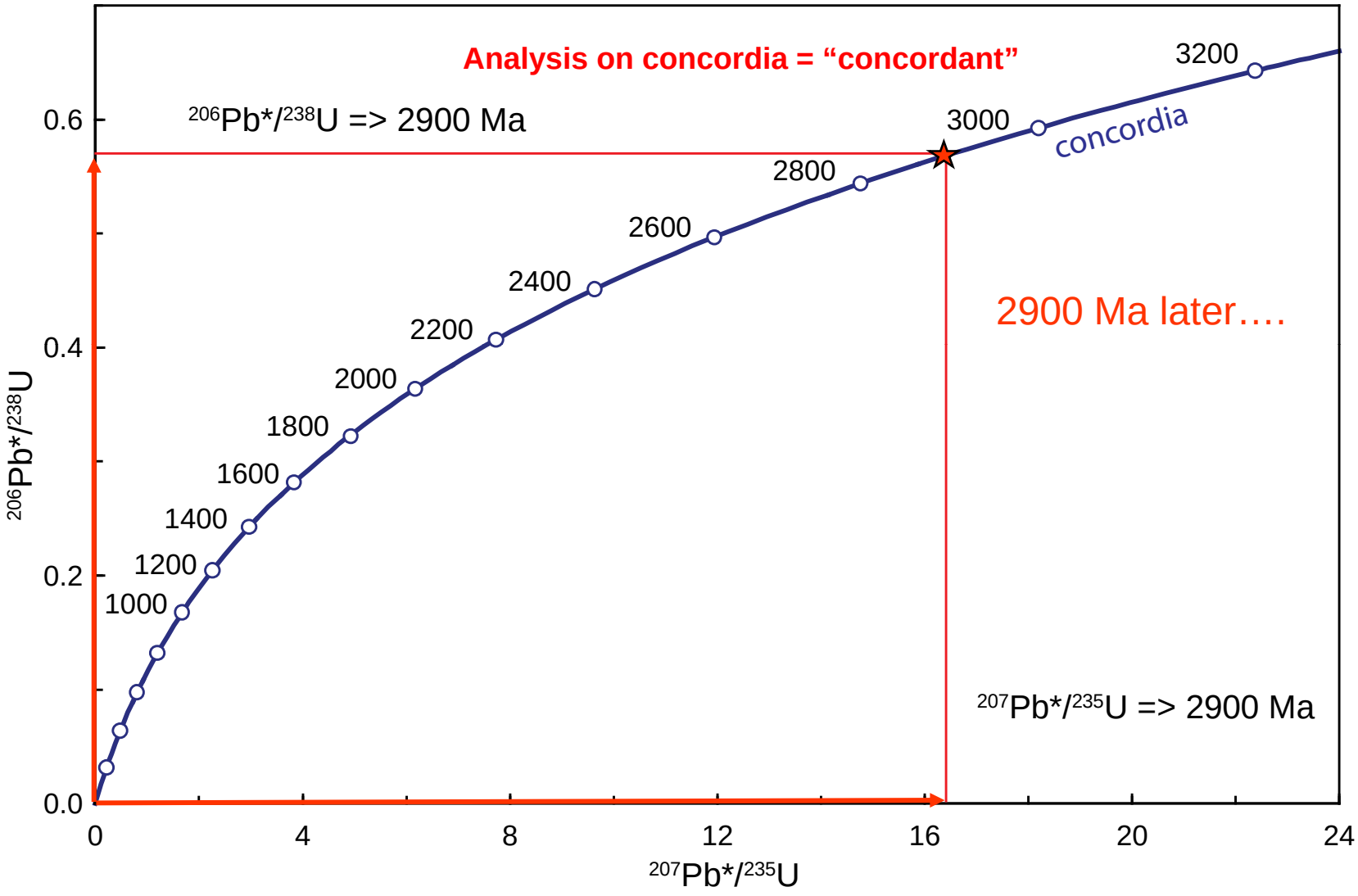
U-Pb concordia diagram



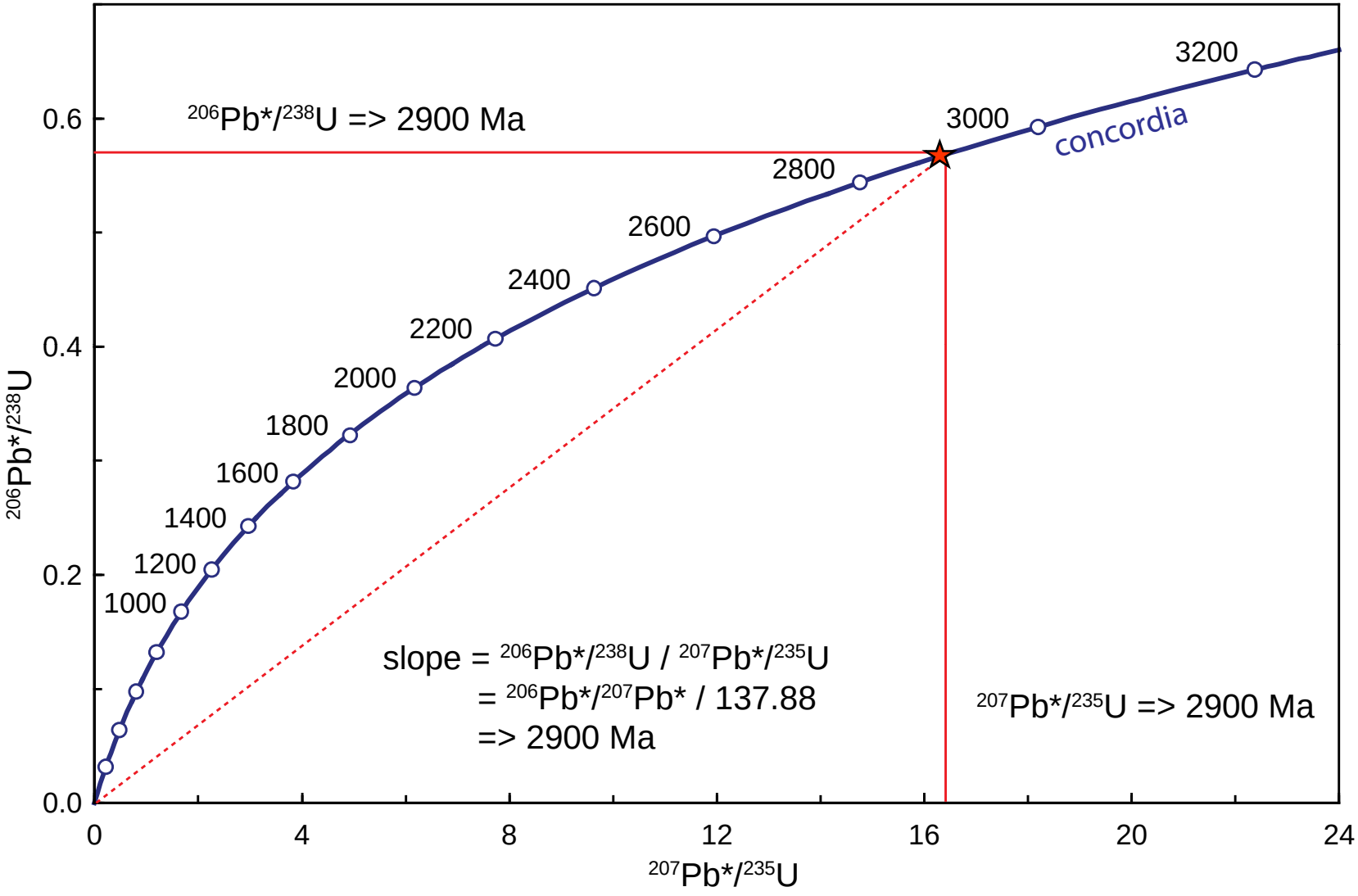
U-Pb concordia diagram



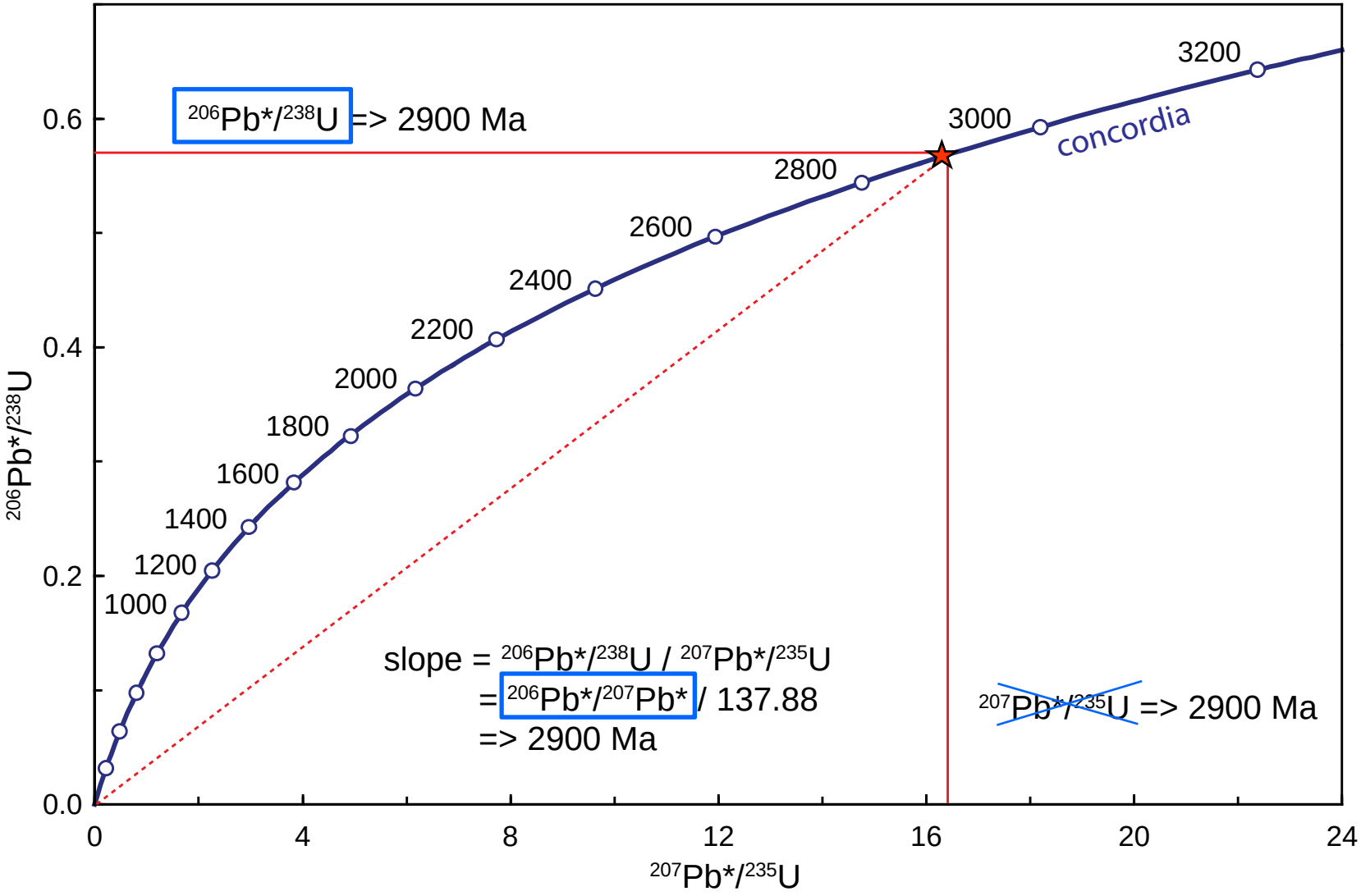
U-Pb concordia diagram



U-Pb concordia diagram ➔ 3 ages!

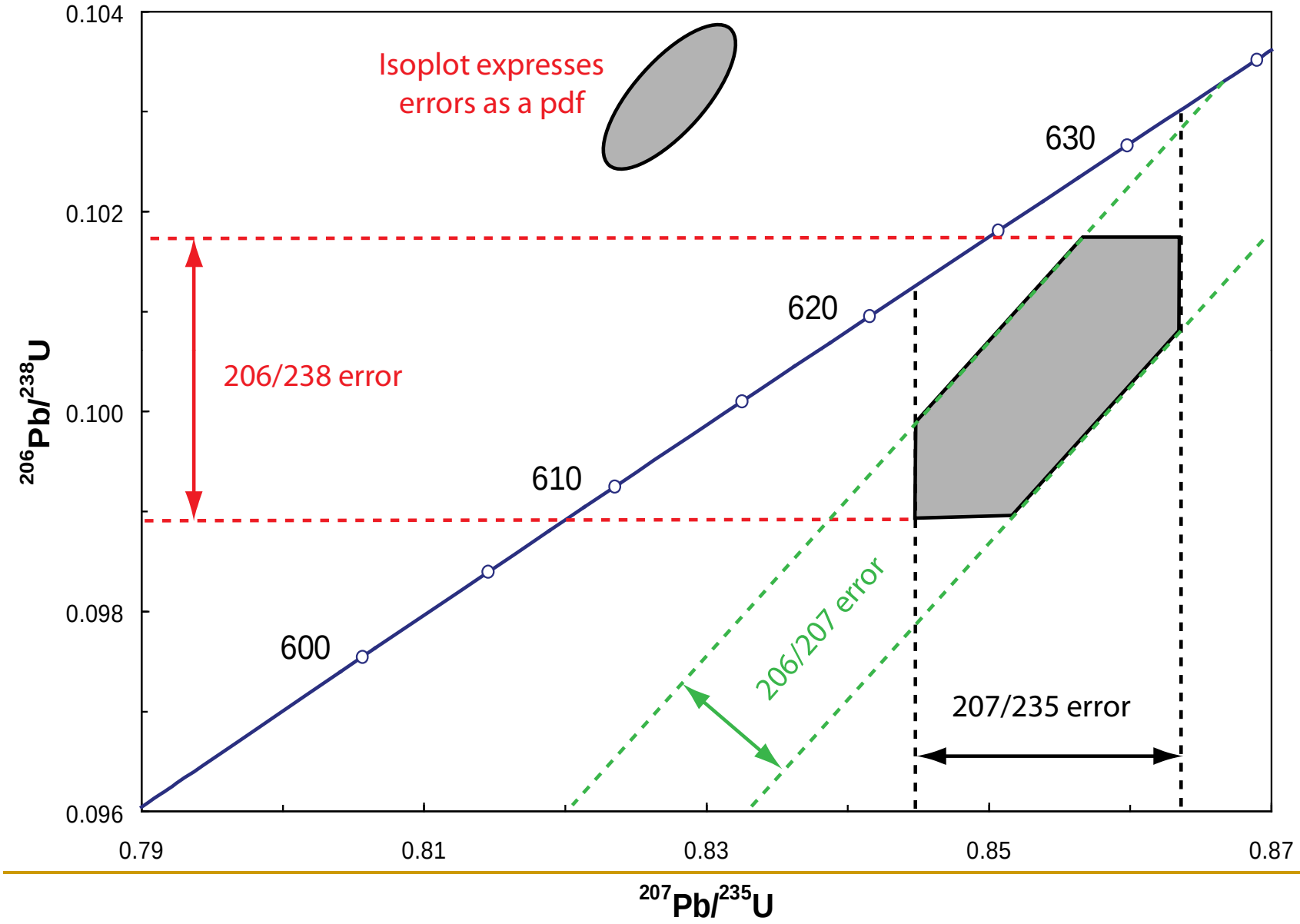


U-Pb concordia diagram: $^{206}Pb^*/^{238}U$ vs $^{206}Pb^*/^{207}Pb^*$

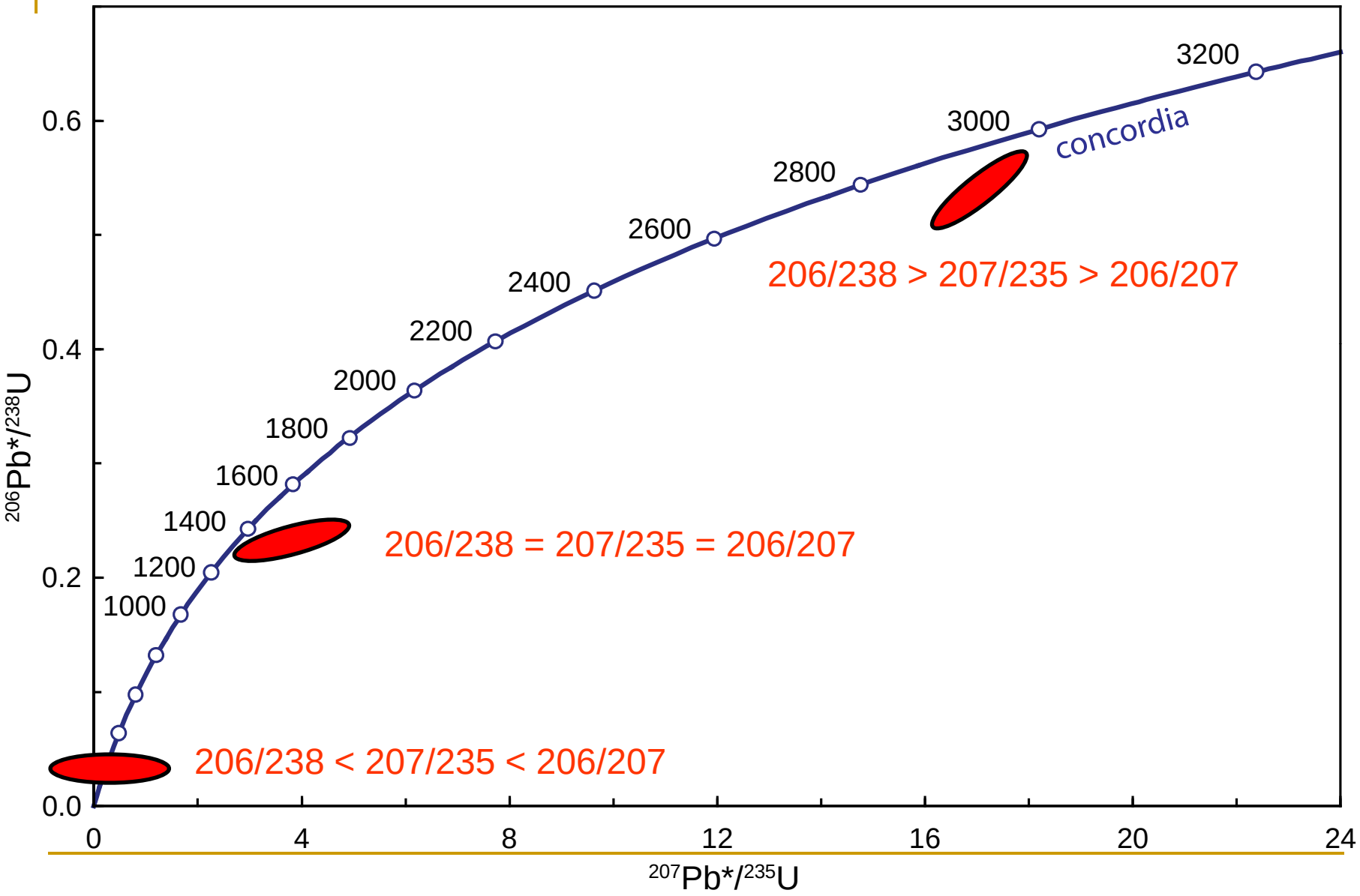


Don't measure $^{207}Pb^*/^{235}U$ (= $^{206}Pb^*/^{238}U$ / $^{206}Pb^*/^{207}Pb^*$ / 137.88)

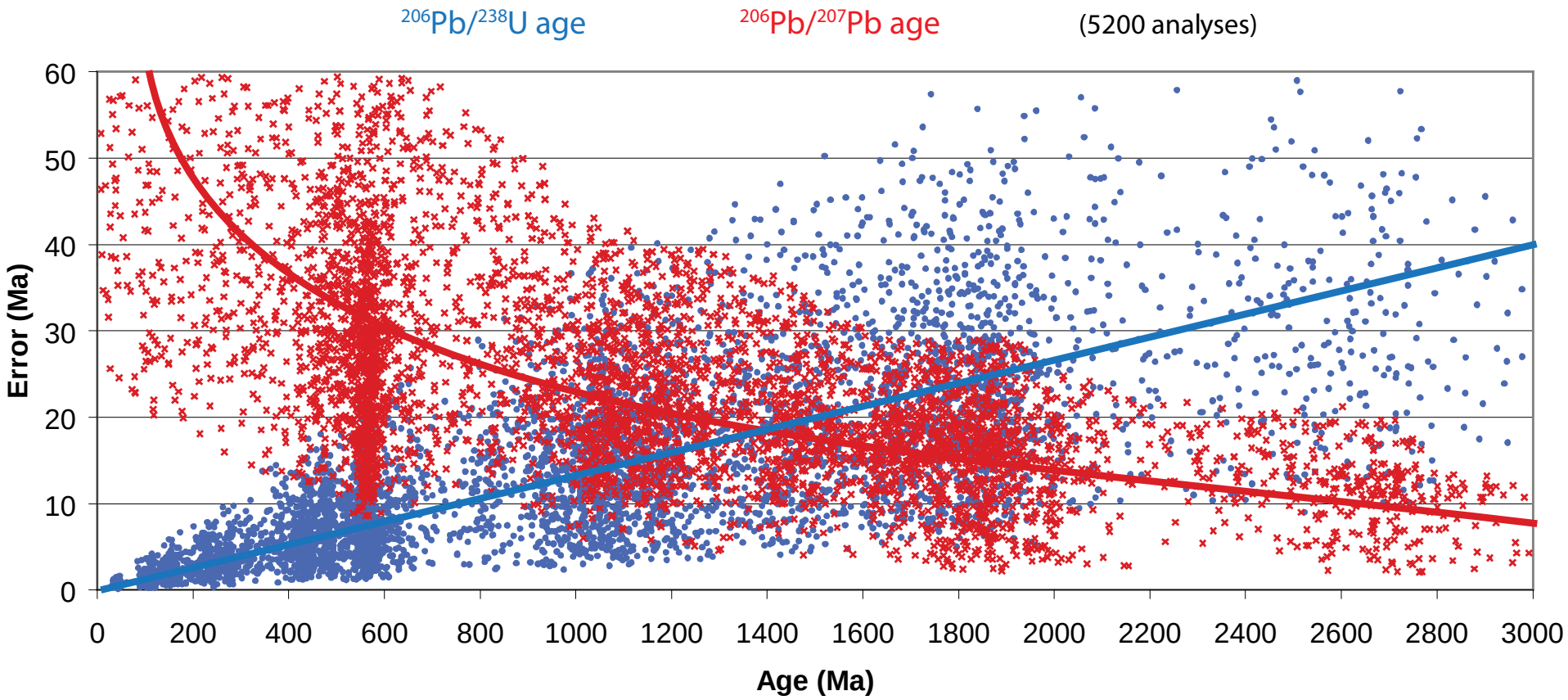
Errors on U-Pb concordia diagram



Errors on U-Pb concordia diagram



Which age to use??



$^{206}Pb^*/^{238}U$ for ages < ~1.4 Ga

$^{206}Pb^*/^{207}Pb^*$ for ages > ~1.4 Ga

Precision only ➔ cutoff = 1.4 Ga