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Геологический факультет

Lu-Hf изотопная система

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Задачи (*.xlsx) и лекции (*.pptx) – на сайте
http://wiki.web.ru/wiki/Геологический_Факультет_МГУ:
Геохимия_Изотопов_и_Геохронология

$$^{176}_{71}Lu \rightarrow ^{176}_{72}Hf + \beta^- + \bar{\upsilon} + Q$$

$\lambda = 1.867\times10^{-11}$ год$^{-1}$
(Sherer et al., 2001, 2007)

Нуклид	at %%	AW
^{175}Lu	97.41	174.97
^{176}Lu	2.59	
^{174}Hf	0.162	178.49
^{176}Hf	5.260	
^{177}Hf	18.596	
^{178}Hf	27.282	
^{179}Hf	13.621	
^{180}Hf	35.080	

$^{179}Hf/^{177}Hf \equiv 0.732$
5

$$\left(\frac{^{176}Lu}{^{177}Hf}\right)_{CHUR} = 0.0336$$

$$\left(\frac{^{176}Hf}{^{177}Hf}\right)_{CHUR} = 0.282785$$

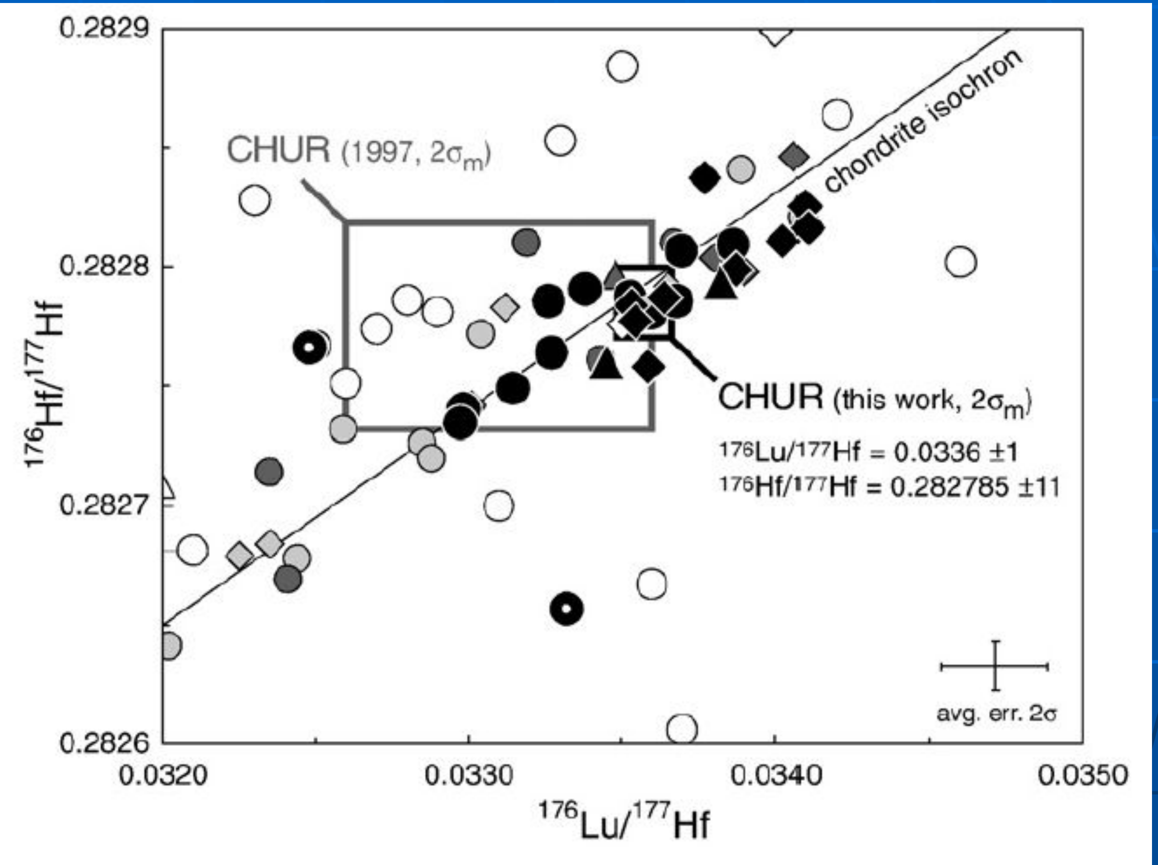


Fig. 2. Lu–Hf CHUR value. New Lu–Hf isotope analyses of unequilibrated carbonaceous, ordinary, and enstatite chondrites provide tighter constraints on the Lu–Hf CHUR parameters compared to previous estimates (Blichert-Toft and Albarède, 1997). Our new CHUR parameters of $^{176}Lu/^{177}Hf = 0.0336 \pm 1$ and $^{176}Hf/^{177}Hf = 0.282785 \pm 11$ ($n = 25$, $2\sigma_m$)

Bouvier, Vervoort, Patchett, EPSL, 2008

Scherer E., Münker C., Mezger K. Calibration of the Lu-Hf clock. Science. 2001. Vol. 293. p. 683-687.

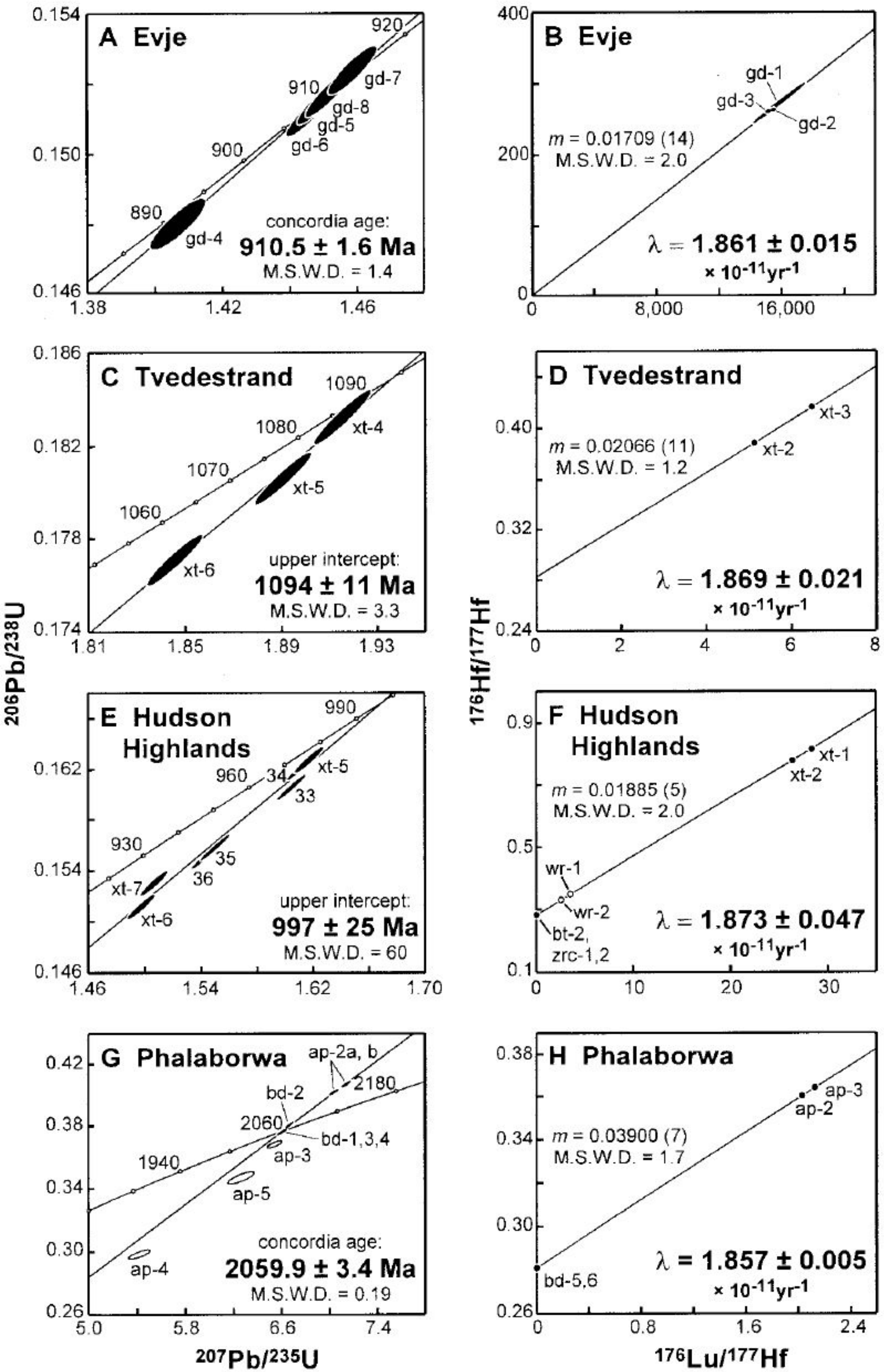
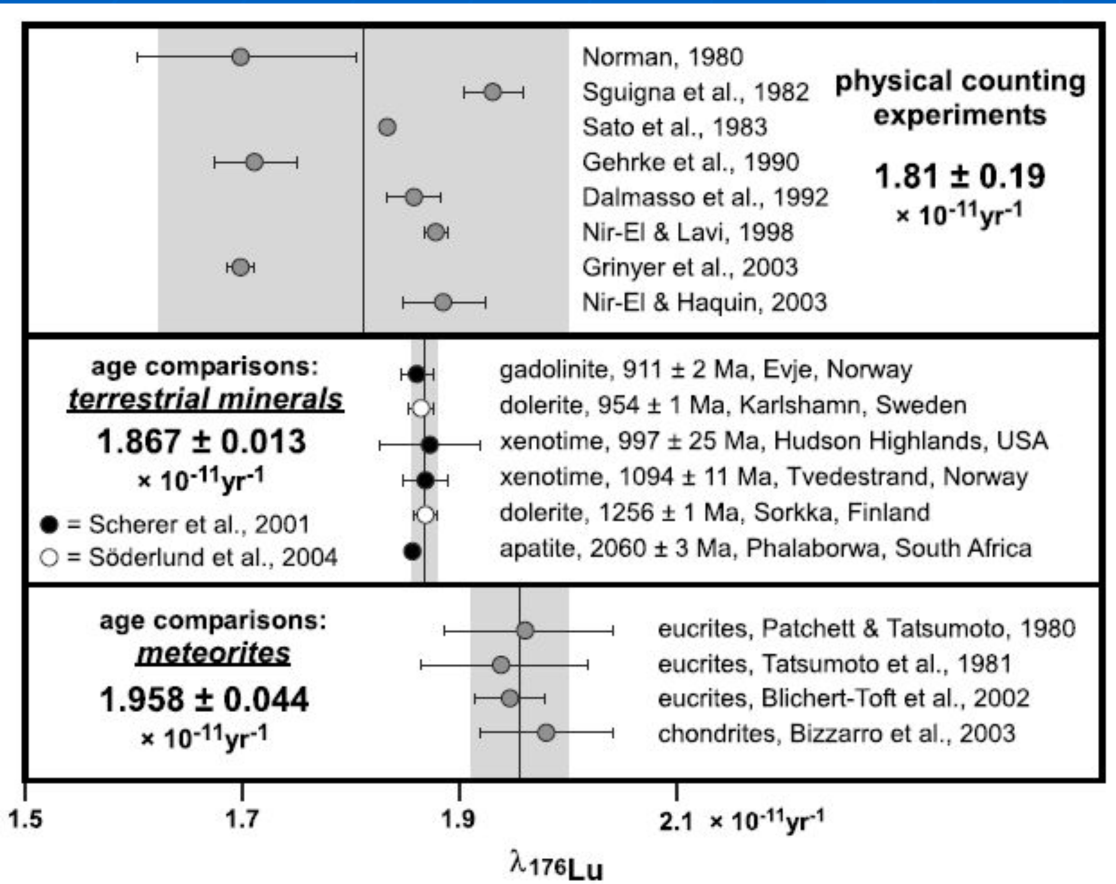


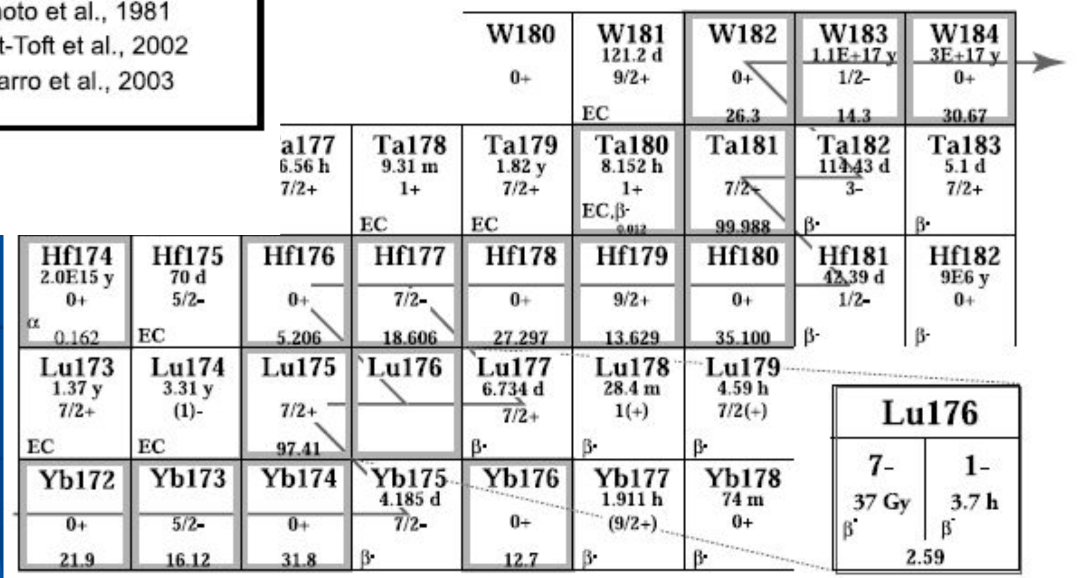
Fig. 1. U-Pb concordia and Lu-Hf isochron diagrams (**A** through **H**). gd, gadolinite; xt, xenotime; ap, apatite; bd, baddeleyite. Open symbols are excluded from the regressions. U-Pb data are available online (*47*). Uranium decay constants: $\lambda^{238}U = 1.55125 \pm 0.00166 \times 10^{-10}$ year^{-1}, $\lambda^{235}U = 9.8485 \pm 0.0134 \times 10^{-10}$ year^{-1} [(*48*); 95% confidence level]. All regressions are model 1 fits (i.e., points weighted according to the inverse square of their errors) except for the Hudson Highlands U-Pb, which is a model 2 fit (i.e., points weighted equally). MSWD statistics of concordia ages (*49*) are for combined equivalence and concordance. Lu-Hf errors are smaller than the symbols, except for Evje where depicted by error ellipses. $\lambda^{176}Lu = \ln(m + 1)/t$, where m is the slope of the Lu-Hf isochron and t is the U-Pb age of the sample in years. Uncertainties on $\lambda^{176}Lu$ values are derived from the 2 SD uncertainties in t and m using $\sigma_\lambda = [\sigma_m^2(\partial\lambda/\partial m)^2 + \sigma_t^2(\partial\lambda/\partial t)^2]^{0.5}$.

Постоянна ли λ_{176Lu}?



Облучение ^{176}Lu γ-квантами с энергией ~1 МэВ переводит его в возбуждённое состояние с периодом полураспада всего 3.7 ч.

Albarede et al., GCA, 2006, Vol. 70, p.1261-1270.



$$\left(\frac{^{176}Hf}{^{177}Hf}\right) = \left(\frac{^{176}Hf}{^{177}Hf}\right)_0 + \left(\frac{^{176}Lu}{^{177}Hf}\right) \cdot [\exp(\lambda \cdot t) - 1]$$

$$\varepsilon_{Hf}^{T} = \left[\frac{(^{176}Hf/^{177}Hf)_{Sample}^{T}}{(^{176}Hf/^{177}Hf)_{CHUR}^{T}} - 1\right] \cdot 10^4$$

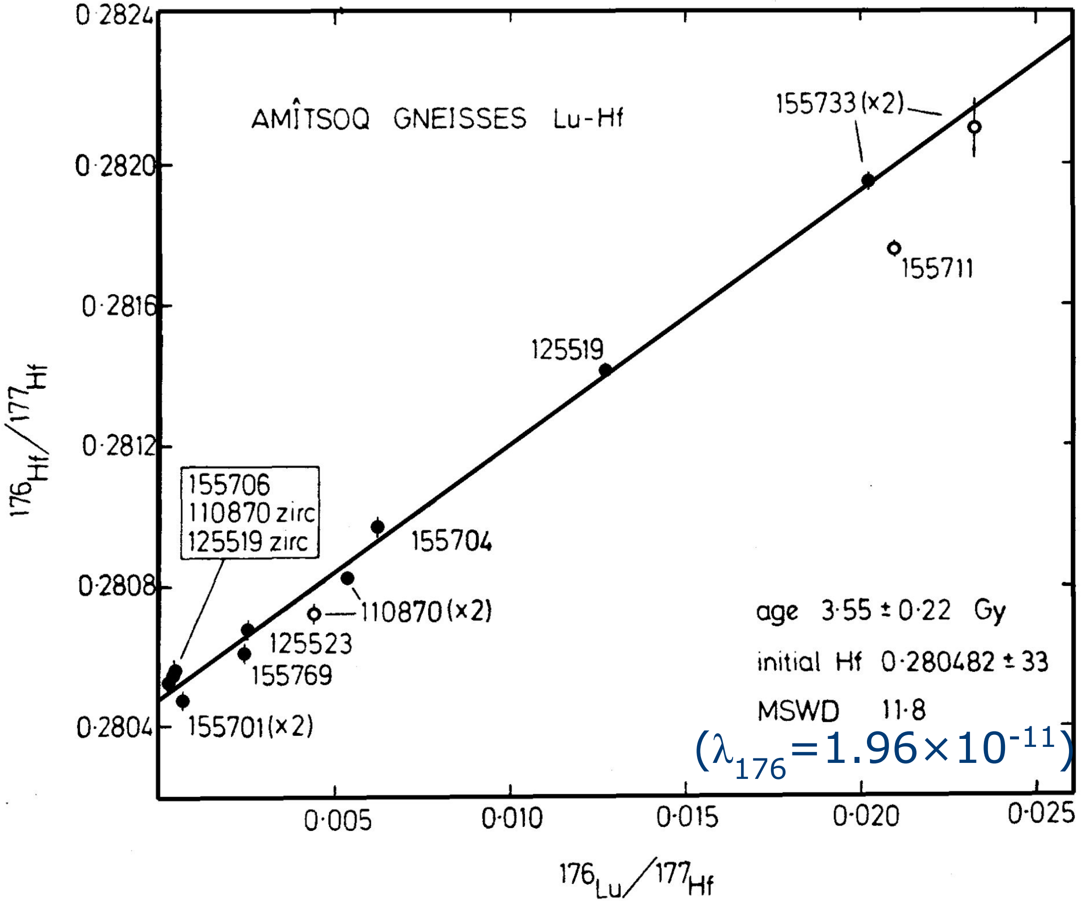


Fig. 1. Lu-Hf regression line for the Amîtsoq gneisses. Uncertainties are at 2σ. Only solid symbols were included in the regression calculation. 155711 lies off the line and was omitted completely. The more precise of two duplicate analyses was always used; note the correlated shifts in $^{176}Lu/^{177}Hf$ and $^{176}Hf/^{177}Hf$ in duplicate analyses, due to sample inhomogeneity. Sample numbers refer to Geological Survey of Greenland sample files.

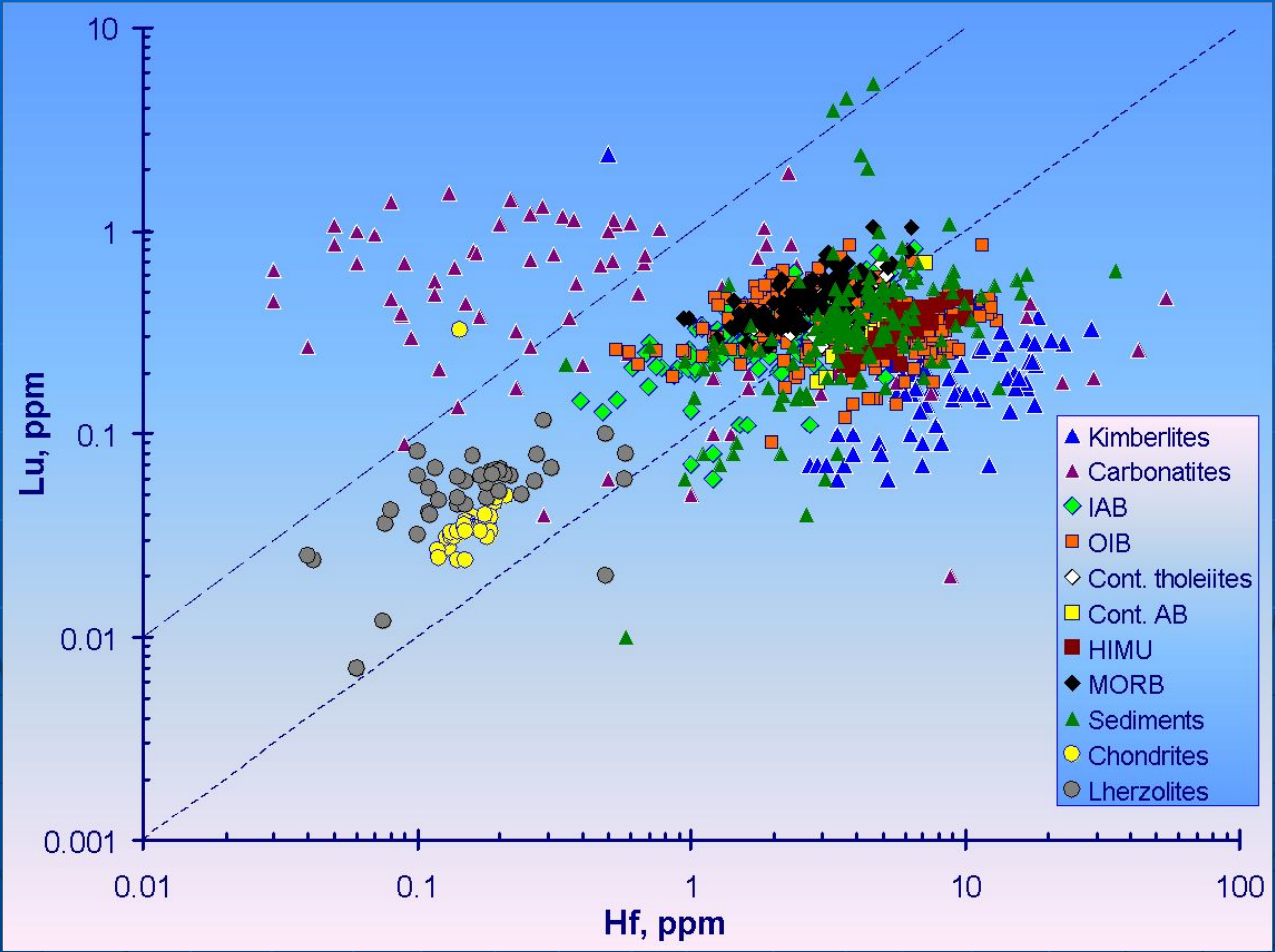
Pettingill, Patchett, 1981

$T_{Sm\text{-}Nd}$=3.64±0.12 Gy [Moorbath et al., 1997]

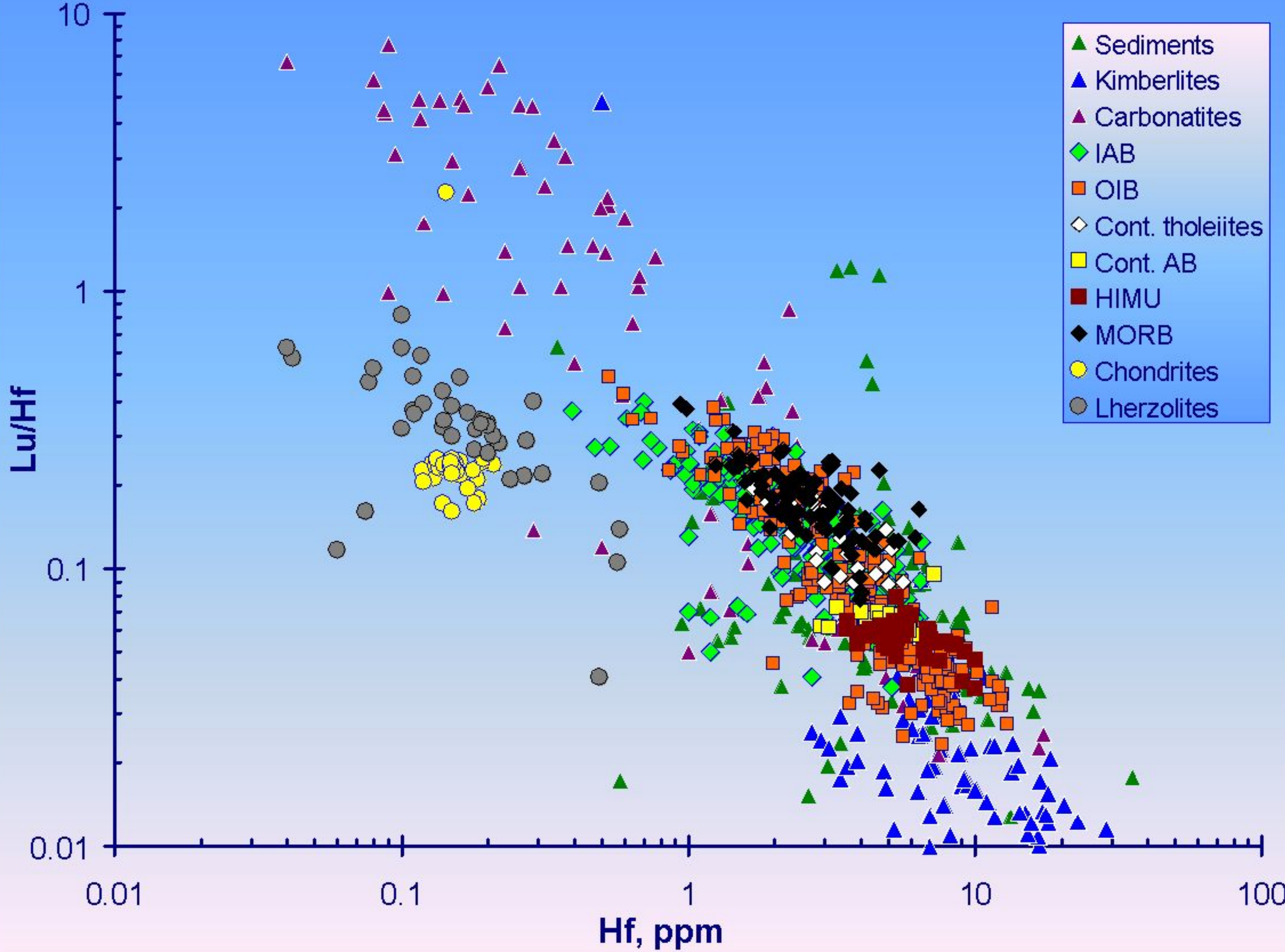
$T_{Lu\text{-}Hf}$=3.73±0.22 Gy (λ=1.867×10−11 год−1)

Lu и Hf в различных типах пород

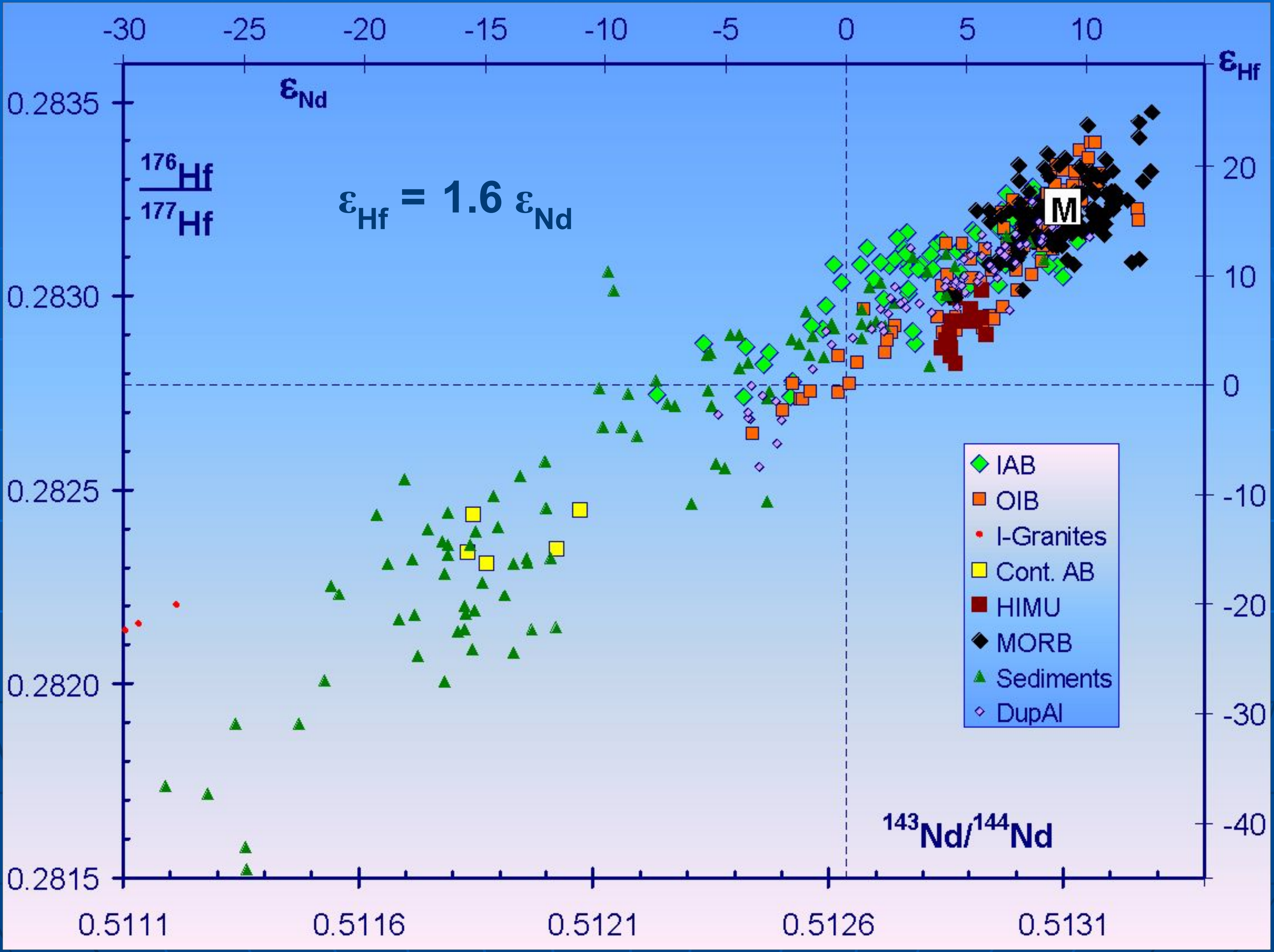
	Lu	Hf	Lu/Hf	ε_{Hf} T	±2σ	N
Chondrites	0.050	0.15	0.237	-0.4	9.1	47
MORB	0.476	2.34	0.224	14.9	5.9	173
HIMU	0.277	6.12	0.047	4.8	4.0	18
OIB	0.328	3.98	0.082	11.7	12.9	133
IAB	0.318	2.46	0.135	12.4	8.4	115
Sediments	0.331	3.74	0.087	-6.6	19.0	207
I-granites	0.569	4.72	0.129	0.9	8.2	16



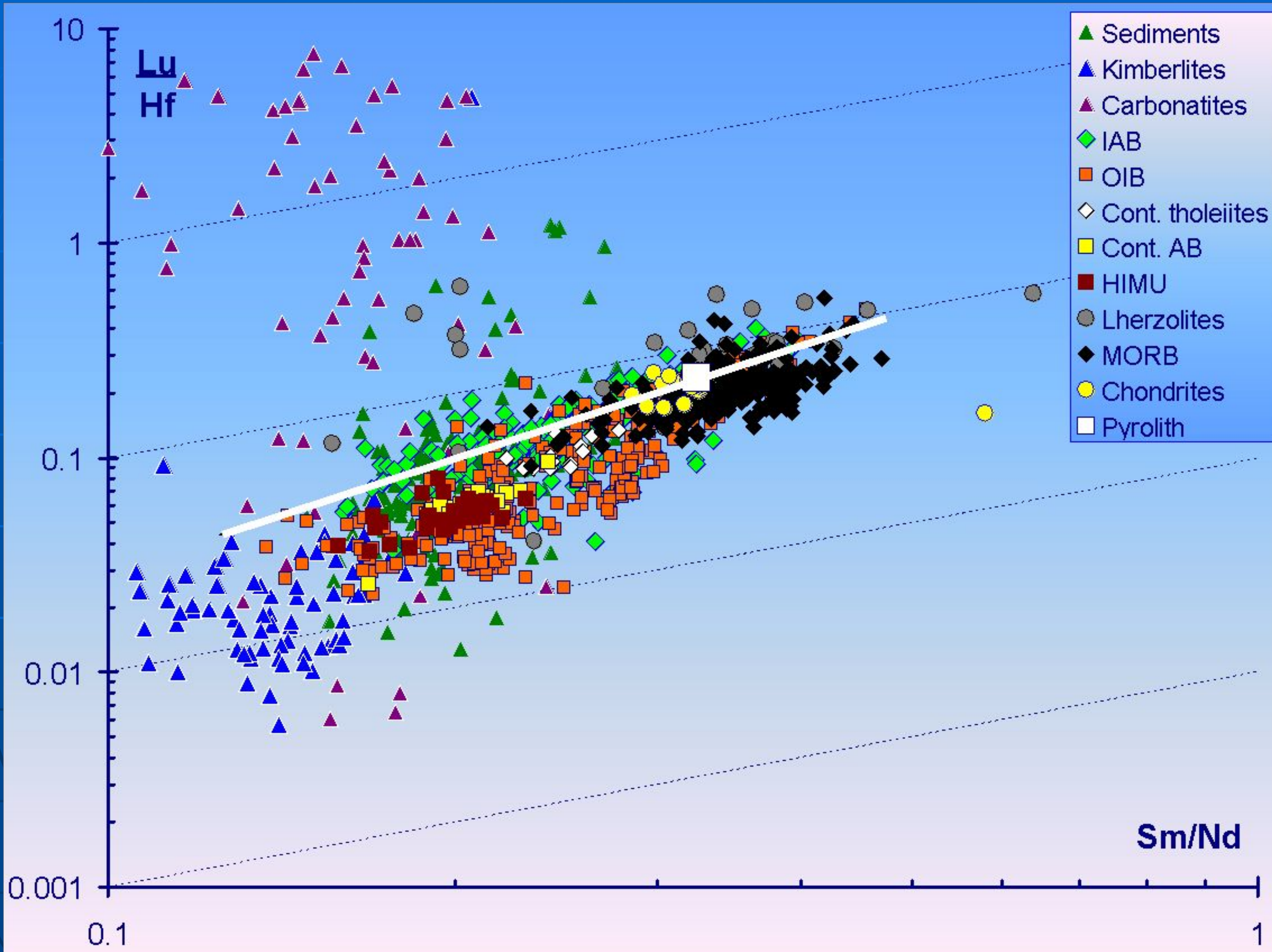
Lu, ppm
Hf, ppm
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
Kimberlites
Carbonatites
IAB
OIB
Cont. tholeiites
Cont. AB
HIMU
MORB
Sediments
Chondrites
Lherzolites



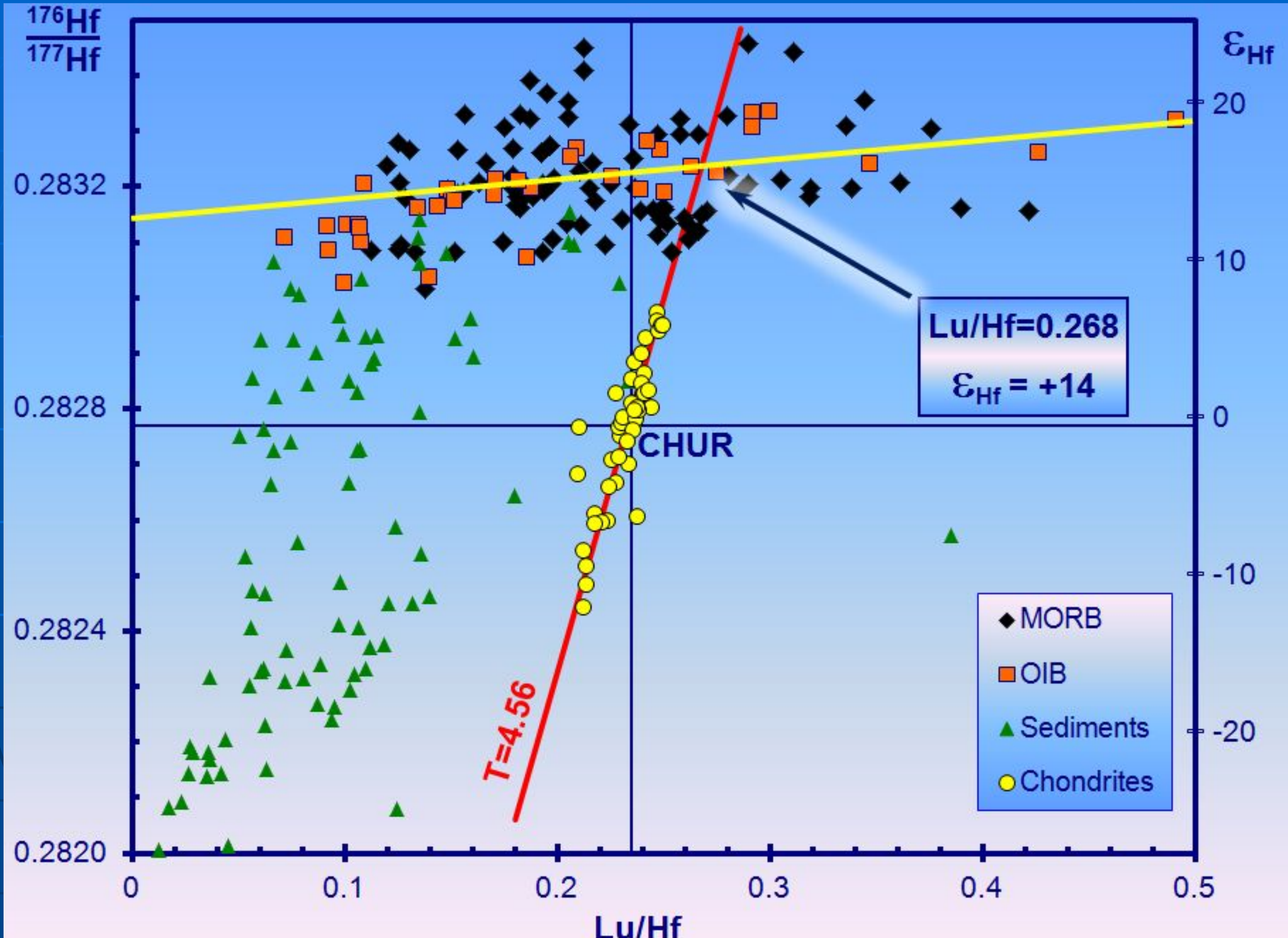
Sediments
Kimberlites
Carbonatites
IAB
OIB
Cont. tholeiites
Cont. AB
HIMU
MORB
Chondrites
Lherzolites
Lu/Hf
Hf, ppm
10
1
0.1
0.01
0.01
0.1
1
10
100



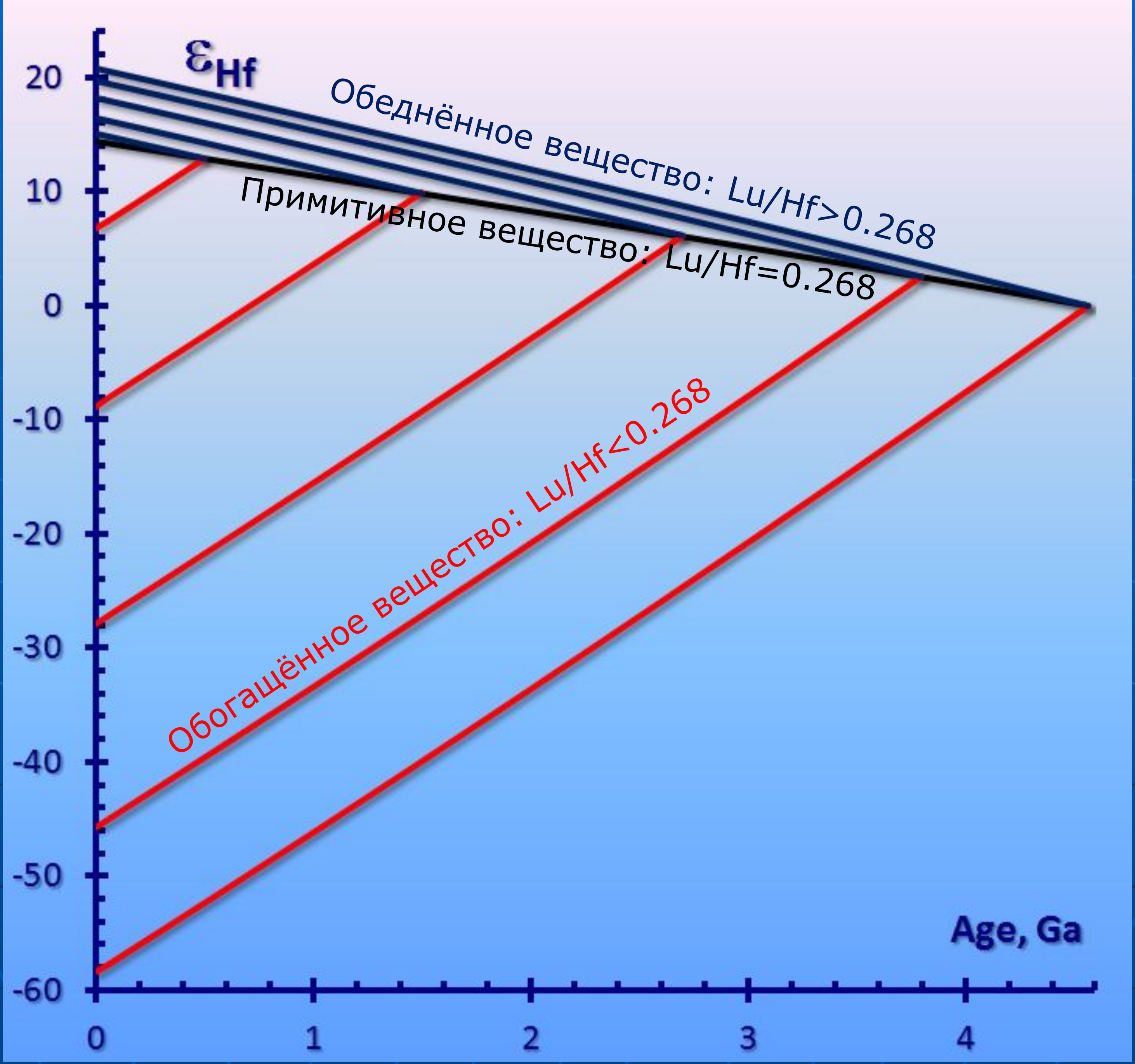
-30
-25
-20
-15
-10
-5
0
5
10
εNd
εHf
176Hf/177Hf
εHf = 1.6 εNd
M
0.2835
0.2830
0.2825
0.2820
0.2815
20
10
0
-10
-20
-30
-40
IAB
OIB
I-Granites
Cont. AB
HIMU
MORB
Sediments
DupAl
143Nd/144Nd
0.5111
0.5116
0.5121
0.5126
0.5131



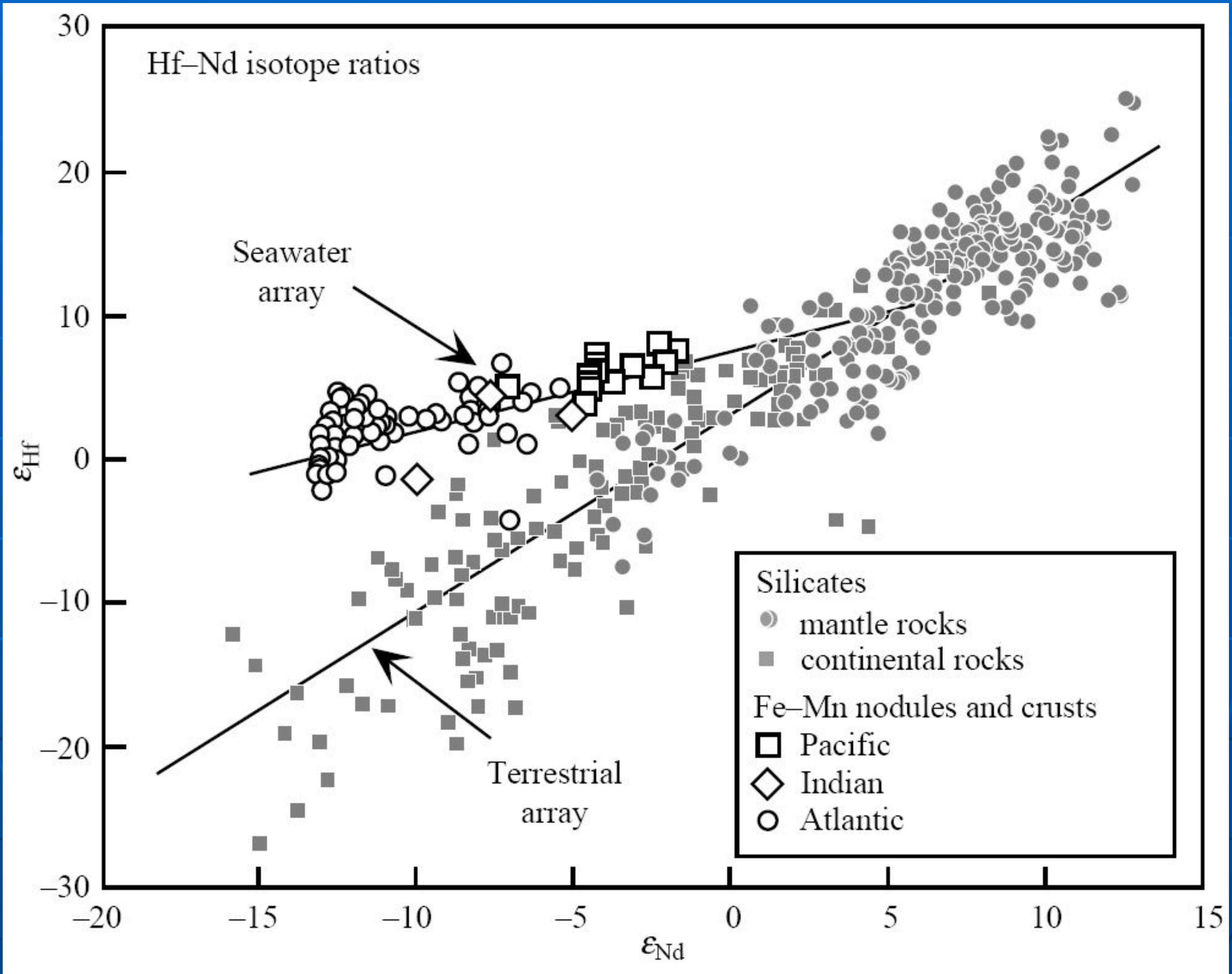
Lu
Hf
10
1
0.1
0.01
0.001
0.1
1
Sm/Nd
Sediments
Kimberlites
Carbonatites
IAB
OIB
Cont. tholeiites
Cont. AB
HIMU
Lherzolites
MORB
Chondrites
Pyrolith



$\frac{^{176}Hf}{^{177}Hf}$
ε_{Hf}
0.2832
0.2828
0.2824
0.2820
20
10
0
-10
-20
0
0.1
0.2
0.3
0.4
0.5
Lu/Hf
CHUR
T=4.56
Lu/Hf=0.268
ε_{Hf} = +14
MORB
OIB
Sediments
Chondrites

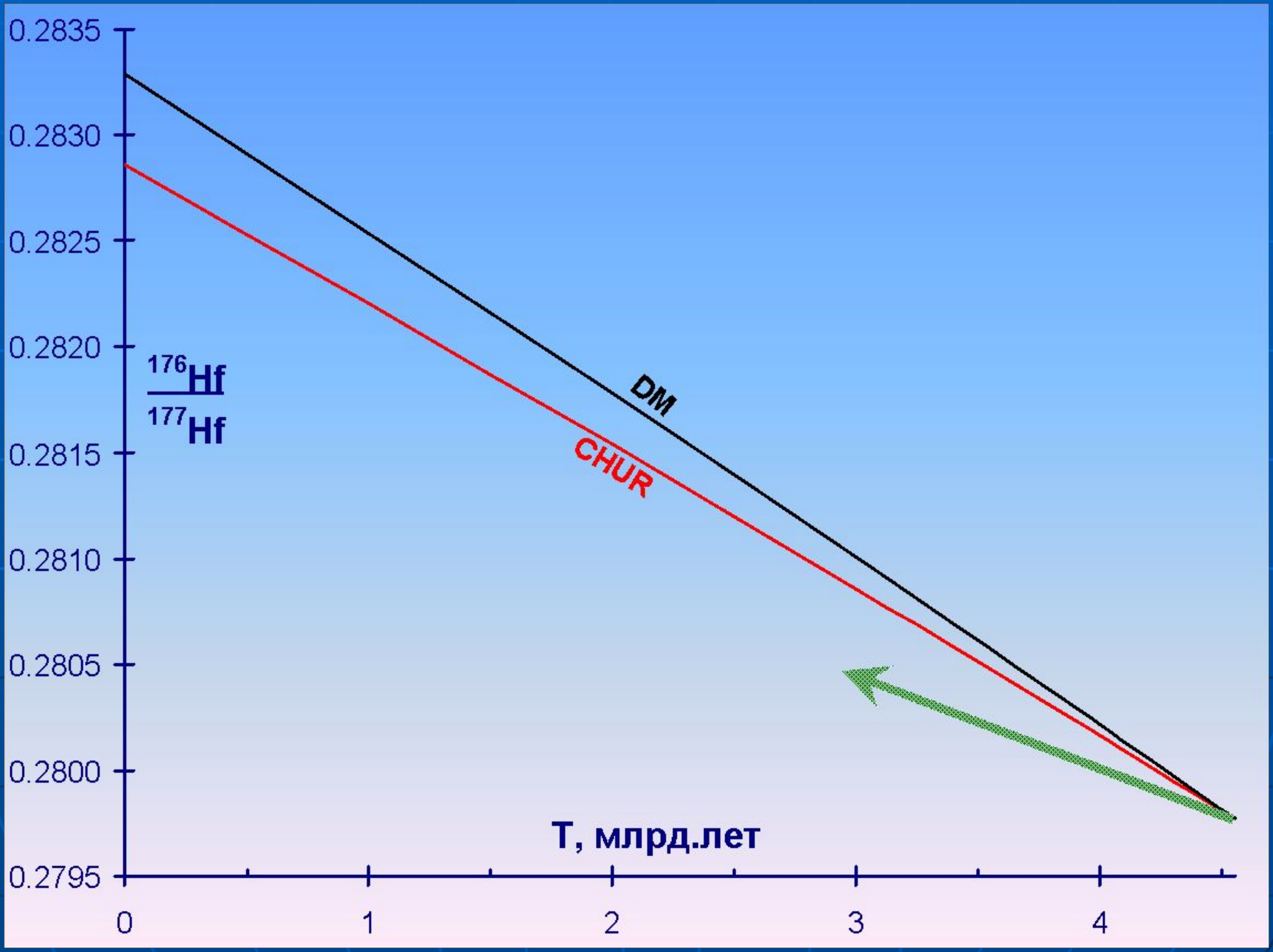


εHf
Обеднённое вещество: Lu/Hf>0.268
Примитивное вещество: Lu/Hf=0.268
Обогащённое вещество: Lu/Hf<0.268
Age, Ga
20
10
0
-10
-20
-30
-40
-50
-60
0
1
2
3
4



S. L. Goldstein and S. R. Hemming, 2003

Задача 18. Найти Lu/Hf в мантии, если в среднем для MORB ε_{Hf}=+14



Kinny, Compston, Williams, 1991

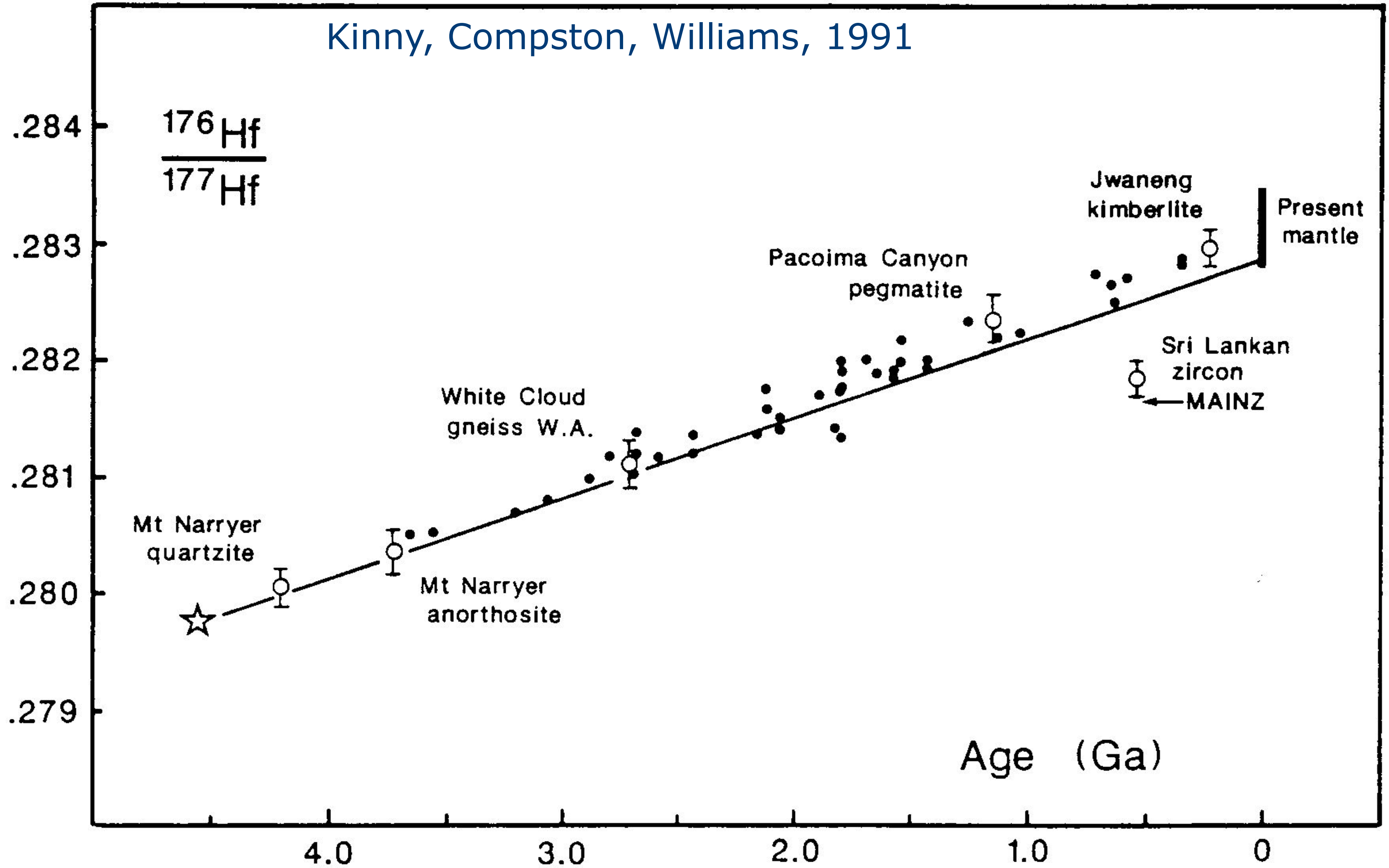
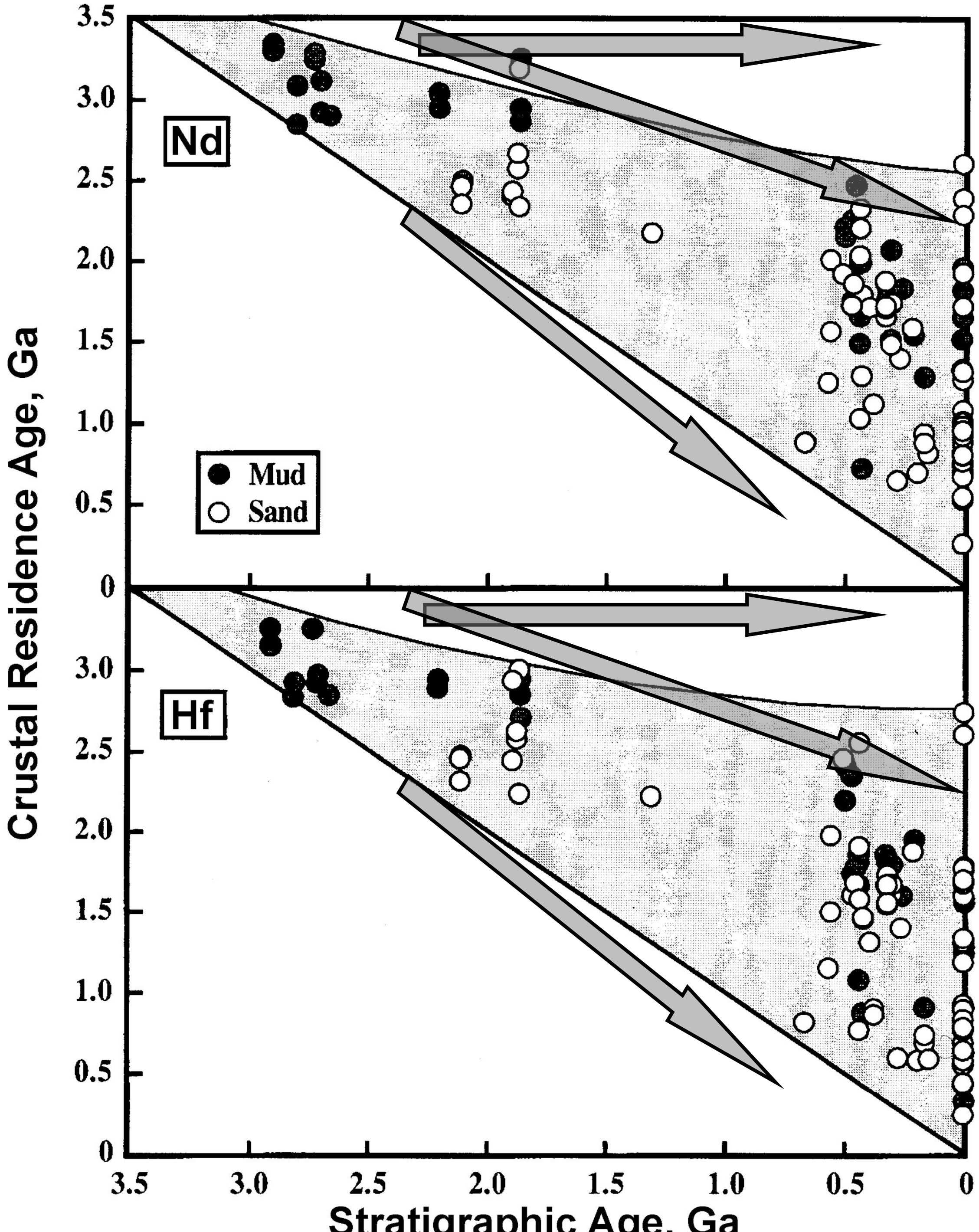


FIG. 3. Hafnium isotopic evolution diagram showing results of ion probe zircon analyses (2σ error bars, labelled), in comparison with orthodox TIMS data for terrestrial rocks (PATCHETT et al., 1981)—black dots. The ion probe data are taken from Tables 4, 5, and 6, and represent the mean composition of several analysed grains. Ages are interpreted from U-Pb isotopic data. "Mt Narryer quartzite" refers to the 4.20 Ga detrital zircons only. "MAINZ" refers to the mean $^{176}Hf/^{177}Hf$ of SL7 as calculated from TIMS analyses by Dr. T. C. Liew (Table 3).

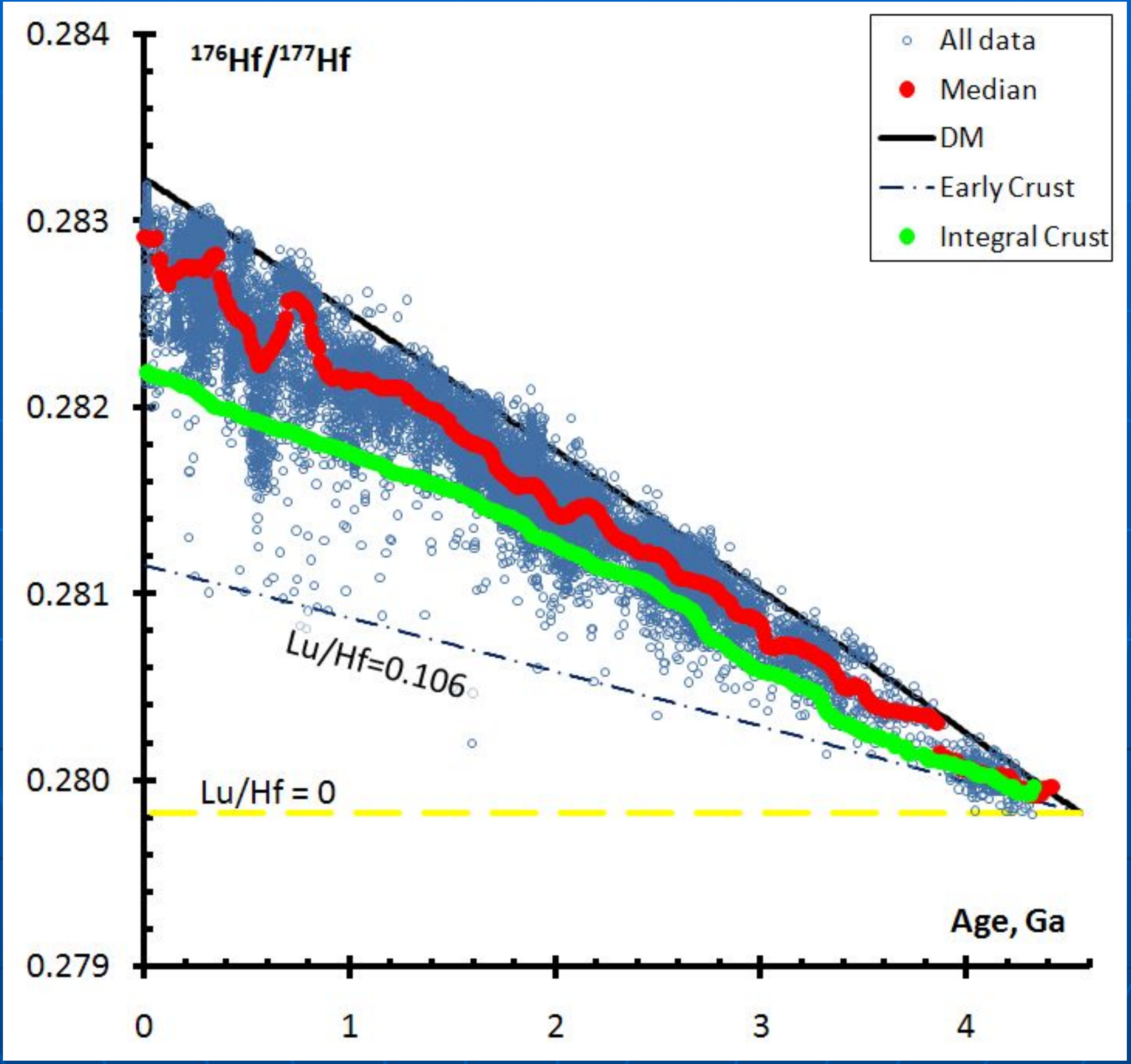


Vervoort et al., 1999

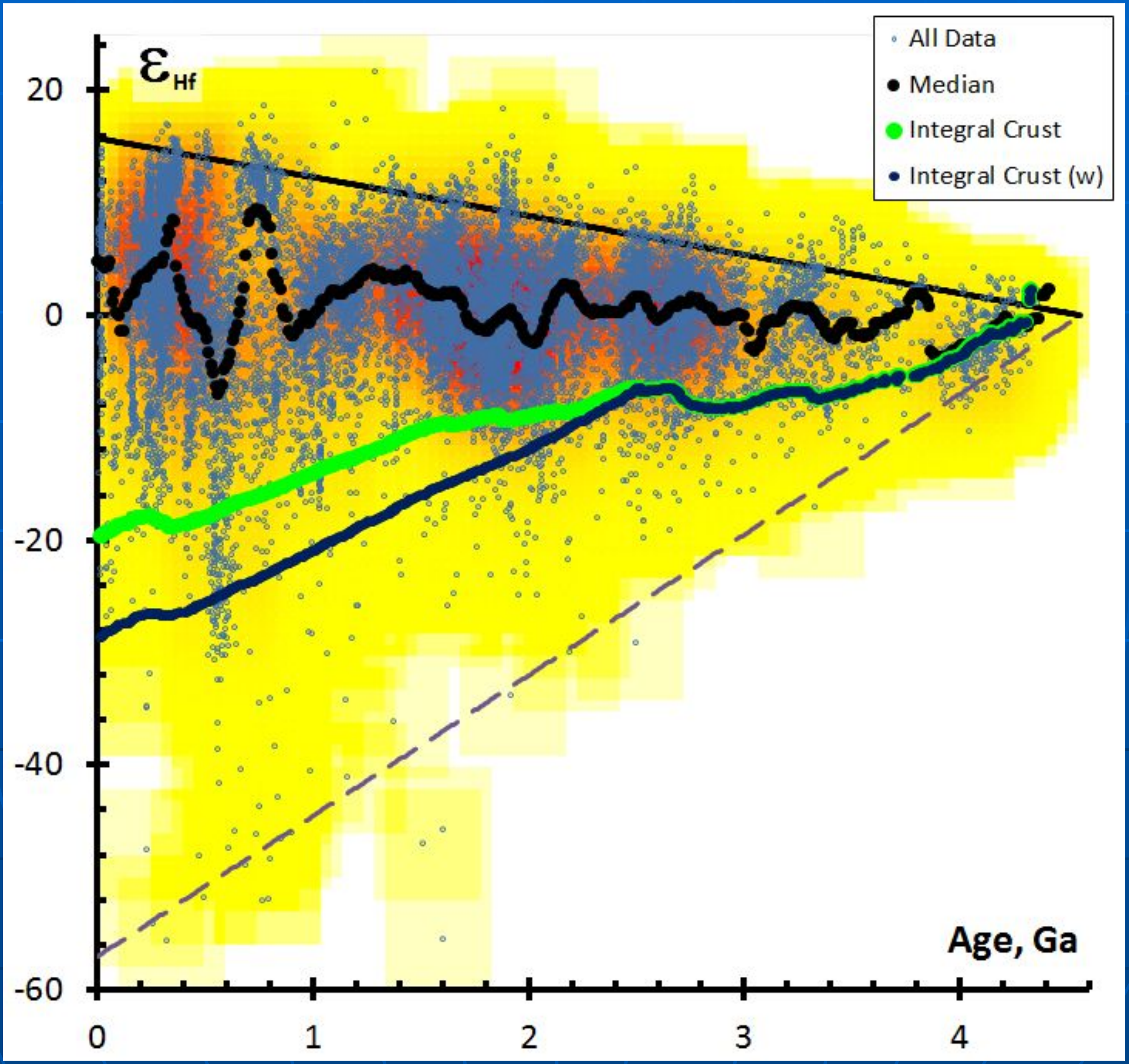
$$T_{DM}^{Nd} = \frac{1}{\lambda_{^{147}Sm}} \ln\left[\frac{\left(\frac{^{143}Nd}{^{144}Nd}\right)_S - \left(\frac{^{143}Nd}{^{144}Nd}\right)_{DM}}{\left(\frac{^{147}Sm}{^{144}Nd}\right)_S - \left(\frac{^{147}Sm}{^{144}Nd}\right)_{DM}} + 1 \right]$$

$$T_{DM}^{Hf} = \frac{1}{\lambda_{^{176}Lu}} \ln\left[\frac{\left(\frac{^{176}Hf}{^{177}Hf}\right)_S - \left(\frac{^{176}Hf}{^{177}Hf}\right)_{DM}}{\left(\frac{^{176}Lu}{^{177}Hf}\right)_S - \left(\frac{^{176}Lu}{^{177}Hf}\right)_{DM}} + 1 \right]$$

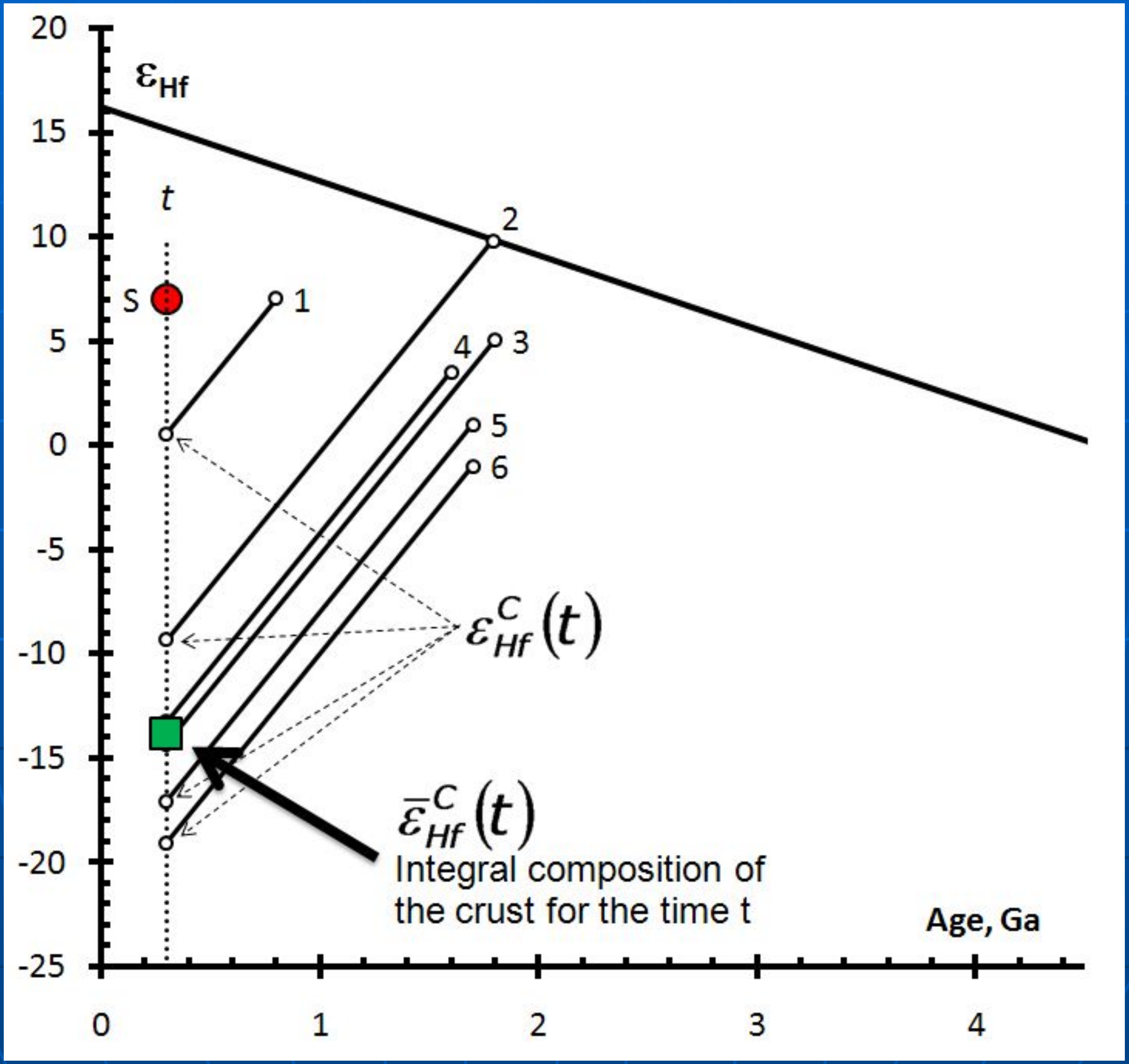
Belousova E.A., Kostitsyn Y.A., Griffin W.L. et al., The growth of the continental crust: Constraints from zircon Hf-isotope data. // Lithos 2010. V. 119. # 3-4 P. 457-466.



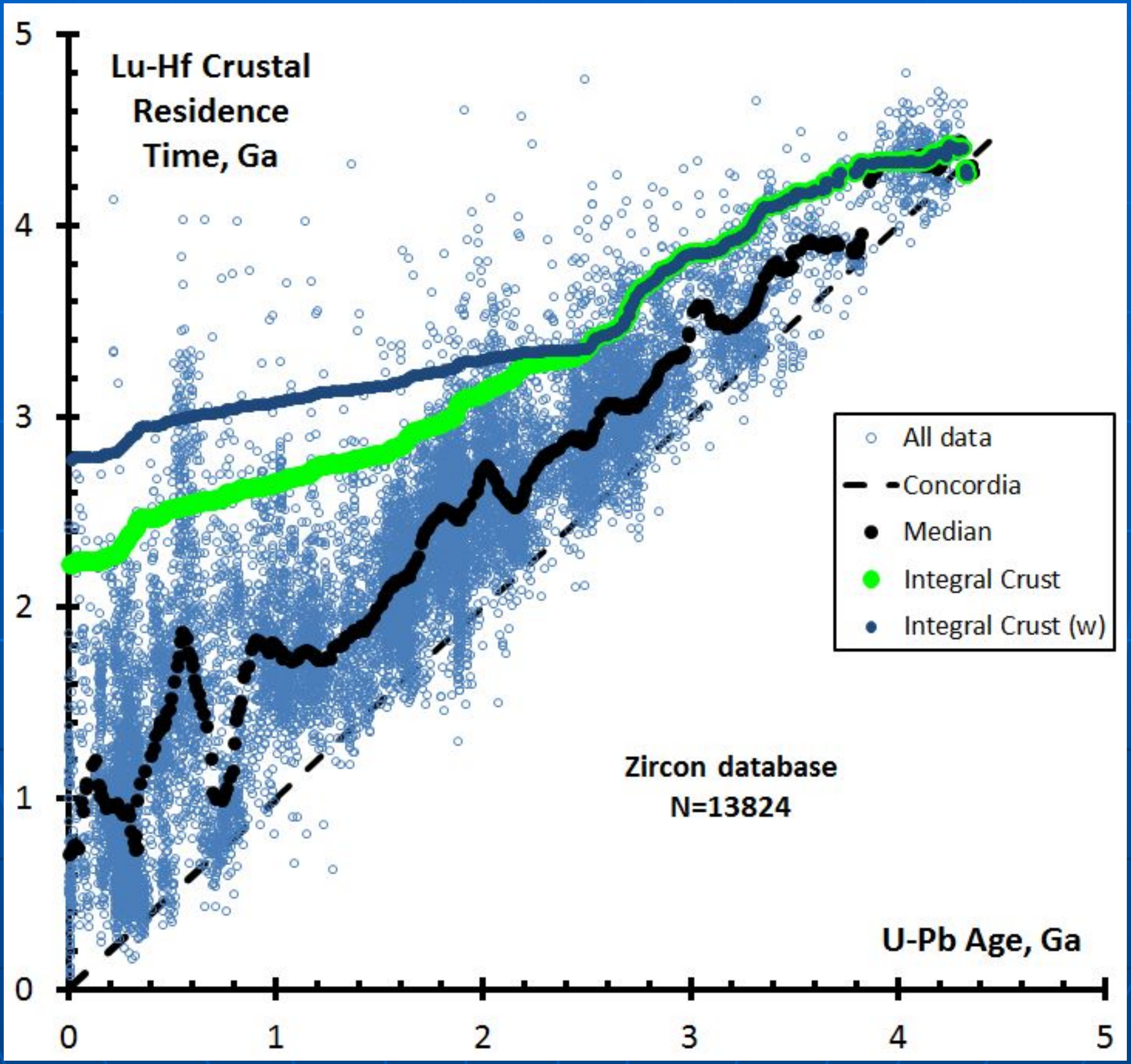
Belousova et al. Lithos 2010. V. 119. # 3-4 P. 457-466.



Belousova et al. Lithos 2010. V. 119. # 3-4 P. 457-466.



Belousova et al. Lithos 2010. V. 119. # 3-4 P. 457-466.



Общие закономерности изотопной геохимии мантии

$$\alpha^i = \alpha_0^i + \mu^i \cdot [\exp(\lambda^i \cdot t) - 1]$$

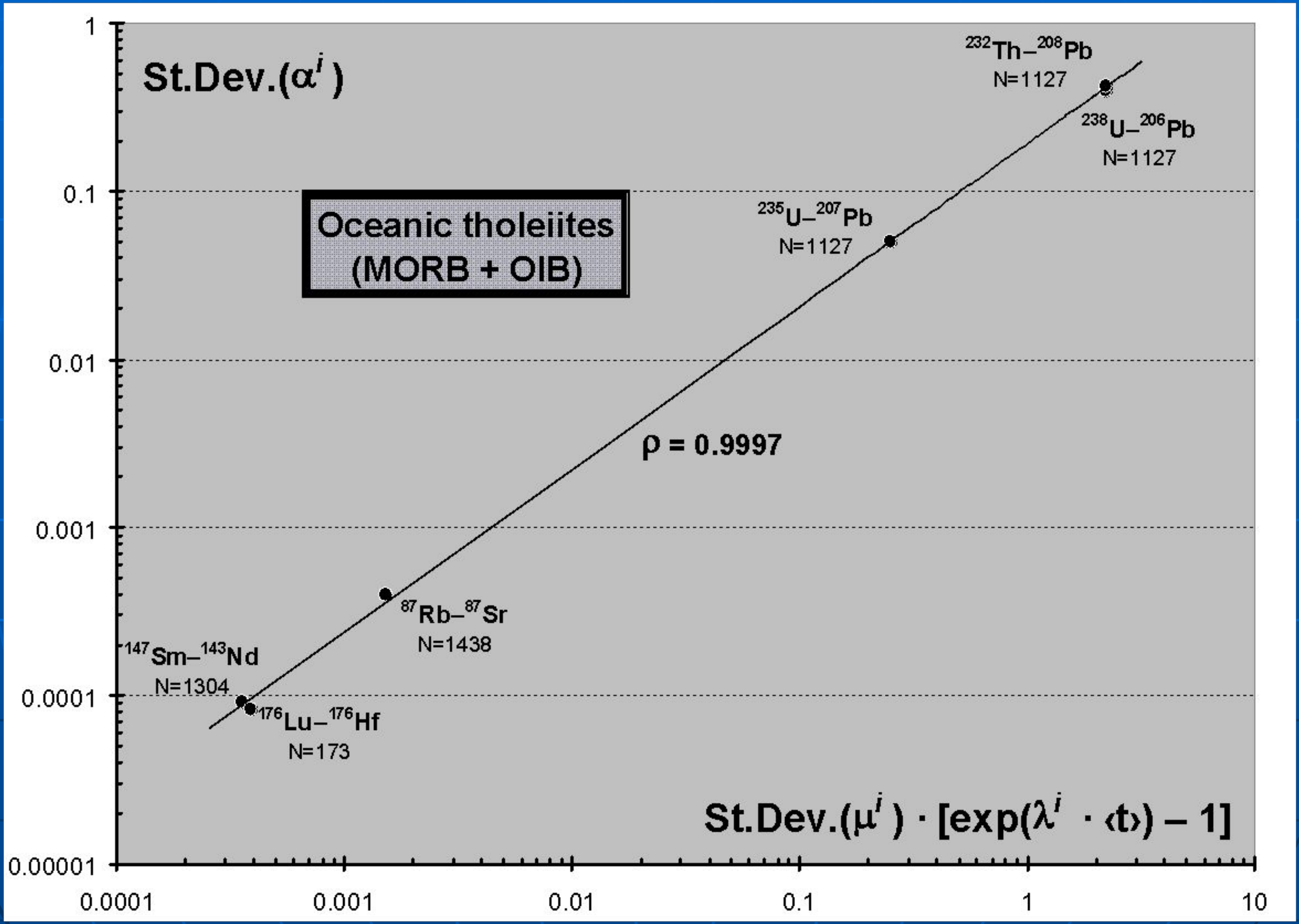
$$Var\left(\alpha^i\right) = Var\left(\alpha_0^i\right) + Var\left(\mu^i \cdot [\exp(\lambda^i \cdot t) - 1]\right)$$

$$Var\left(\alpha^i\right) \approx Var\left(\alpha_0^i\right)$$

или

?

$$Var\left(\alpha^i\right) \approx Var\left(\mu^i \cdot [\exp(\lambda^i \cdot t) - 1]\right)$$

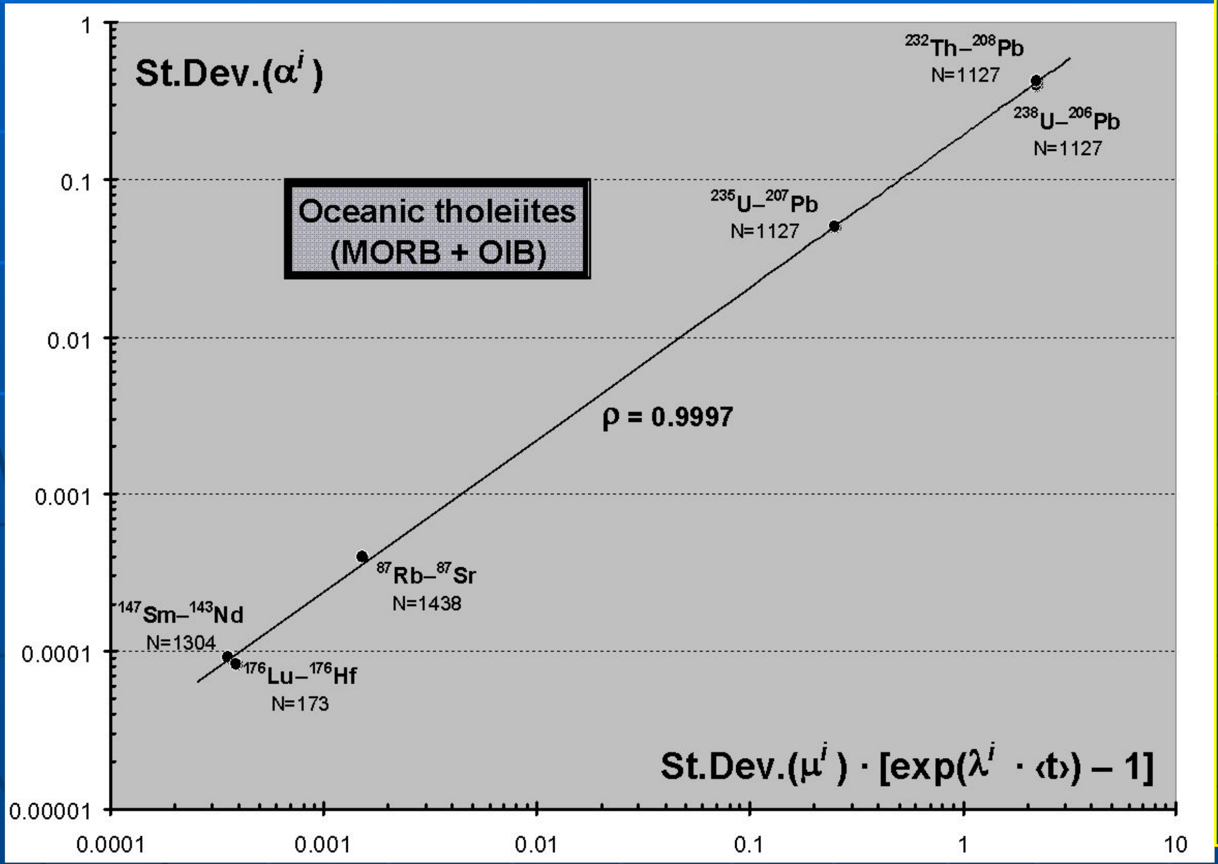


St.Dev.(αi)
Oceanic tholeiites
(MORB + OIB)
232Th–208Pb
N=1127
238U–206Pb
N=1127
235U–207Pb
N=1127
ρ = 0.9997
87Rb–87Sr
N=1438
147Sm–143Nd
N=1304
176Lu–176Hf
N=173
St.Dev.(μi) · [exp(λi · ‹t›) – 1]
1
0.1
0.01
0.001
0.0001
0.00001
0.0001
0.001
0.01
0.1
1
10

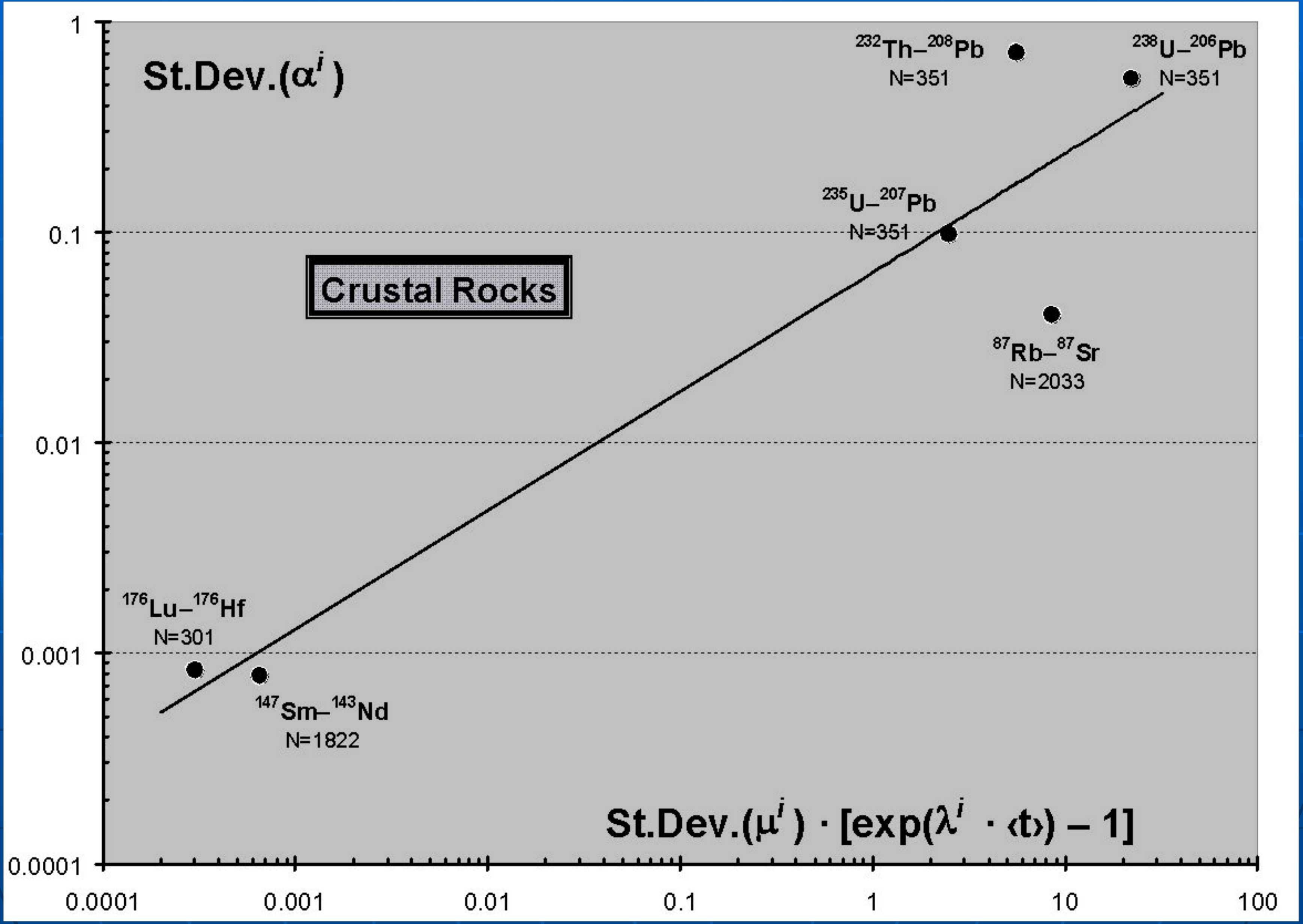
Все μ и α взяты из данных для толеитовых базальтов;

Наилучшее приближение при <t>~1.8 Ga;

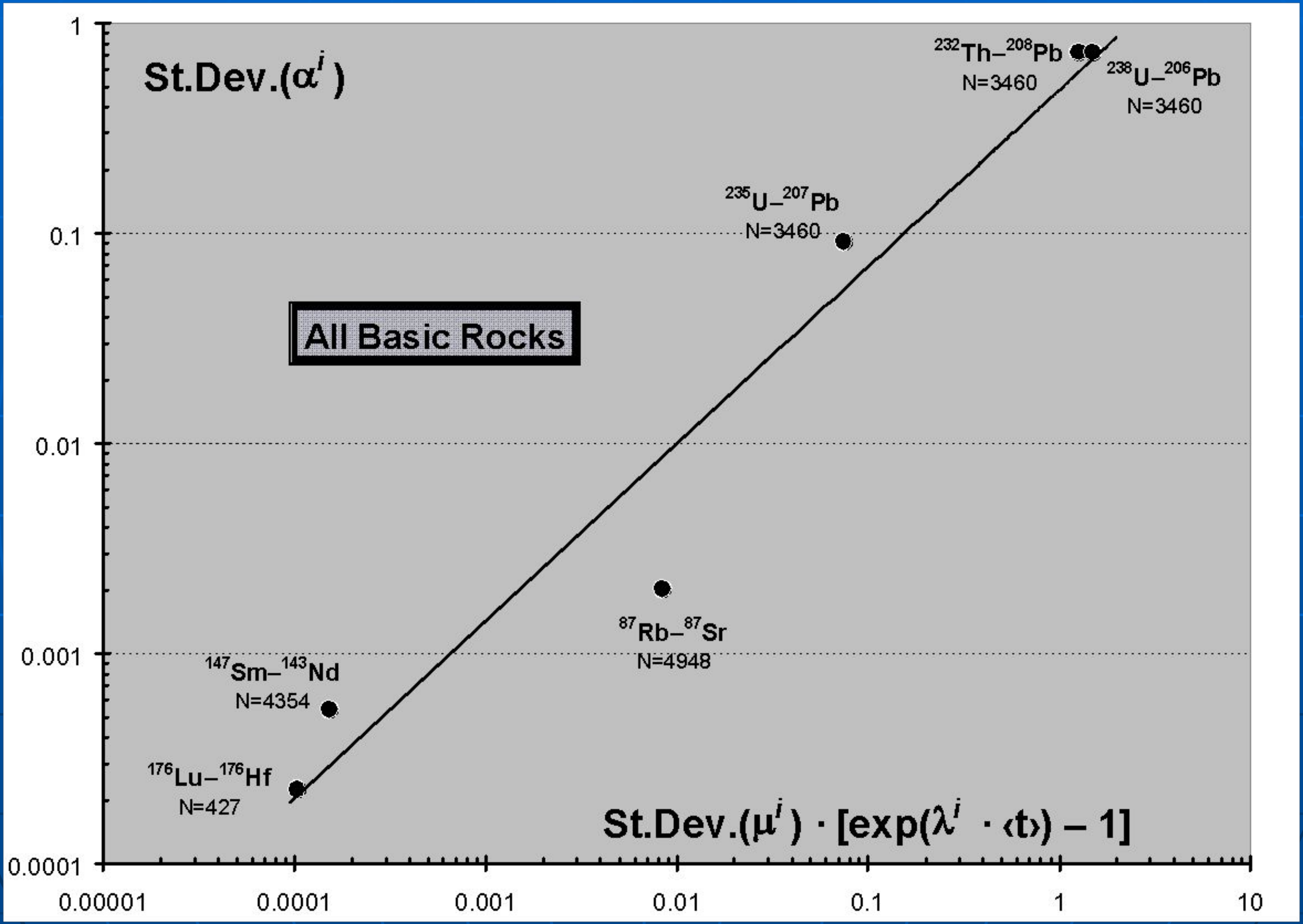
Оценка <t> имеет смысл среднего возраста всех процессов, запечатлённых в ‘изотопной памяти' источника этих пород.



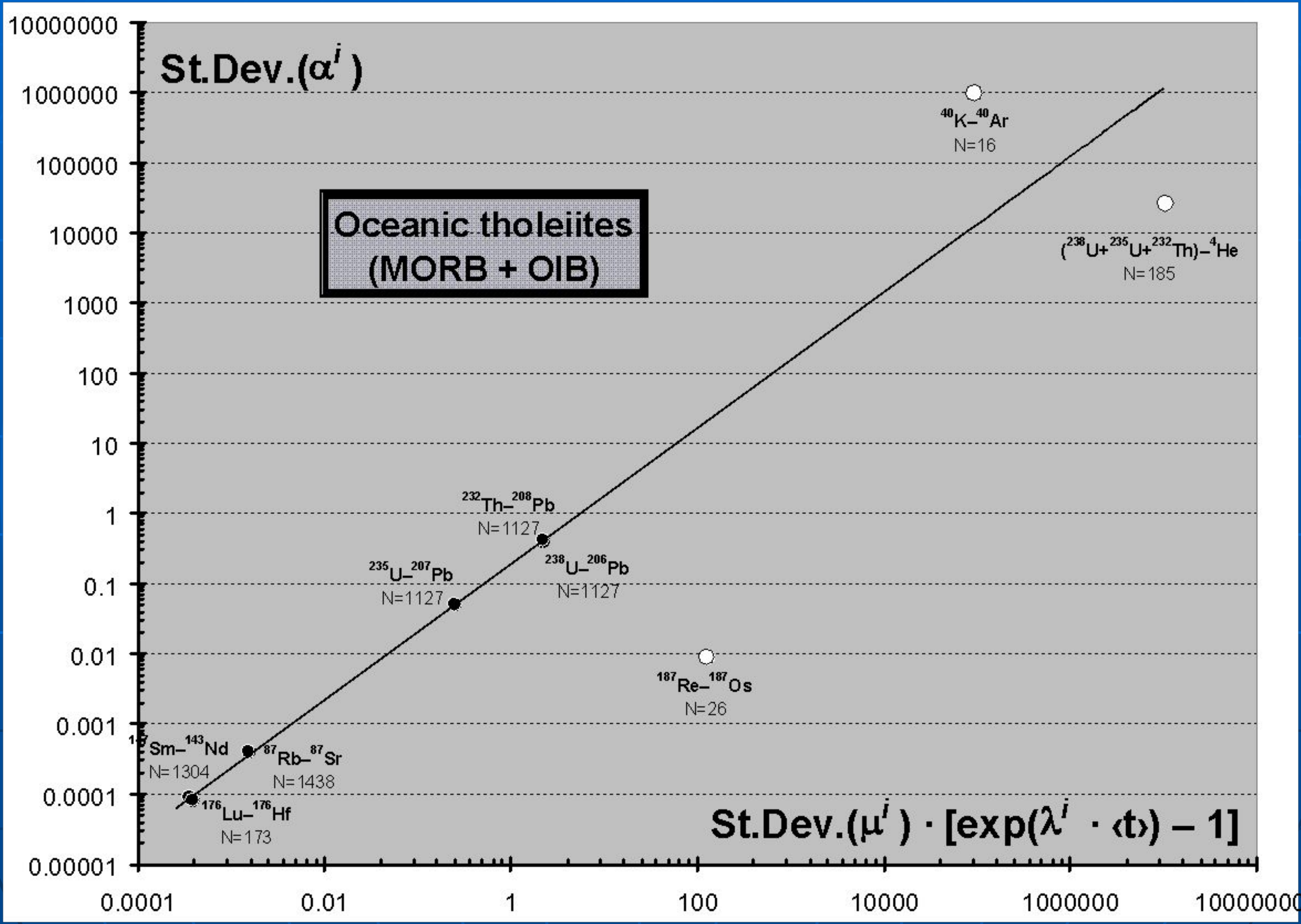
- Столь строгая зависимость вряд ли случайна;
- Это – не результат распада in-situ;
- График отражает развитие некоторого единого процесса в источнике пород;
- График показывает, что изотопная гетерогенность мантии определяется её собственной химической гетерогенностью;
- Все представленные здесь изотопные системы имеют в мантии общую историю развития, и мы не можем для различных изотопных аномалий (DM, EM-I, EM-II, HIMU, DUPAL) подбирать разные объяснения.



St.Dev.(α^i)
Crustal Rocks
^{232}Th–^{208}Pb
N=351
^{238}U–^{206}Pb
N=351
^{235}U–^{207}Pb
N=351
^{87}Rb–^{87}Sr
N=2033
^{176}Lu–^{176}Hf
N=301
^{147}Sm–^{143}Nd
N=1822
St.Dev.(μ^i) · [exp(λ^i · ‹t›) – 1]
1
0.1
0.01
0.001
0.0001
0.0001
0.001
0.01
0.1
1
10
100



St.Dev.(α^i)
All Basic Rocks
232Th–208Pb
N=3460
238U–206Pb
N=3460
235U–207Pb
N=3460
87Rb–87Sr
N=4948
147Sm–143Nd
N=4354
176Lu–176Hf
N=427
St.Dev.(μ^i) · [exp(λ^i · ‹t›) – 1]
1
0.1
0.01
0.001
0.0001
0.00001
0.0001
0.001
0.01
0.1
1
10



St.Dev.(α^i)
Oceanic tholeiites
(MORB + OIB)
40K–40Ar
N=16
(238U+235U+232Th)–4He
N=185
232Th–208Pb
N=1127
238U–206Pb
N=1127
235U–207Pb
N=1127
187Re–187Os
N=26
147Sm–143Nd
N=1304
87Rb–87Sr
N=1438
176Lu–176Hf
N=173
St.Dev.(μ^i) · [exp(λ^i · ‹t›) – 1]
10000000
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001
0.0001
0.01
1
100
10000
1000000
10000000