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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](http://wiki.web.ru/wiki/Геологический_Факультет_МГУ:Геохимия_Изотопов_и_Геохронология)



$$\lambda = 1.867 \times 10^{-11} \text{ год}^{-1}$$

(Sherer et al., 2001, 2007)

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

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

5

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

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

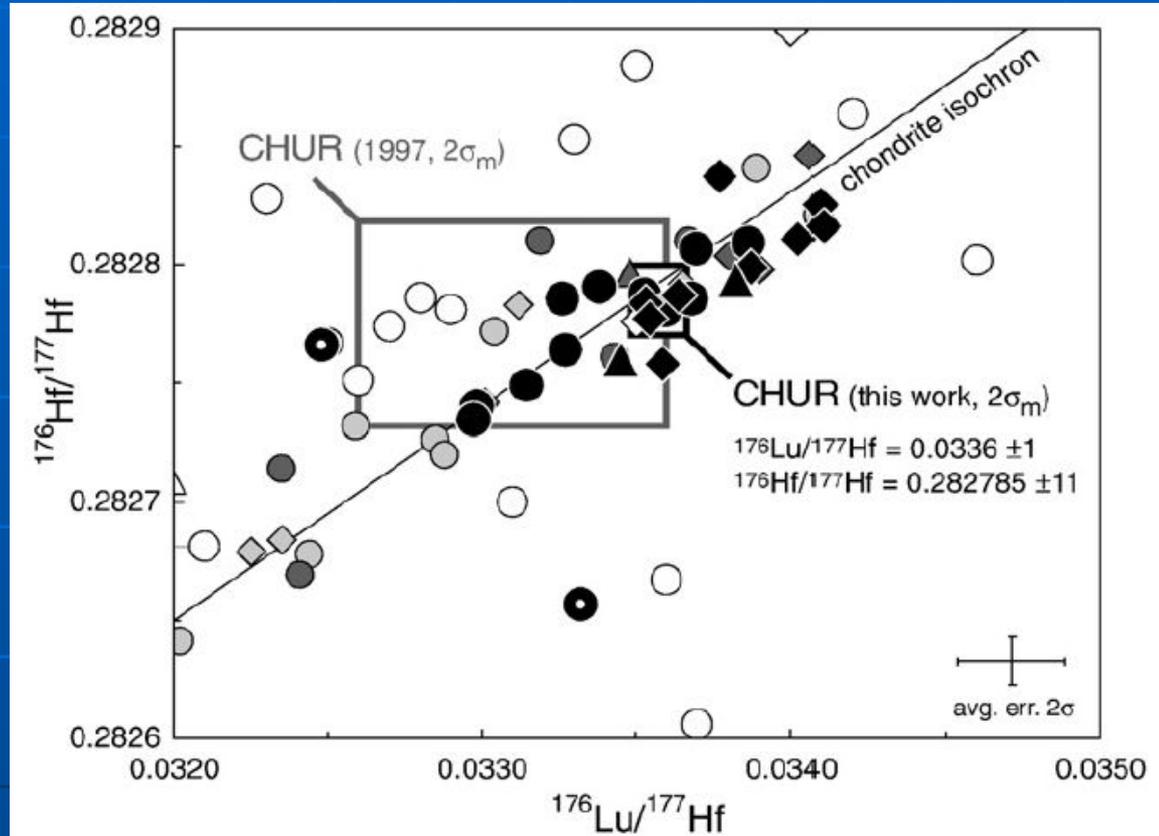


Fig. 2. Lu–Hf CHUR value. New Lu–Hf isotope analyses of unequilibrated carbonaceous, ordinary, and enstatite chondrites provide tighter constraints on the Lu–Hf CHUR parameters compared to previous estimates (Blichert-Toft and Albarède, 1997). Our new CHUR parameters of ${}^{176}\text{Lu}/{}^{177}\text{Hf}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

Bouvier, Vervoort, Patchett, EPSL, 2008

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

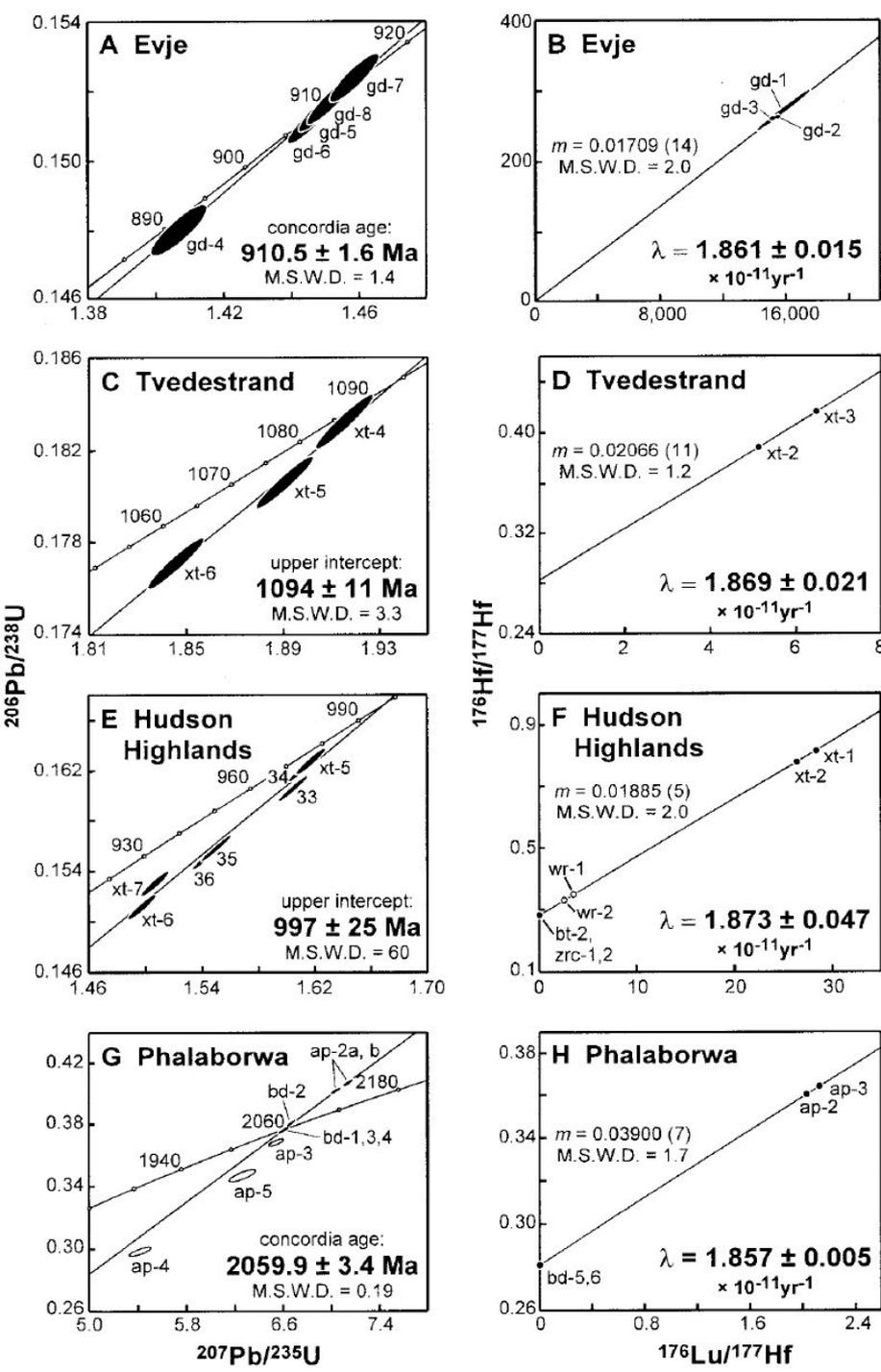
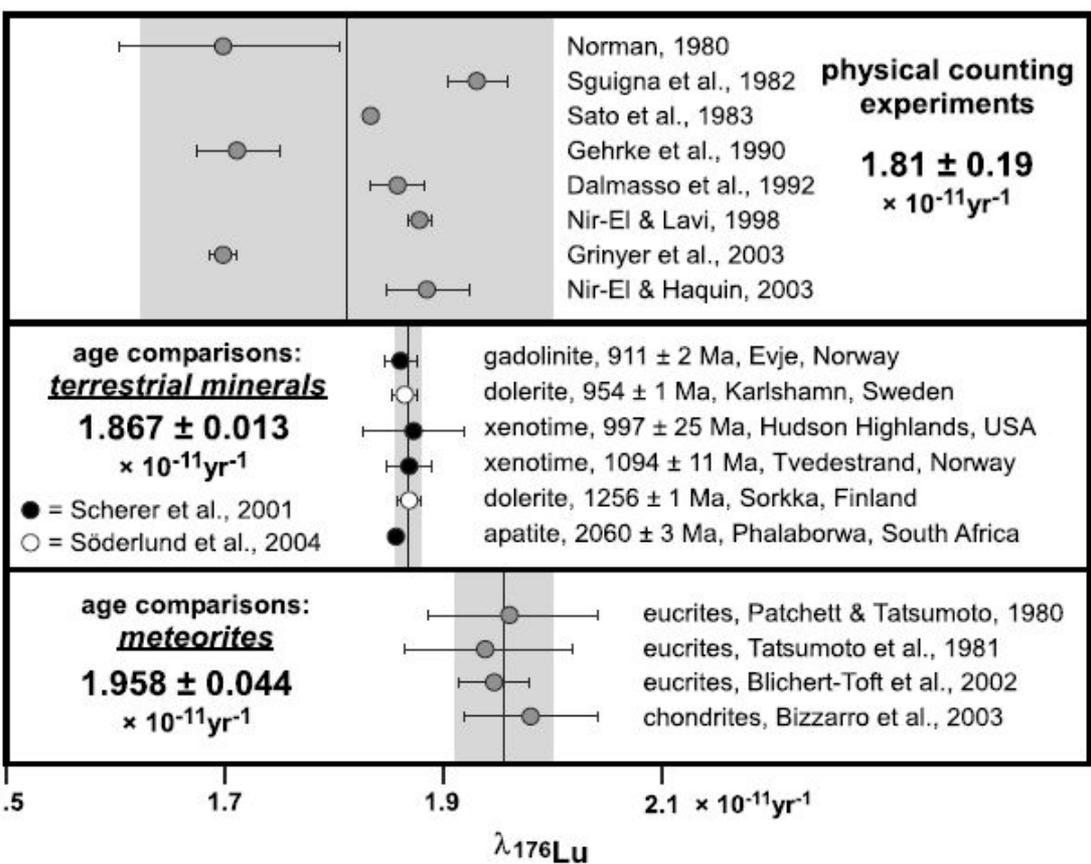


Fig. 1. U-Pb concordia and Lu-Hf isochron diagrams (A through H). gd, gadolinite; xt, xenotime; ap, apatite; bd, baddeleyite. Open symbols are excluded from the regressions. U-Pb data are available online (47). Uranium decay constants: $\lambda^{238}\text{U} = 1.55125 \pm 0.00166 \times 10^{-10} \text{ year}^{-1}$, $\lambda^{235}\text{U} = 9.8485 \pm 0.0134 \times 10^{-10} \text{ year}^{-1}$ [(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. $\lambda^{176}\text{Lu} = \ln(m + 1)/t$, where m is the slope of the Lu-Hf isochron and t is the U-Pb age of the sample in years. Uncertainties on $\lambda^{176}\text{Lu}$ 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 $\lambda_{176\text{Lu}}$?

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



	W180	W181	W182	W183	W184			
	0+	121.2 d 9/2+	0+	$1.1\text{E}+17$ y 1/2-	$3\text{E}+17$ y 0+			
		EC	26.3	14.3	30.67			
a177	Ta178	Ta179	Ta180	Ta181	Ta182	Ta183		
6.56 h 7/2+	9.31 m 1+	1.82 y 7/2+	8.152 h 1+	7/2-	$11\text{E}+13$ d 3-	5.1 d 7/2+		
	EC	EC	EC, β^- 0.012	99.988	β^-	β^-		
Hf174	Hf175	Hf176	Hf177	Hf178	Hf179	Hf180	Hf181	Hf182
$2.0\text{E}15$ y 0+	70 d 5/2-	0+	7/2-	0+	9/2+	0+	$4\text{E}+39$ d 1/2-	$9\text{E}6$ y 0+
α 0.162	EC	5.206	18.606	27.297	13.629	35.100	β^-	β^-
Lu173	Lu174	Lu175	Lu176	Lu177	Lu178	Lu179	Lu176	
1.37 y 7/2+	3.31 y (1)-	7/2+		6.734 d 7/2+	28.4 m 1(+)	4.59 h 7/2(+)	7-	1-
EC	EC	97.41		β^-	β^-	β^-	37 Gy	3.7 h
Yb172	Yb173	Yb174	Yb175	Yb176	Yb177	Yb178	β^-	β^-
0+	5/2-	0+	4.185 d 7/2-	0-	1.911 h (9/2+)	74 m 0+	2.59	
21.9	16.12	31.8	β^-	12.7	β^-	β^-		

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

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

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

Pettingill, Patchett,
1981

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

$T_{\text{Lu-Hf}} = 3.73 \pm 0.22 \text{ Gy}$
($\lambda = 1.867 \times 10^{-11} \text{ год}^{-1}$)

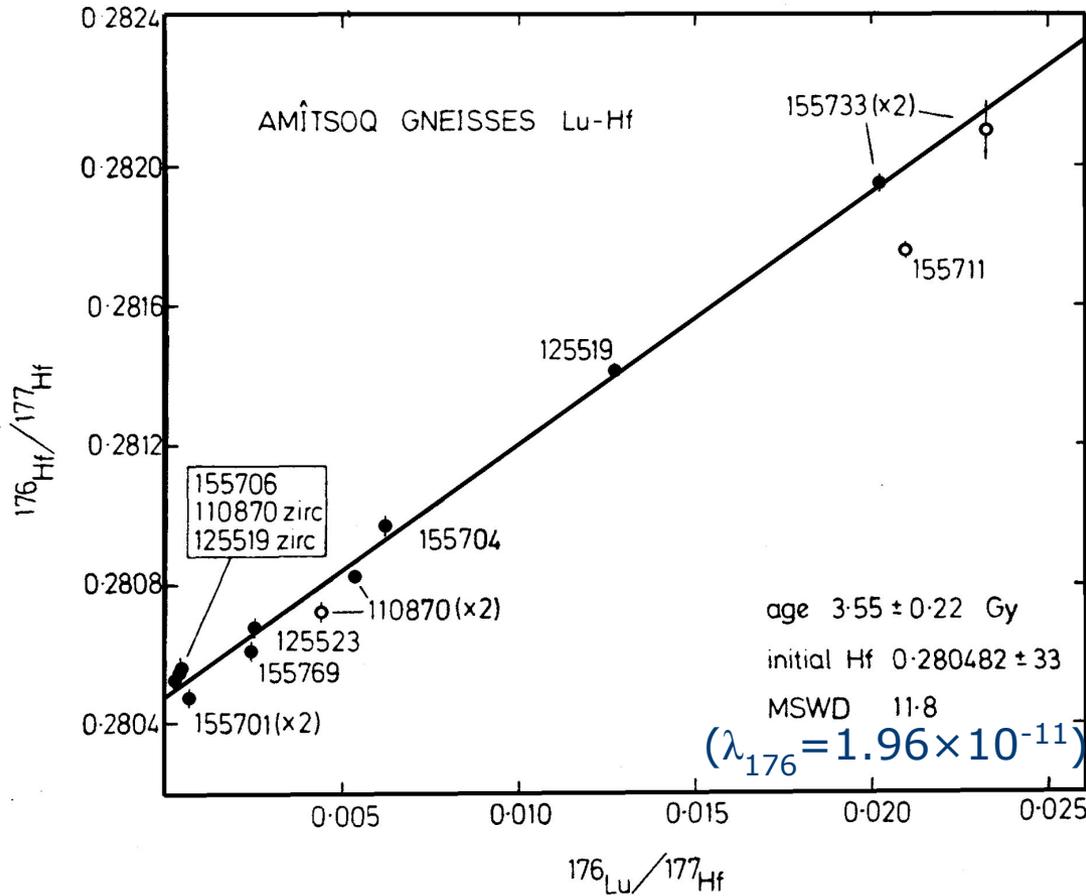
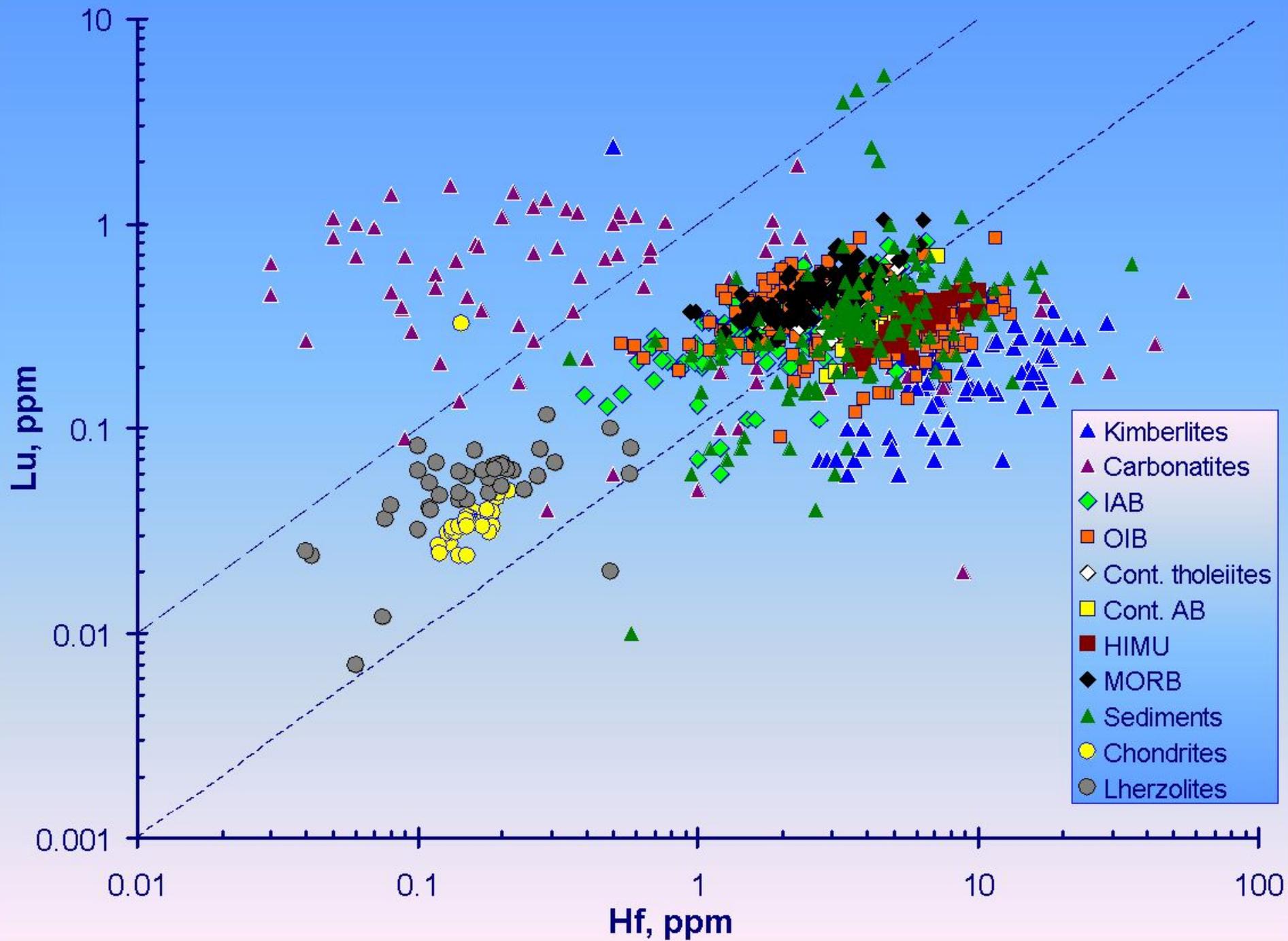
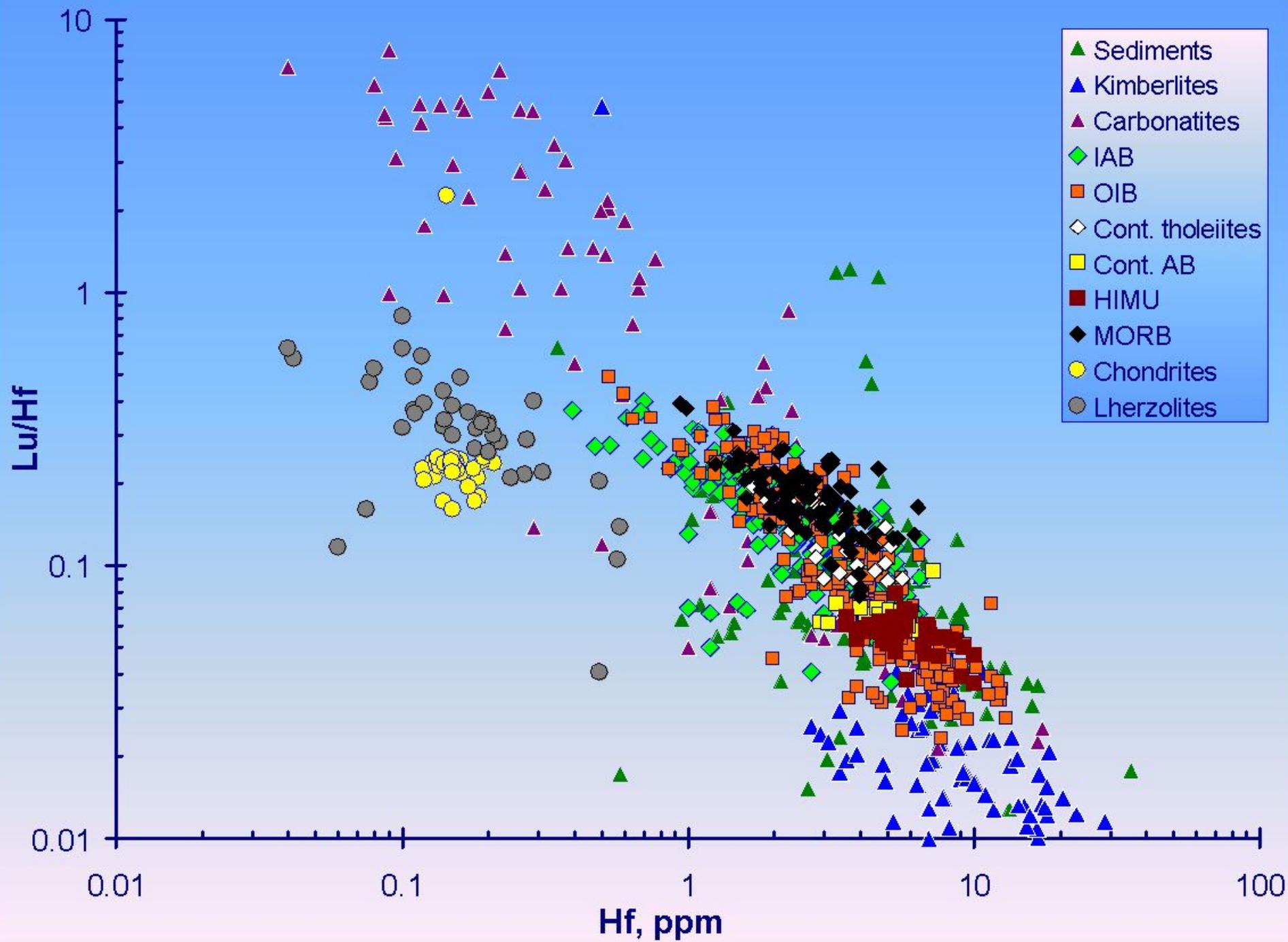


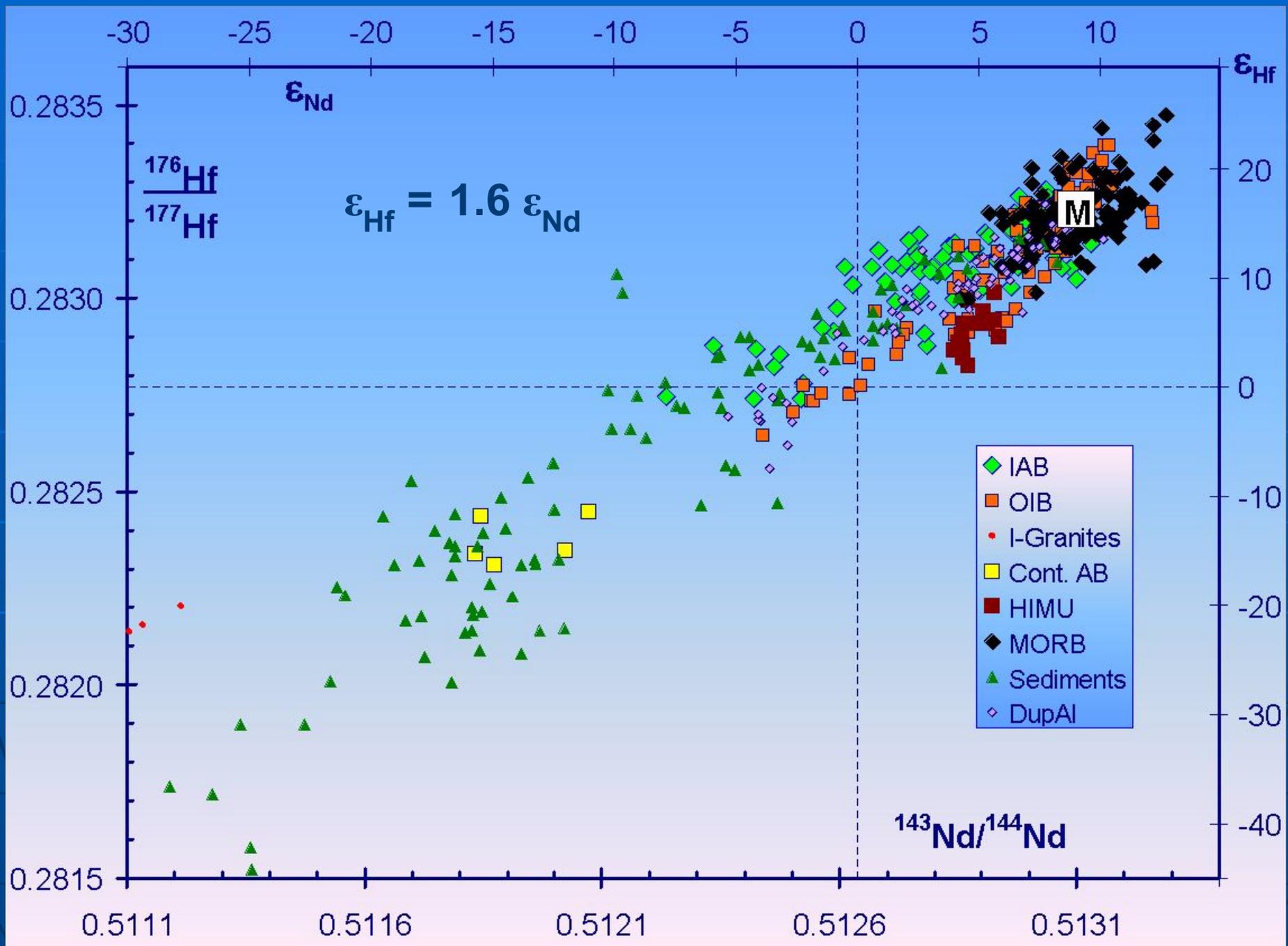
Fig. 1. Lu-Hf regression line for the Amîtsoq gneisses. Uncertainties are at 2σ . Only solid symbols were included in the regression calculation. 155711 lies off the line and was omitted completely. The more precise of two duplicate analyses was always used; note the correlated shifts in $^{176}\text{Lu}/^{177}\text{Hf}$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

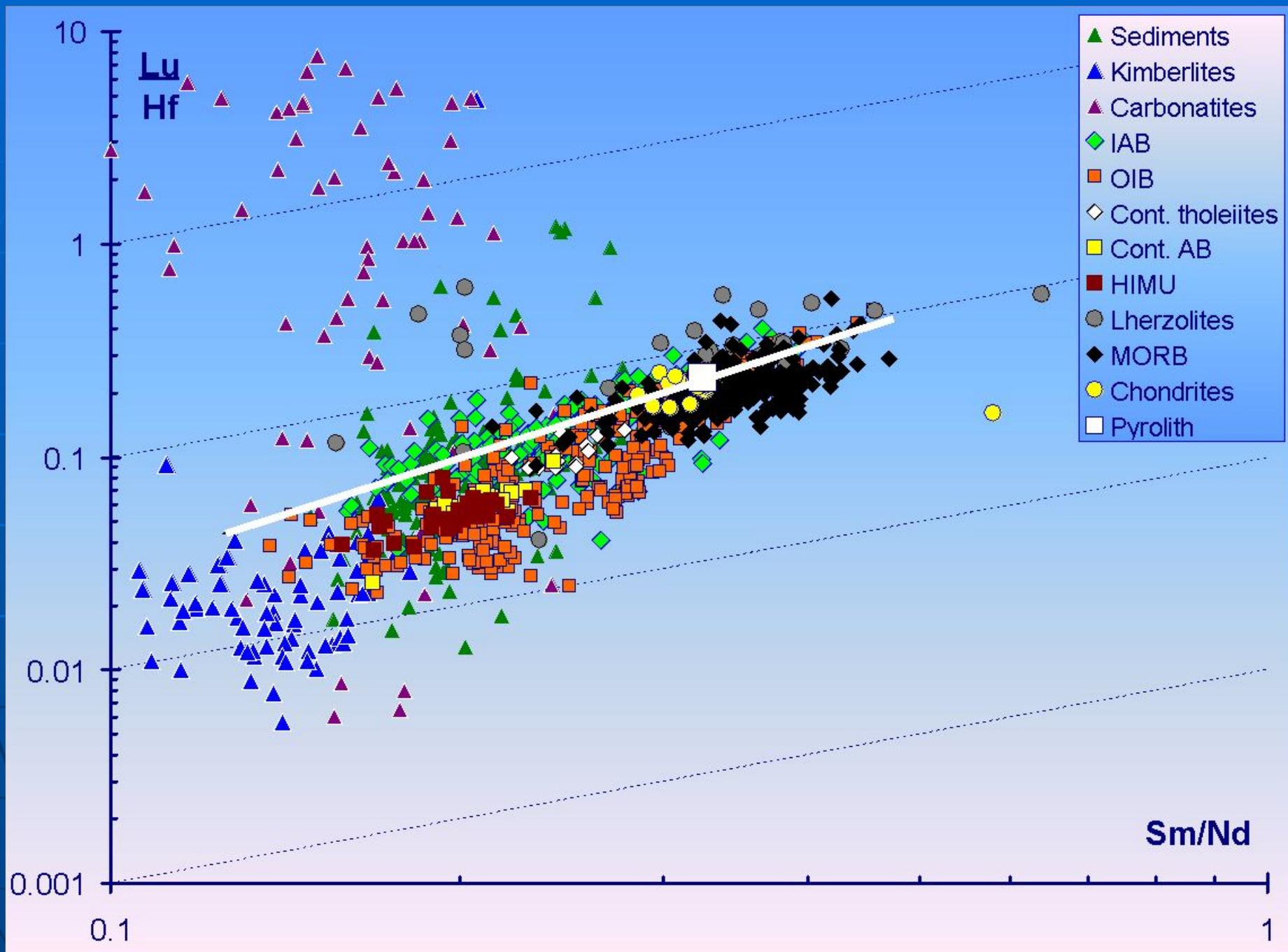
Lu и Hf в различных типах пород

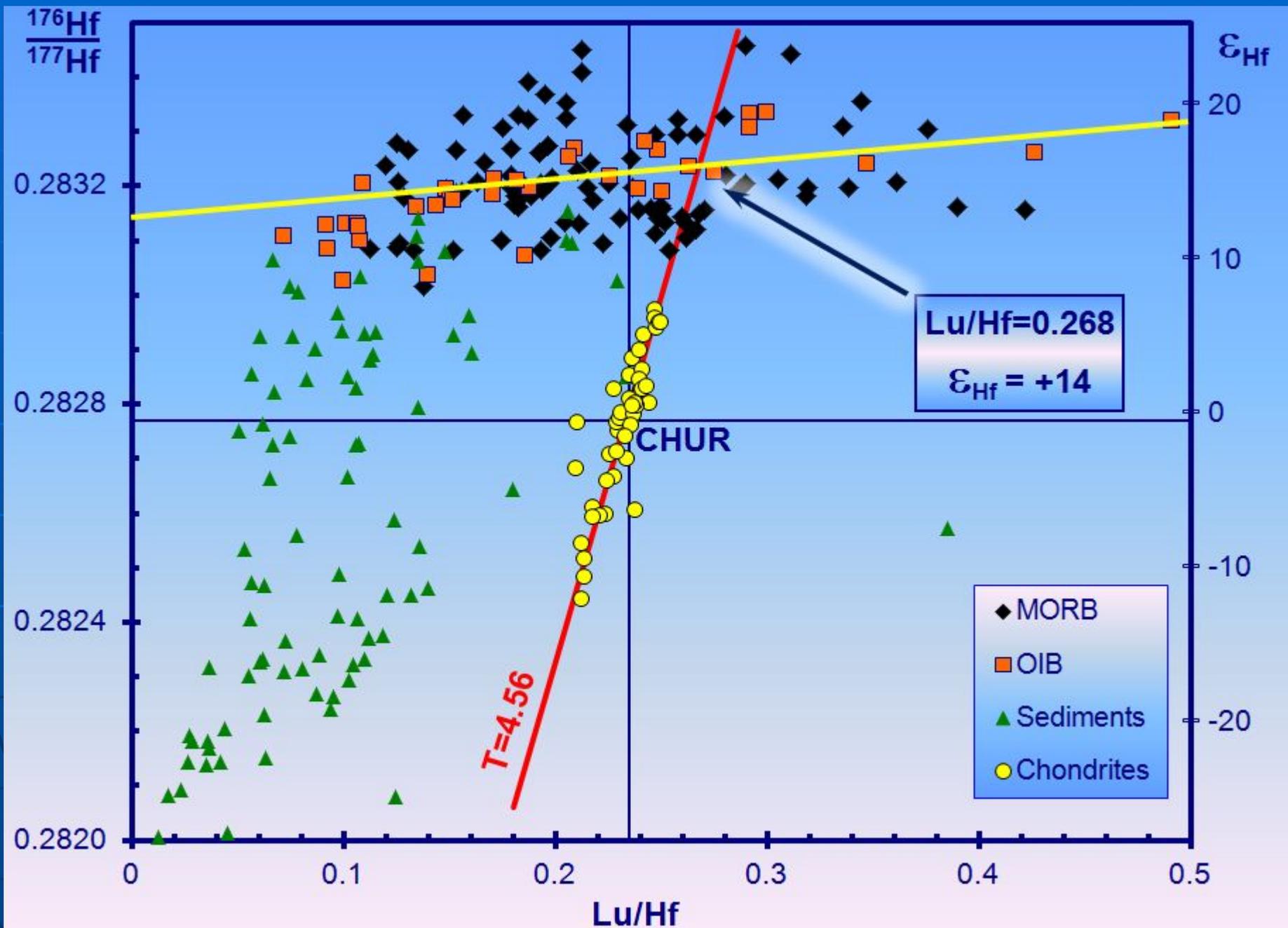
	Lu	Hf	Lu/Hf	ϵ_{Hf}^T	$\pm 2\sigma$	N
Chondrites	0.050	0.15	0.237	-0.4	9.1	47
MORB	0.476	2.34	0.224	14.9	5.9	173
HIMU	0.277	6.12	0.047	4.8	4.0	18
OIB	0.328	3.98	0.082	11.7	12.9	133
IAB	0.318	2.46	0.135	12.4	8.4	115
Sediments	0.331	3.74	0.087	-6.6	19.0	207
I-granites	0.569	4.72	0.129	0.9	8.2	16

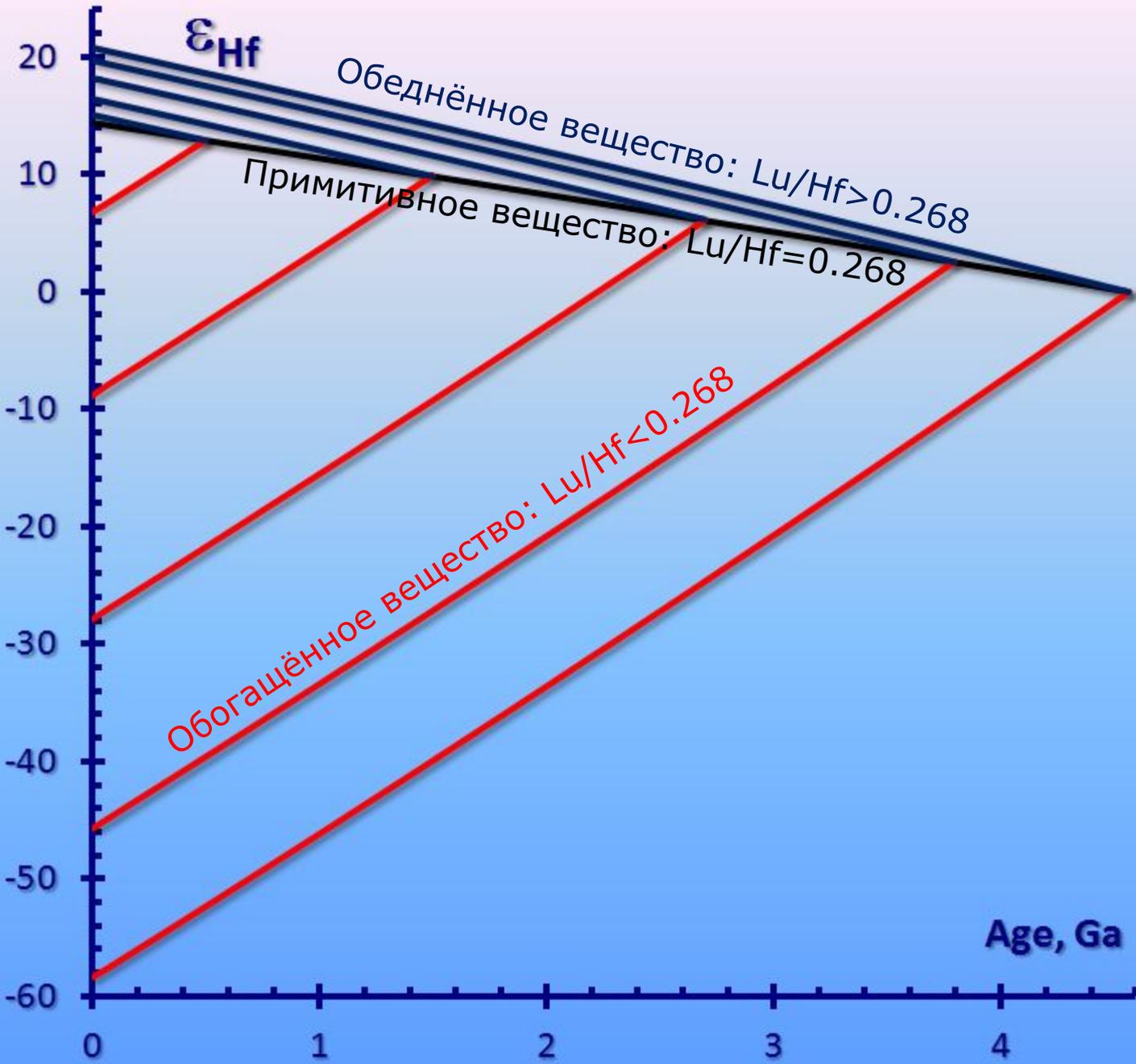


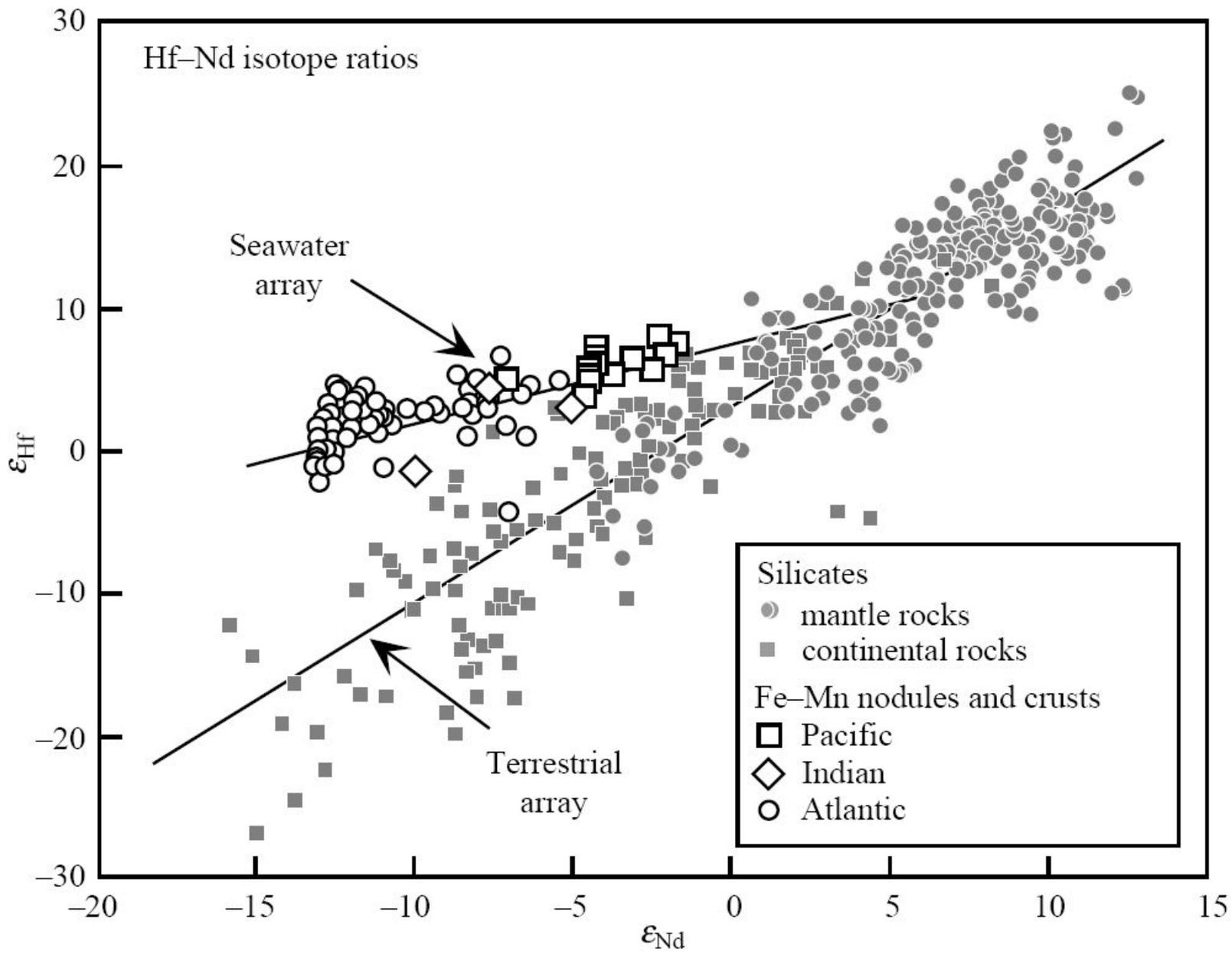




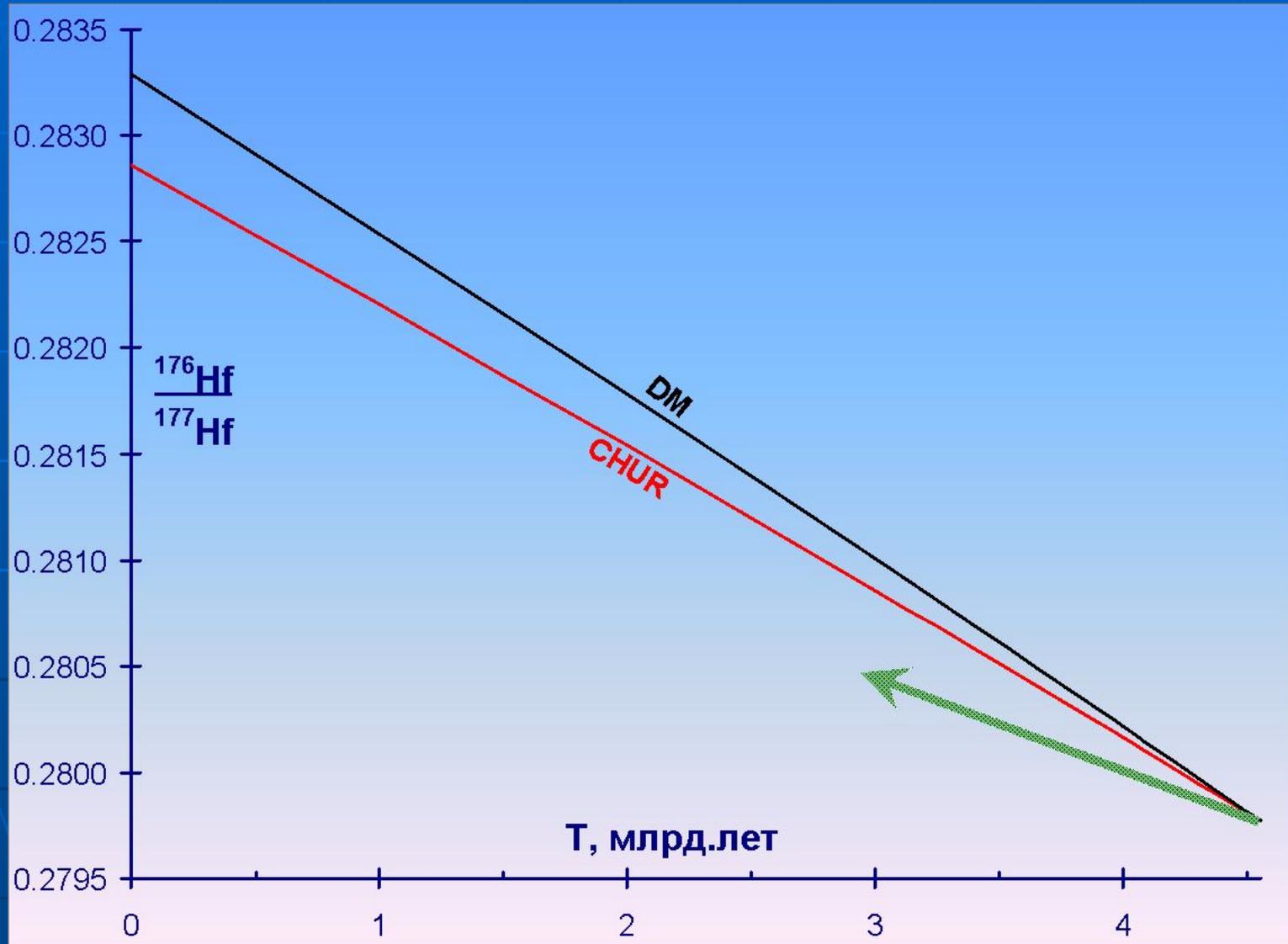








Задача 18. Найти Lu/Hf в мантии, если в среднем для MORB $\epsilon_{\text{Hf}} = +14$



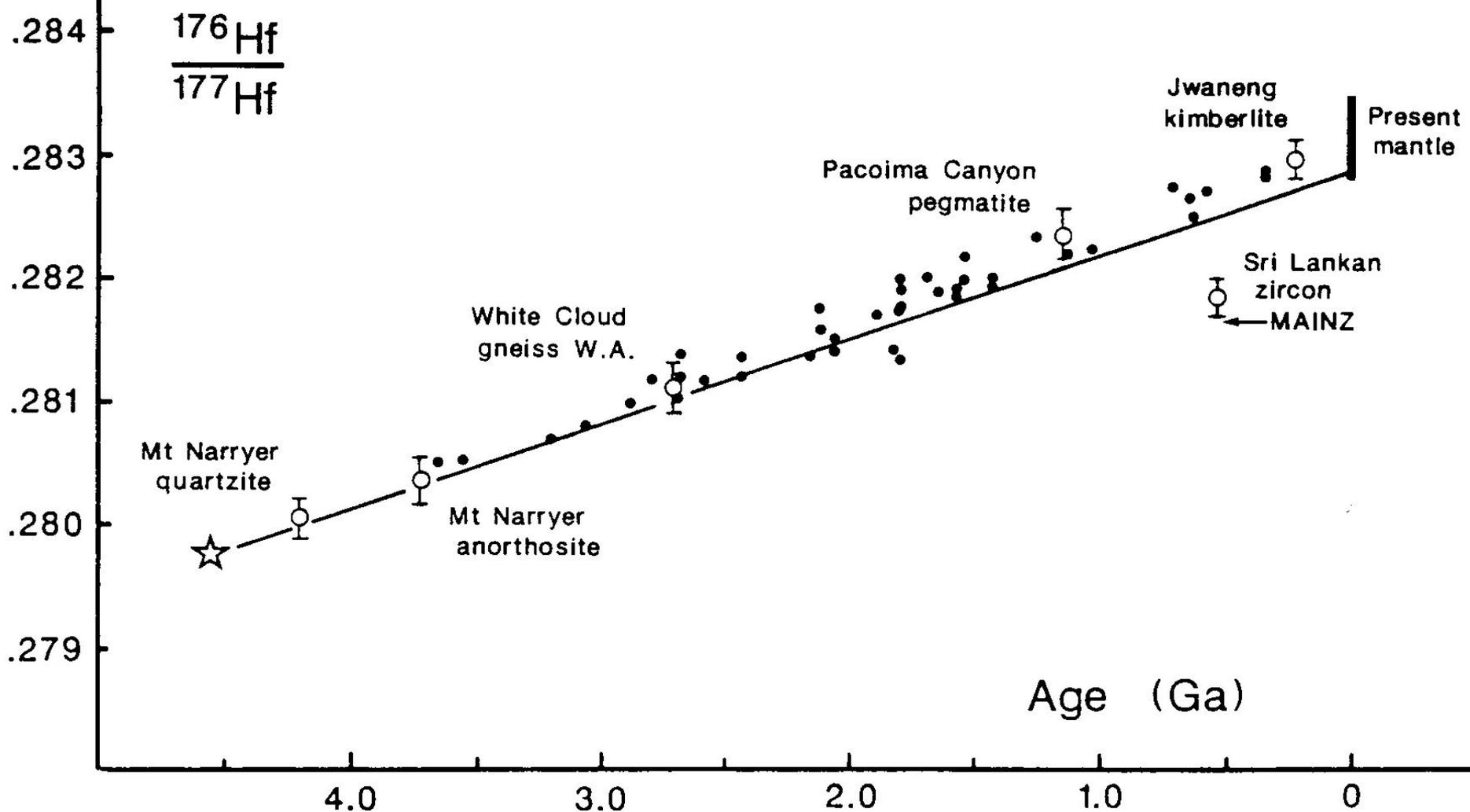
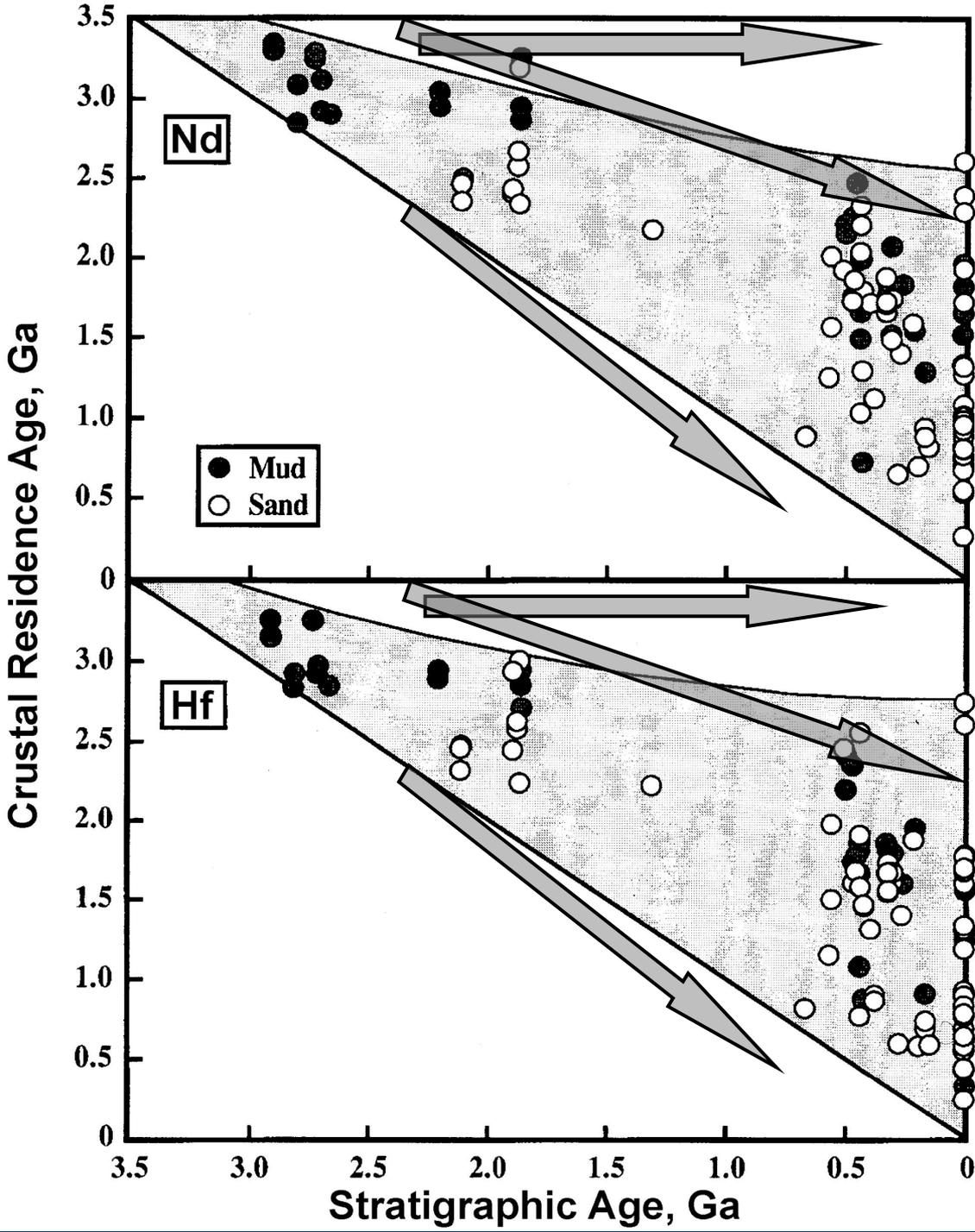


FIG. 3. Hafnium isotopic evolution diagram showing results of ion probe zircon analyses (2σ error bars, labelled), in comparison with orthodox TIMS data for terrestrial rocks (PATCHETT et al., 1981)—black dots. The ion probe data are taken from Tables 4, 5, and 6, and represent the mean composition of 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 $^{176}\text{Hf}/^{177}\text{Hf}$ of SL7 as calculated from TIMS analyses by Dr. T. C. Liew (Table 3).

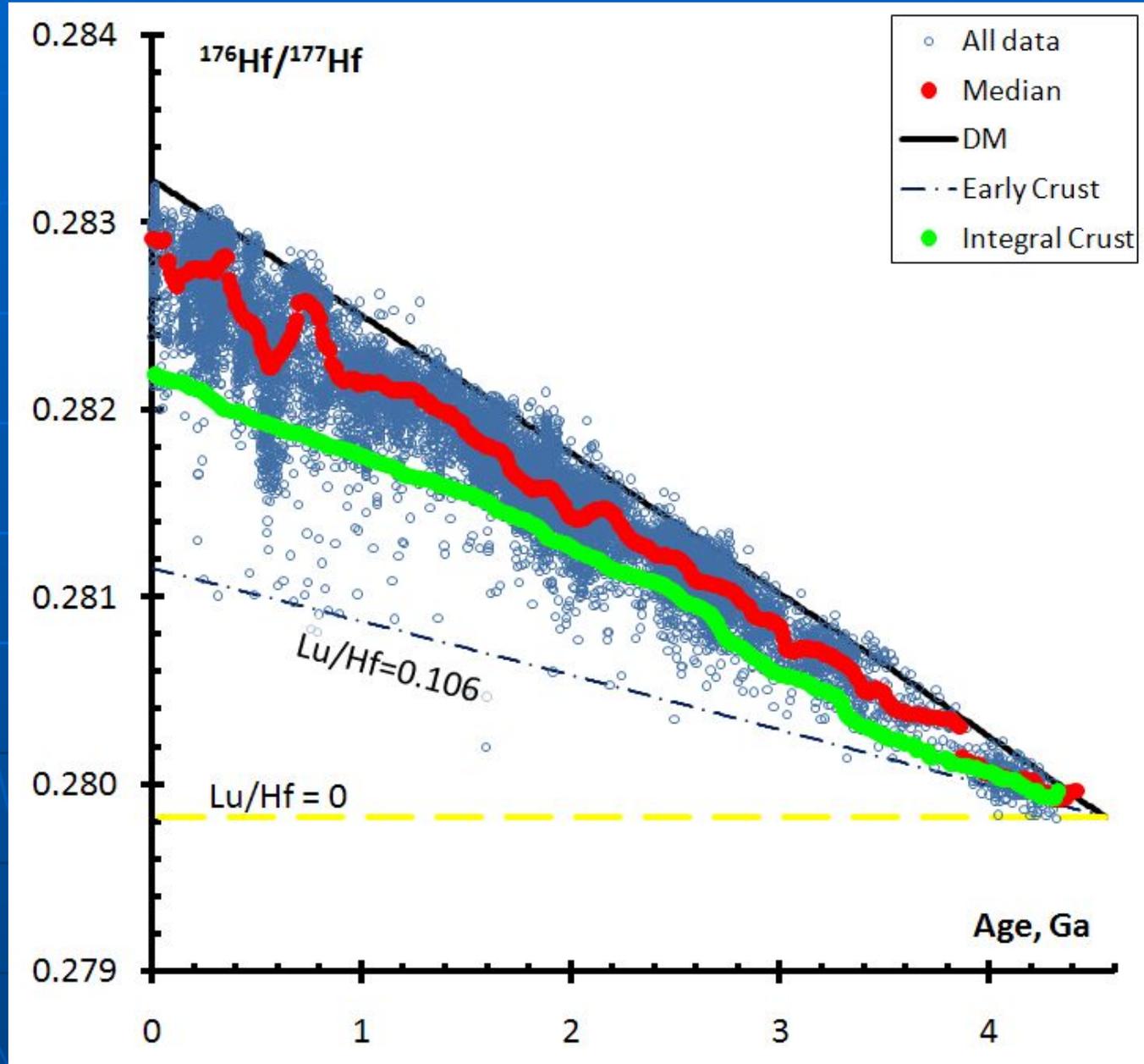


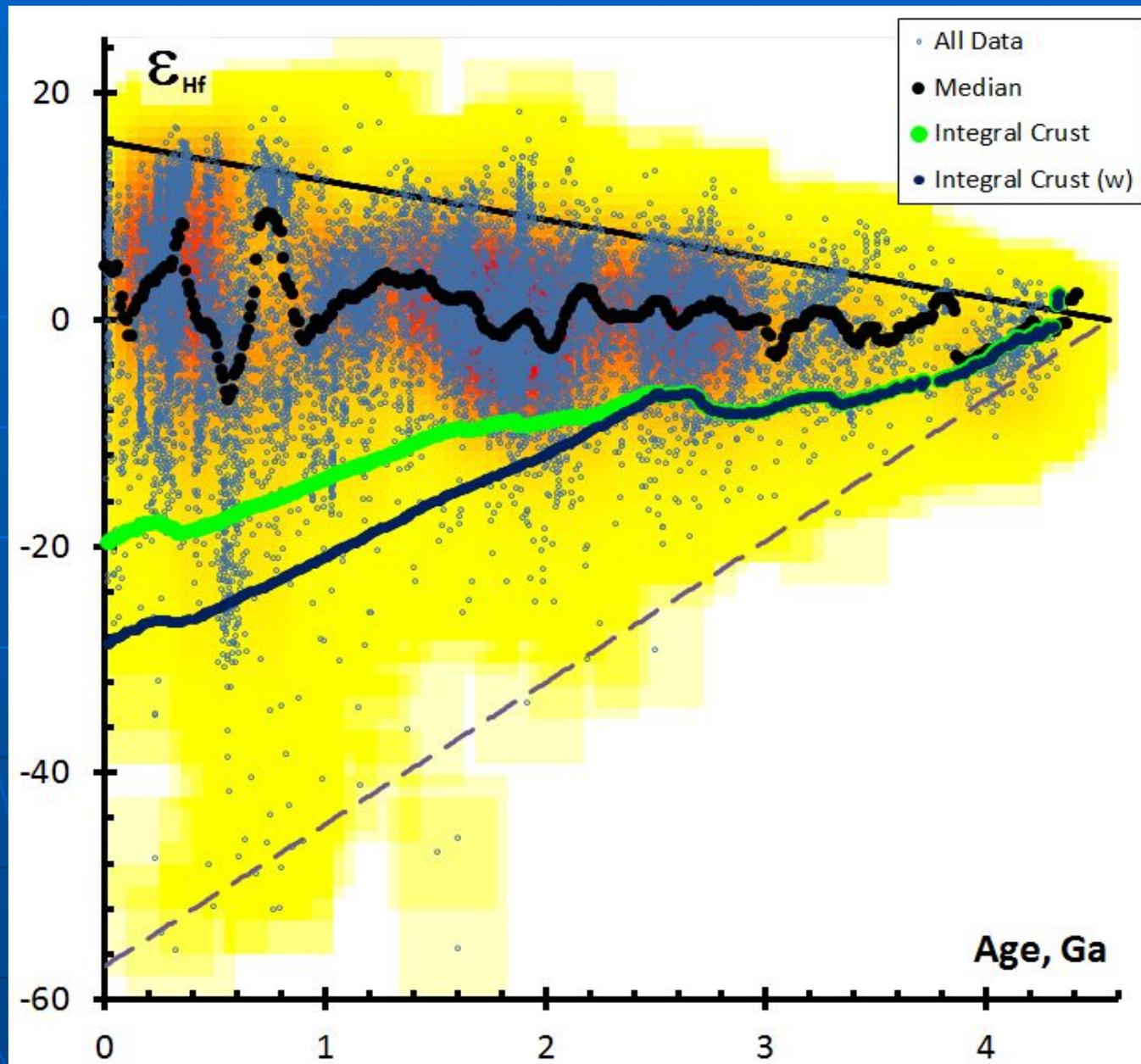
Vervoort et al., 1999

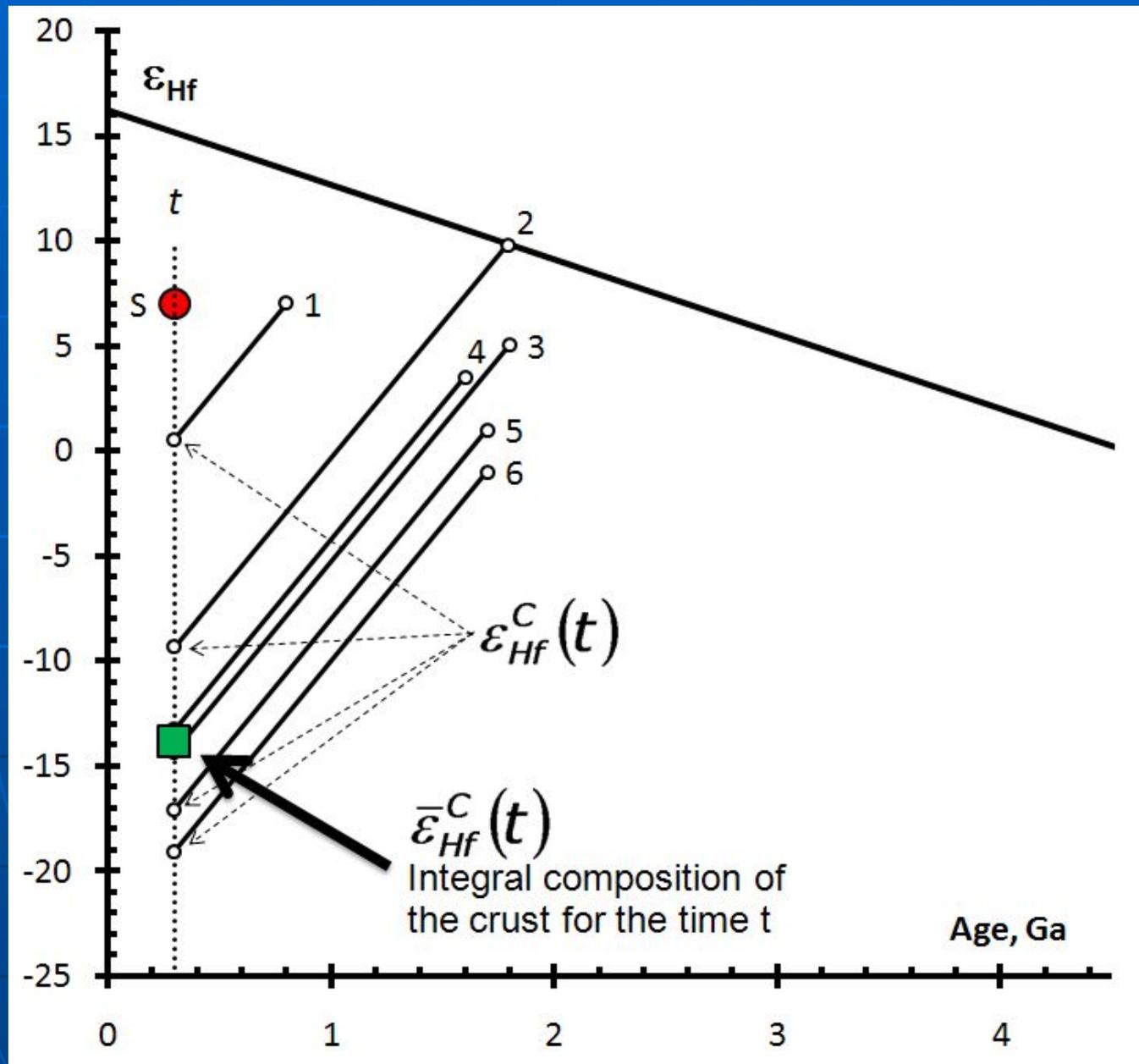
$$T_{DM}^{Nd} = \frac{1}{\lambda_{147Sm}} \ln \left[\frac{\left(\frac{^{143}Nd}{^{144}Nd} \right)_S - \left(\frac{^{143}Nd}{^{144}Nd} \right)_{DM} + 1}{\left(\frac{^{147}Sm}{^{144}Nd} \right)_S - \left(\frac{^{147}Sm}{^{144}Nd} \right)_{DM}} + 1 \right]$$

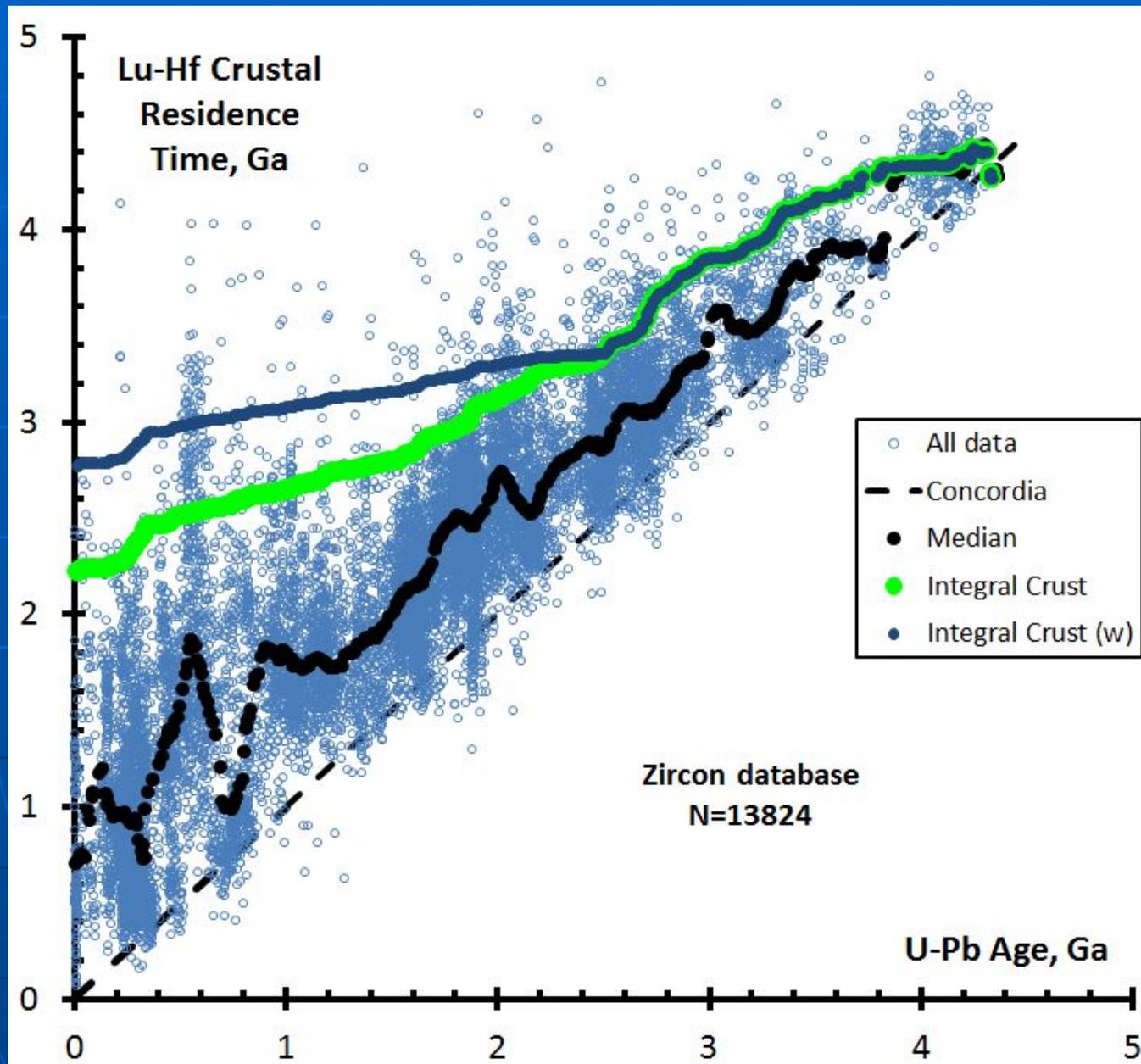
$$T_{DM}^{Hf} = \frac{1}{\lambda_{176Lu}} \ln \left[\frac{\left(\frac{^{176}Hf}{^{177}Hf} \right)_S - \left(\frac{^{176}Hf}{^{177}Hf} \right)_{DM} + 1}{\left(\frac{^{176}Lu}{^{177}Hf} \right)_S - \left(\frac{^{176}Lu}{^{177}Hf} \right)_{DM}} + 1 \right]$$

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.

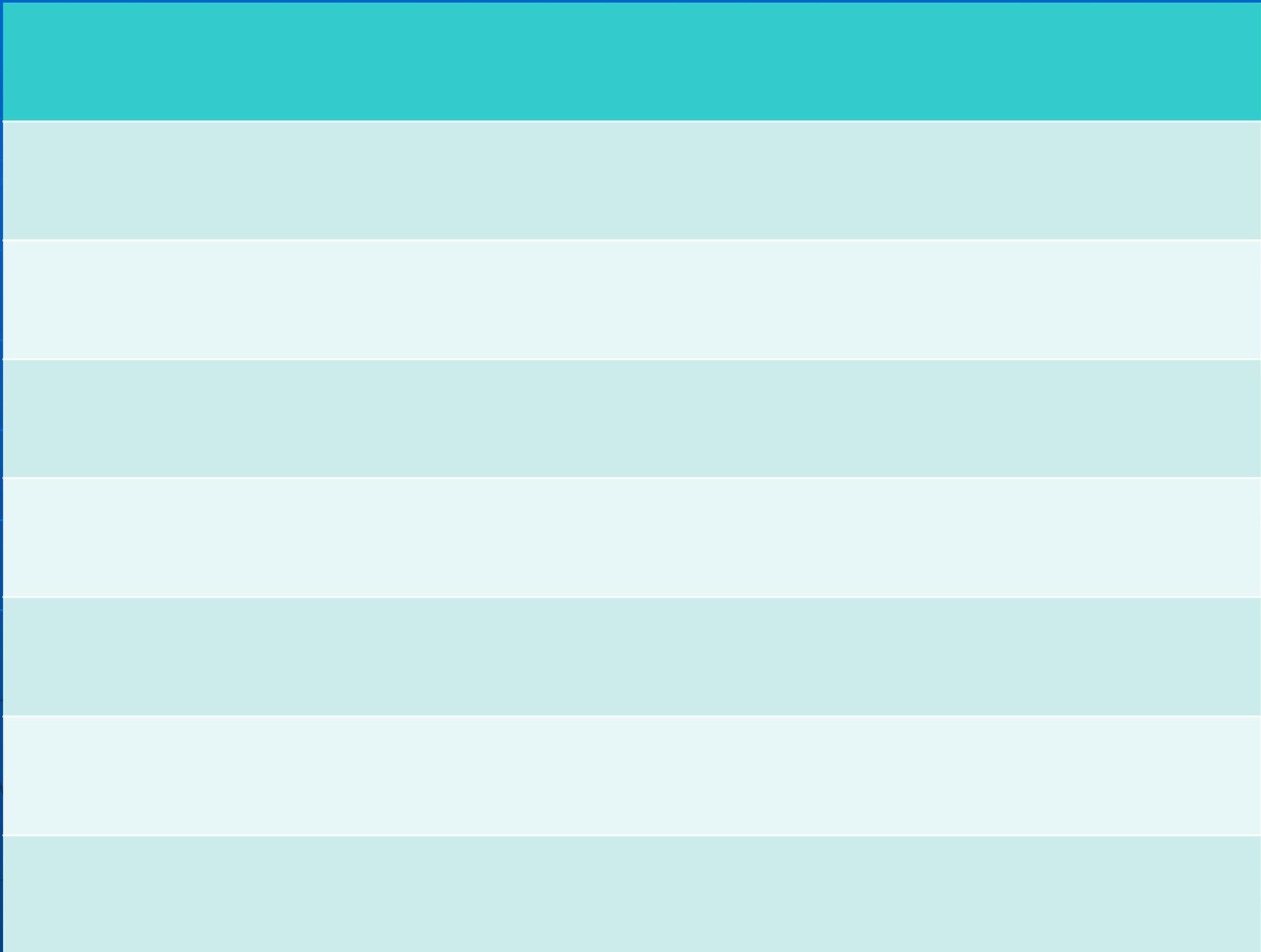








Общие закономерности изотопной геохимии мантии



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

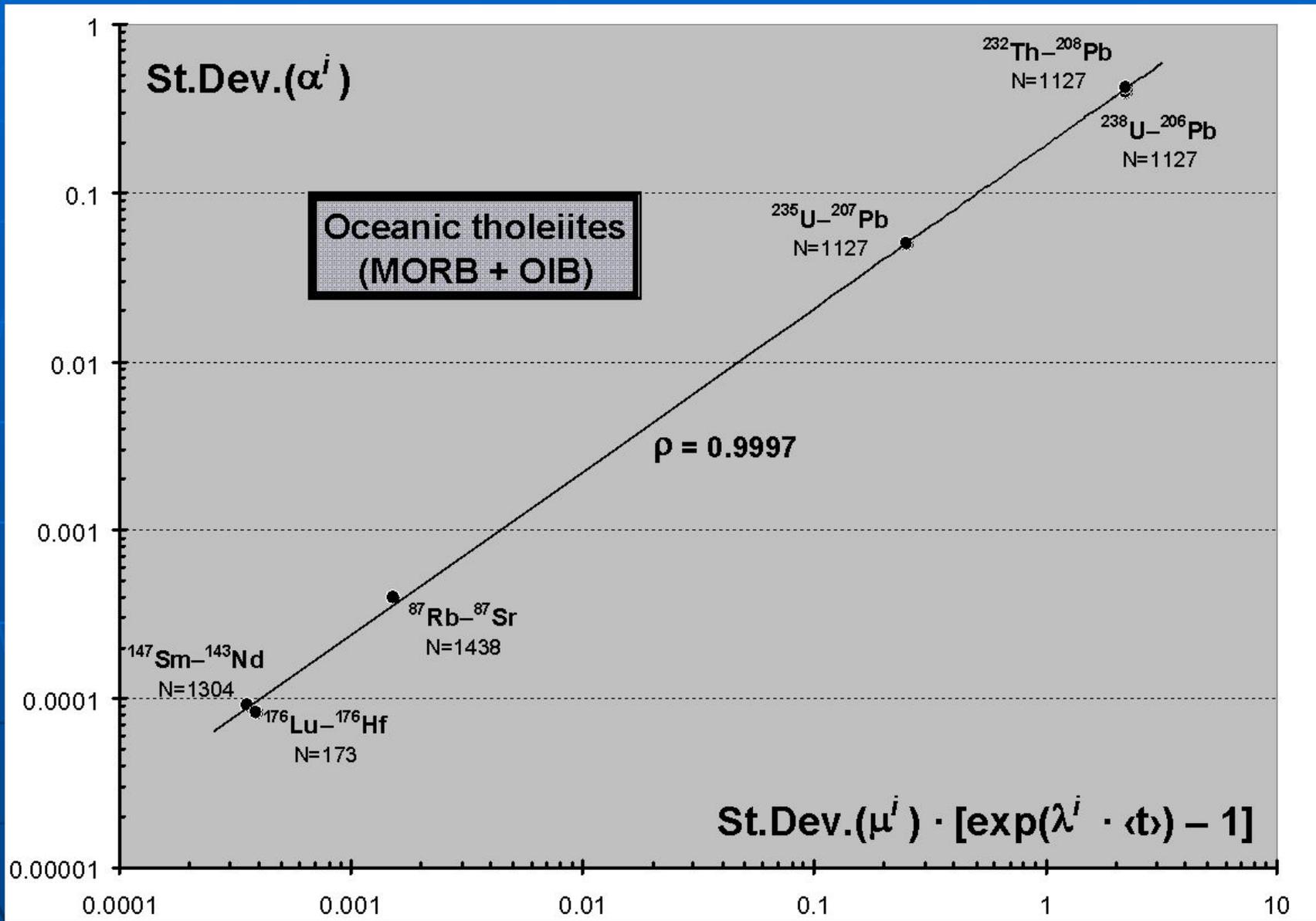
$$\text{Var}(\alpha^i) = \text{Var}(\alpha_0^i) + \text{Var}(\mu^i \cdot [\exp(\lambda^i \cdot t) - 1])$$

$$\text{Var}(\alpha^i) \approx \text{Var}(\alpha_0^i)$$

ИЛИ

$$\text{Var}(\alpha^i) \approx \text{Var}(\mu^i \cdot [\exp(\lambda^i \cdot t) - 1])$$

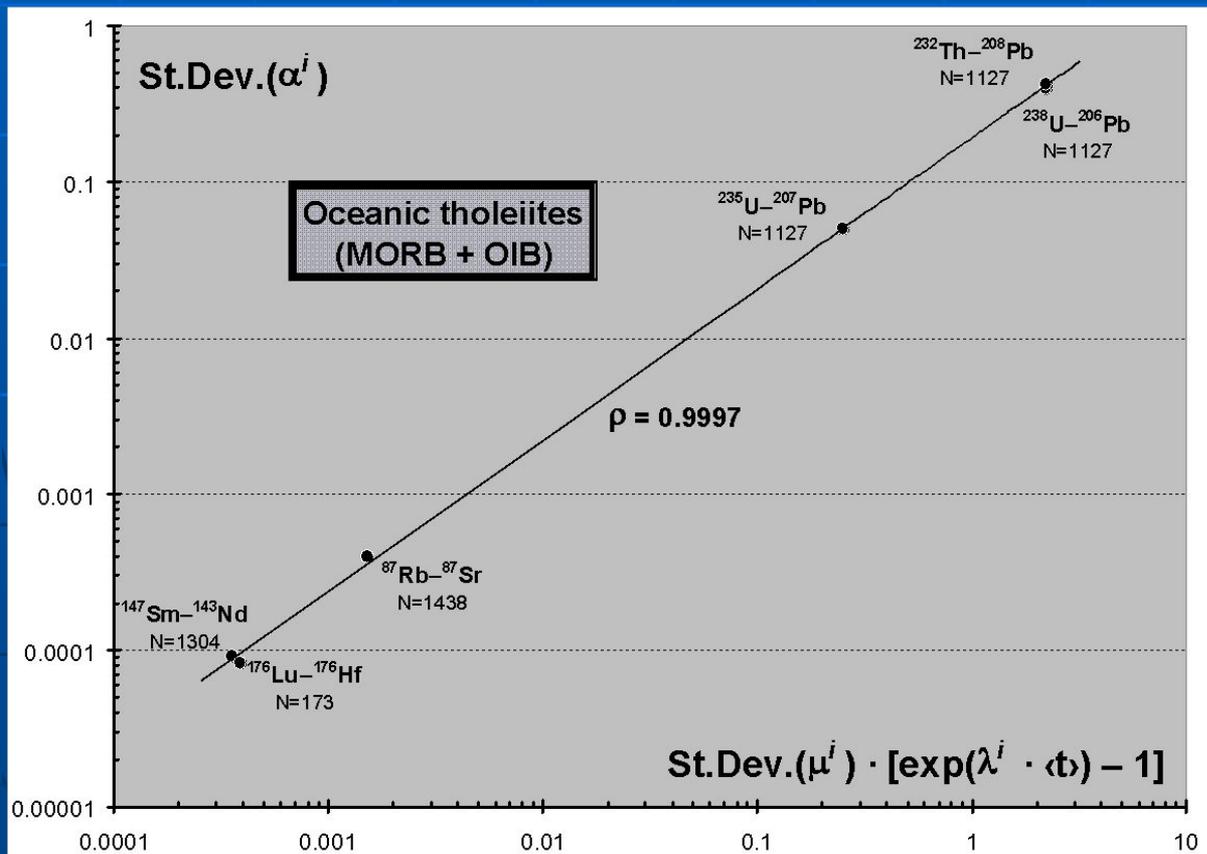
?



Все μ и α взяты из данных для толеитовых базальтов;

Наилучшее приближение при $\langle t \rangle \sim 1.8$ Ga;

Оценка $\langle t \rangle$ 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.

