

МГУ им. М. В. Ломоносова
Геологический факультет

Sm-Nd 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)



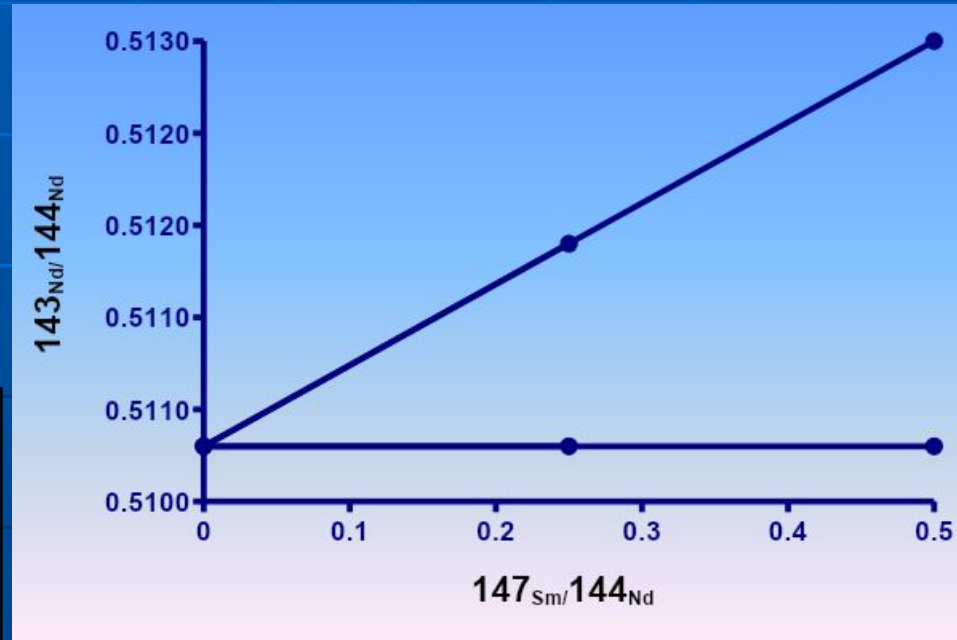
$$\lambda = 6.54 \times 10^{-12} \text{ год}^{-1} \rightarrow T_{1/2} = 106 \text{ млрд. лет}$$

Lugmair G.W. Sm-Nd ages: a new dating method (abs). // Meteoritics. 1974. V.9. P. 369.

$$\frac{^{143}\text{Nd}}{^{144}\text{Nd}} = \left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}} \right)_0 + \left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}} \right) \cdot [\exp(\lambda \cdot t) - 1]$$

$$t = \frac{1}{\lambda} \ln \left[\frac{\frac{^{143}\text{Nd}}{^{144}\text{Nd}} - \left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}} \right)_0}{\frac{^{147}\text{Sm}}{^{144}\text{Nd}}} + 1 \right]$$

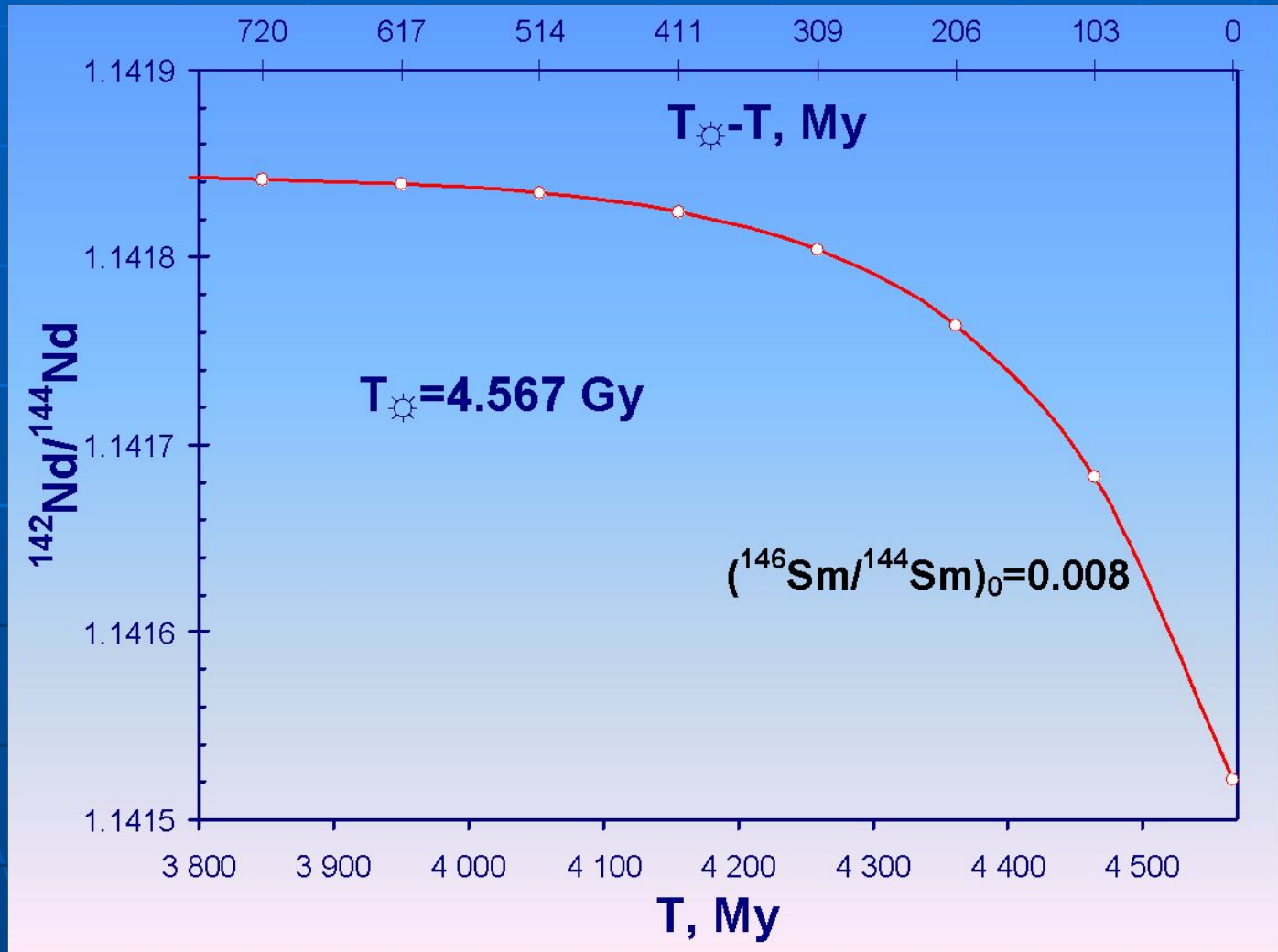
$$t = \frac{1}{\lambda} \ln \left[\frac{\left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}} \right)_1 - \left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}} \right)_2}{\left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}} \right)_1 - \left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}} \right)_2} + 1 \right]$$





$$\lambda = 6.74 \times 10^{-9} \text{ год}^{-1}$$

$$T_{1/2} = 103 \text{ млн.лет}$$

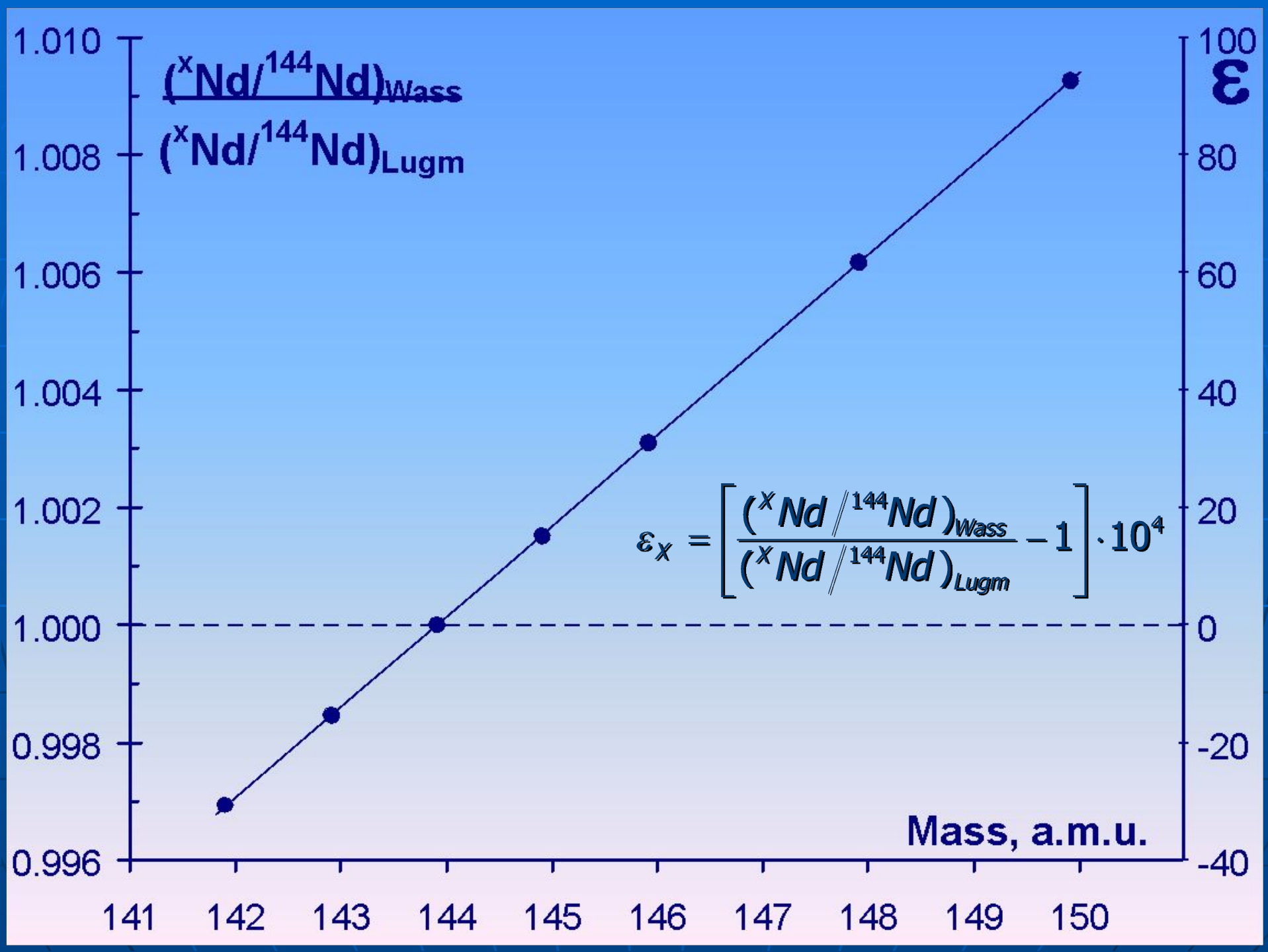


Изотопный состав Sm и Nd

		At. %	AW
$^{144}\text{Sm}/^{154}\text{Sm} =$	0.13516	^{144}Sm	3.075% 143.91207
$^{147}\text{Sm}/^{154}\text{Sm} =$	0.65918	^{147}Sm	14.996% 146.91493
$^{148}\text{Sm}/^{154}\text{Sm} =$	0.49419	^{148}Sm	11.242% 147.91485
$^{149}\text{Sm}/^{154}\text{Sm} =$	0.6075	^{149}Sm	13.820% 148.91721
$^{150}\text{Sm}/^{154}\text{Sm} =$	0.3244	^{150}Sm	7.380% 149.91730
$^{152}\text{Sm}/^{154}\text{Sm} =$	1.17537	^{152}Sm	26.738% 151.91976
		^{154}Sm	22.749% 153.92222
		Sm	150.3656

	University of California, San Diego, La Jolla (UCSD), G.W.Lugmair	California Institute of Technology, Pasadena (CIT), G.J.Wasserburg	At.%		AW
$^{142}\text{Nd}/^{144}\text{Nd} =$	1.141817	1.138305	^{142}Nd	27.168%	141.9077
$^{143}\text{Nd}/^{144}\text{Nd} =$	(0.512638)	(0.511847)	^{143}Nd	12.198%	142.9099
			^{144}Nd	23.794%	143.9101
$^{145}\text{Nd}/^{144}\text{Nd} =$	0.348404	0.348933	^{145}Nd	8.290%	144.9126
$^{146}\text{Nd}/^{144}\text{Nd} \equiv$	0.7219	0.724137	^{146}Nd	17.177%	145.9132
$^{148}\text{Nd}/^{144}\text{Nd} =$	0.241572	0.243062	^{148}Nd	5.748%	147.9169
$^{150}\text{Nd}/^{144}\text{Nd} =$	0.236431	0.238621	^{150}Nd	5.626%	149.9209
			Nd		144.240

$$(^{147}\text{Sm}/^{144}\text{Nd})_{at} = (\text{Sm} / \text{Nd})_W \cdot 0.60456$$



$$\varepsilon_{Nd}^T = \left[\frac{(^{143}Nd / ^{144}Nd)_{Sample}^T}{(^{143}Nd / ^{144}Nd)_{CHUR}^T} - 1 \right] \cdot 10^4$$

где :

$$\left(\frac{^{143}Nd}{^{144}Nd} \right)_{Sample}^T = \frac{^{143}Nd}{^{144}Nd} - \left(\frac{^{147}Sm}{^{144}Nd} \right) \cdot [\exp(\lambda \cdot t) - 1]$$

$$\left(\frac{^{143}Nd}{^{144}Nd} \right)_{CHUR}^T = \left(\frac{^{143}Nd}{^{144}Nd} \right)_{CHUR} - \left(\frac{^{147}Sm}{^{144}Nd} \right)_{CHUR} \cdot [\exp(\lambda \cdot t) - 1]$$

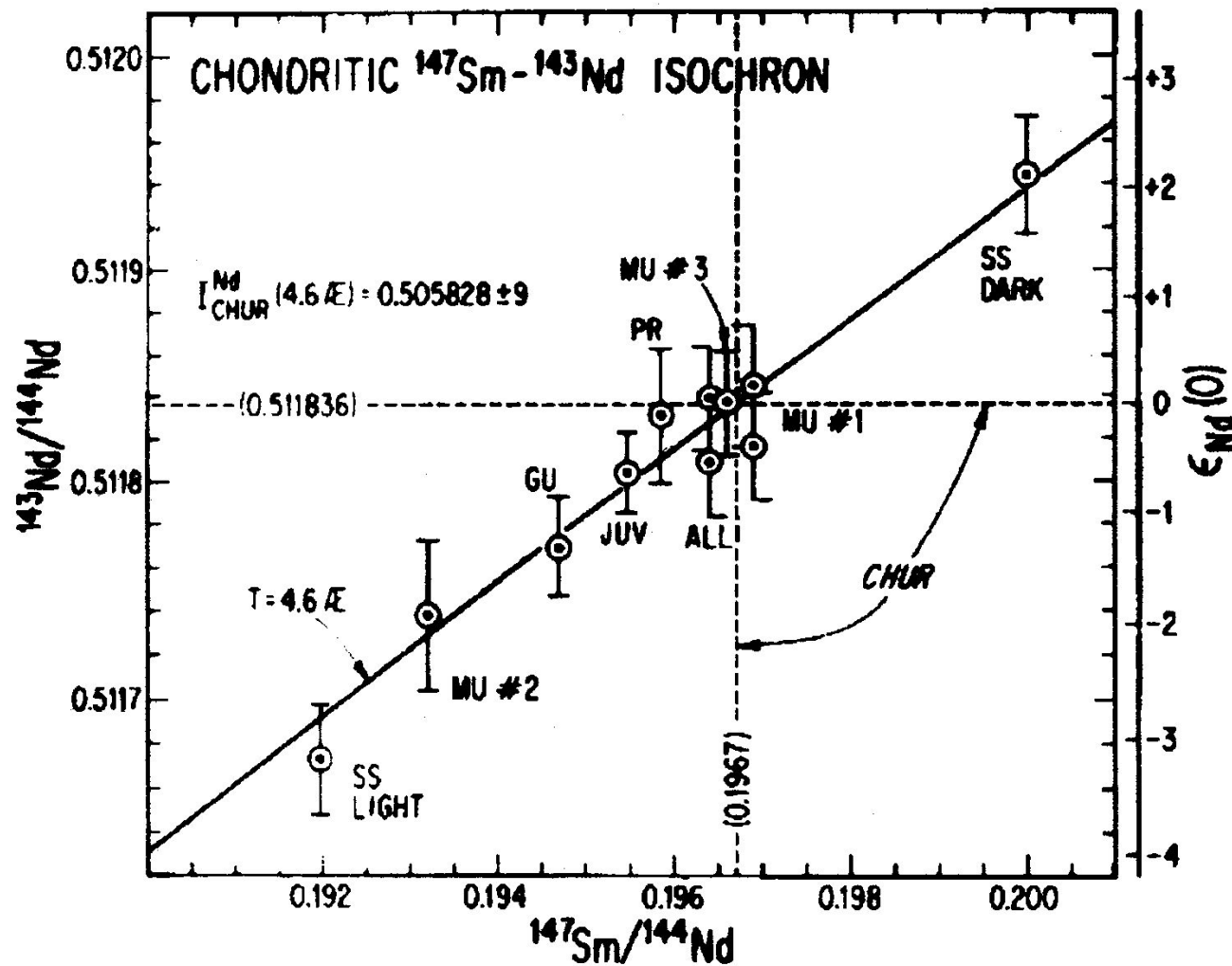


Fig. 2. Sm-Nd evolution diagram for chondrite samples and Juvinas. A reference line with a slope of 4.6 AE is shown. The dashed lines represent the new values selected for average chondrites (CHUR).

Jacobsen S.B.,
Wasserburg G.J.,
Sm-Nd isotopic
evolution of
chondrites. // Earth
and Planetary
Science Letters,
1980. 50: 139-155.

CHUR =
Chondritic
Uniform
Reservoir

$$\left(\frac{{}^{143}\text{Nd}}{{}^{144}\text{Nd}} \right)^{t=1.0 \text{ млрд.лет}} = 0.511399$$

$$\varepsilon_{\text{Nd}} = ?$$

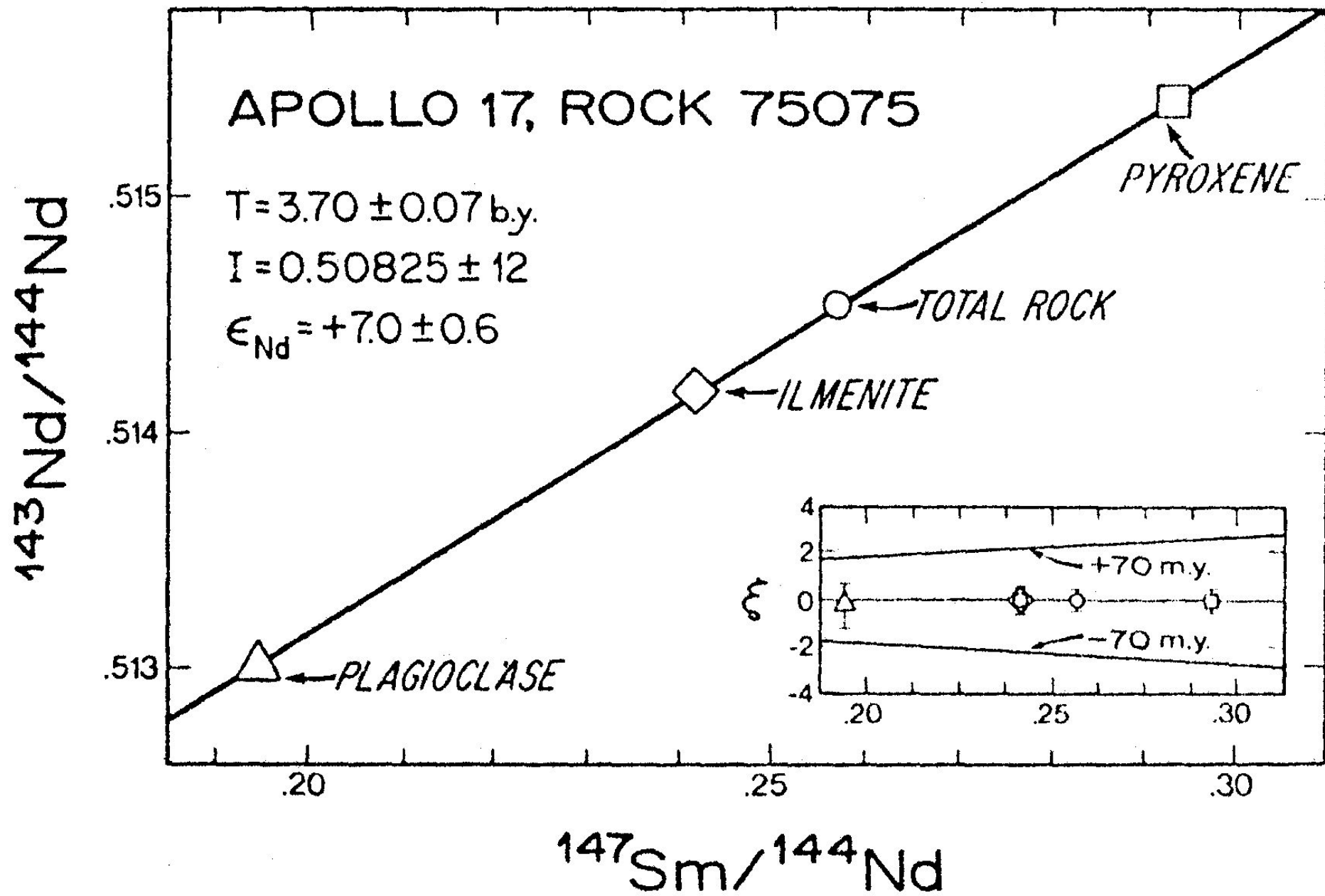
$$\left(\frac{{}^{143}\text{Nd}}{{}^{144}\text{Nd}} \right)^{t=1 \text{ млрд.лет}}_{\text{CHUR}} = 0.512638 - 0.1967 \cdot [\exp(0.00654 \cdot 1.0) - 1]$$

$$\varepsilon_{\text{Nd}} = (0.511399/0.511347 - 1) \cdot 10^4 = 1.0$$

$$\left(\frac{{}^{143}\text{Nd}}{{}^{144}\text{Nd}} \right)_{CHUR}^{t=0} = 0.512638 \quad \text{или} \quad 0.511847 \text{ (Wass)}$$

$$\left(\frac{{}^{147}\text{Sm}}{{}^{144}\text{Nd}} \right)_{CHUR} = 0.1967$$

$$\left(\frac{{}^{143}\text{Nd}}{{}^{144}\text{Nd}} \right)_{CHUR}^{t=4.5} = 0.506763 \quad \text{или} \quad 0.505972$$



Mineral isochron for lunar basalt 75075 (Lugmair et al. 1975)

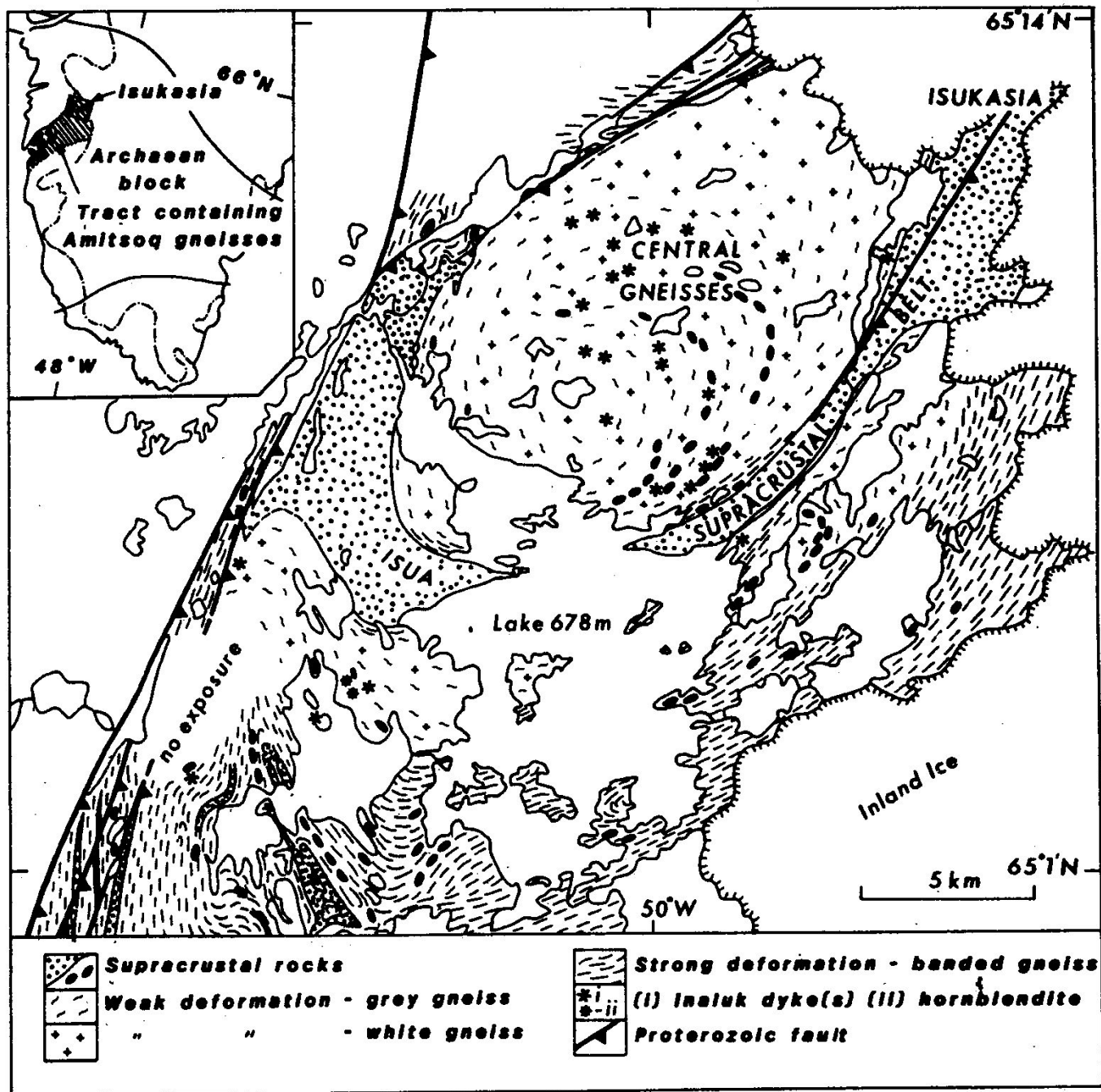
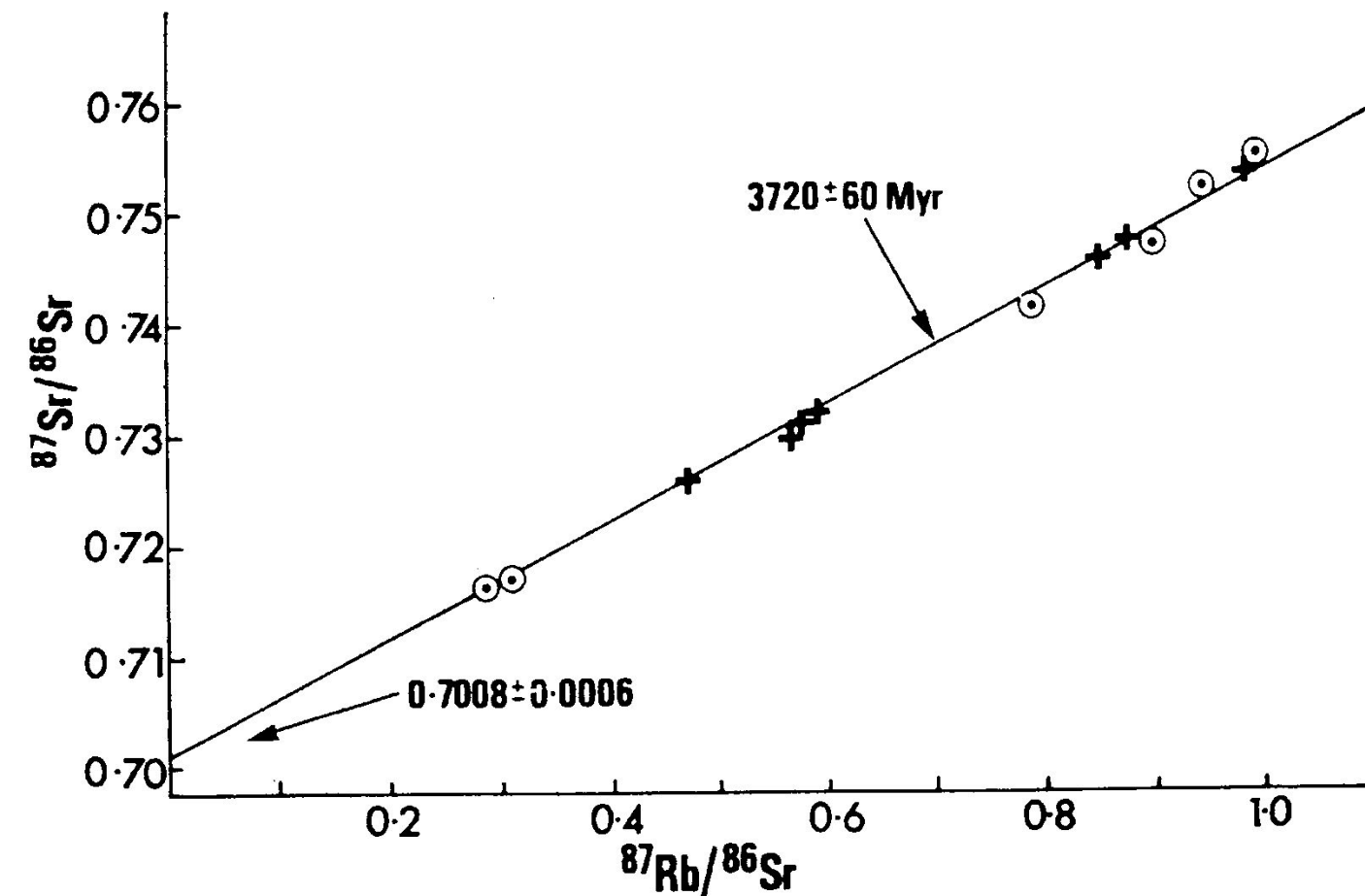


FIG. 1. Geological sketch map of the Isukasia area.

described elsewhere⁸. Rb/Sr ratios were determined by a precise X-ray fluorescence technique⁹. The decay constant of ^{87}Rb was taken as $1.39 \times 10^{-11} \text{ yr}^{-1}$.

Fig. 2 Rb–Sr whole rock isochron plot for Amitsoq gneisses from Isua. $\odot$, Gneissic veins cutting supracrustals (Group 1, Table 1) and Gneisses far away from contact with supracrustals (Group 2, Table 1). +, Gneisses from near contact with supracrustals (for full details and analytical data, see ref. 6).



Moorbath, S, Allaart, JH, Bridgwater, D and McGregor, VR (1977). "Rb-Sr ages of early Archaean supracrustal rocks and Amitsoq gneisses at Isua." *Nature* 270: 43-45.

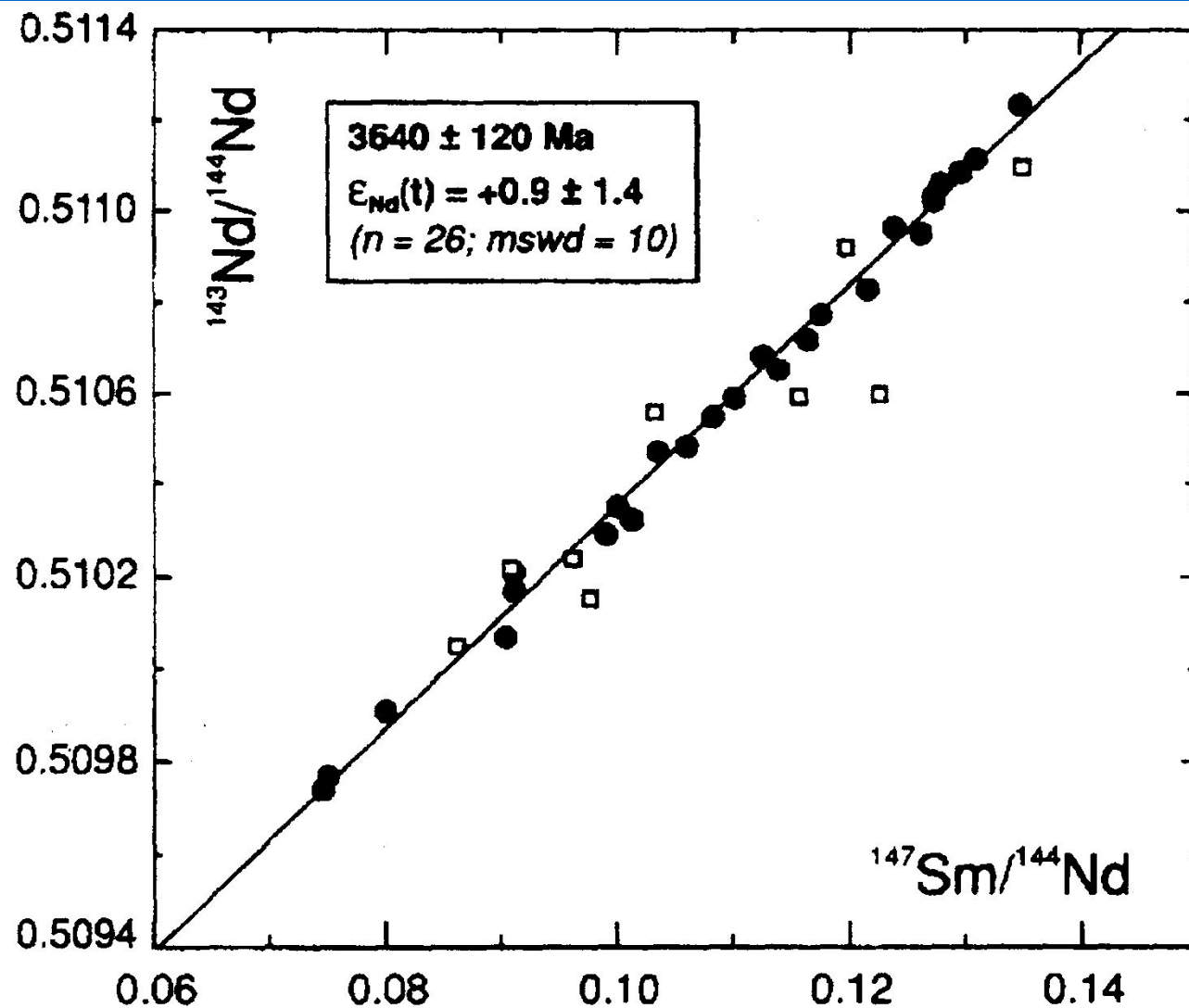
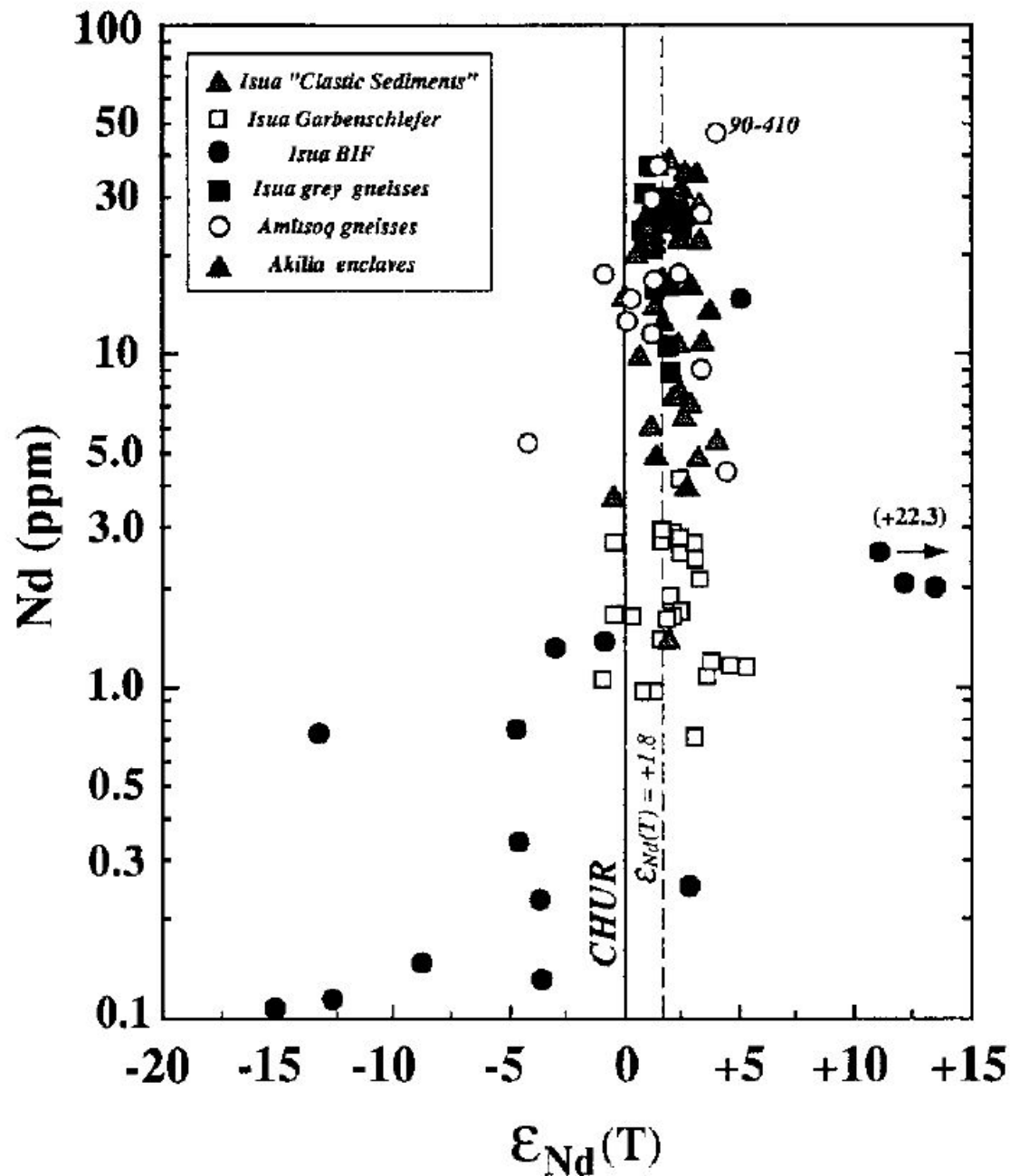
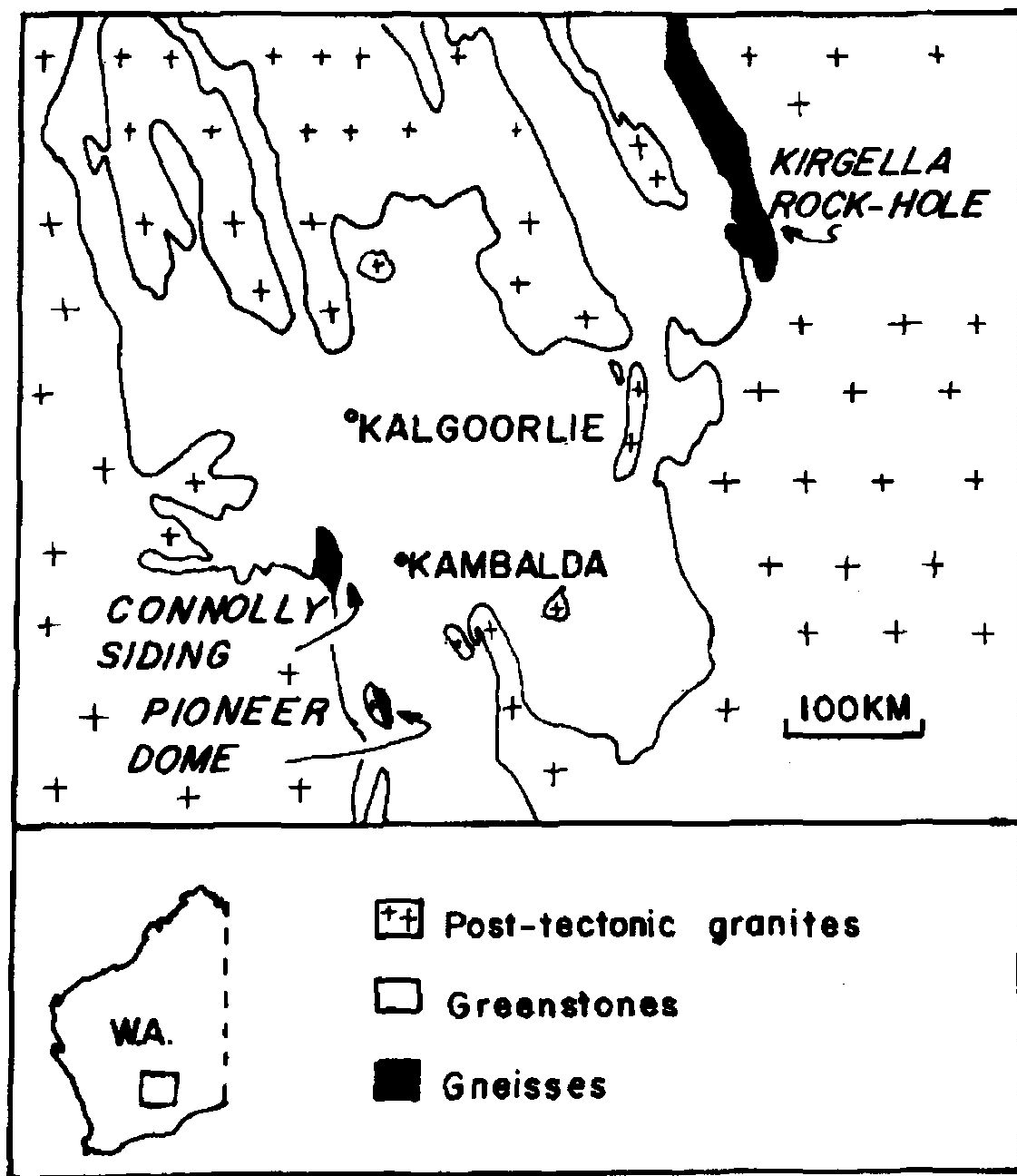


Fig. 6. Combined Sm–Nd regression (*filled circles*) for Amîtsoq gneiss samples from Baadsgaard et al. (1986b), Moorbath et al. (1986), and Shimizu et al. (1988). The Amîtsoq gneiss data of Bennett et al. (1993) are shown for comparison (*open squares*), and omitted from the regression calculation.

Moorbath, S,
 Whitehouse, MJ and
 Kamber, BS (1997).
 "Extreme Nd-Isotope
 Heterogeneity in the
 Early Archean - Fact
 or Fiction -
 Case-Histories from
 Northern Canada and
 West Greenland."
 Chemical Geology
 135(3-4): 213-231.



Gruau G., Rosing M.,
Bridgwater D., Gill R.C.O.
Resetting of Sm-Nd
systematics during
metamorphism of >3.7 Ga
rocks: implications for
isotopic models of early
Earth differentiation.
Chemical Geology. 1996.
V.133. P.225-240.



McCulloch M.T., Compston W., Froude D.
Sm-Nd and Rb-Sr dating of
Archaean gneisses, eastern
Yilgarn Block, Western
Australia. // Journal of the
Geological Society of
Australia, 1983. 30:
149-153.

Fig. 1. Map of the eastern Yilgarn Block of Western Australia, showing the gneiss localities.

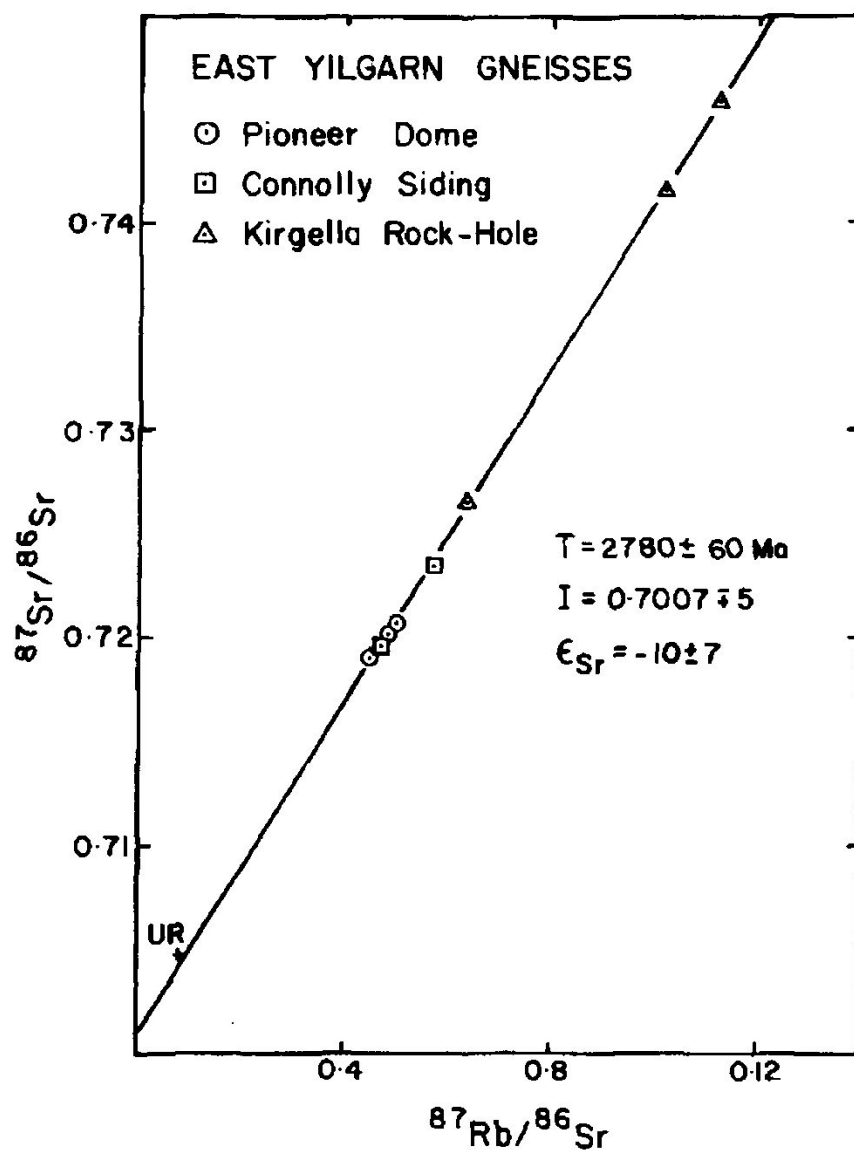


Fig. 2. Rb-Sr whole-rock isochron for the eastern Yilgarn gneisses. Despite the regional sampling, all points lie close to a single line. The cross shows the present-day bulk earth point (UR).

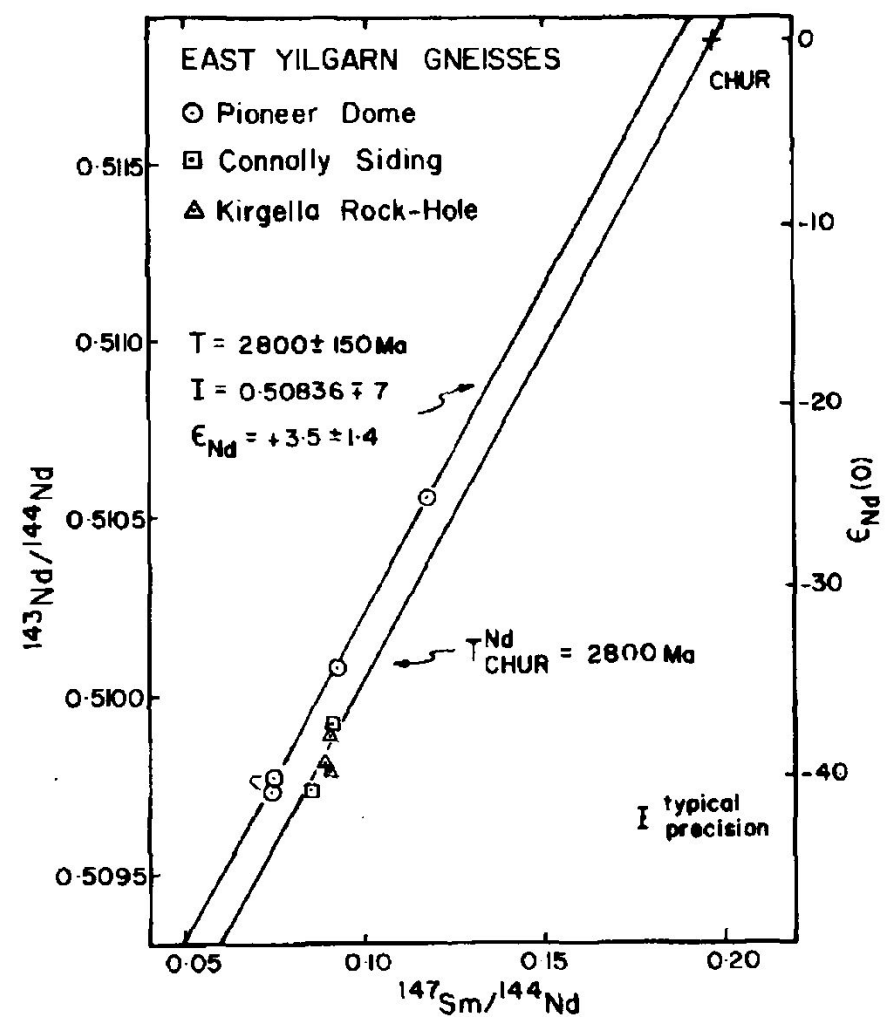


Fig. 3. Sm-Nd isochron diagram for the eastern Yilgarn gneisses. In contrast to Rb-Sr, the points do not define a single array, although individual localities form broadly coherent groups. This disparity is consistent with the Pioneer Dome gneisses being derived from a depleted Nd/Sm source at c. 2800 Ma, whereas the Connolly Siding and Kirgella Rock-hole gneisses were derived from a chondritic Nd/Sm source (CHUR) at approximately the same time. The cross shows the present-day bulk earth point (CHUR).

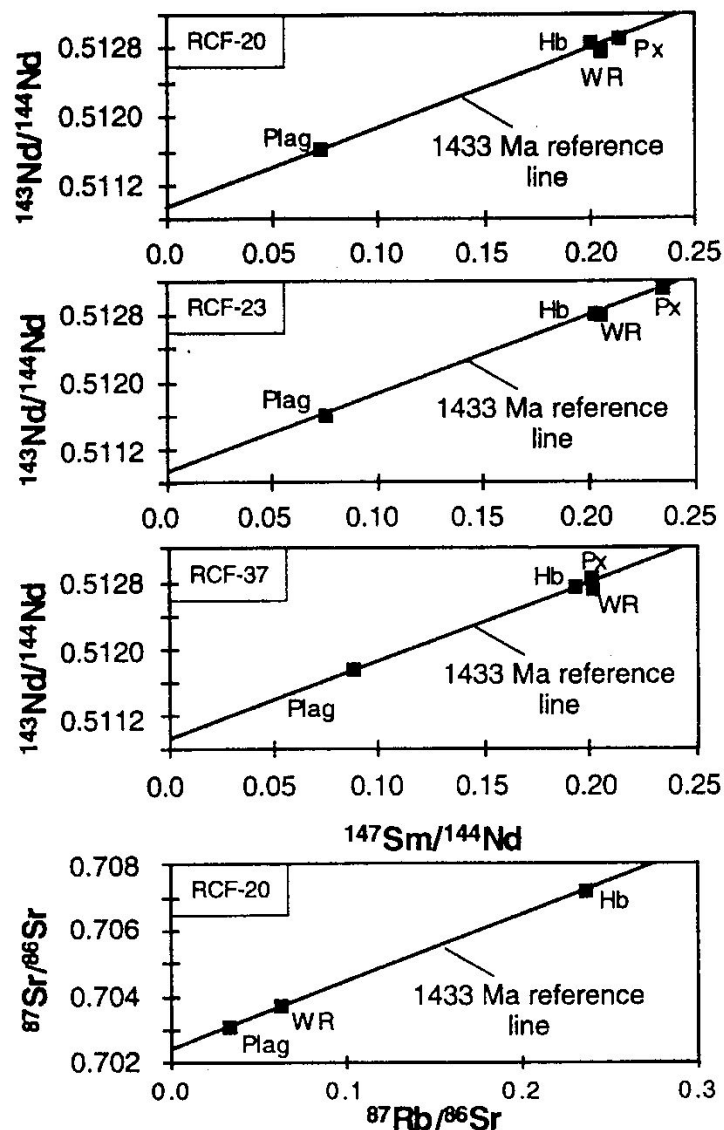


Figure 10. Sm-Nd and Rb-Sr mineral isochrons for metabasite samples RCF-20, RCF-23 and RCF-37. Isochron fits using the ISOPLOT program (Ludwig 1989) gave the following results: RCF-20 Sm-Nd = 1.40 ± 0.23 Ga, MSWD = 37; RCF-23 Sm-Nd = 1433 ± 17 Ma, MSWD = 1.0; RCF-37 Sm-Nd = 1.40 ± 0.23 Ga, MSWD = 23; RCF-20 Rb-Sr = 1385 ± 31 Ma, MSWD = 1.2. All errors are calculated at the 95% confidence level.

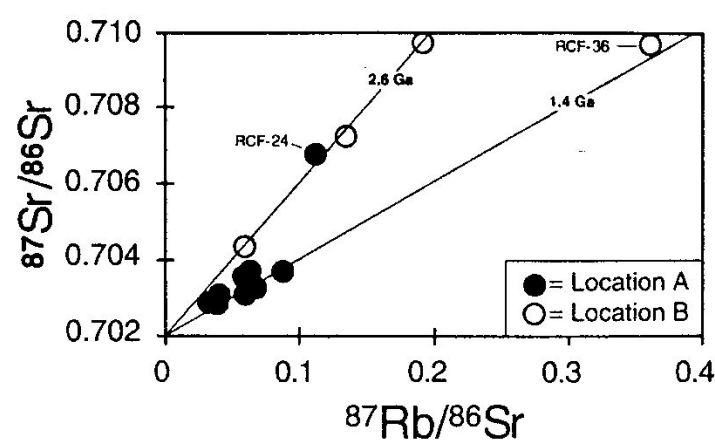


Figure 11. Rb-Sr isochron diagram for whole rock metabasite samples from Morton Pass. Samples containing more than 35% hornblende plot along a 2.6 Ga reference line, whereas samples in which greater amounts of hornblende has broken down plot near a 1.4 Ga reference line.

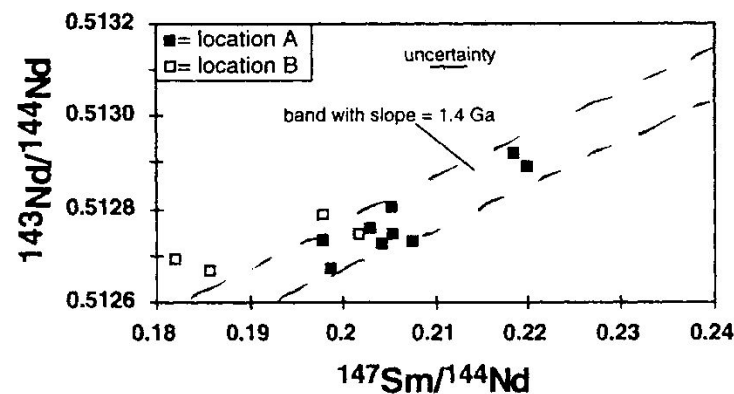


Figure 9. Sm-Nd whole rock isochron diagram for metabasites from location A (filled squares) and location B (open squares). The slope of the shaded band corresponds to an age of 1.4 Ga.

Frost C.D.,
Frost B.R.
Open-System
dehydration of
amphibolite,
Morton Pass,
Wyoming -
elemental and Nd
and Sr isotopic
effects. // Journal
of Geology. 1995.
103(3): 269-284.

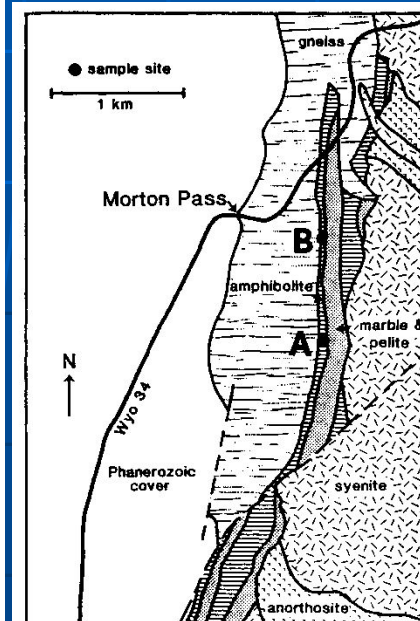


Figure 2. Geologic map of the Morton Pass area. Filled circles locate the two sample localities discussed in the text.

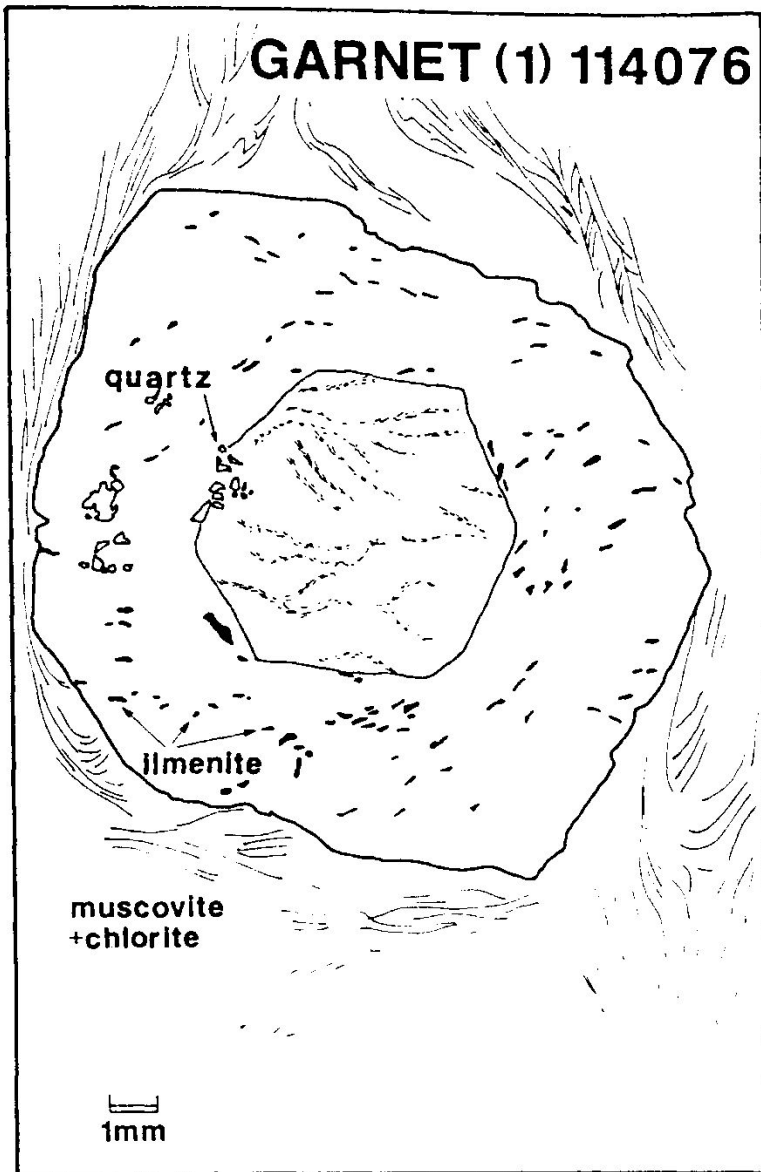
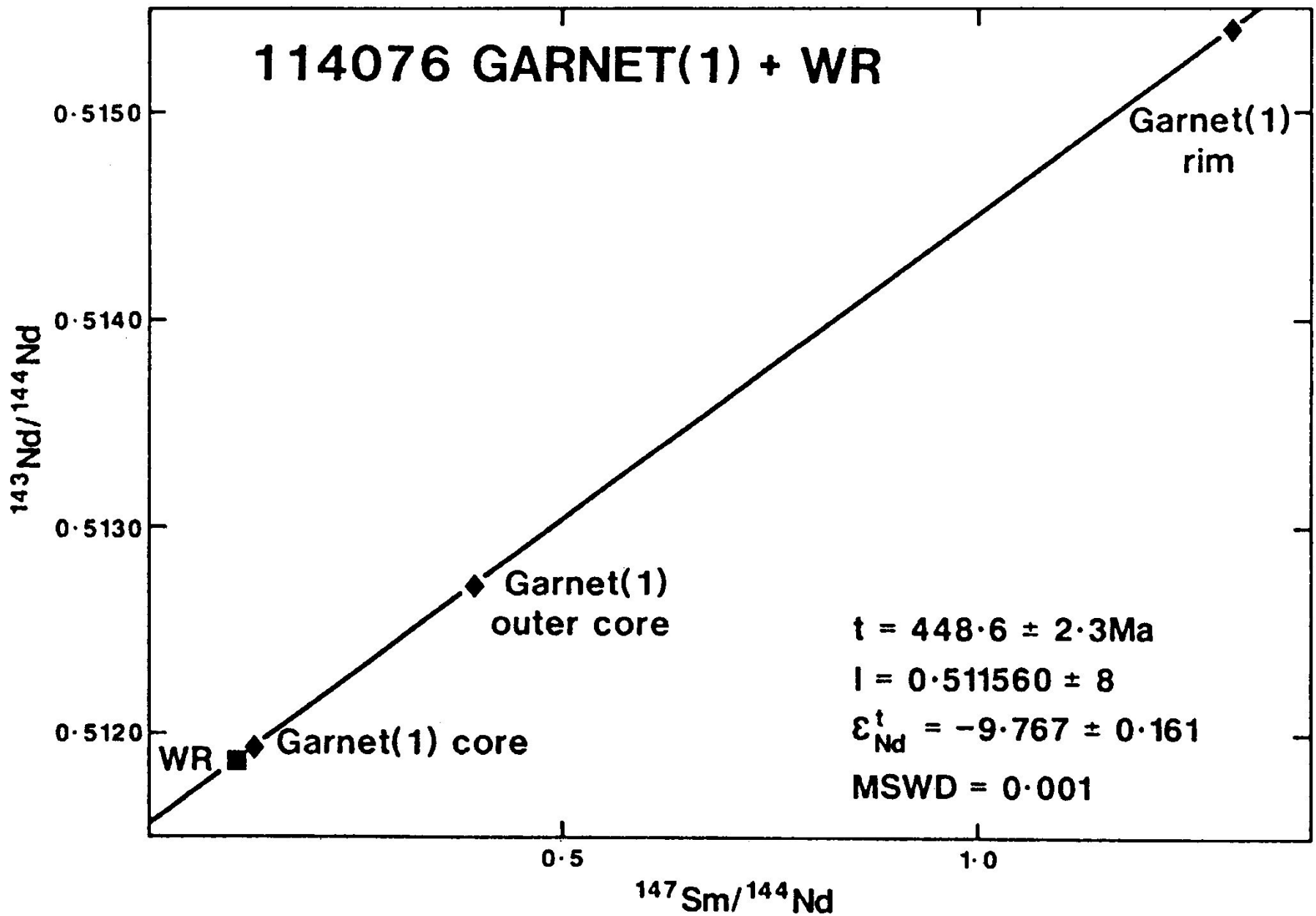
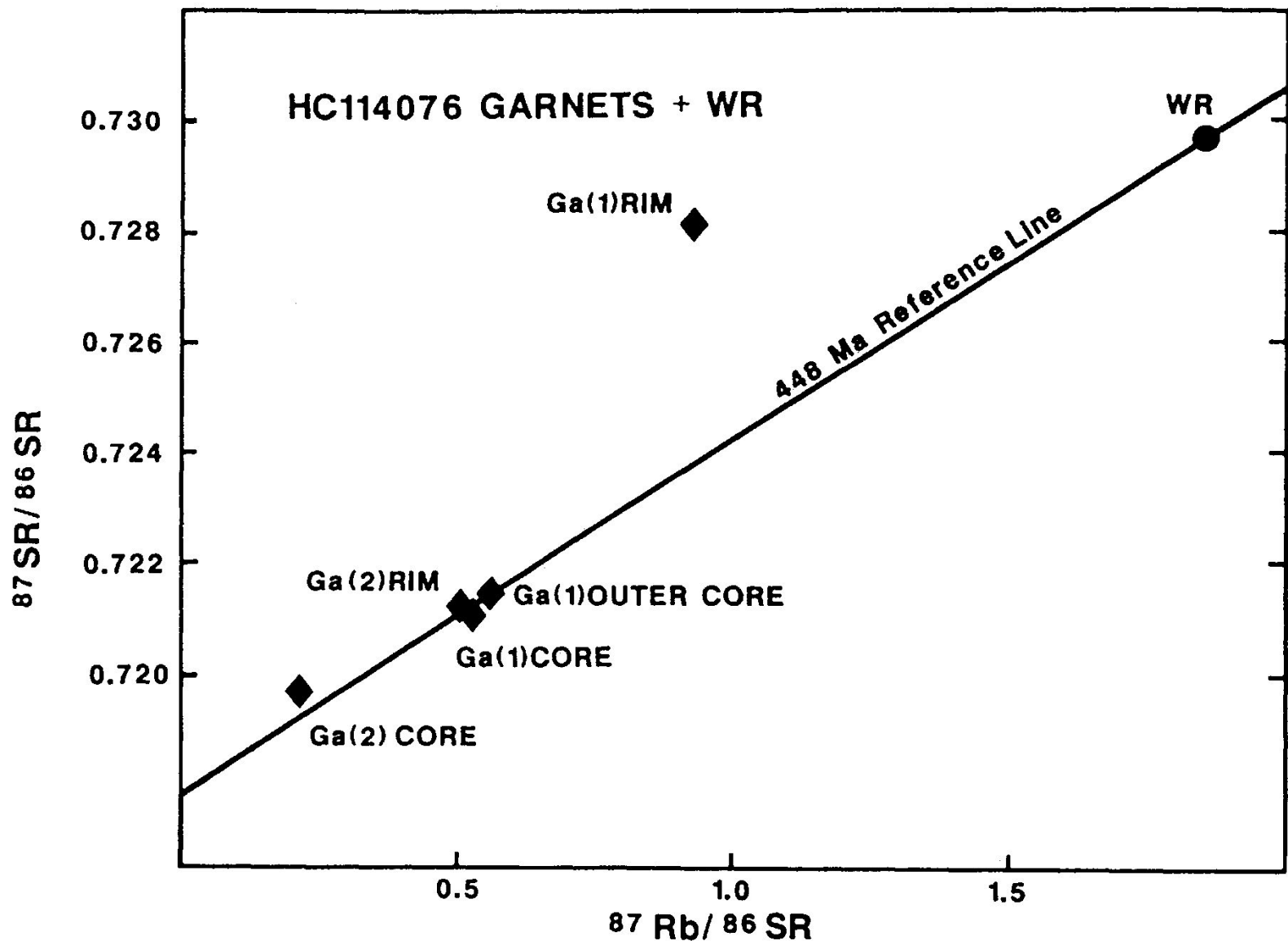


Fig. 1. Sketch of 114076 Garnet(1), Pigeon Island, Newfoundland, showing the inclusion-rich core containing needles of rutile and epidote $< 50 \mu\text{m}$ long, and an optically clear outer core with 0.5 mm inclusions of ilmenite. The matrix is largely retrogressed to muscovite and chlorite.

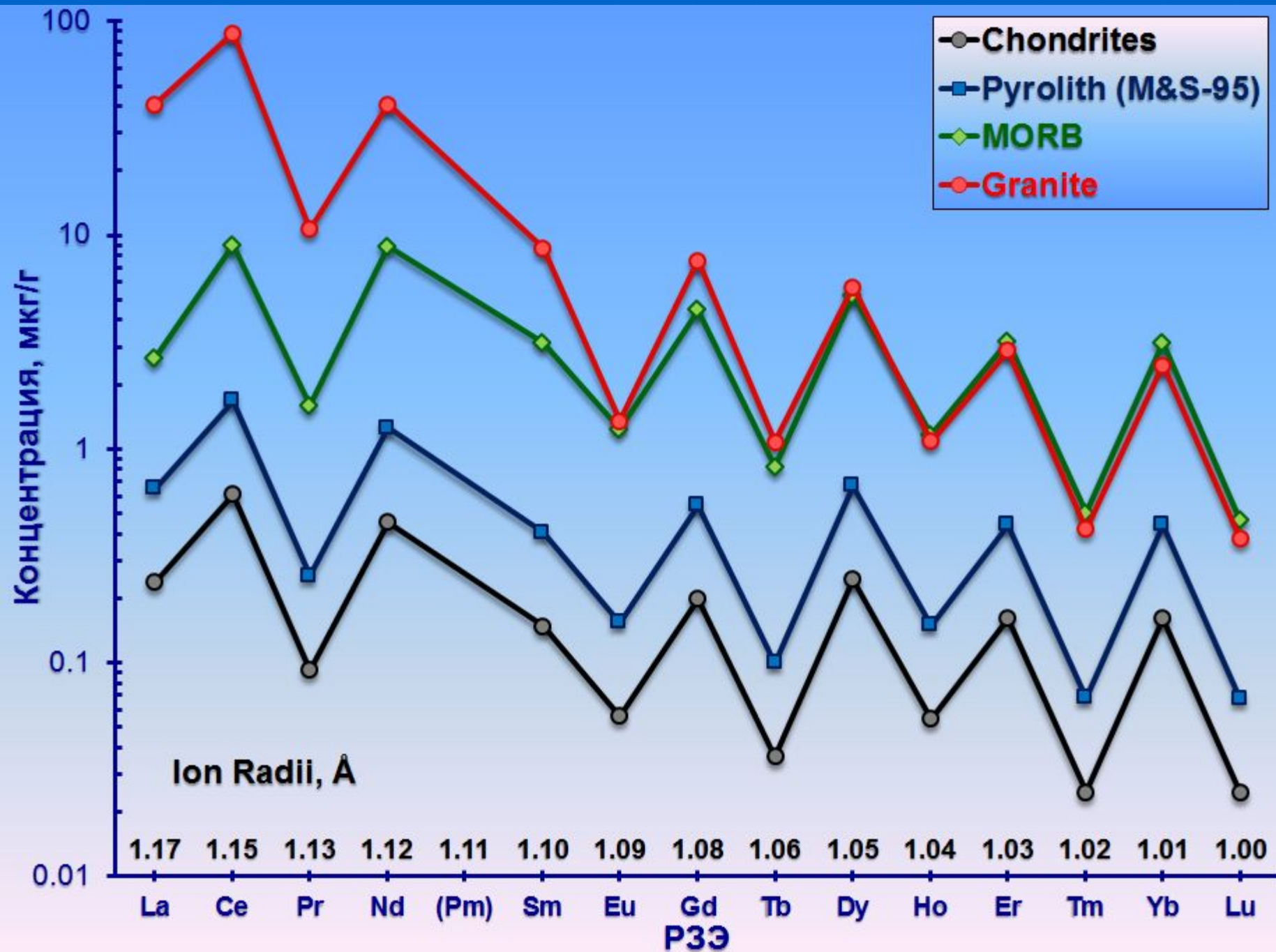
Vance D., O'Nions R.K.
Isotopic Chronometry of Zoned
Garnets - Growth-Kinetics and
Metamorphic Histories. // Earth
and Planetary Science Letters.
1990. 97(3-4): 227-240.

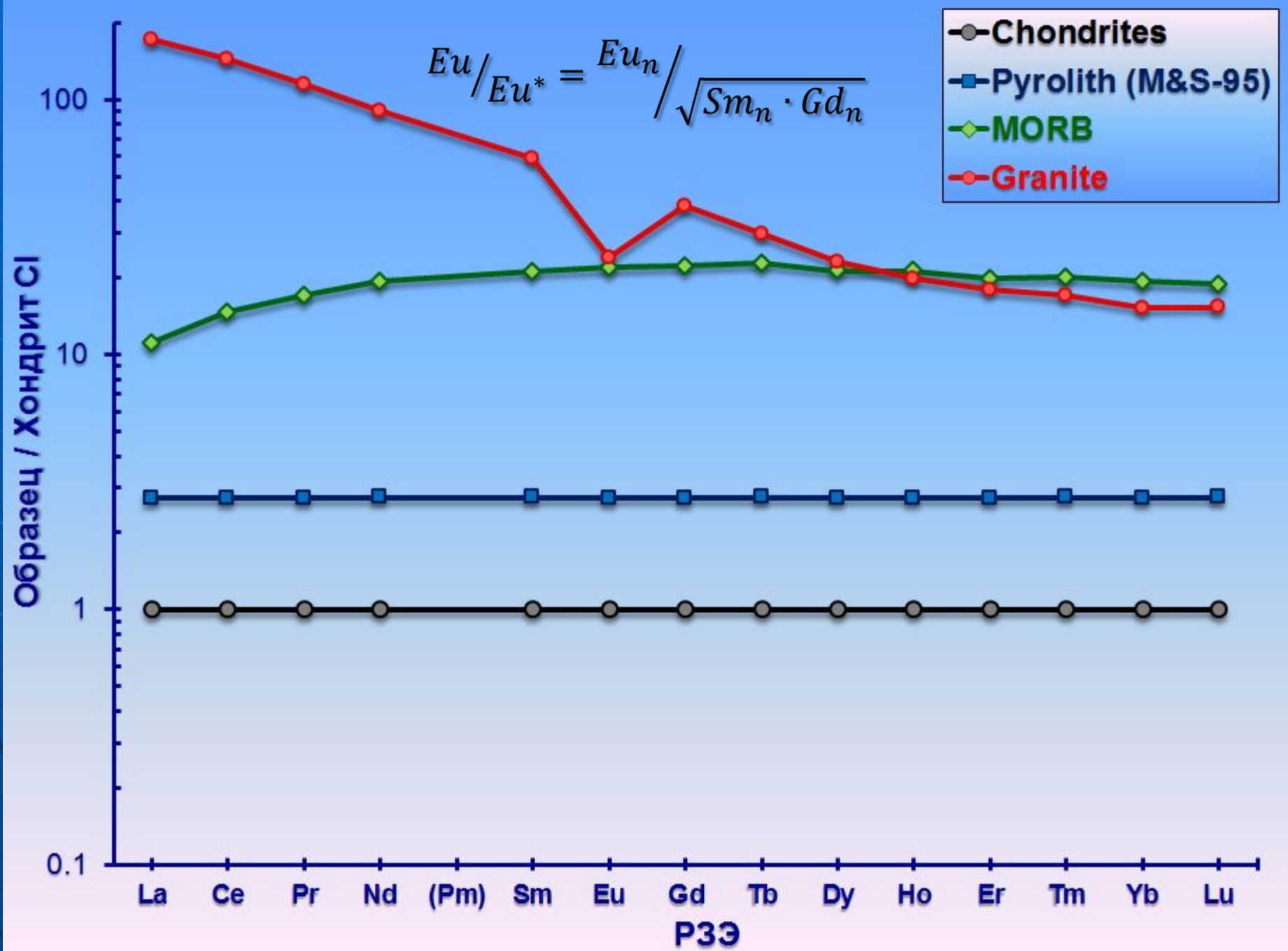


Sm-Nd evolution diagram showing results for the whole rock (WR) and the three fractions for sample HC114076 Garnet(1).

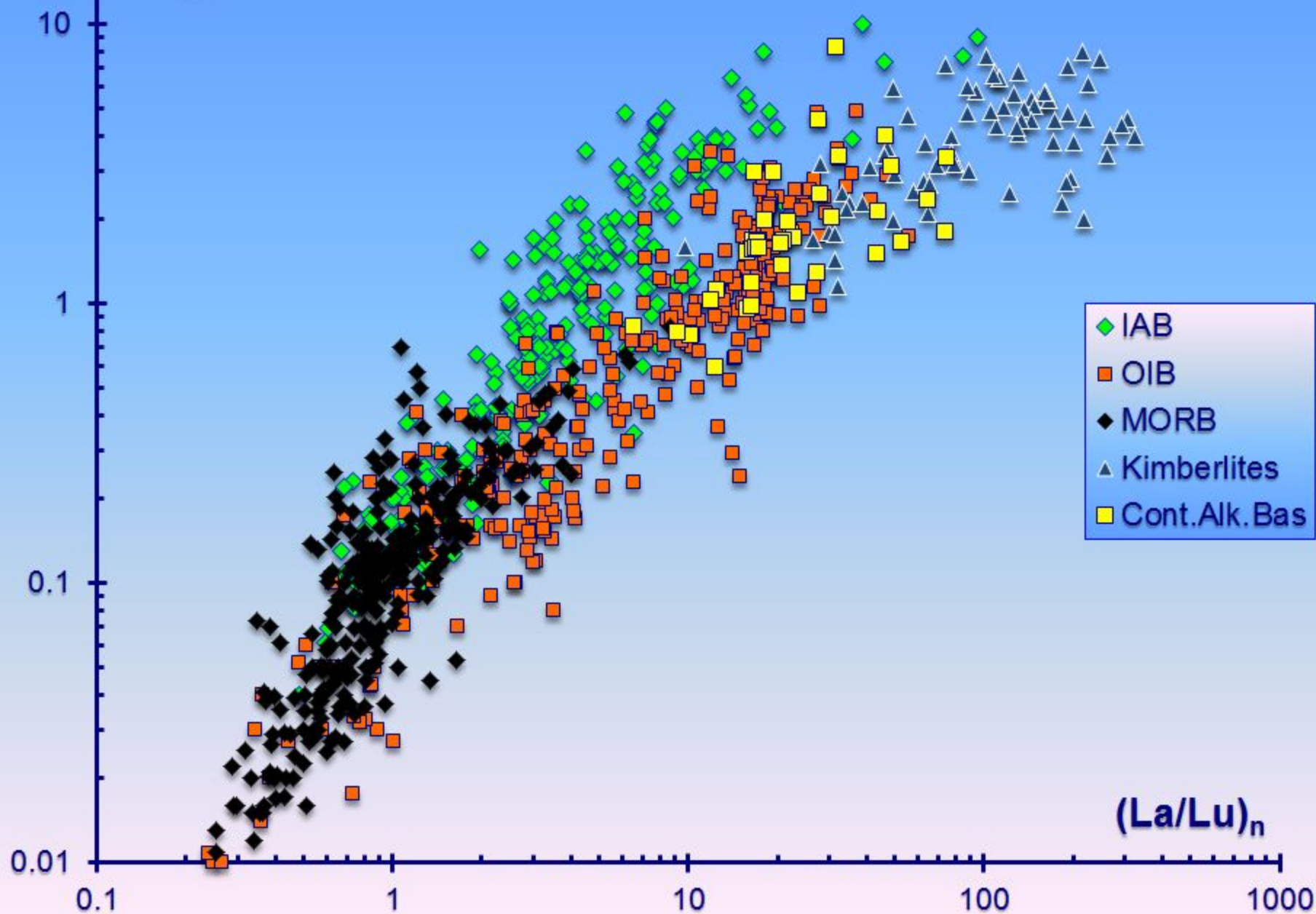


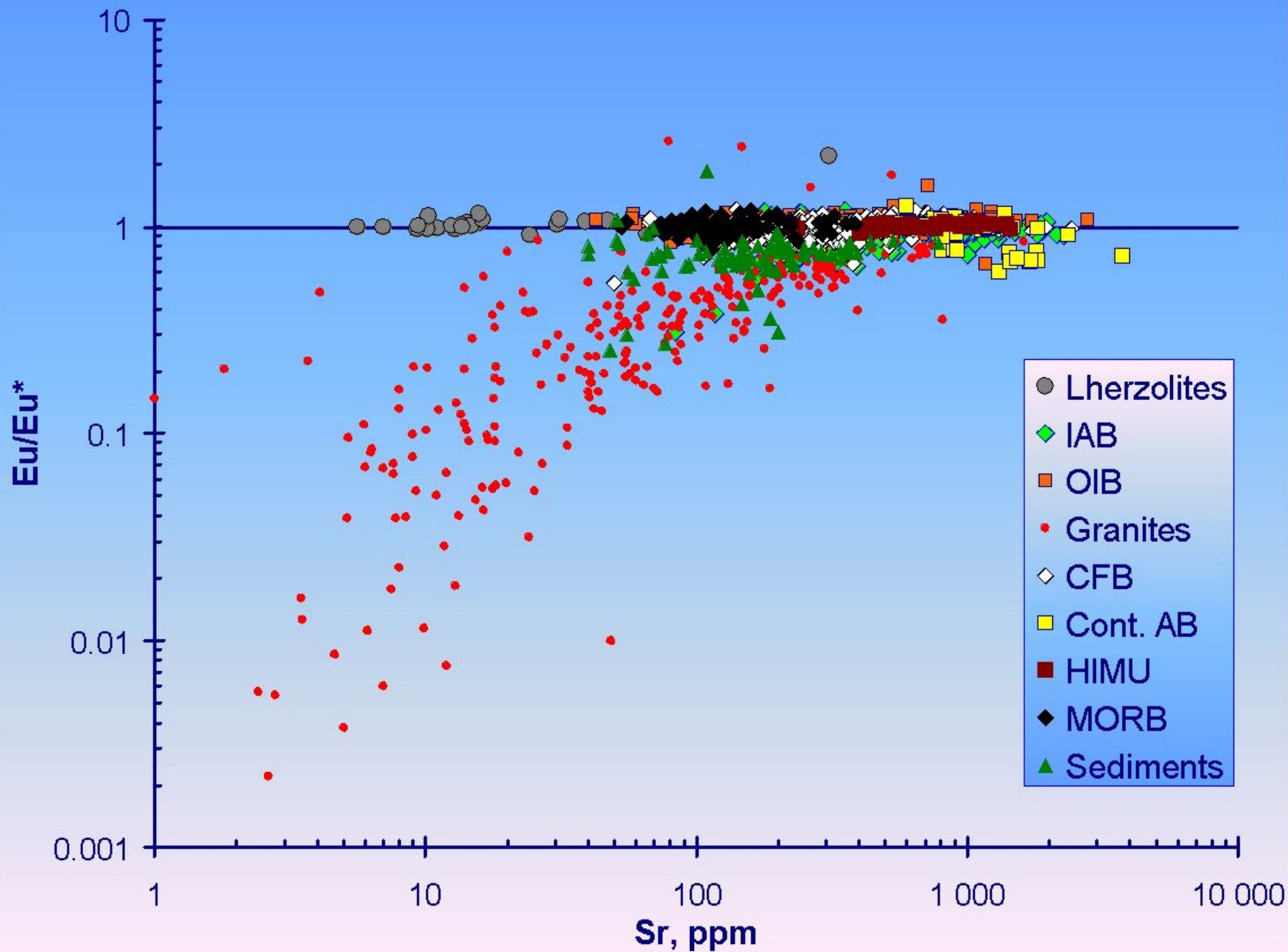
Rb–Sr evolution diagram for garnets in HC114076 and the whole rock (WR). The garnet samples all fall close to the 448 Ma reference line (calculated using the whole rock, and presumed to be the time of growth as given by the Sm–Nd data) except for Garnet(1) rim, which is also the only garnet showing a retrograde rim zonation pattern.





U, ppm





Задача 11. Построить графики нормированных РЗЭ, рассчитать Eu/Eu^* и $(La/Lu)_n$

	Chond-rite s	82LI4Aa, Carbo-nati te	907-3, Raumid granite-1	972-1, Raumid granite-7	GL49S, Basalt glass (N.Chile)
La	0.367	698	39.7	10.1	1.3
Ce	0.957	1500	77.6	29.9	4.9
Pr	0.137	184	8.0	5.0	1.04
Nd	0.711	705	25.9	24.8	6.2
Sm	0.231	113	4.06	9.49	2.4
Eu	0.087	30.6	0.506	0.015	0.97
Gd	0.306	79.0	2.97	7.74	3.4
Tb	0.058	9.64	0.44	1.79	0.65
Dy	0.381	45.3	2.47	15.2	4.3
Ho	0.0851	7.36	0.53	3.27	0.95
Er	0.249	17.1	1.63	8.13	2.7
Tm	0.036	1.96	0.27	1.93	0.38
Yb	0.248	11.5	1.91	15.5	2.5
Lu	0.0381	1.03	0.3	1.89	0.35

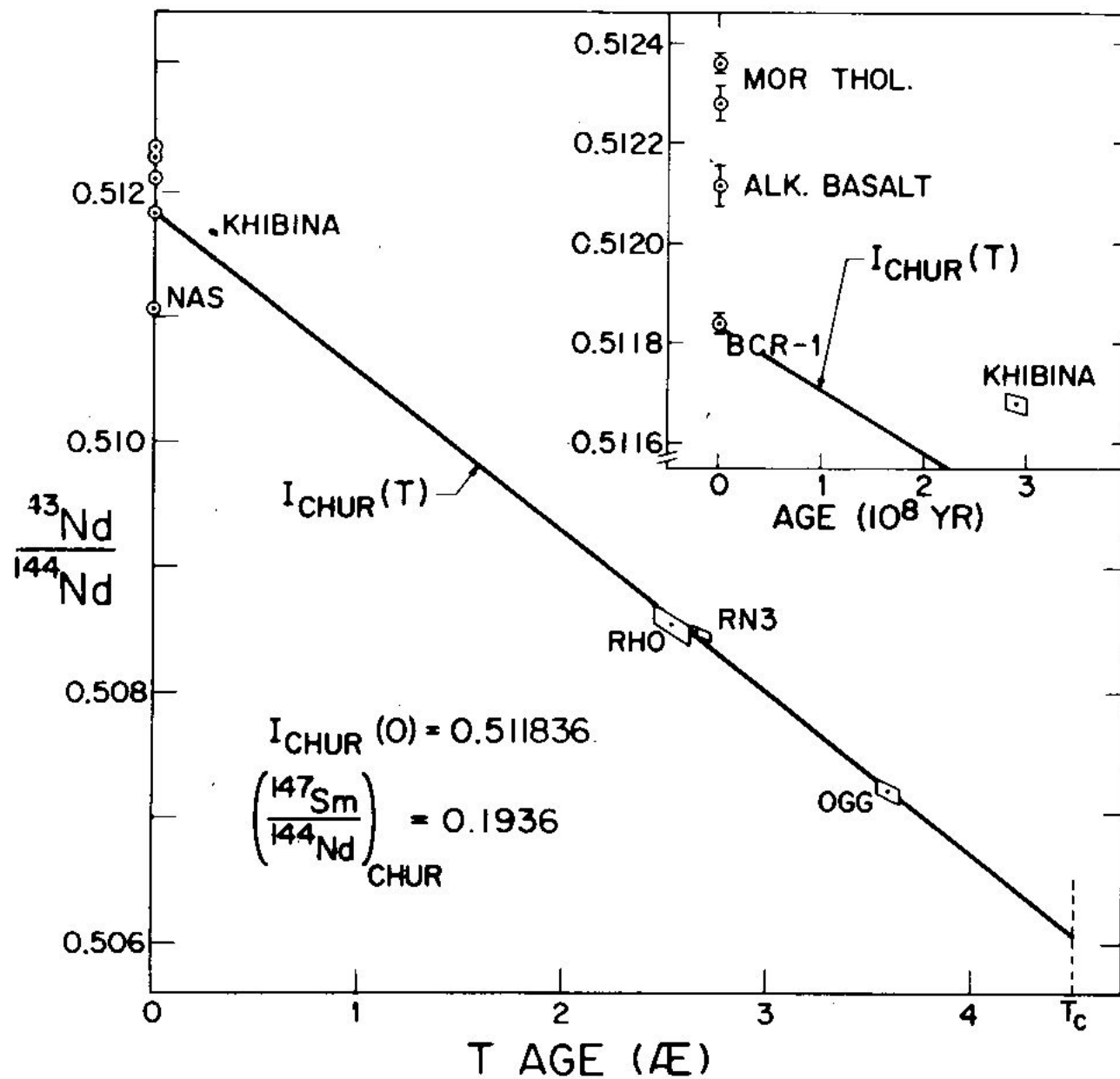
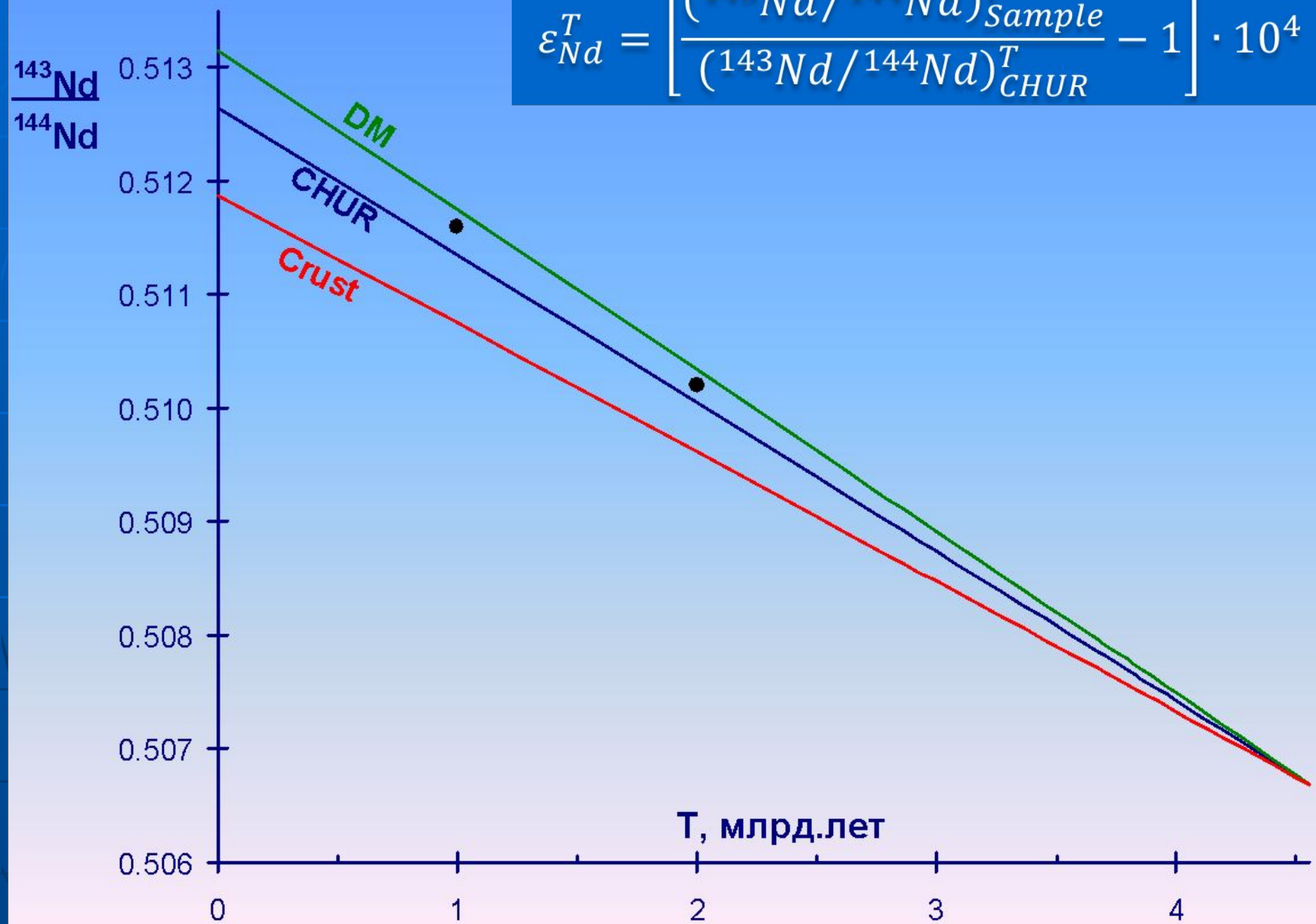


Fig. 2: Observed initial $^{143}\text{Nd}/^{144}\text{Nd}$ versus time. $I_{\text{CHUR}}(T)$ represents evolution of $^{143}\text{Nd}/^{144}\text{Nd}$ in a reservoir with chondritic Sm/Nd.

DePaolo D.J.,
Wasserburg G.J., Nd
isotopic variations
and petrogenetic
models. //
Geophysical
Research Letters,
1976. 3(5):
249-252.

$$\varepsilon_{Nd}^T = \left[\frac{(^{143}\text{Nd}/^{144}\text{Nd})_{Sample}^T}{(^{143}\text{Nd}/^{144}\text{Nd})_{CHUR}^T} - 1 \right] \cdot 10^4$$



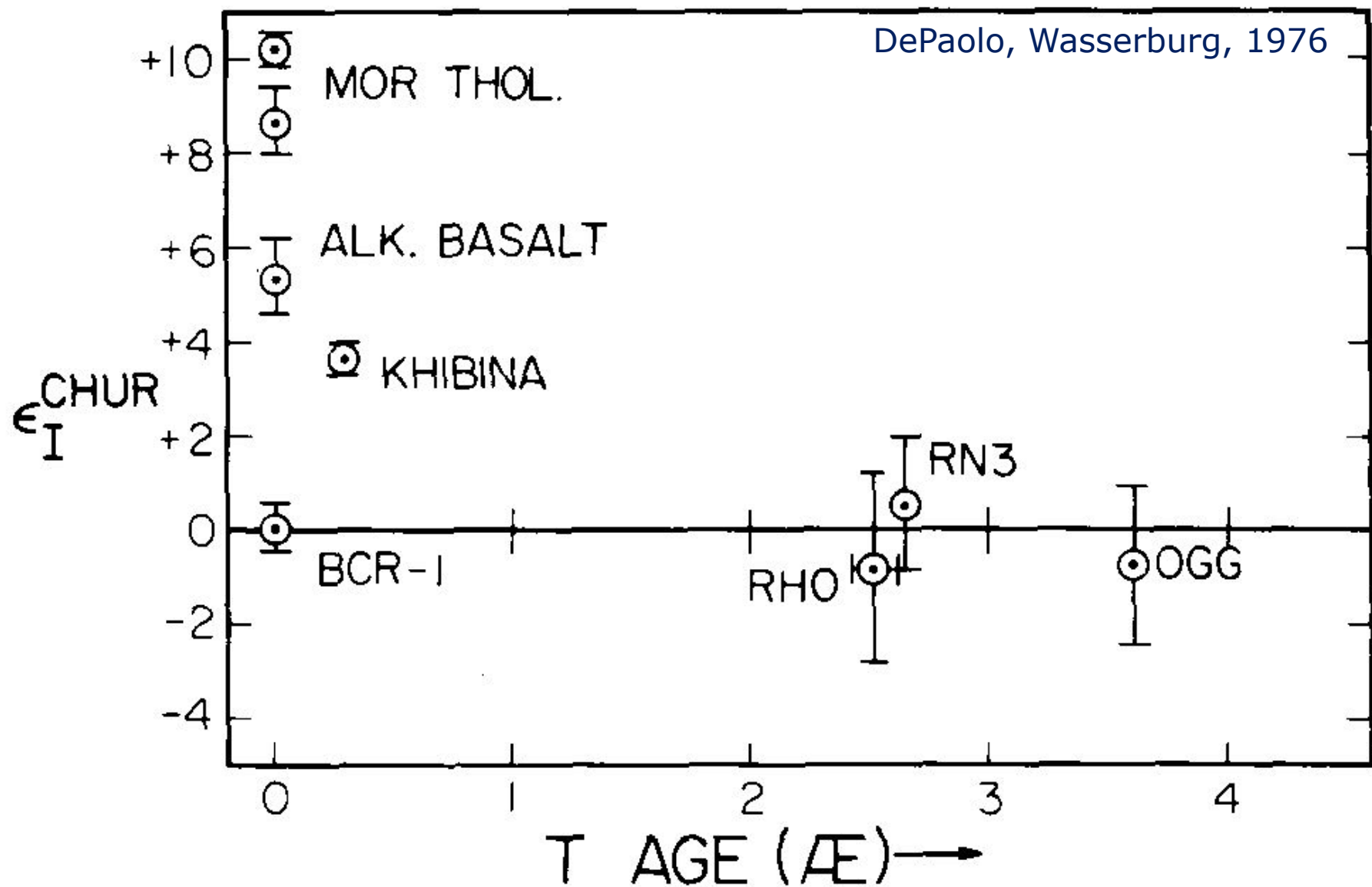
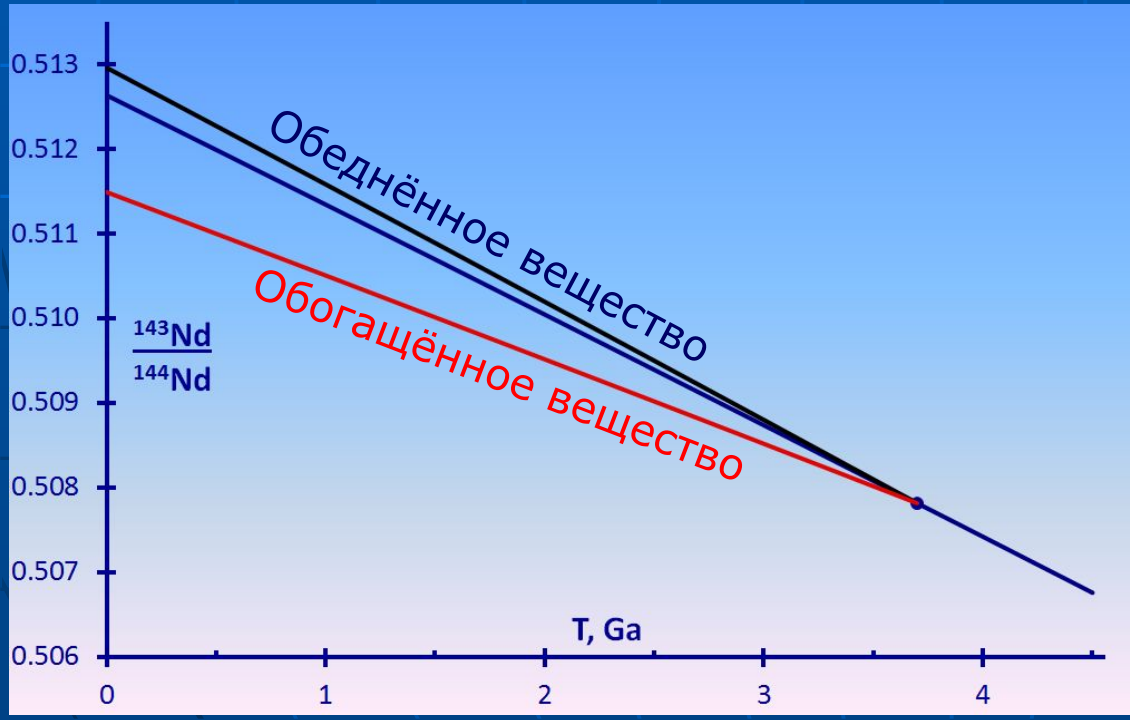
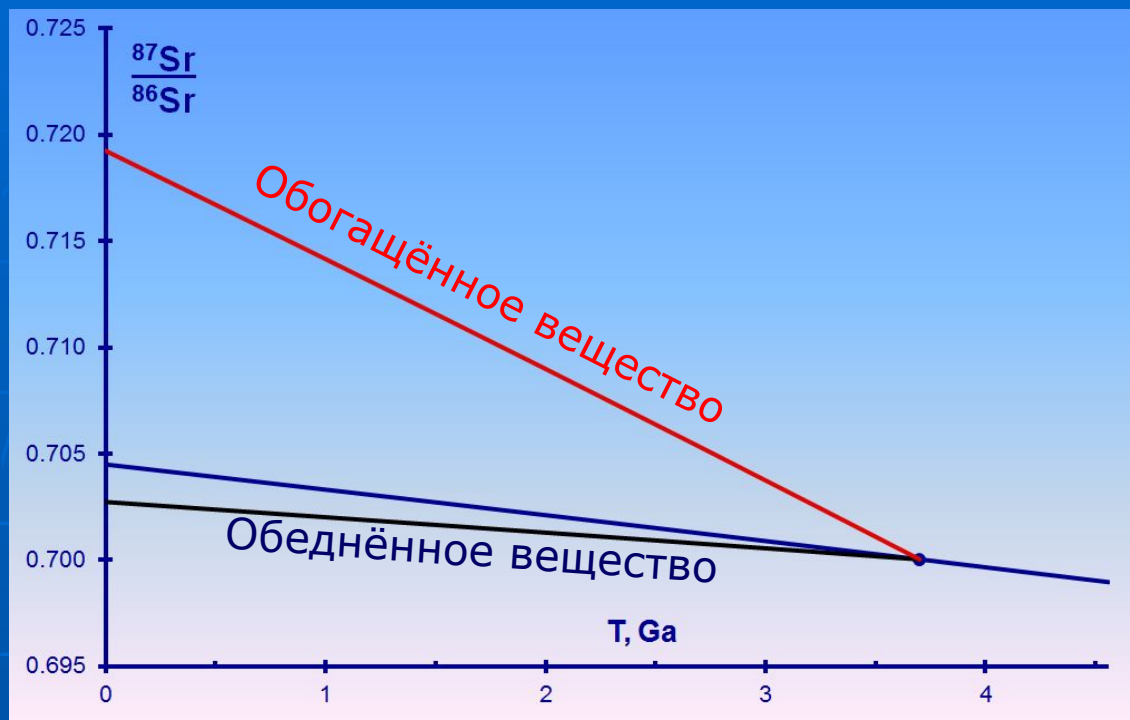


Fig. 3: Fractional deviations in parts in 10^4 of initial $^{143}\text{Nd}/^{144}\text{Nd}$ from evolution in a chondritic Sm/Nd reservoir (CHUR) vs. time.



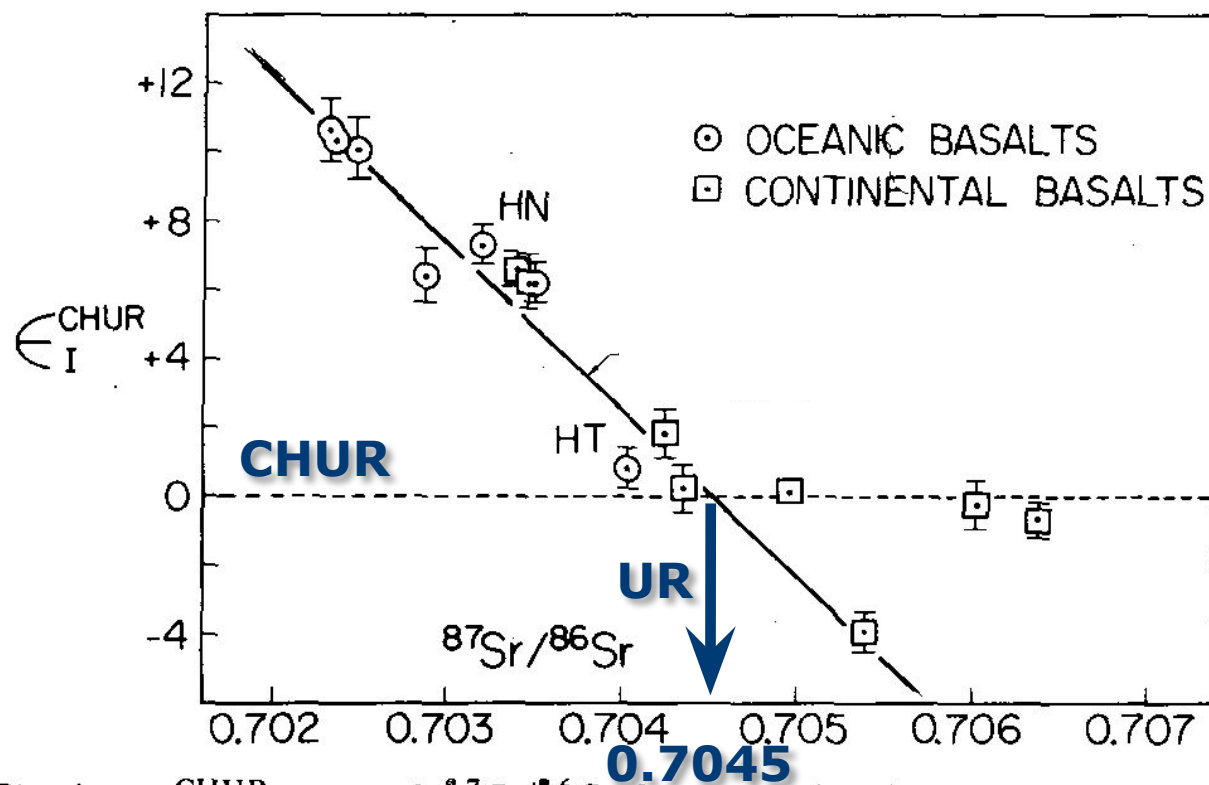


Fig. 4: ϵ_I^{CHUR} vs. initial $^{87}\text{Sr}/^{86}\text{Sr}$ for young basalts. Included are two samples from *Richard, et. al. (1976)* (PD1P, ARP74) and BCR-1 ($^{87}\text{Sr}/^{86}\text{Sr}$ for BCR-1 from *Pankhurst and O'Nions, 1973*). The solid line shows the inferred trend of the correlation and the relative magnitudes of correlated variations of Rb/Sr and Sm/Nd necessary to produce such a trend. The dashed line indicates the trend defined by four continental basalt samples which have $\epsilon_I^{\text{CHUR}} \approx 0$ but different $^{87}\text{Sr}/^{86}\text{Sr}$, all lying to the right of the main correlation line. This trend may result from contamination of magmas with crustal radiogenic Sr or indicate the existence of magma sources which have become enriched in Rb relative to Sr, but have retained unchanged Sm/Nd. Should new data populate the correlation line to values of ϵ_I^{CHUR} much less than zero, it would require serious revision of the simple two-reservoir model.

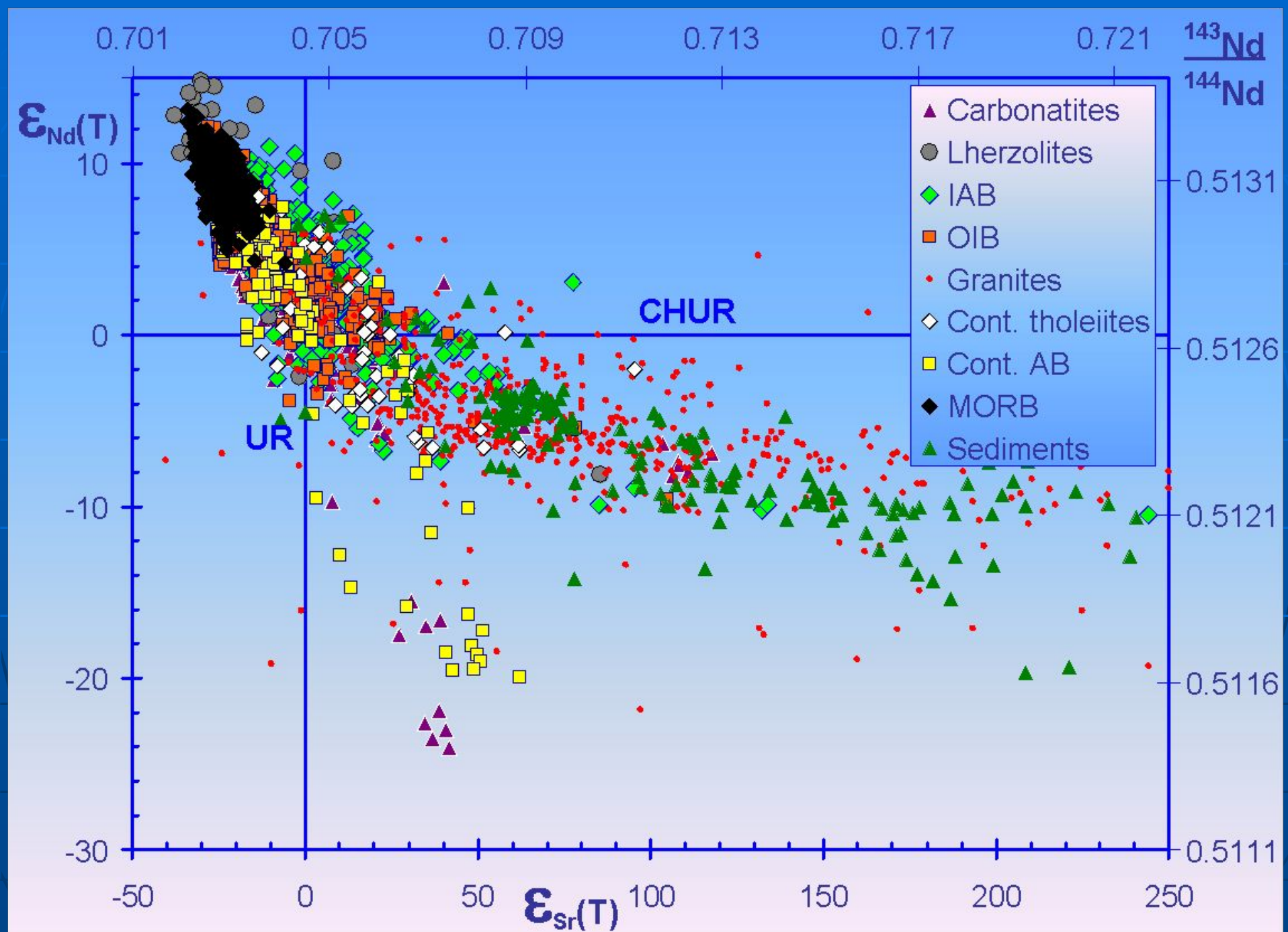
DePaolo D.J., Wasserburg G.J. Inferences about magma sources and mantle structure from variations of $^{143}\text{Nd}/^{144}\text{Nd}$. // *Geophysical Research Letters*, 1976. 3(12): 743-746.

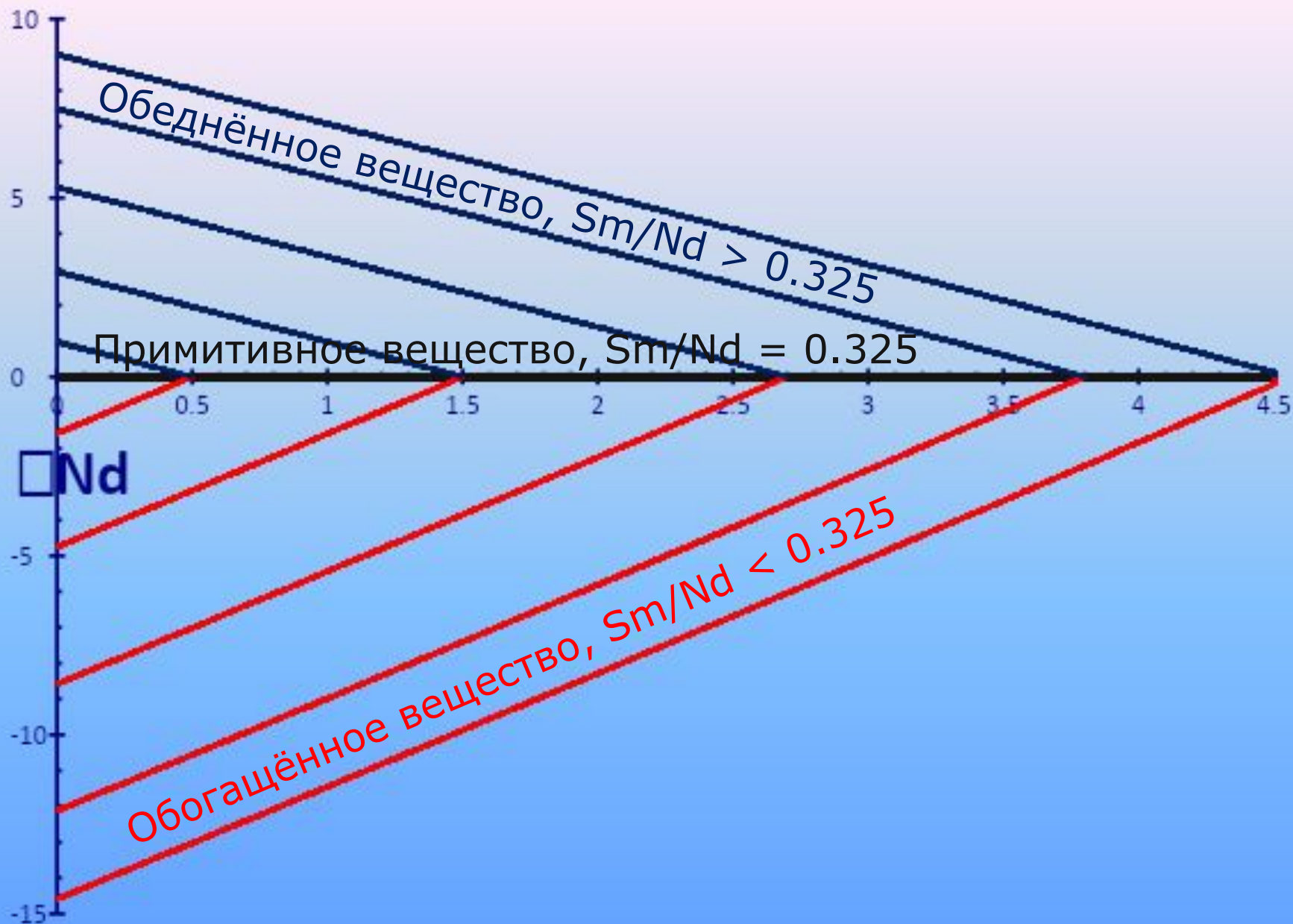
CHUR = Chondritic Uniform Reservoir

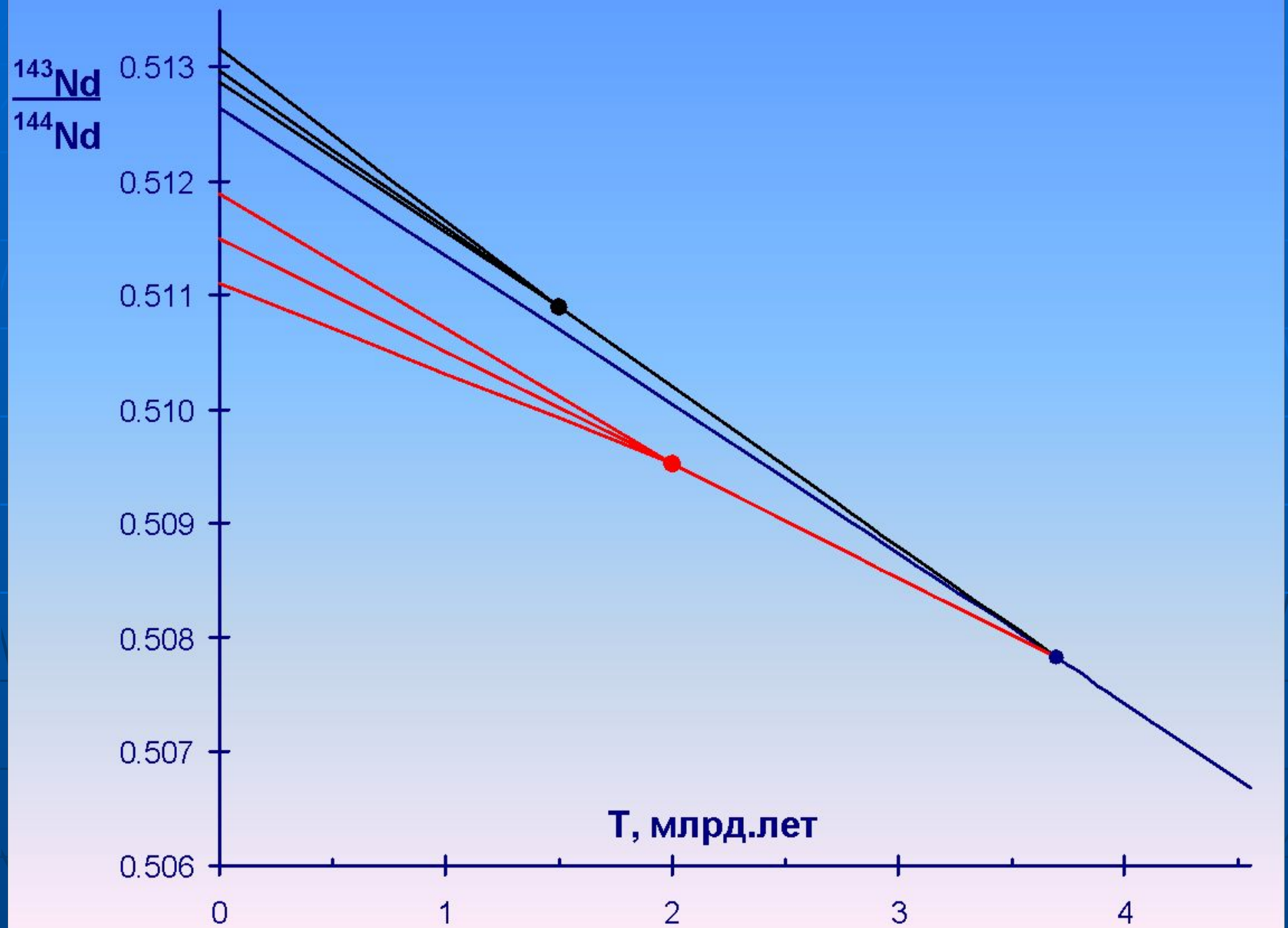
UR = Uniform Reservoir

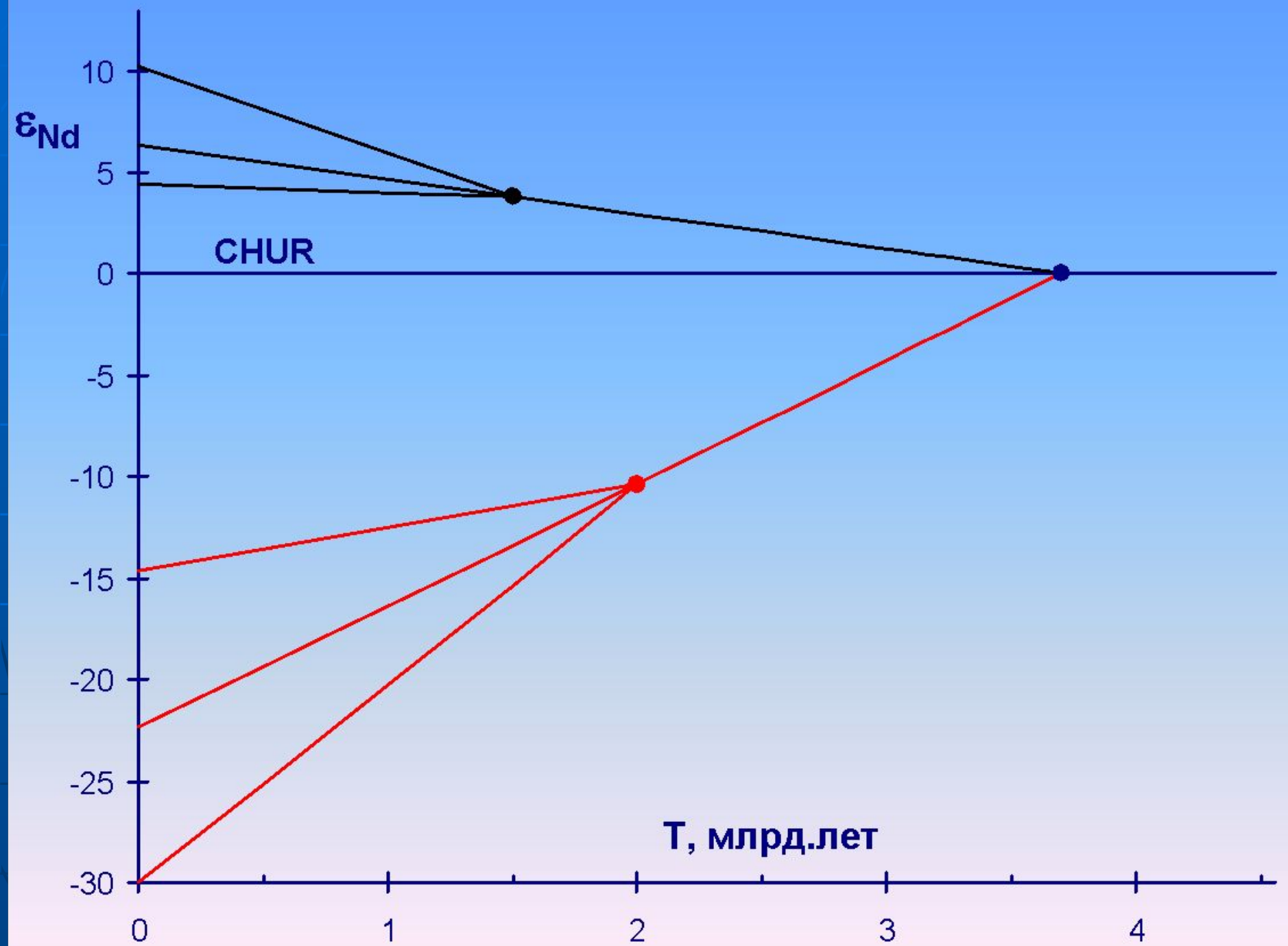
BSE = Bulk Silicate Earth

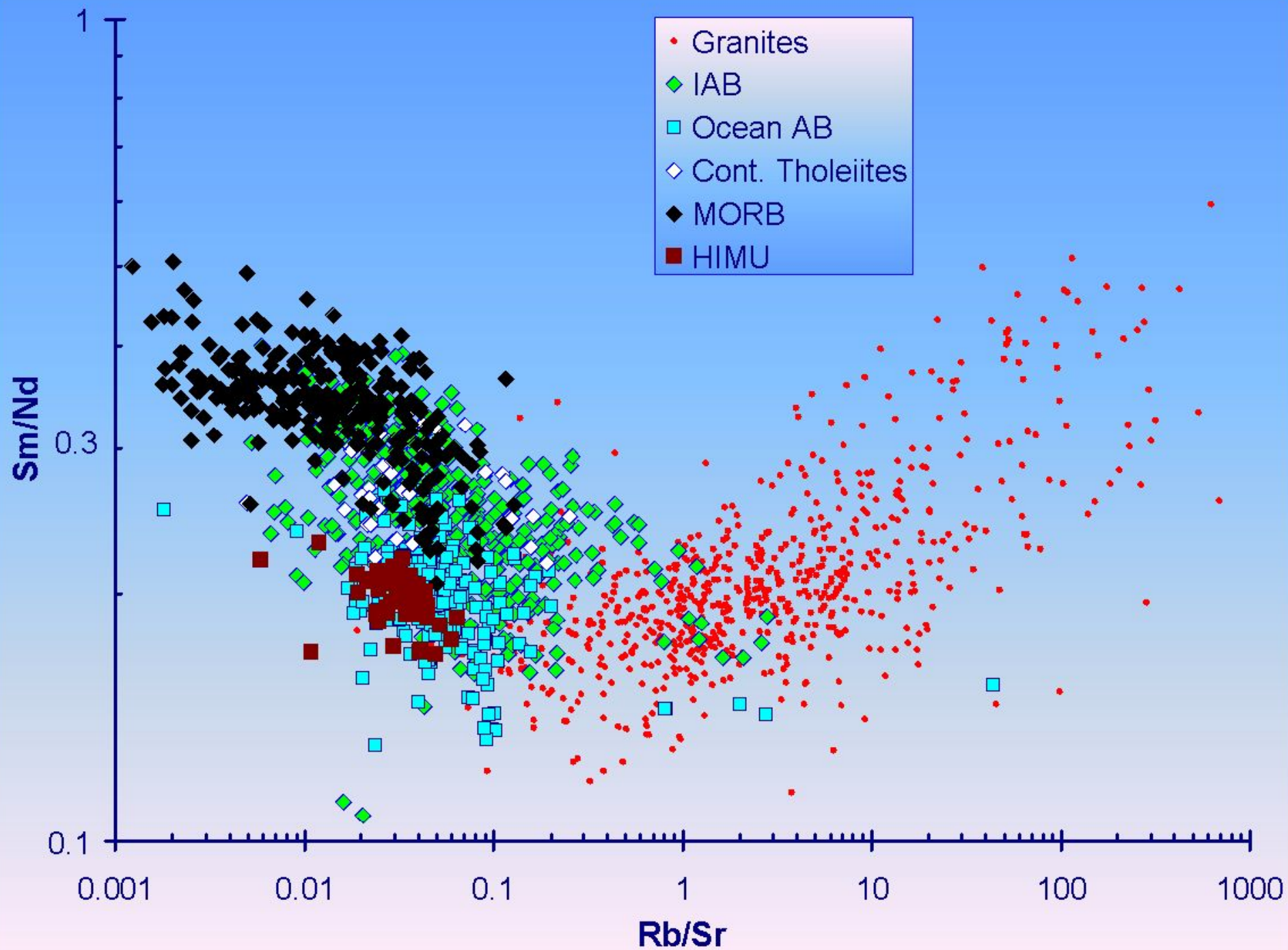
UR: $^{87}\text{Sr}/^{86}\text{Sr}=0.7045$
 BABI: $^{87}\text{Sr}/^{86}\text{Sr}=0.69897$
 Rb/Sr=0.0286







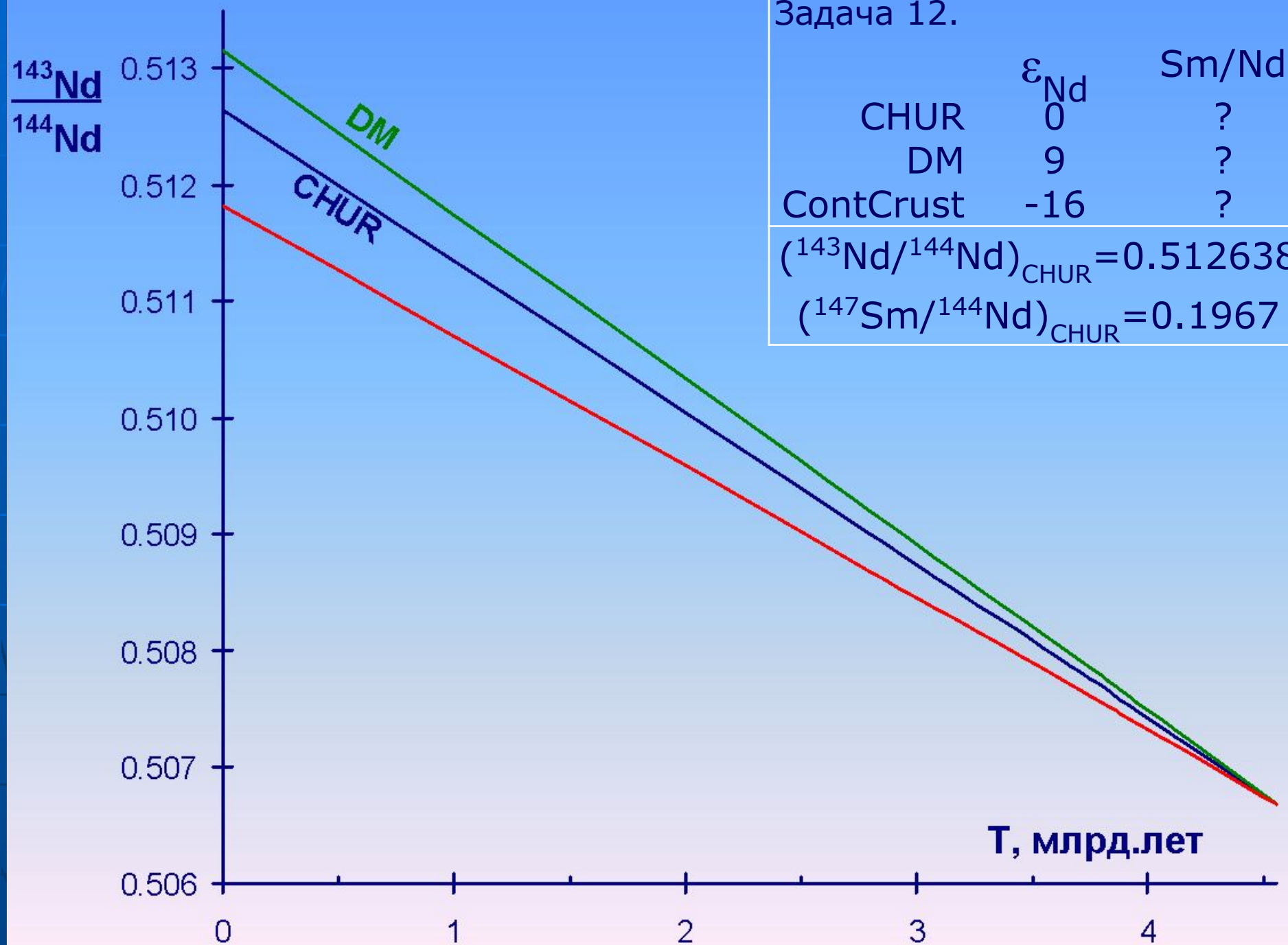


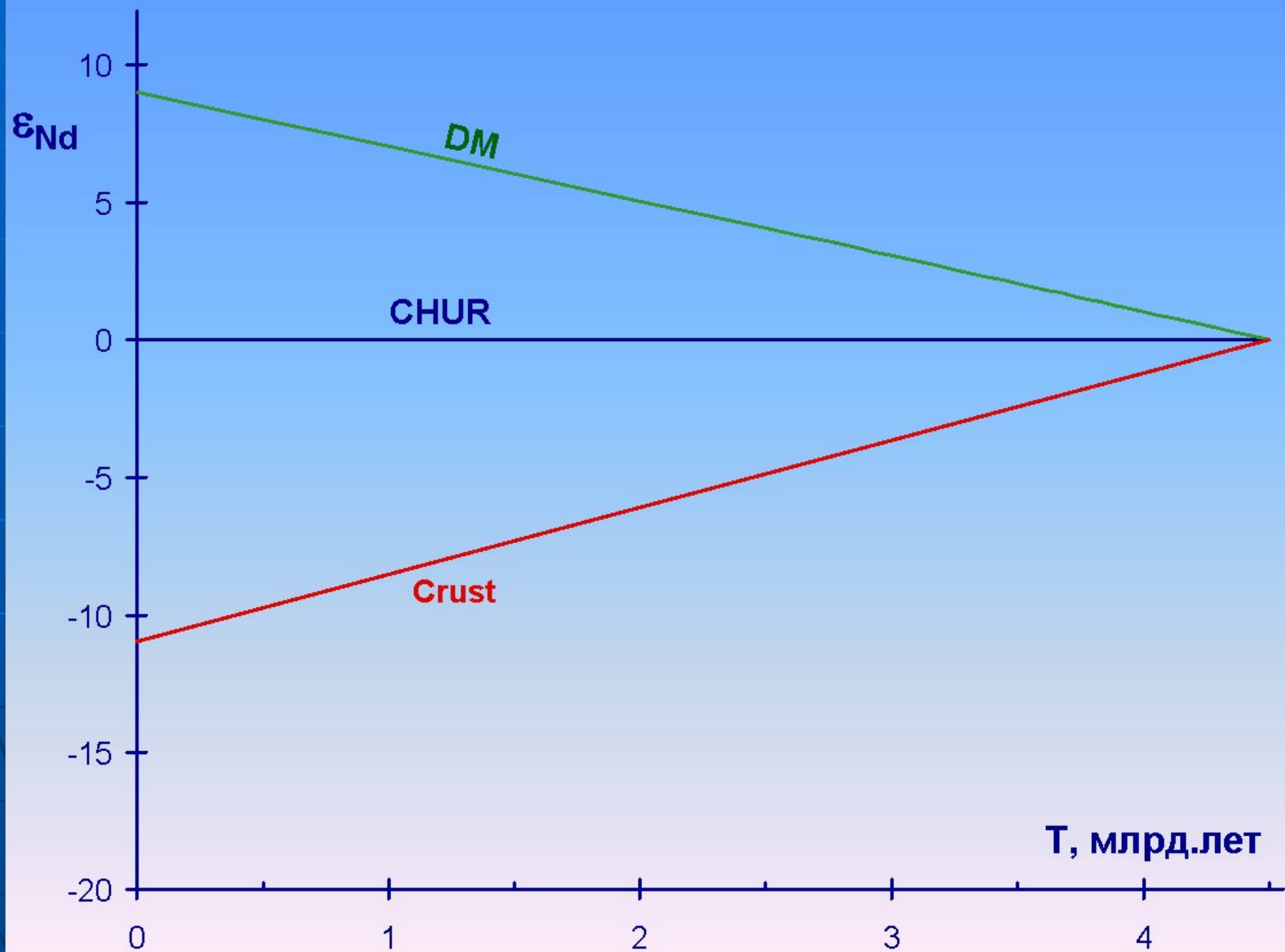


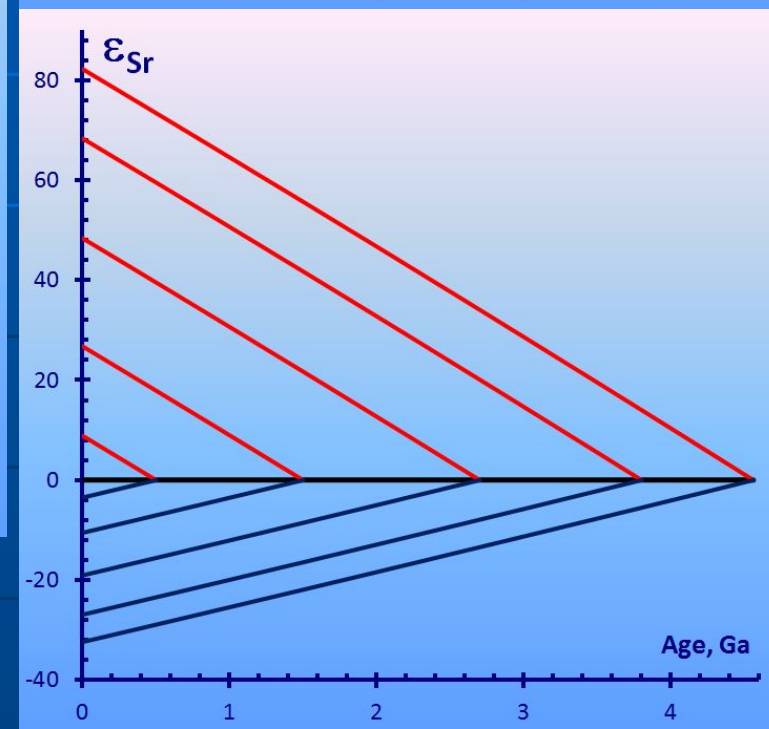
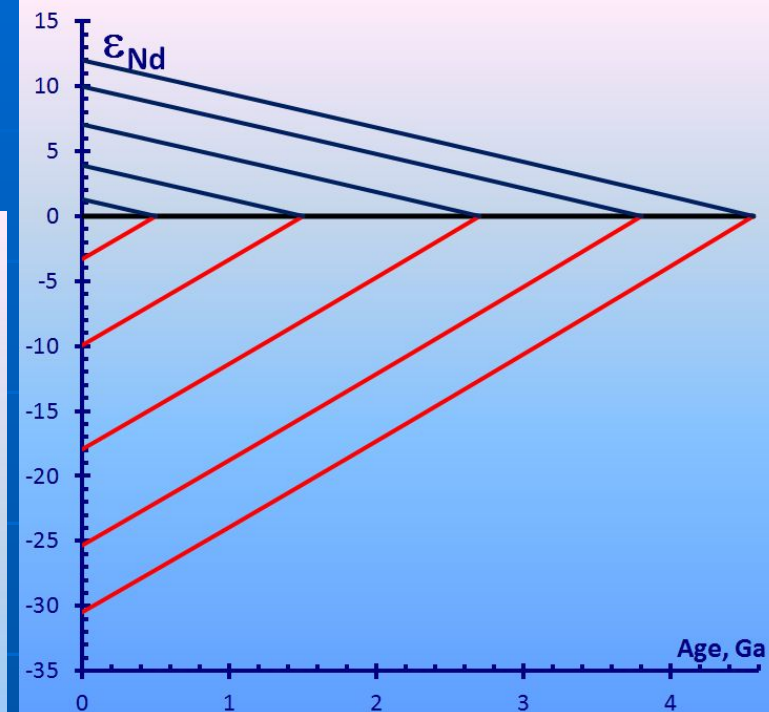
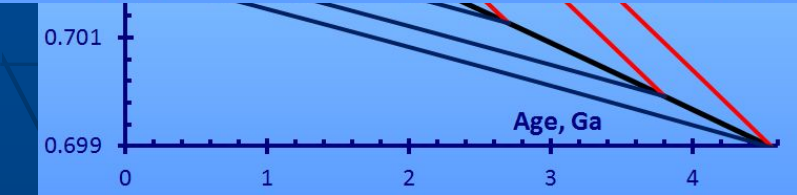
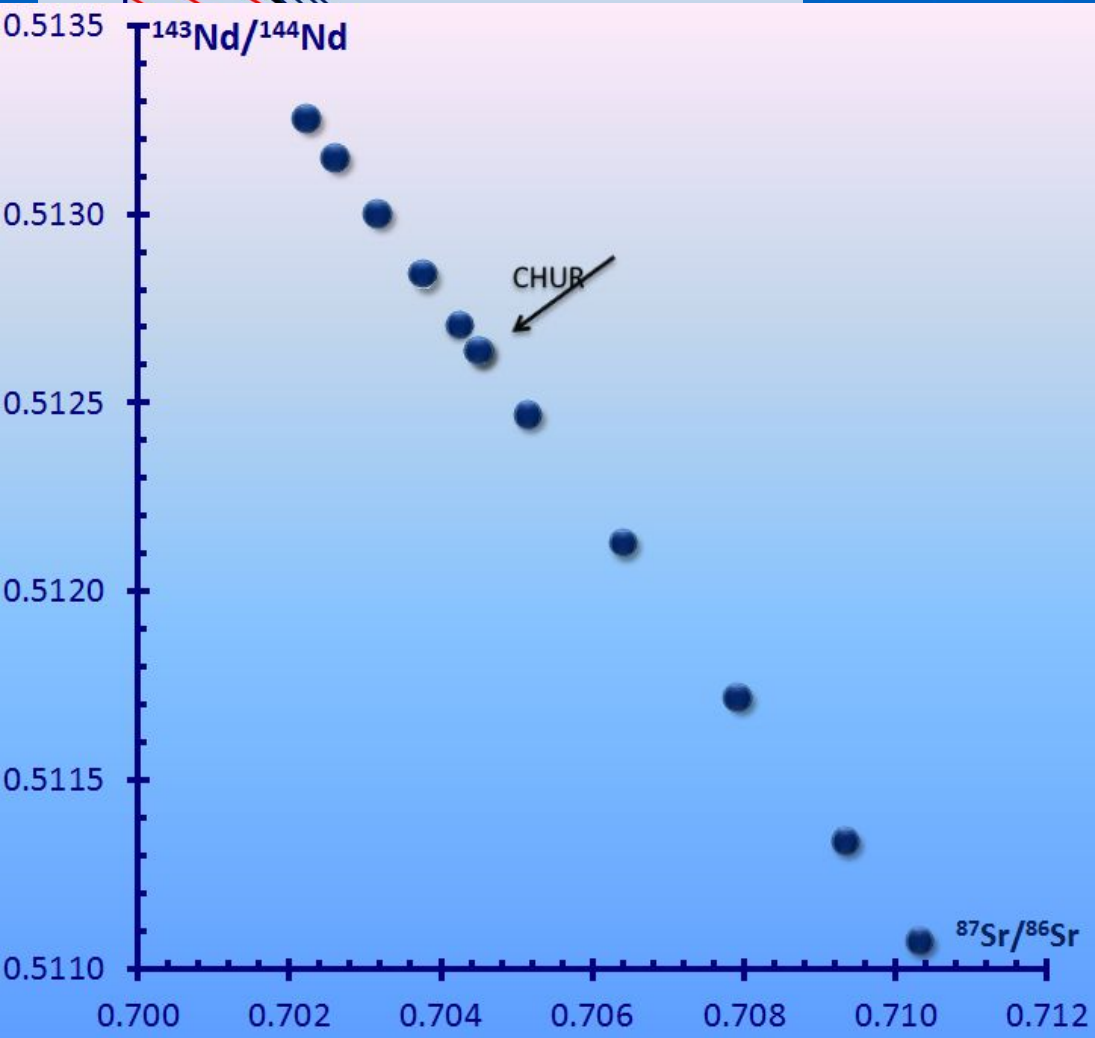
Задача 12.

	ϵ_{Nd}	Sm/Nd
CHUR	0	?
DM	9	?
ContCrust	-16	?

$(^{143}\text{Nd}/^{144}\text{Nd})_{\text{CHUR}} = 0.512638$
 $(^{147}\text{Sm}/^{144}\text{Nd})_{\text{CHUR}} = 0.1967$







Модельный возраст в Sm-Nd системе

- Позволяет оценить время отделения породы (или её протолита) от мантийного источника

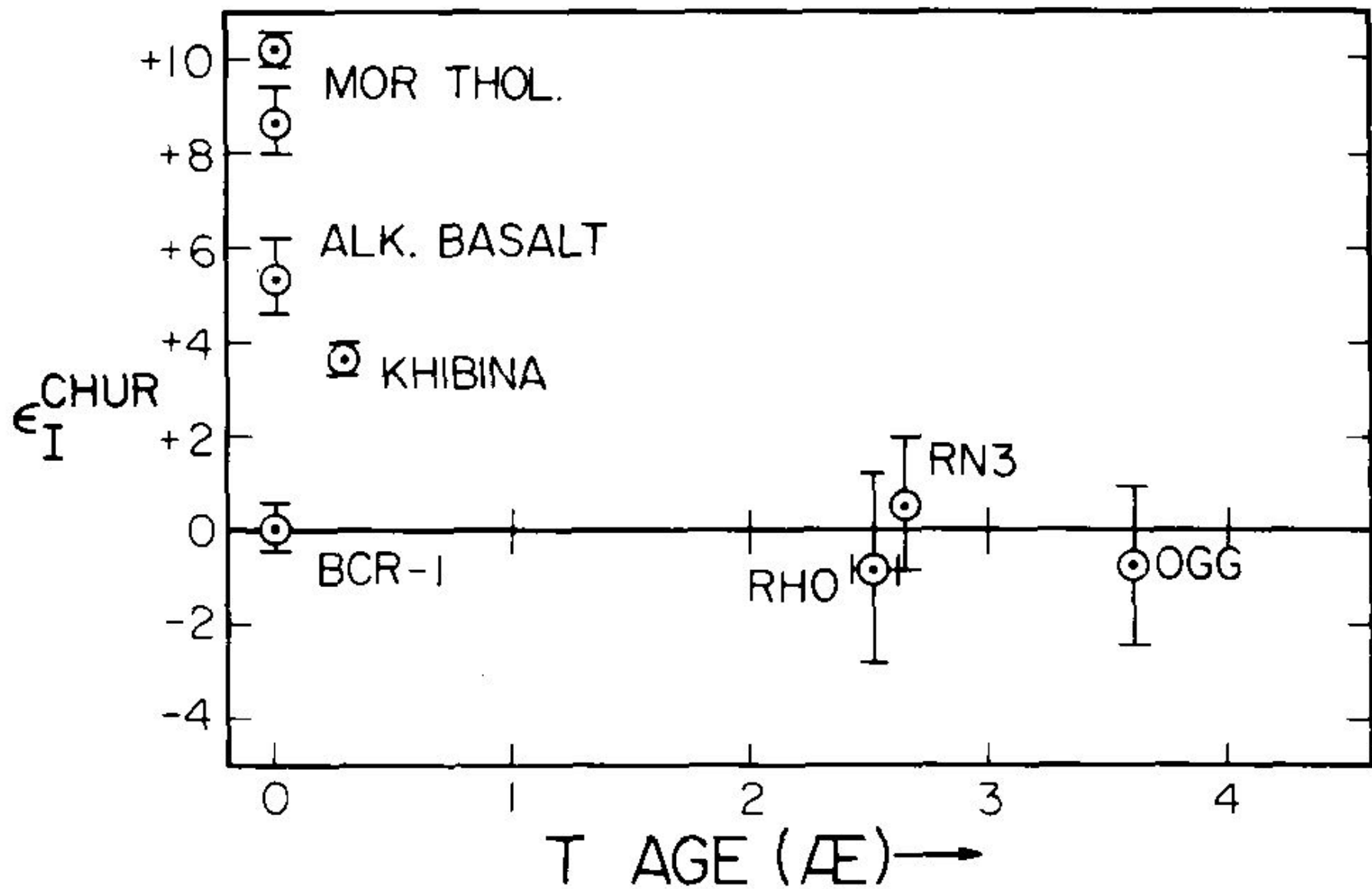
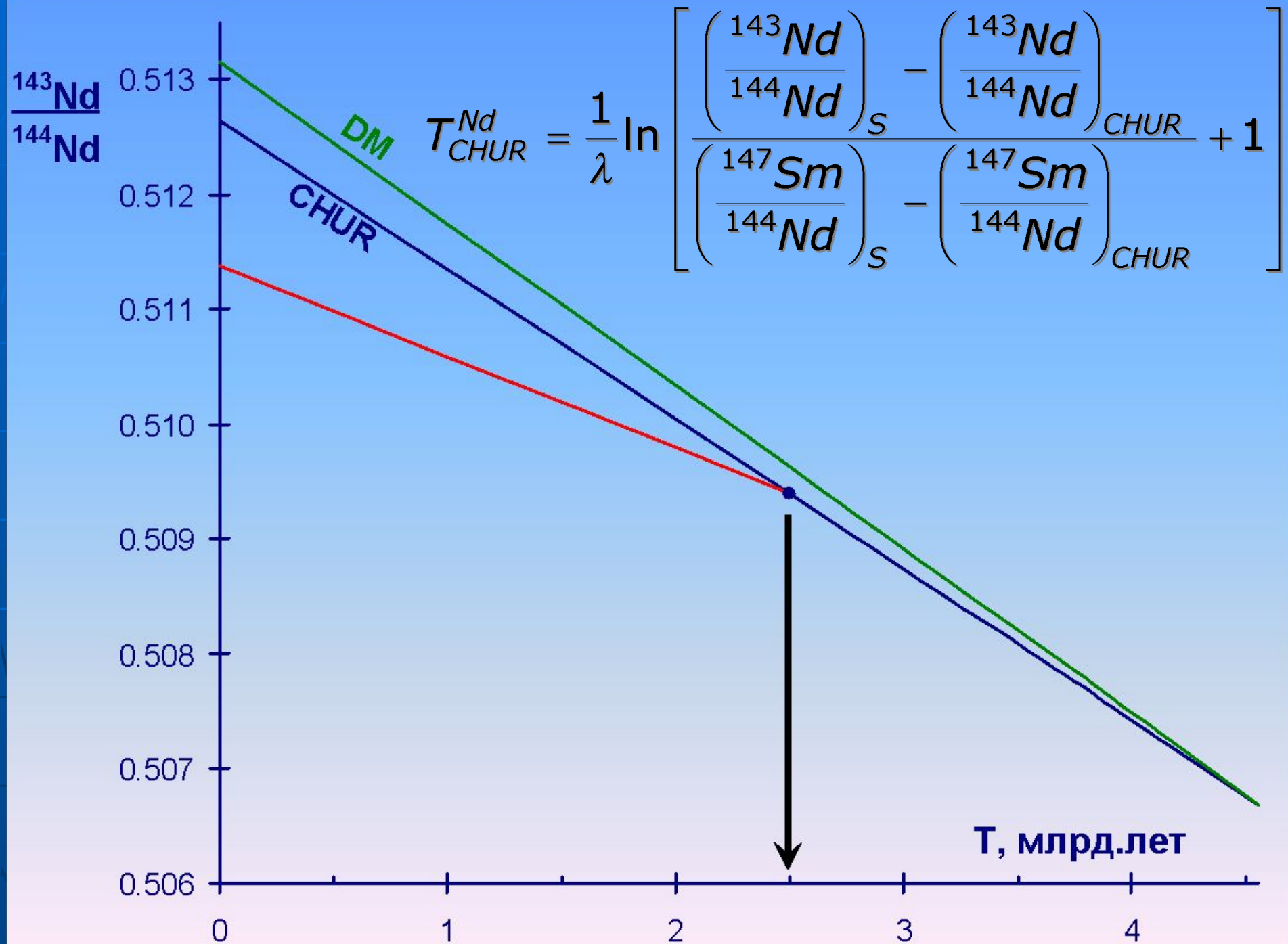


Fig. 3: Fractional deviations in parts in 10^4 of initial $^{143}\text{Nd}/^{144}\text{Nd}$ from evolution in a chondritic Sm/Nd reservoir (CHUR) vs. time.



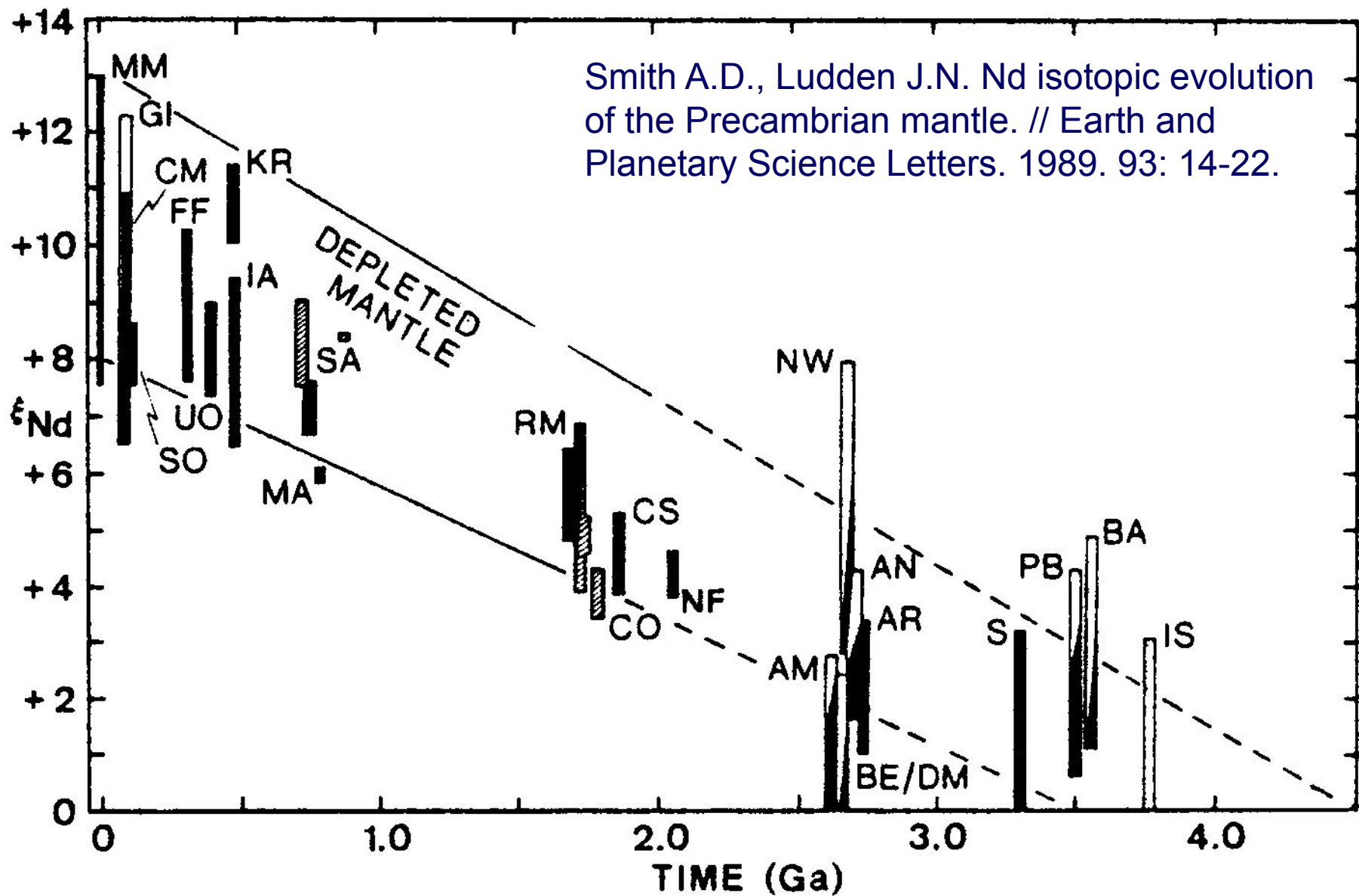
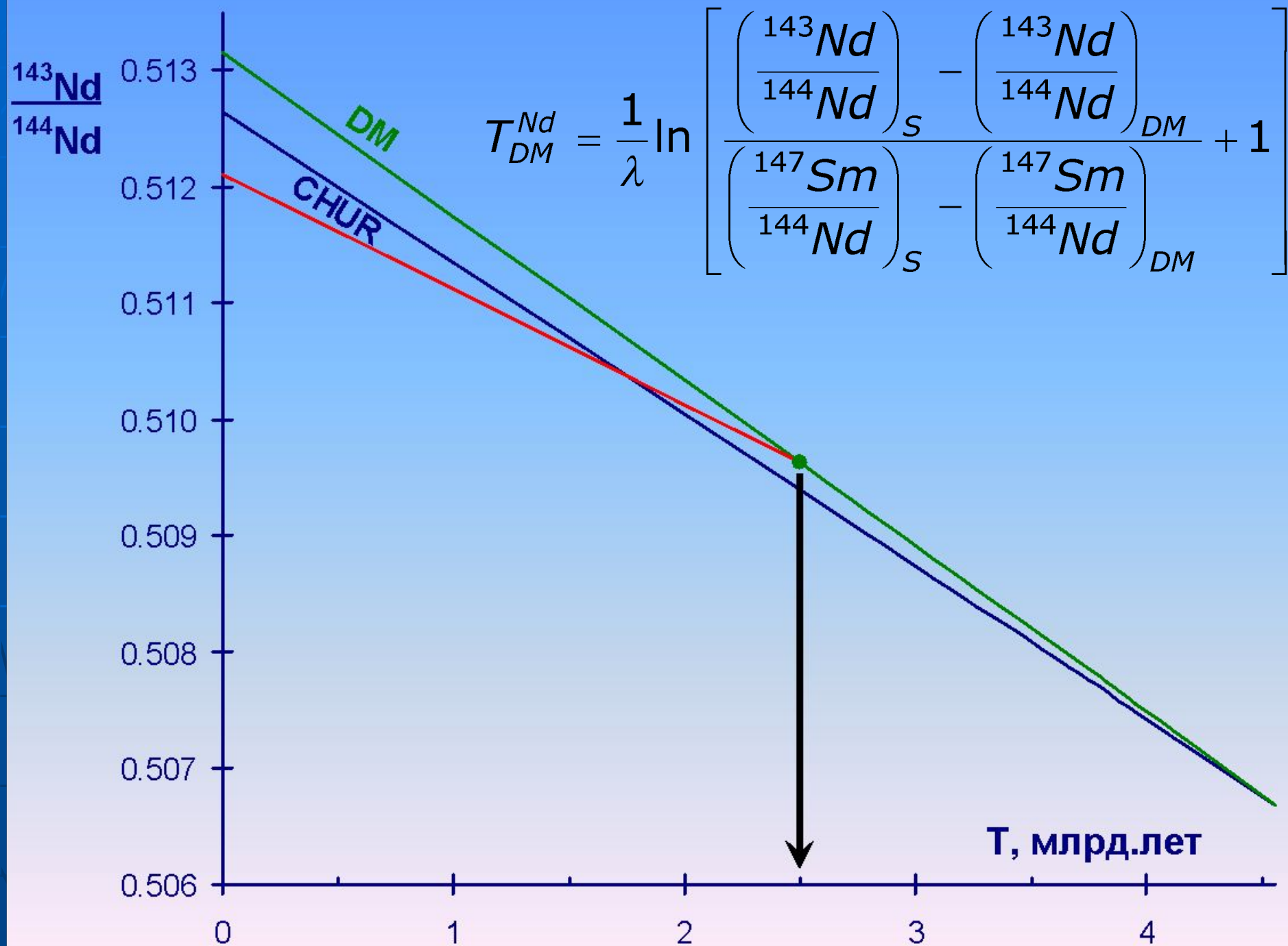
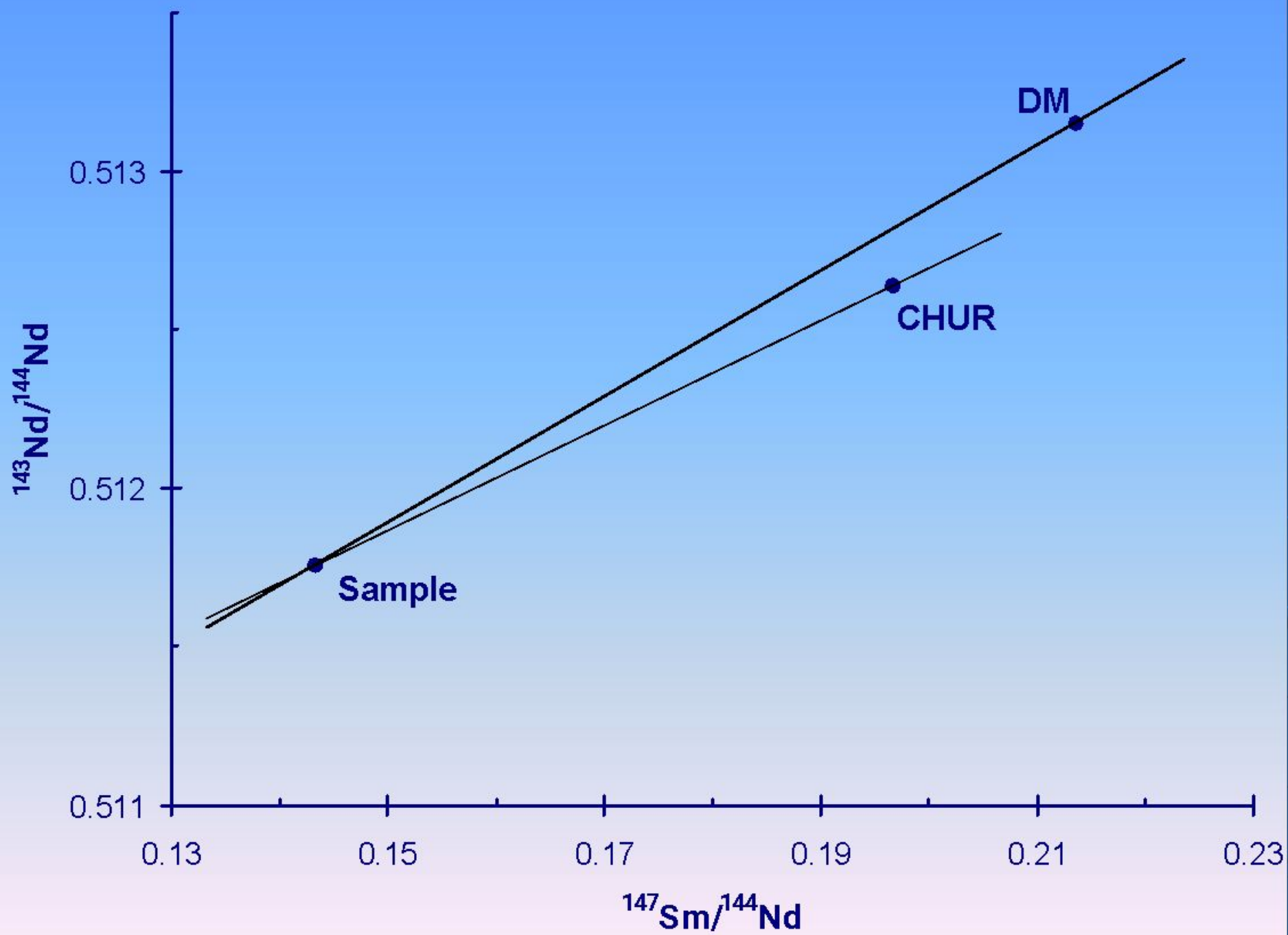
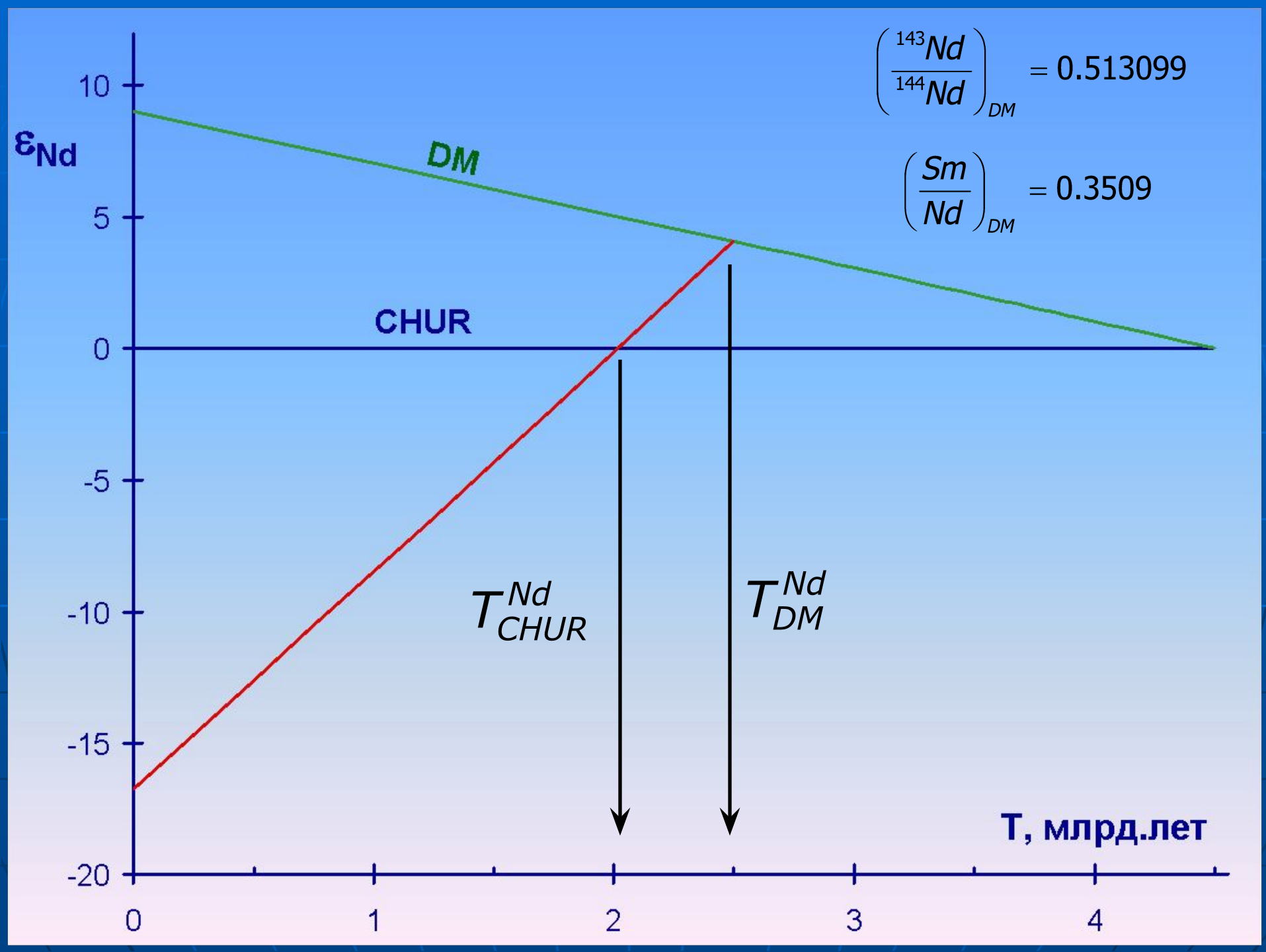


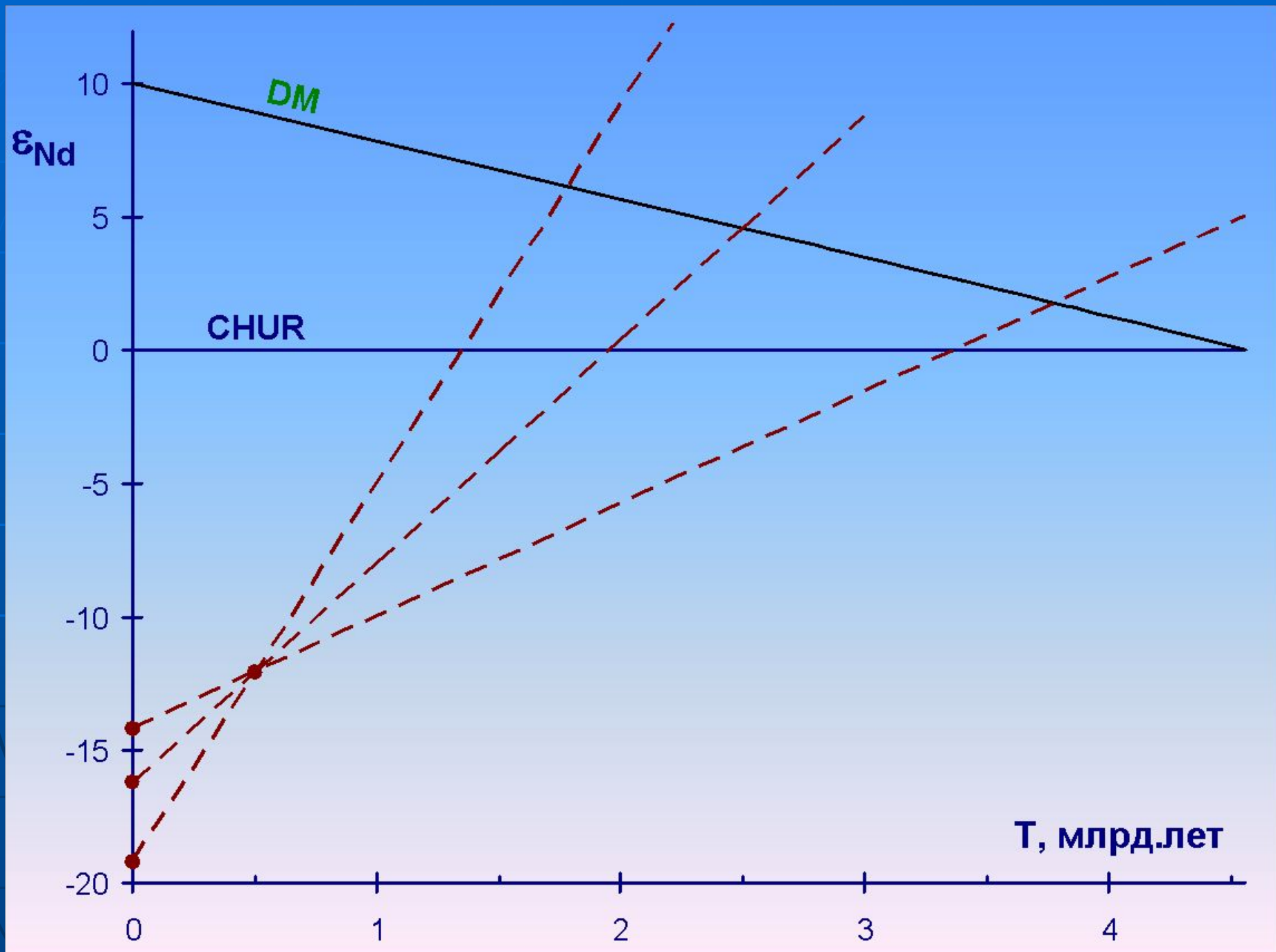
Fig. 3. Variation in ϵ_{Nd} with time for mantle-derived rocks (unshaded: komatiites; shaded: tholeiites; hatched: primitive island arc volcanics) and sediments (stippled).

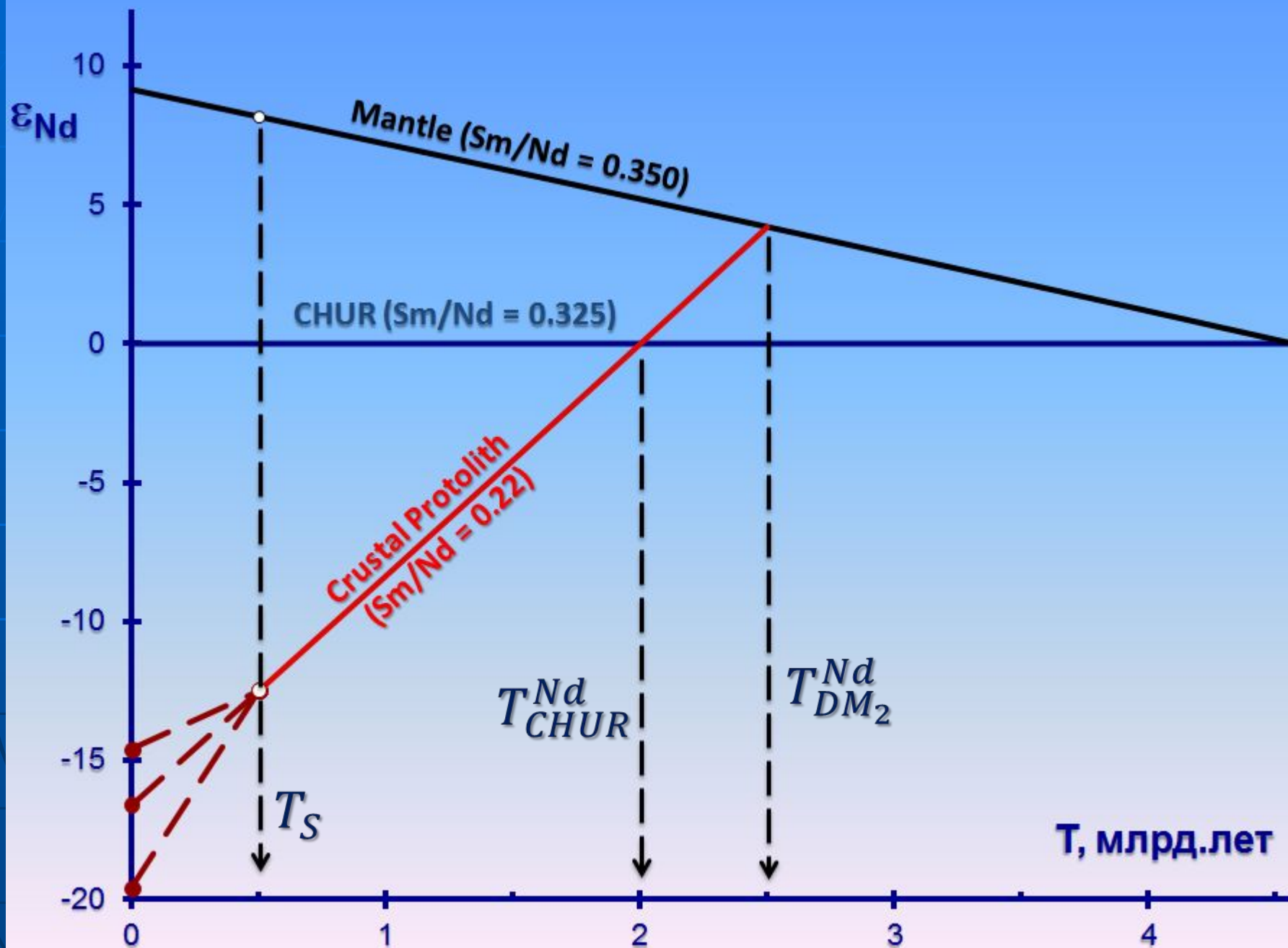
Fig. 3. Variation in ϵ_{Nd} with time for mantle-derived rocks (unshaded: komatiites; shaded: tholeiites; hatched: primitive island arc volcanics) and sediments (stippled). In order of increasing age: *MM* = modern MORB [17,18]; *GI* = Gorgona Island [19]; *CM* = Cretaceous MORB [20]; *SO* = Semail ophiolite [21]; *FF* = Fennel Formation [22]; *UO* = Urals ophiolite [23]; *KR* = Kings River ophiolite [24]; *IA* = Iapetus basalts [25,26]; *SA* = Saudi Arabian ophiolites and arcs [27–29]; *MA* = Matchless Amphibolite [30]; *RM* = Rocky Mountain greenstones [16]; *CO* = Colorado Front Range greenstones [15]; *CS* = Circum-Superior Belt ([8,12], this study); *NF* = Jouttiaapa Formation [14]; *DM/BE* = Belingwe [31] and Die-mals-Marda [32]; *AM* = Abitibi, Munro Township [33]; *AN* = Abitibi, Newton Township [12,34]; *AR* = Abitibi, Rainy Lake [35]; *NW* = Norseman-Wiluna [36–38]; *S* = Saglek [39]; *PB* = Pilbara [40,41]; *BA* = Barberton [42,43]; *IS* = Isua [1].

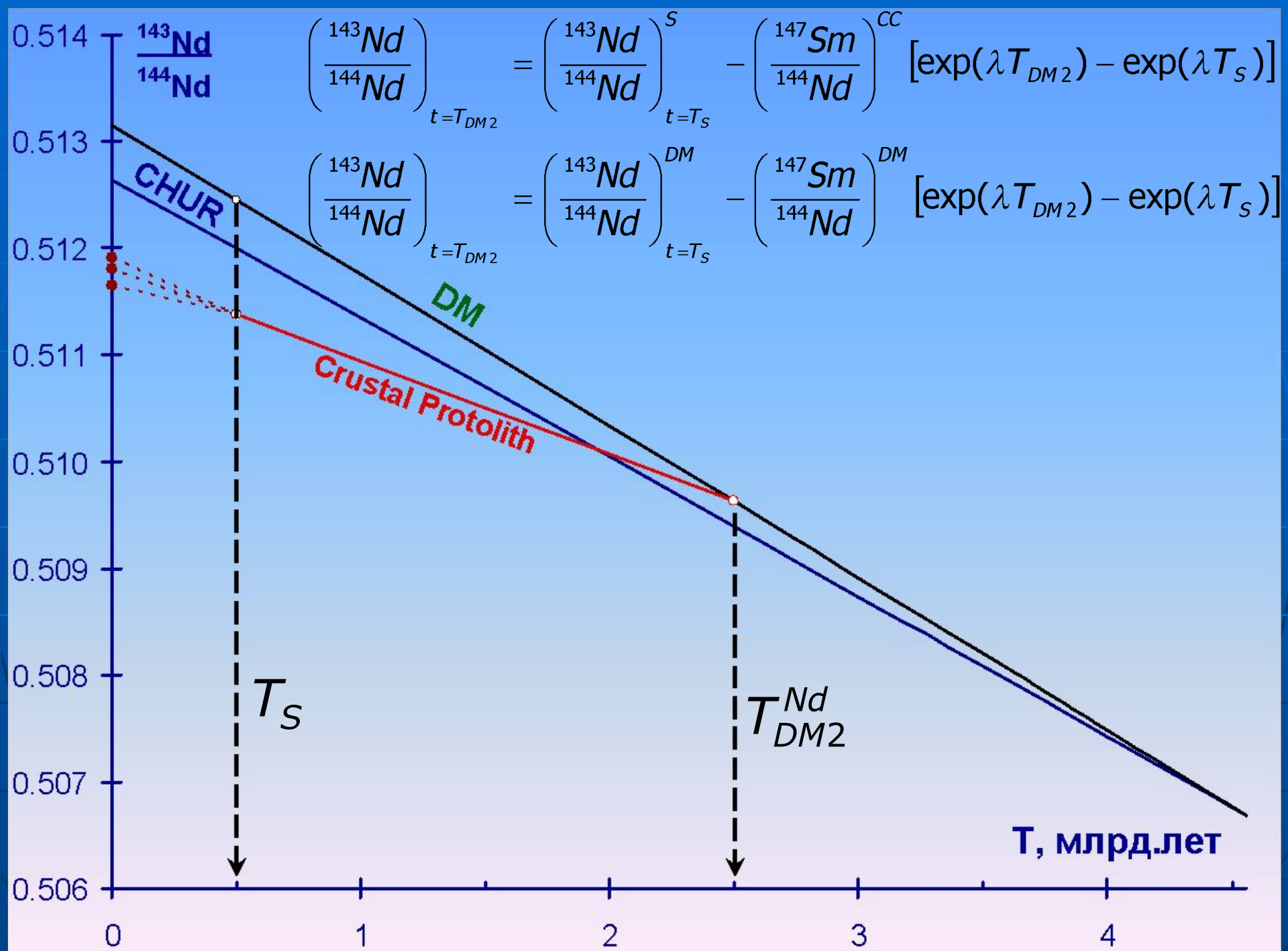












$$\frac{\left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=T_S}^{DM} - \left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=T_S}^S}{\left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=T_S}^{DM} - \left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=T_S}^{CC}} = [\exp(\lambda T_{DM2}) - \exp(\lambda T_S)]$$

$$T_{DM2}^{Nd} = \frac{1}{\lambda} \ln \left[\frac{\left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=T_S}^{DM} - \left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=T_S}^S}{\left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=T_S}^{DM} - \left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=T_S}^{CC}} + \exp(\lambda T_S) \right]$$

где

$$\left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=T_S}^{DM} = \left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=0}^{DM} - \left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=0}^{DM} [\exp(\lambda T_S) - 1]$$

$$\left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=T_S}^S = \left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=0}^S - \left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=0}^S [\exp(\lambda T_S) - 1]$$

$$T_{\text{DM2}}^{\text{Nd}} = \frac{1}{\lambda} \ln \left[\frac{\left(\frac{{}^{143}\text{Nd}}{{}^{144}\text{Nd}} \right)^{\text{DM}} + \left(\frac{{}^{147}\text{Sm}}{{}^{144}\text{Nd}} \right)^{\text{DM}} - \left(\frac{{}^{143}\text{Nd}}{{}^{144}\text{Nd}} \right)^{\text{S}} + \left(\frac{{}^{147}\text{Sm}}{{}^{144}\text{Nd}} \right)^{\text{S}} [\exp(\lambda T_{\text{S}}) - 1] - \left(\frac{{}^{147}\text{Sm}}{{}^{144}\text{Nd}} \right)^{\text{CC}} \cdot \exp(\lambda T_{\text{S}})}{\left(\frac{{}^{147}\text{Sm}}{{}^{144}\text{Nd}} \right)^{\text{DM}} - \left(\frac{{}^{147}\text{Sm}}{{}^{144}\text{Nd}} \right)^{\text{CC}}} \right]$$

$$\frac{\left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=T_S}^{\text{DM}} - \left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=T_S}^{\text{S}}}{\left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=T_S}^{\text{DM}} - \left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=T_S}^{\text{CC}}} \cong [\lambda T_{\text{DM2}} - \lambda T_S]$$

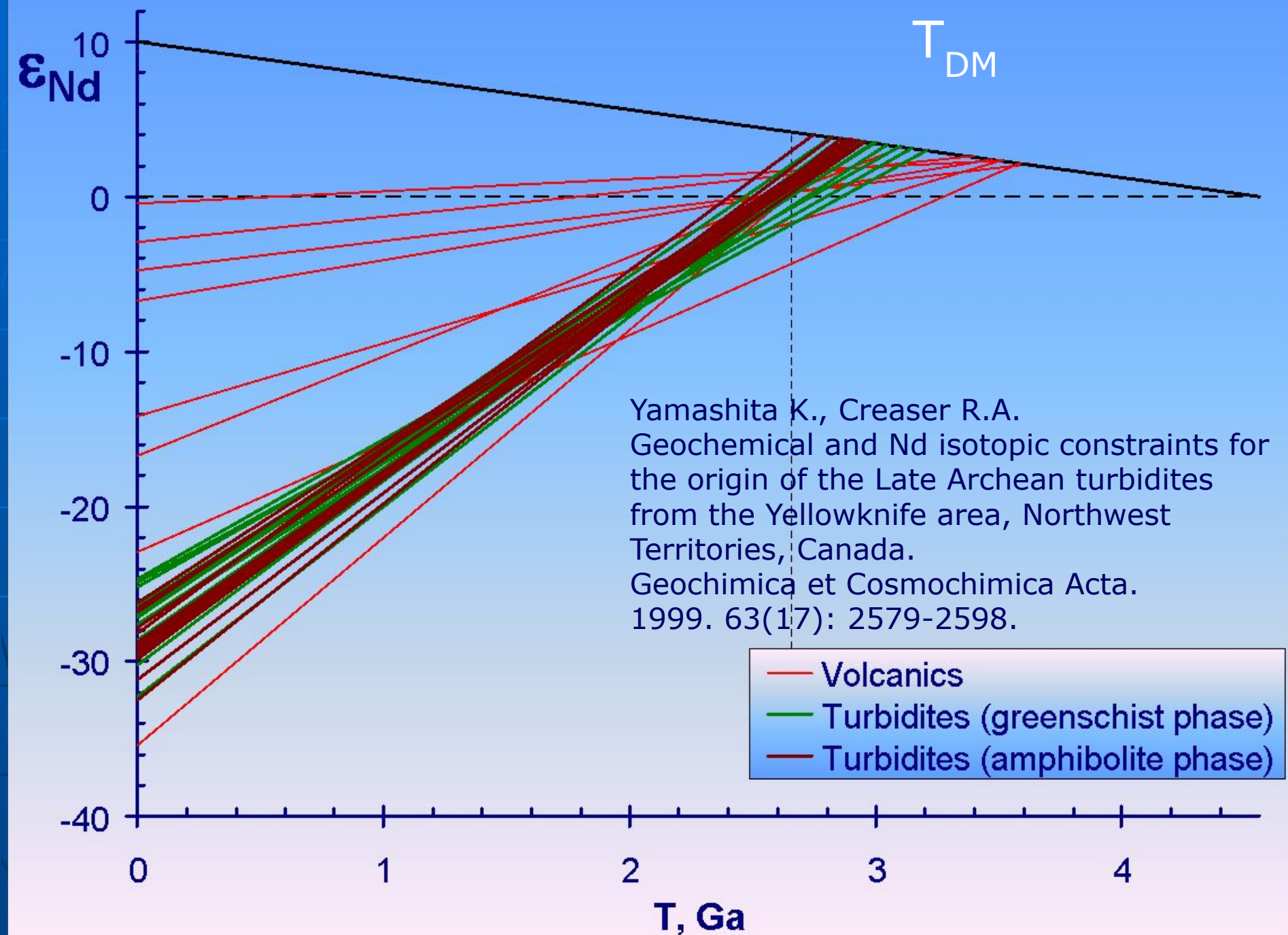
$$\exp(\lambda t) = 1 + \lambda t + \frac{(\lambda t)^2}{2!} + \frac{(\lambda t)^3}{3!} + \dots$$

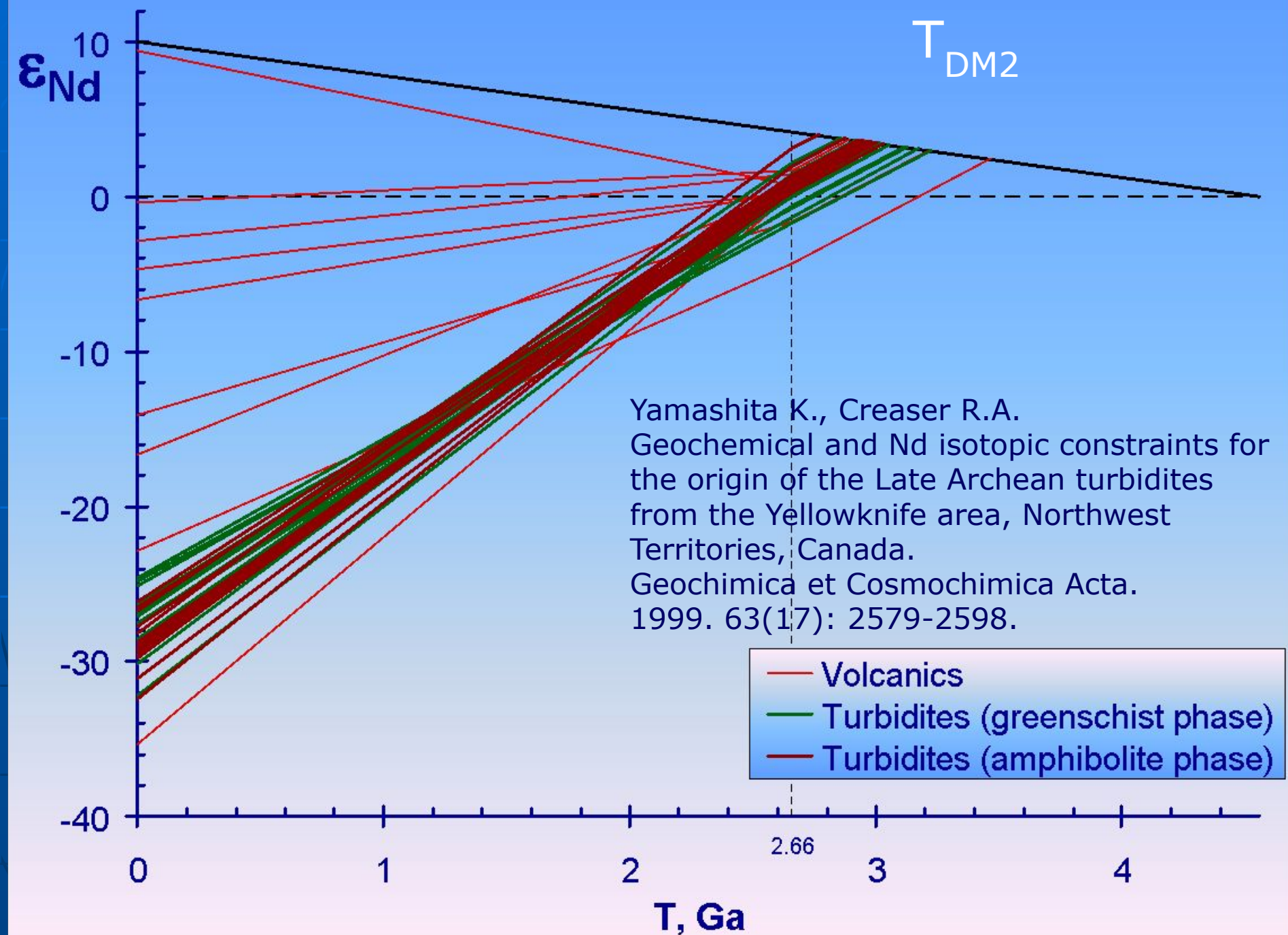
$$\text{если } \lambda t \ll 1,$$

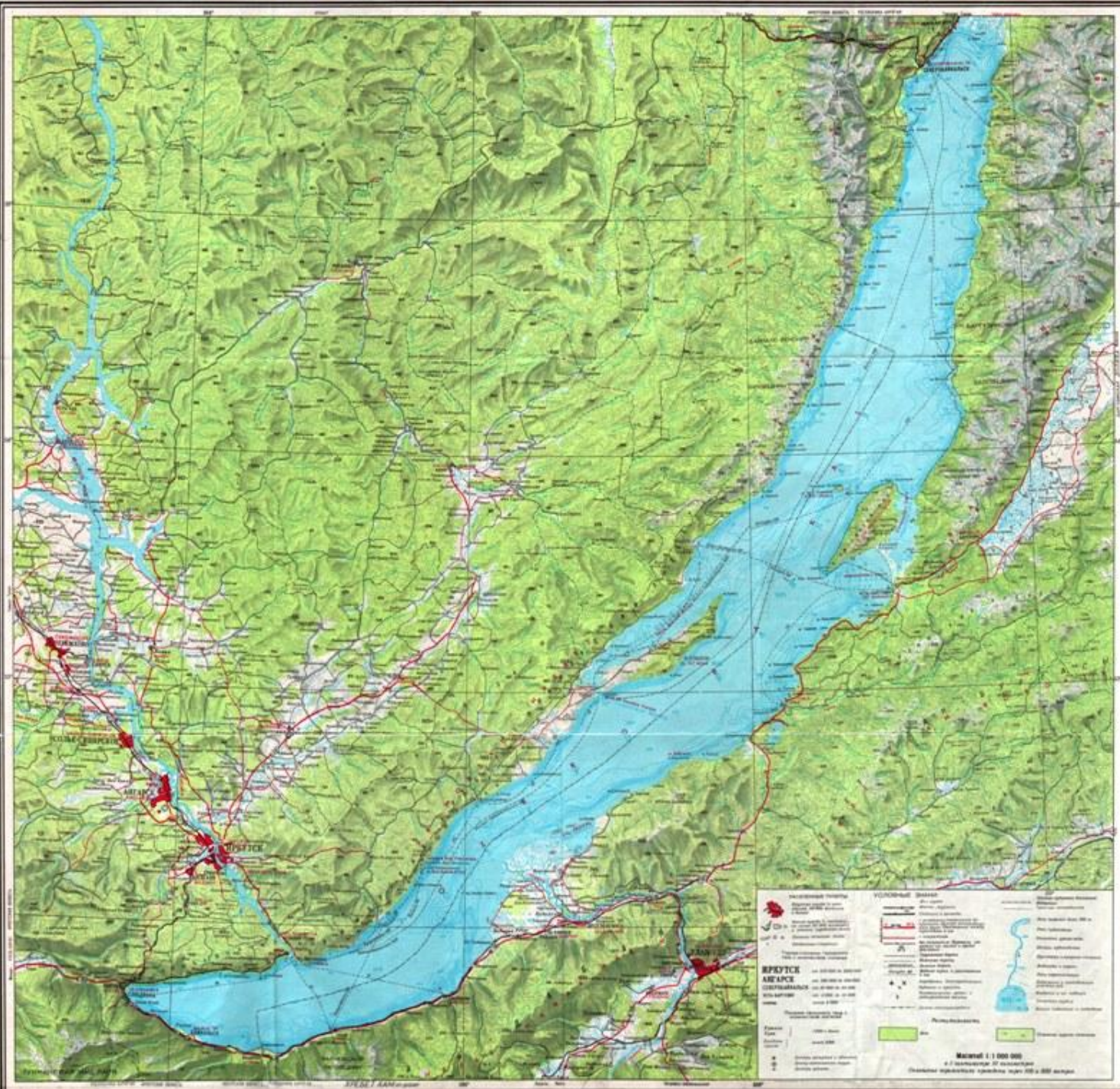
$$D_{\text{rad}} \cong N \lambda t$$

$$T_{\text{DM2}}^{\text{Nd}} \cong T_S + \frac{1}{\lambda} \cdot \frac{\left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=T_S}^{\text{DM}} - \left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=T_S}^{\text{S}}}{\left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=T_S}^{\text{DM}} - \left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=T_S}^{\text{CC}}}$$

$$T_{\text{DM2}}^{\text{Nd}} \cong T_S + \frac{1}{\lambda} \cdot \frac{\left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=0}^{\text{DM}} - \left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{t=0}^{\text{S}} - \left[\left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=0}^{\text{DM}} - \left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=0}^{\text{S}} \right] \lambda T_S}{\left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=0}^{\text{DM}} - \left(\frac{^{147}\text{Sm}}{^{144}\text{Nd}}\right)_{t=0}^{\text{CC}}}$$







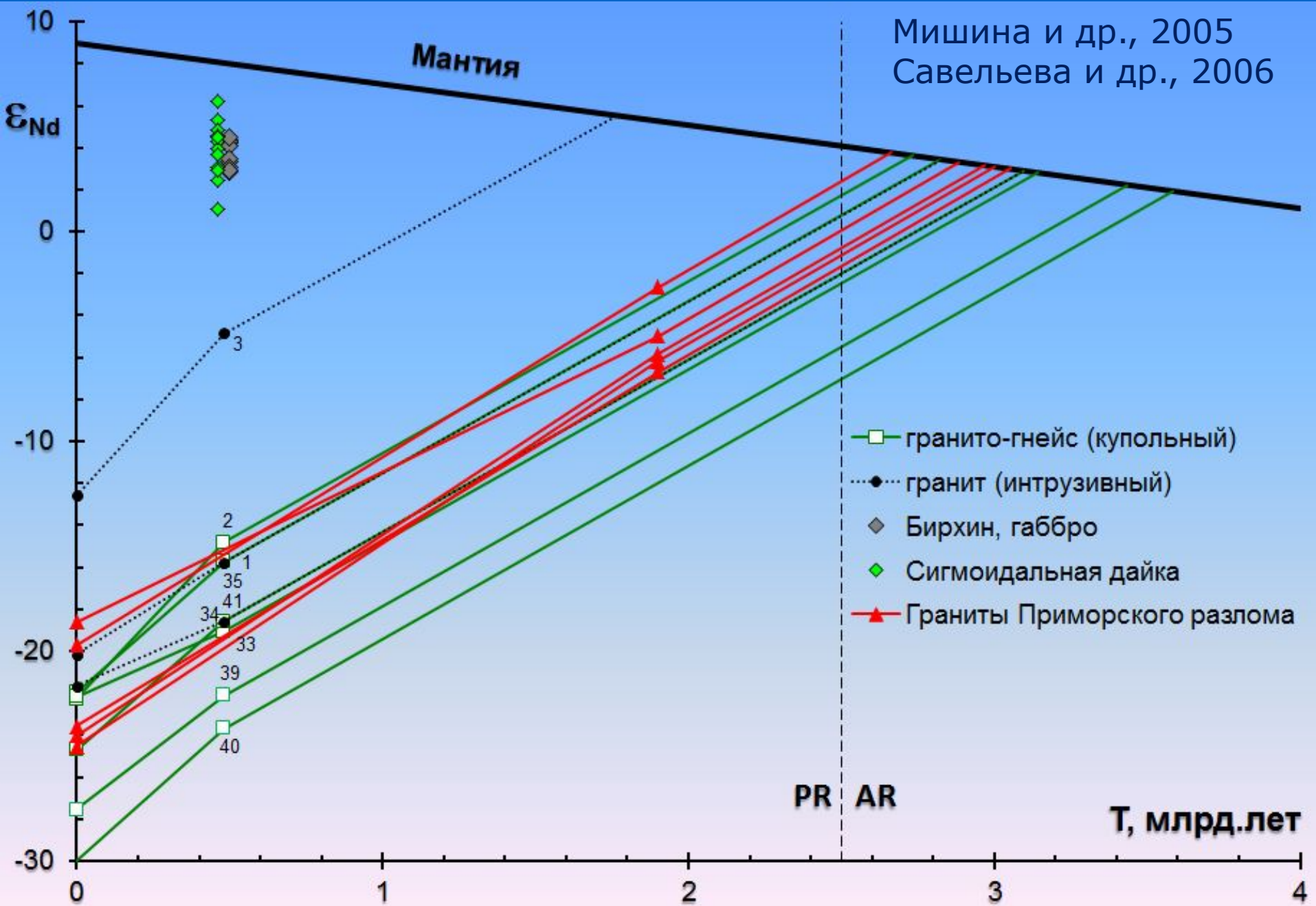
ГЕОЛОГИЧЕСКАЯ КАРТА

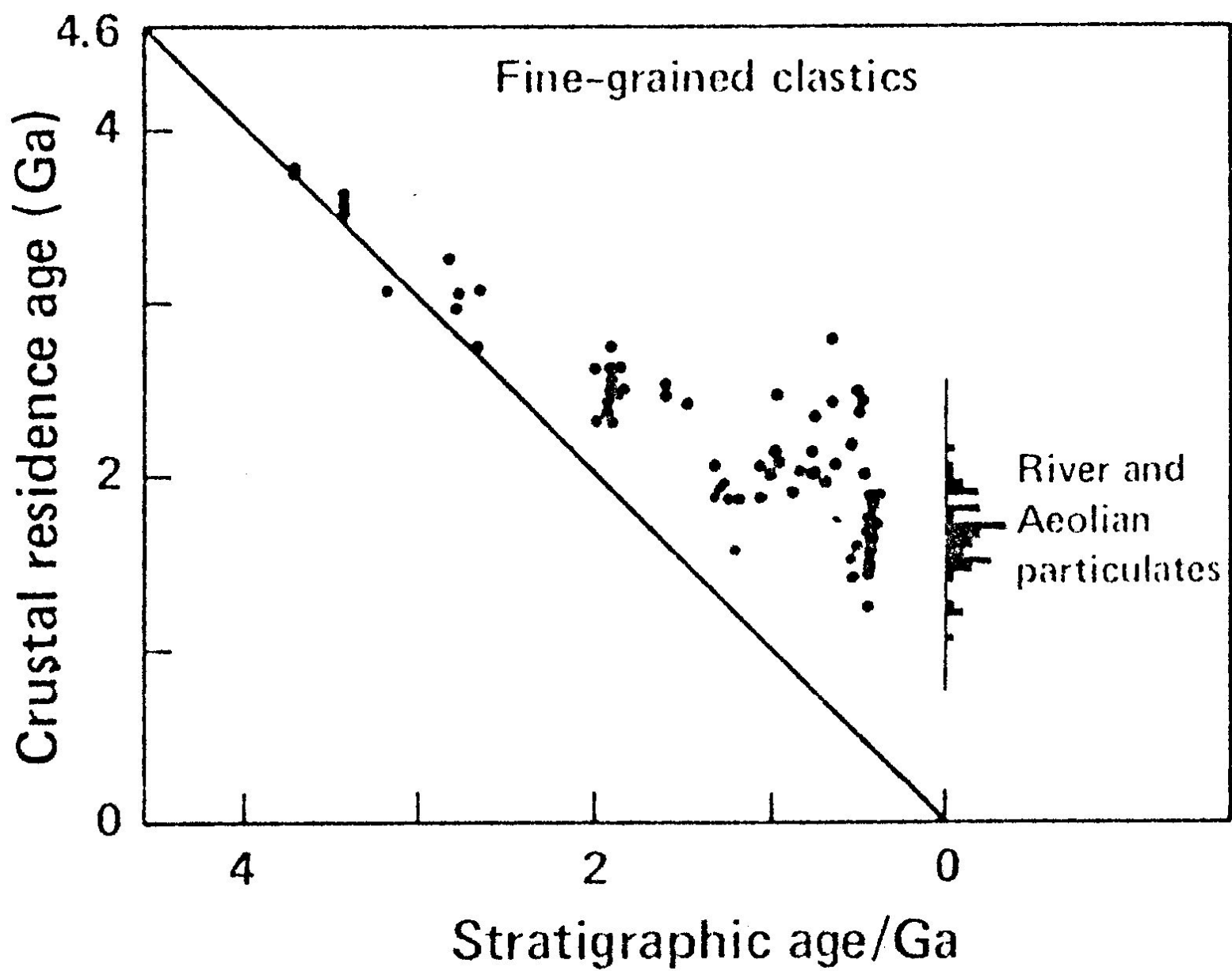
юго-западной части
Ольхонского региона



Составил В.С.Федоровский
ГИН РАН, Москва
2004







Model age versus depositional age
for sediments worldwide (O'Nions 1984)

Задача 13. Вычислить T_{DM} и T_{DM2}

Sample	Sm/Nd	$^{143}\text{Nd}/^{144}\text{Nd}$	Age
1	0.1467	0.512030	1.00
2	0.1500	0.512014	1.02
3	0.1533	0.511999	1.04
4	0.1566	0.511984	1.06
5	0.1599	0.511969	1.08
6	0.1633	0.511955	1.10
7	0.1666	0.511942	1.12
8	0.1699	0.511929	1.14
9	0.1732	0.511916	1.16
10	0.1765	0.511904	1.18
...	...	...	...
31	0.2460	0.511774	1.60
32	0.2493	0.511774	1.62
33	0.2526	0.511774	1.64
34	0.2559	0.511774	1.66

DM:

$$\epsilon_{\text{Nd}}(0) = +9$$

$$\epsilon_{\text{Nd}}(4.56) = 0$$

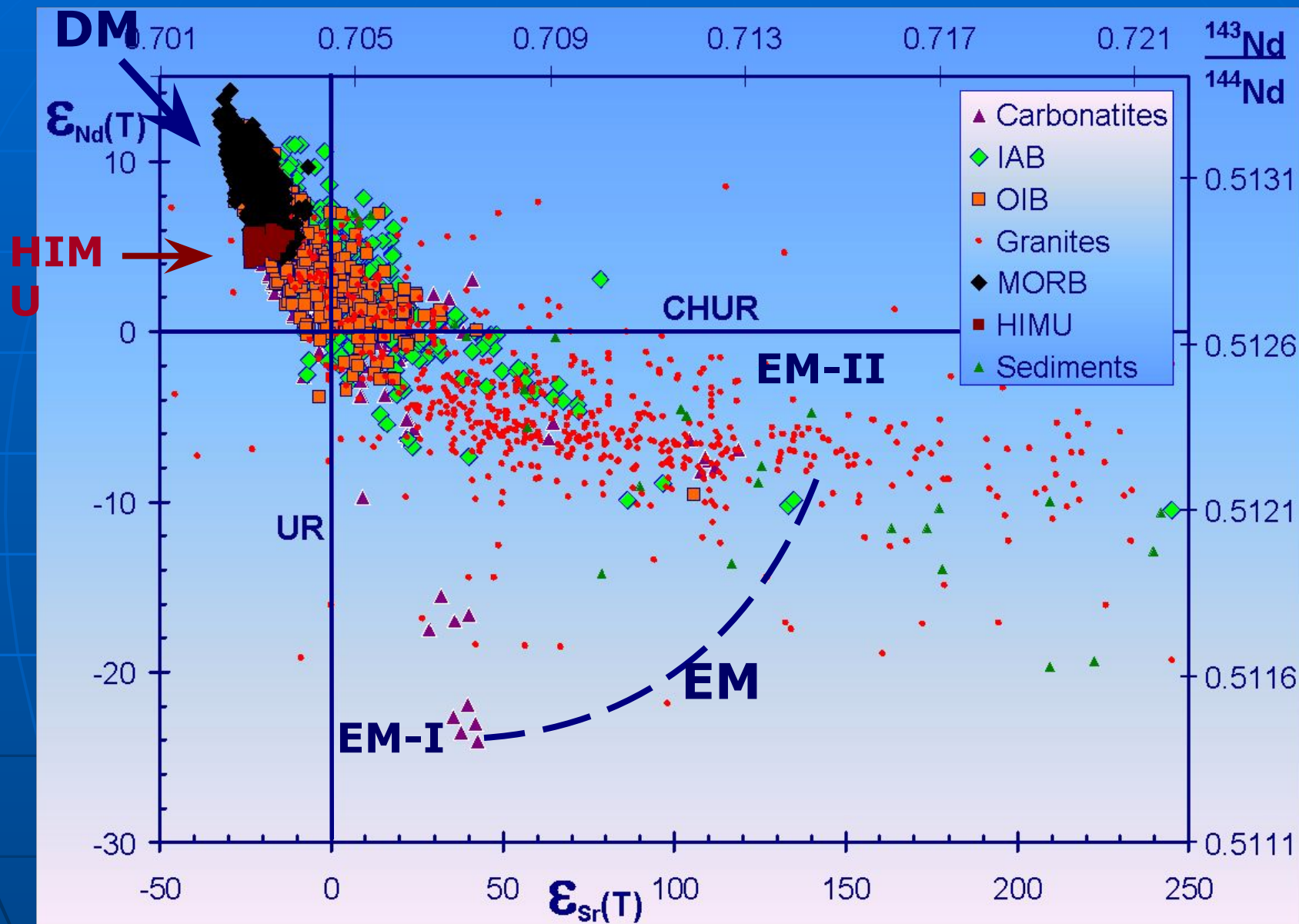
Cont.Crust:

$$[\text{Sm}] = 3.5 \text{ ppm}$$

$$[\text{Nd}] = 16.0 \text{ ppm}$$

Остальные варианты
в файле Ex13.xlsx на
сайте wiki.web.ru

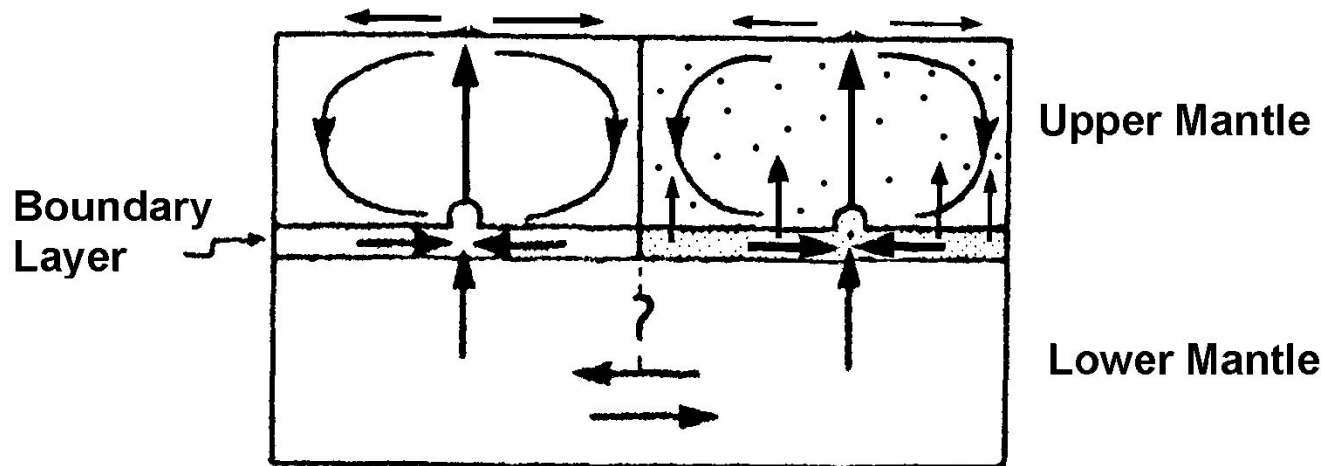
Проблема баланса кора-мантия



North Atlantic
and
East Pacific

Hamelin & Allègre, 1985

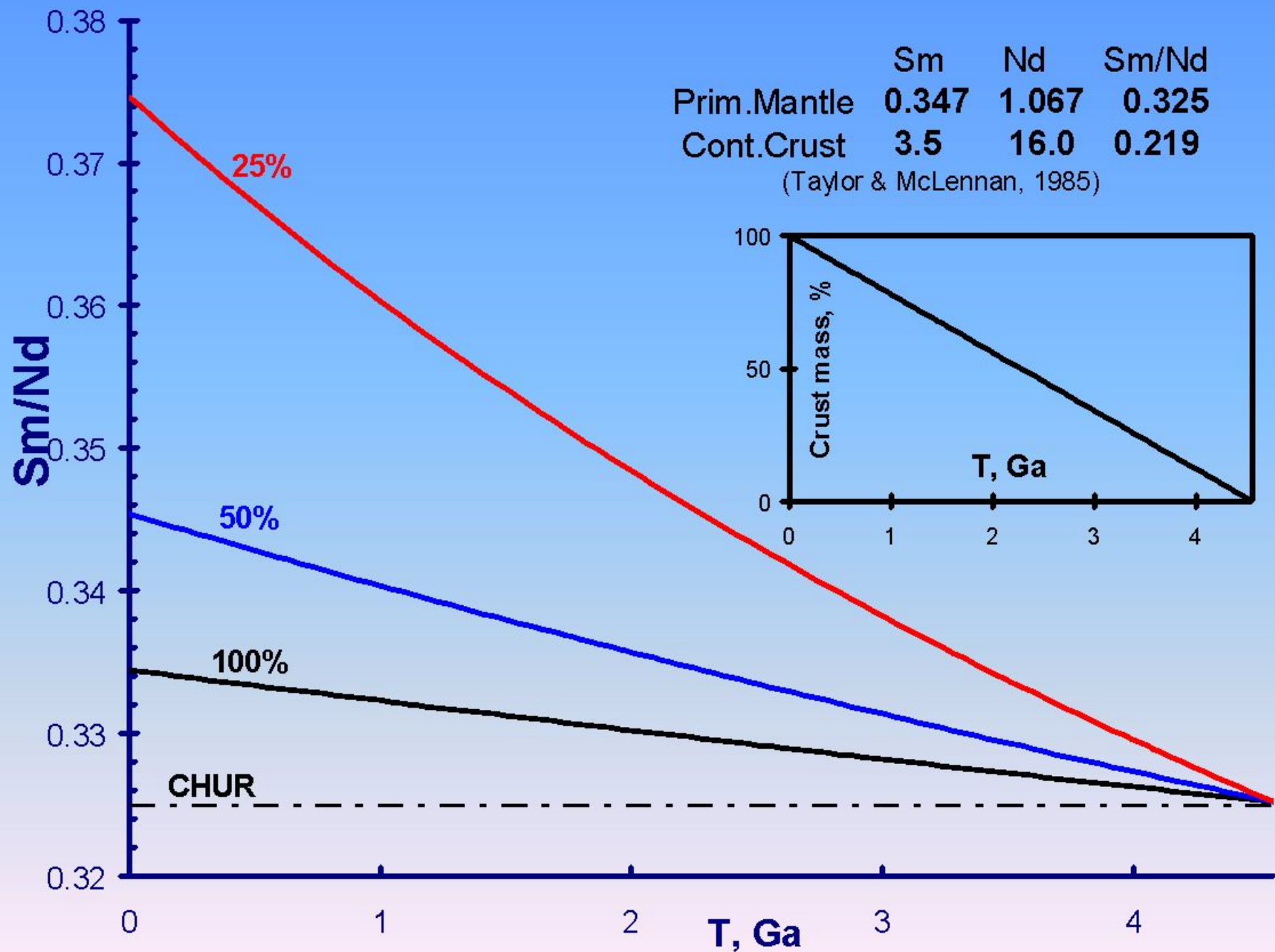
Indian Ocean

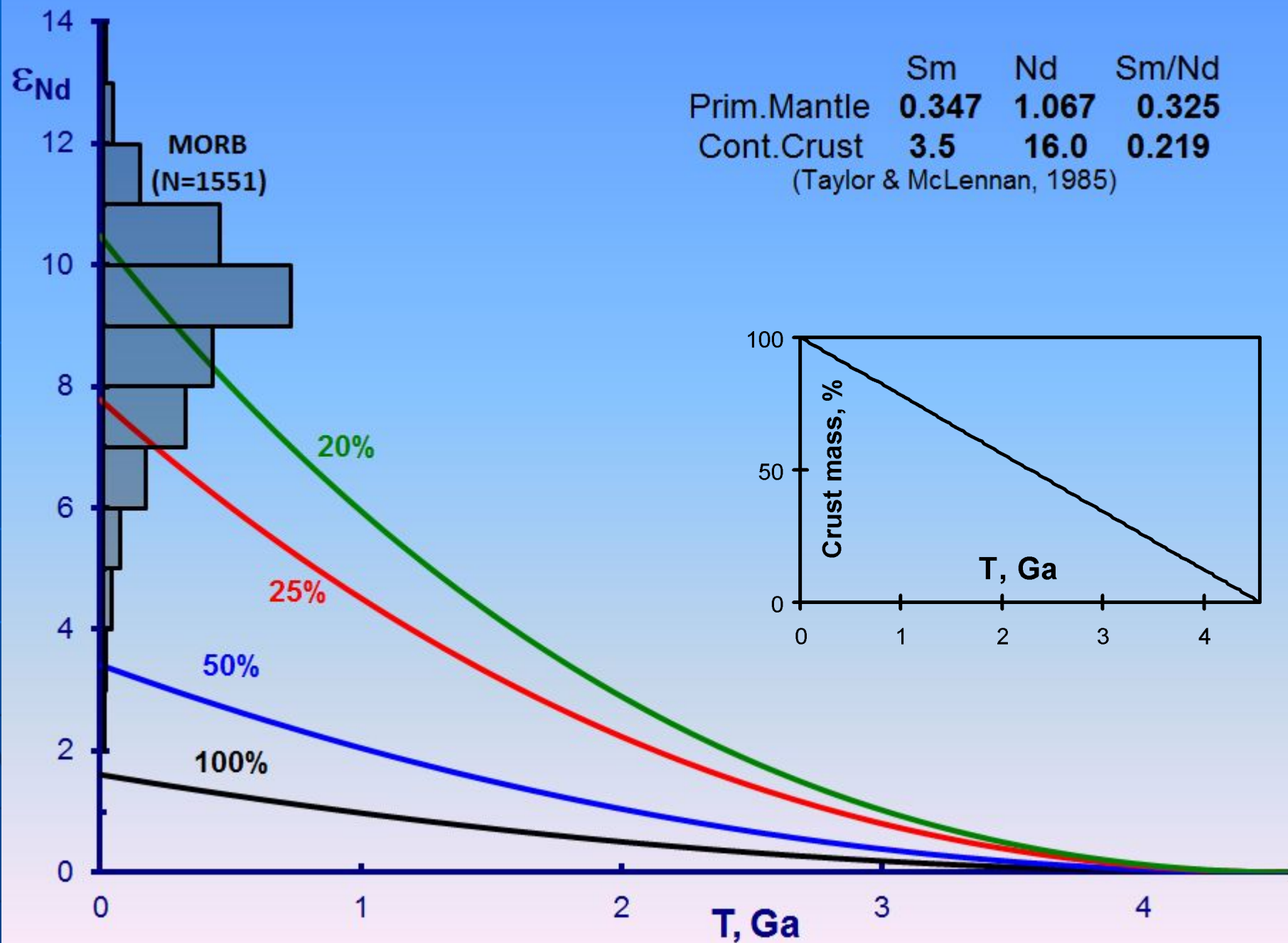


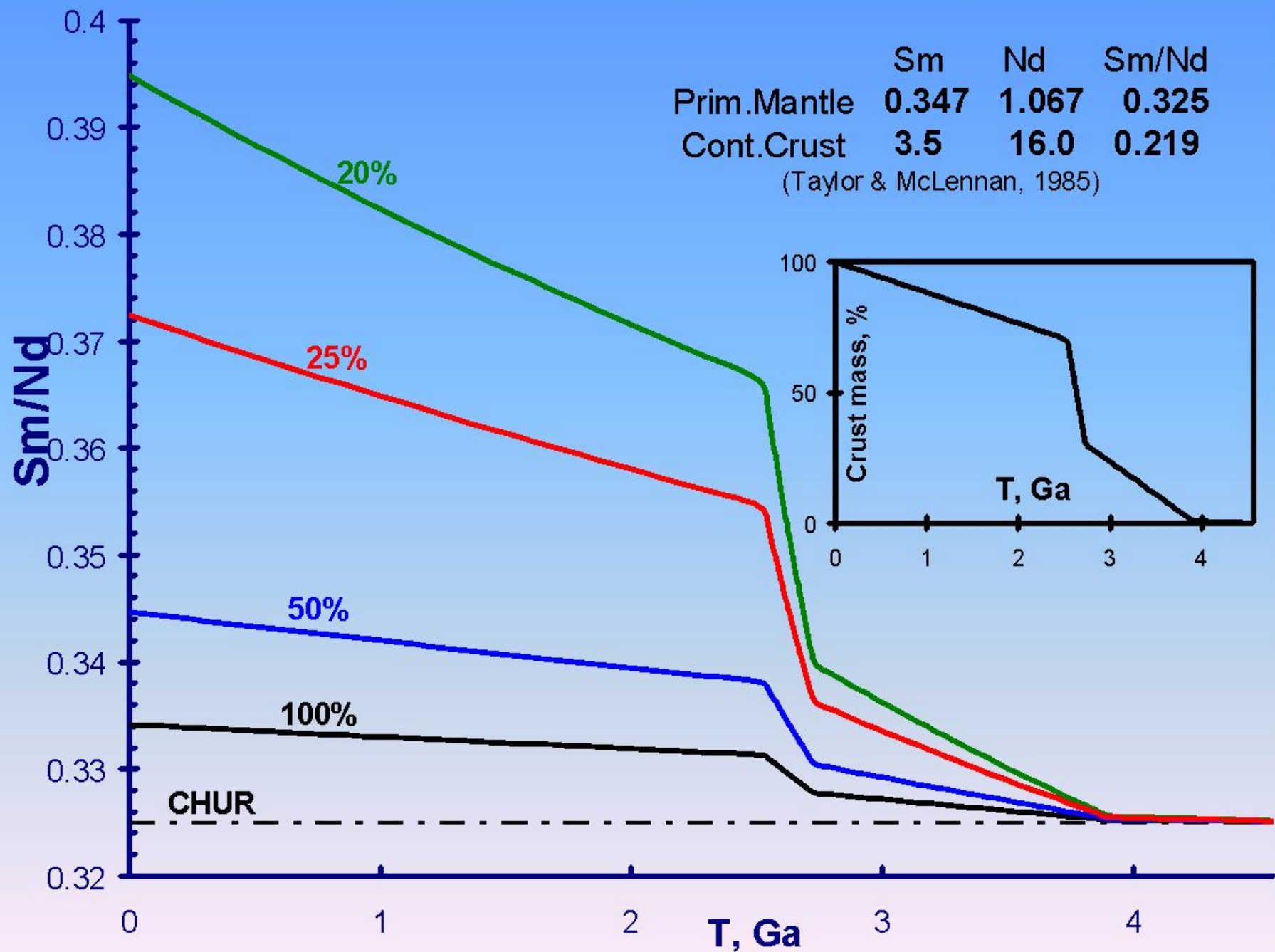
BOX MODEL OF MANTLE CIRCULATION

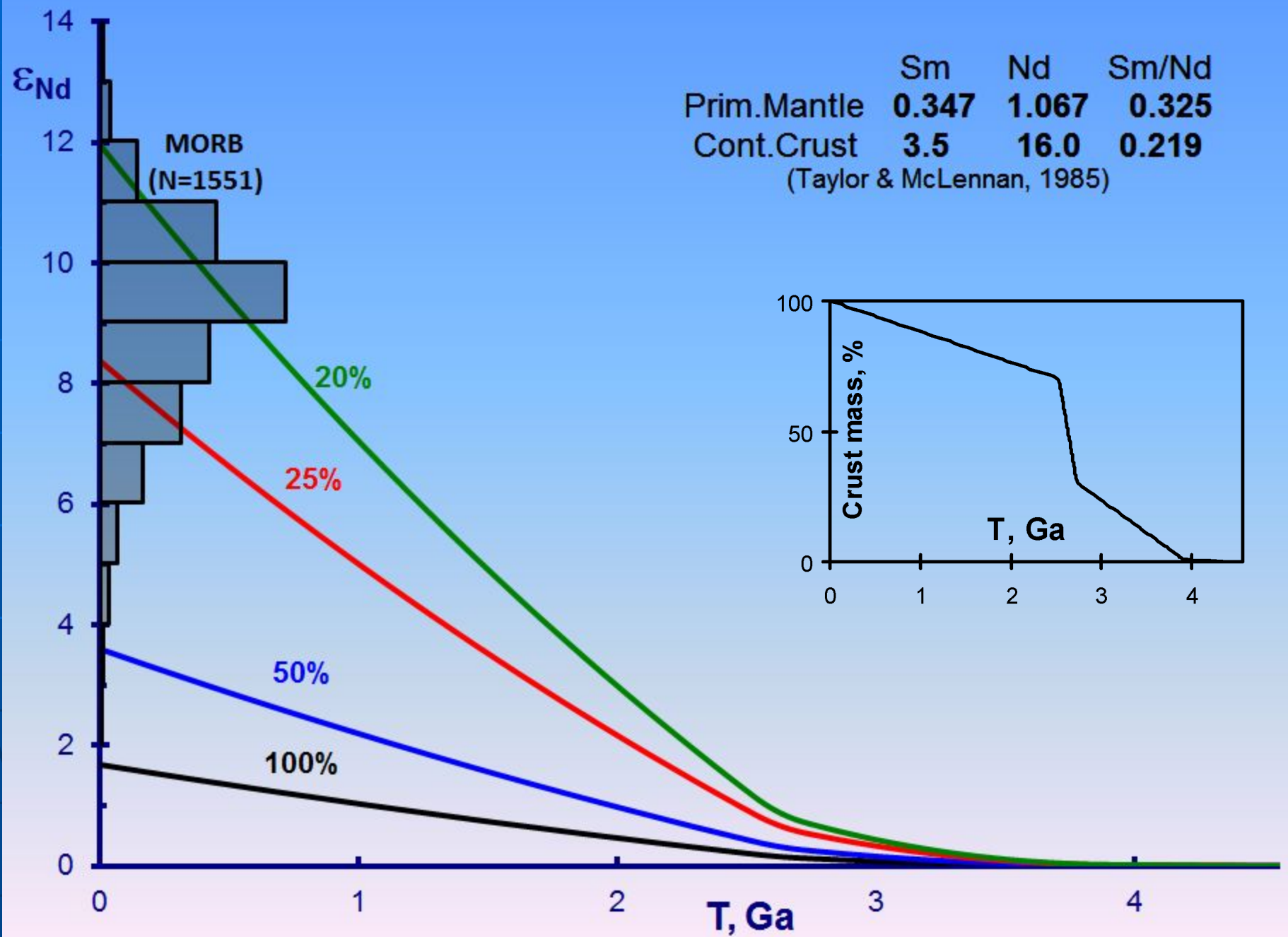
Fig. 5 Possible scheme of mantle dynamics. The upper mantle is divided in different discontinuous boxes, according to the SWIR MORB isotope results. The model where ocean island basalts originate in the boundary layer between upper and lower mantle³⁸ is illustrated as an example. Since the Indian Ocean island basalt source material (dotted area) is different from other parts of the world, the sub-Indian upper mantle is contaminated specifically by these Indian blobs, some of which reach the surface and others becoming progressively mixed within the upper mantle convection cell.











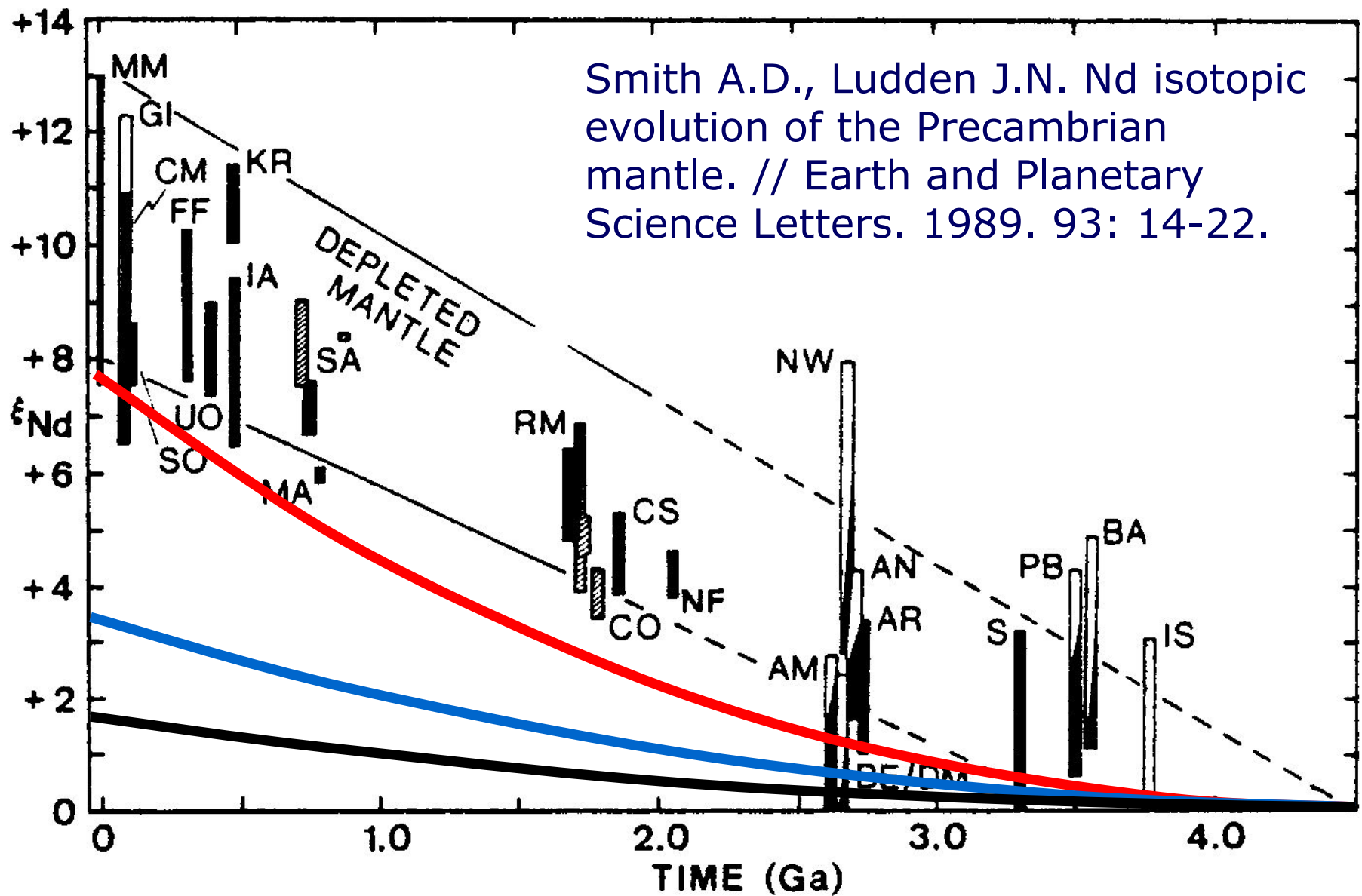
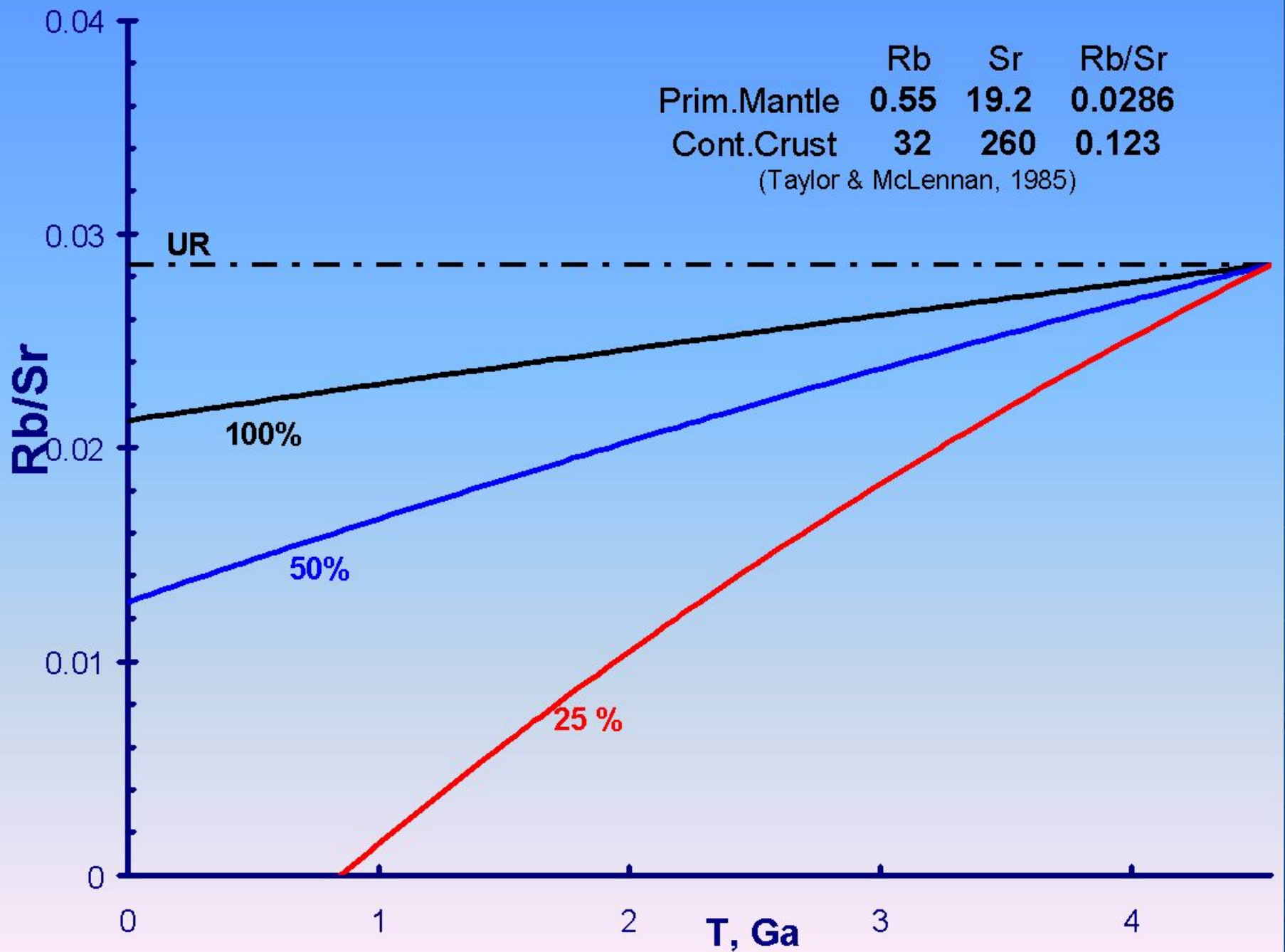
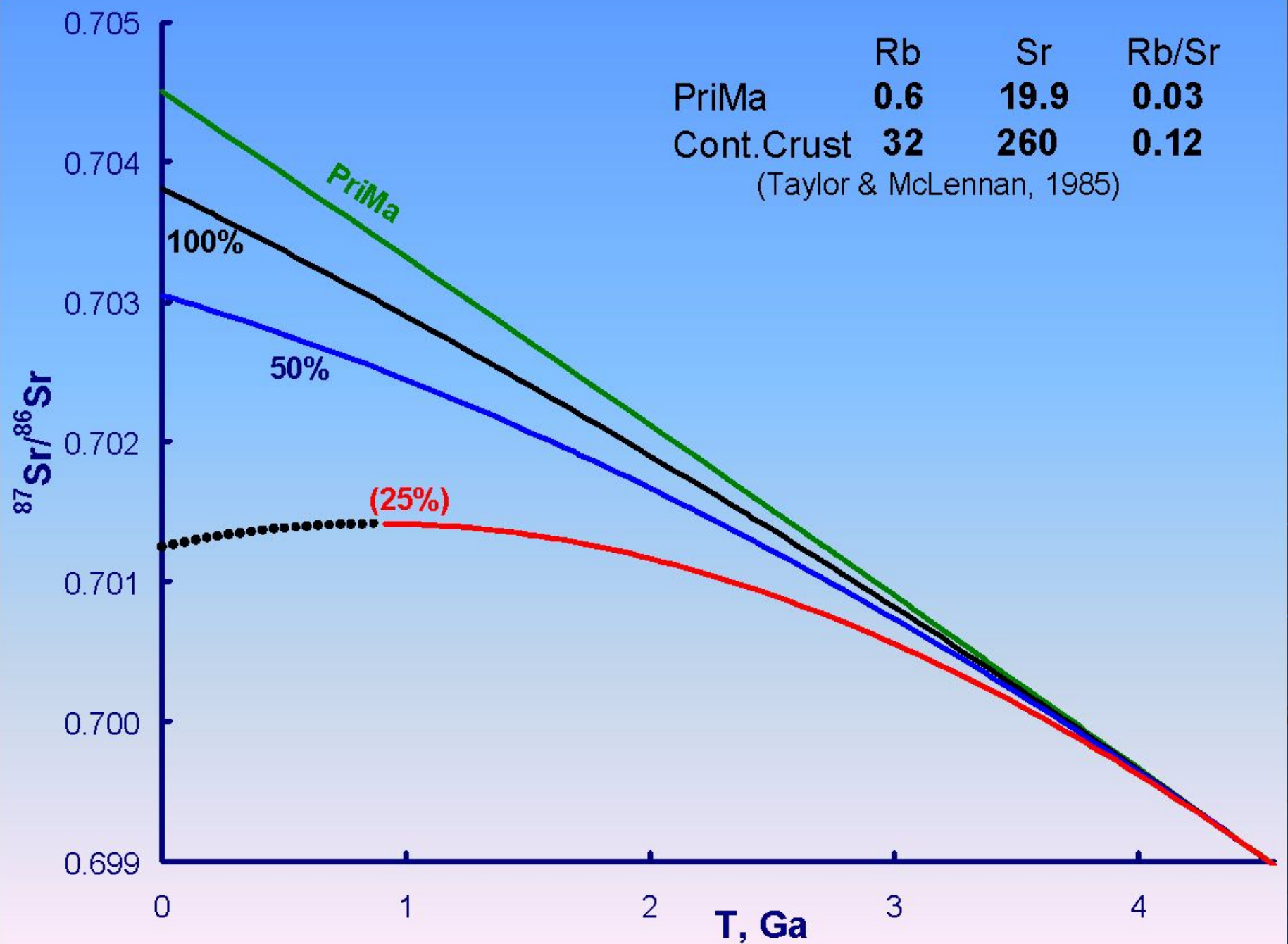


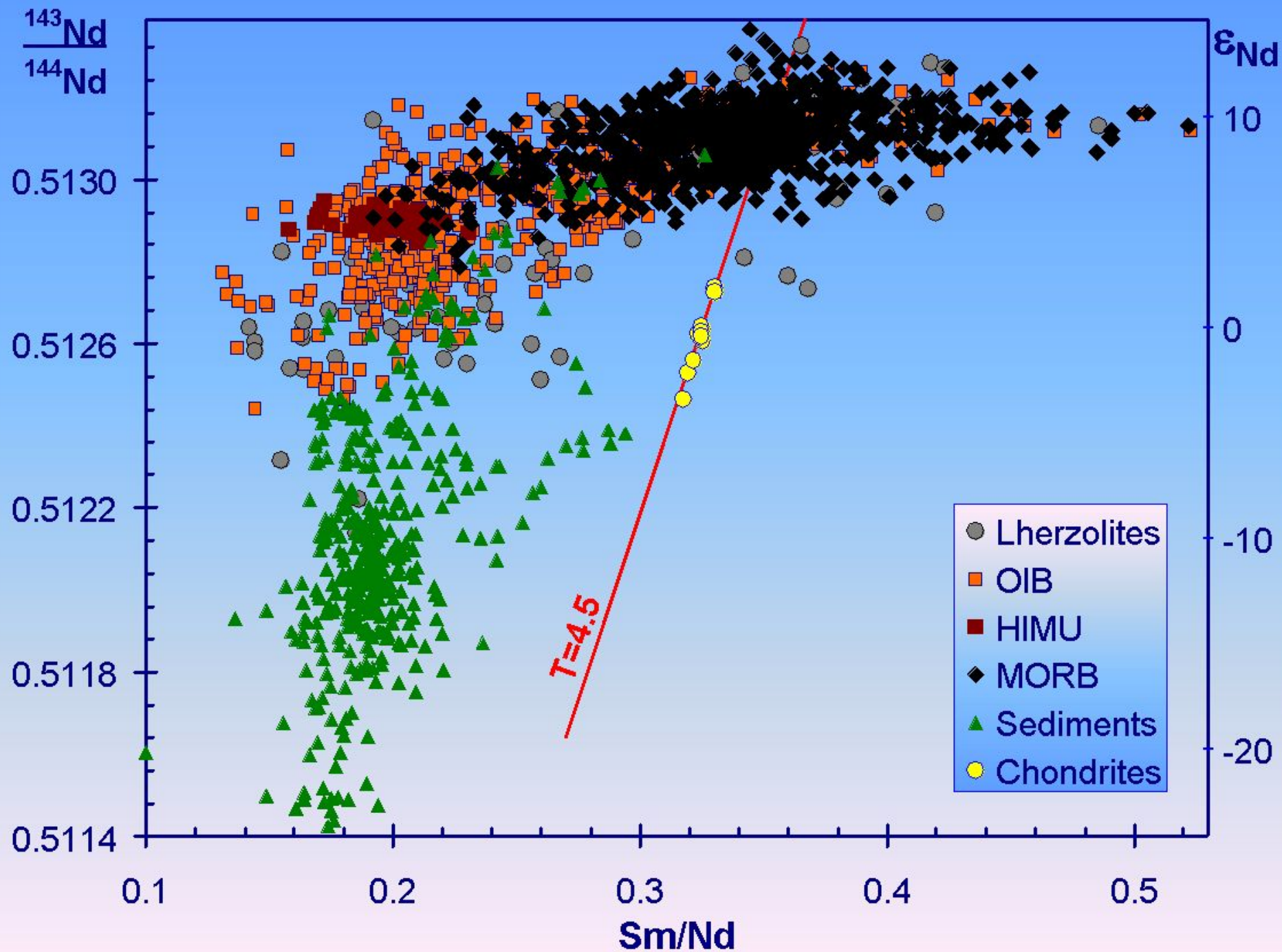
Fig. 3. Variation in ϵ_{Nd} with time for mantle-derived rocks (unshaded: komatiites; shaded: tholeiites; hatched: primitive island arc volcanics) and sediments (stippled).

	Rb	Sr	Rb/Sr
Prim.Mantle	0.55	19.2	0.0286
Cont.Crust	32	260	0.123

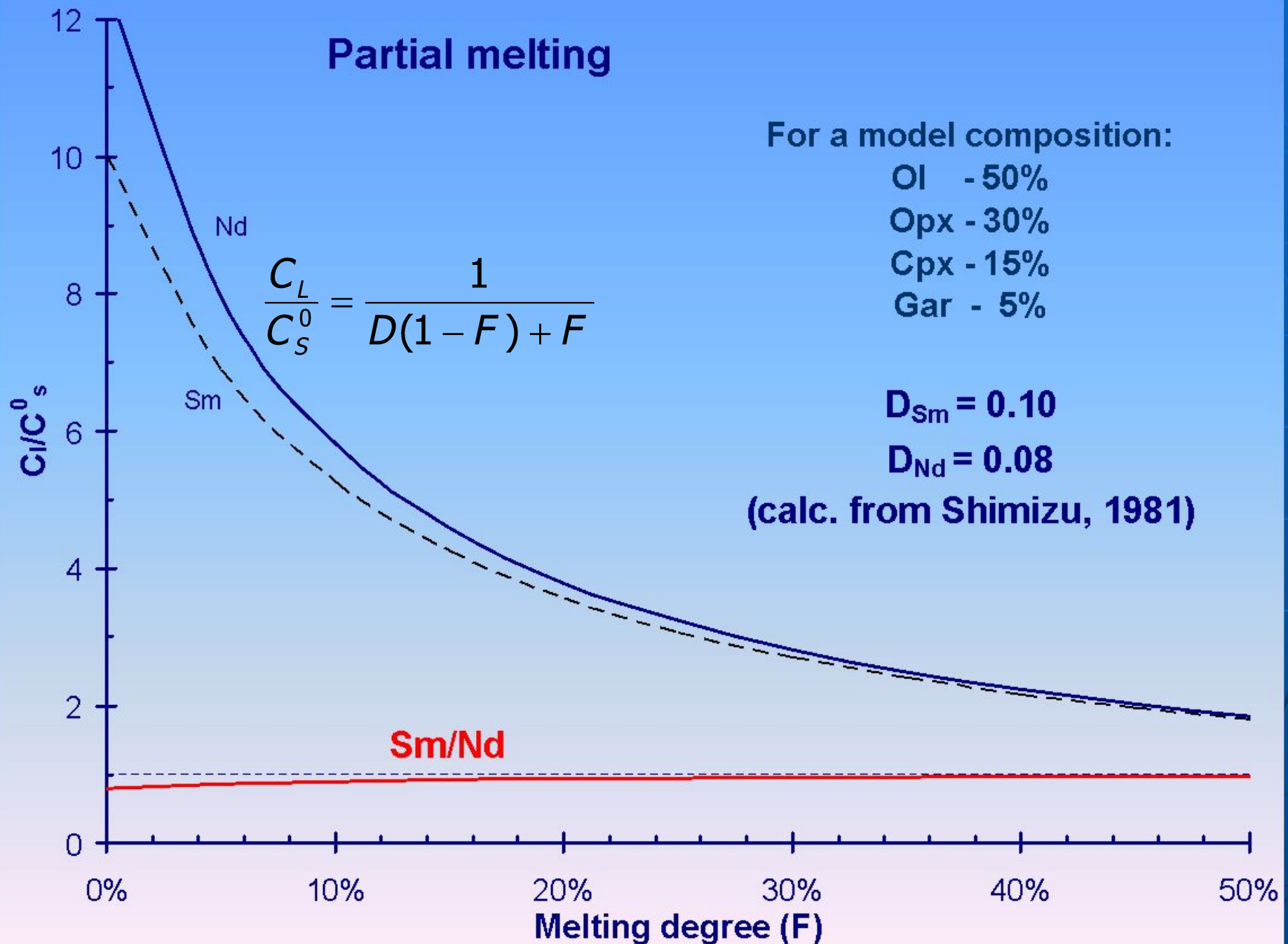
(Taylor & McLennan, 1985)





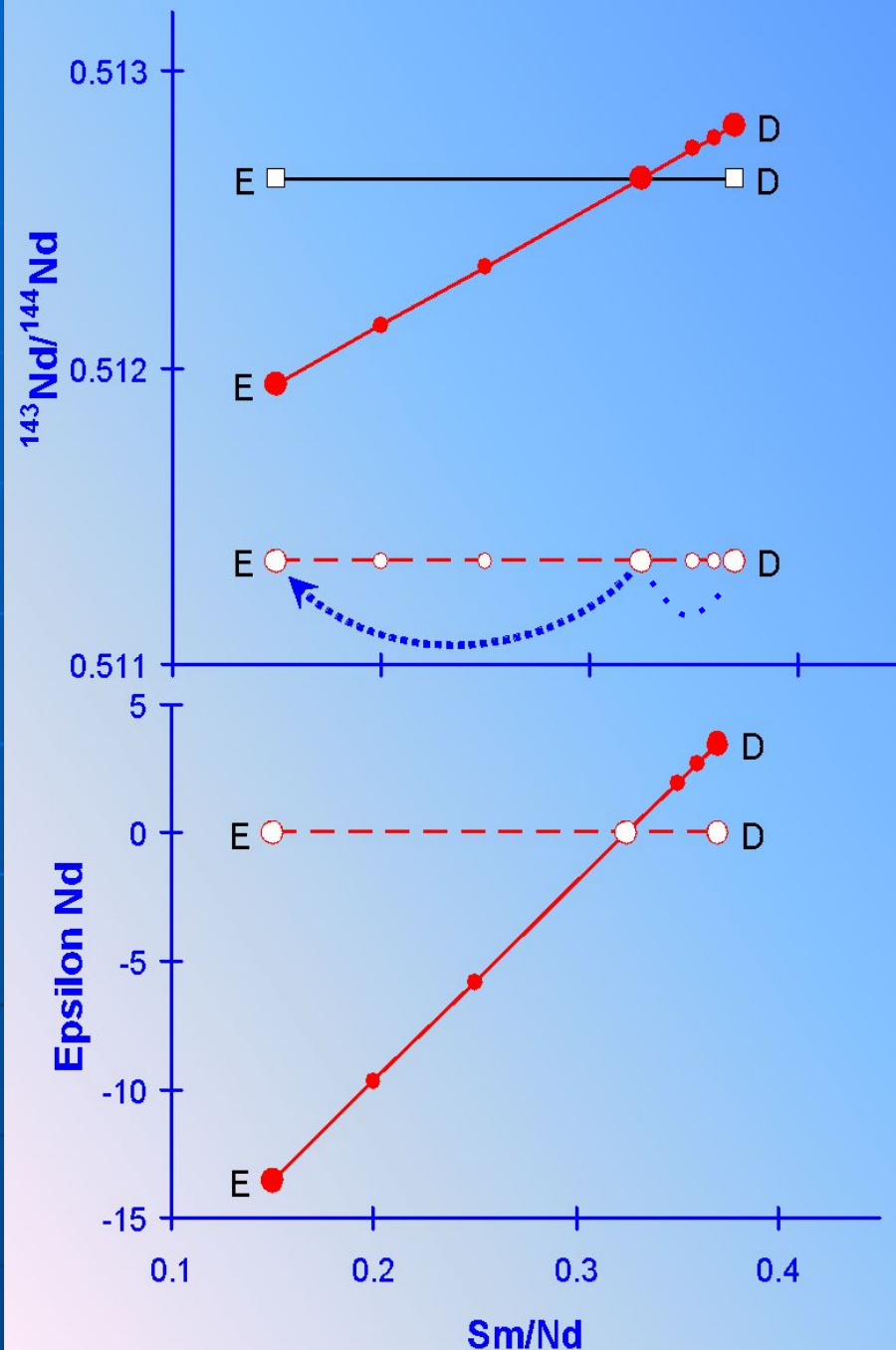


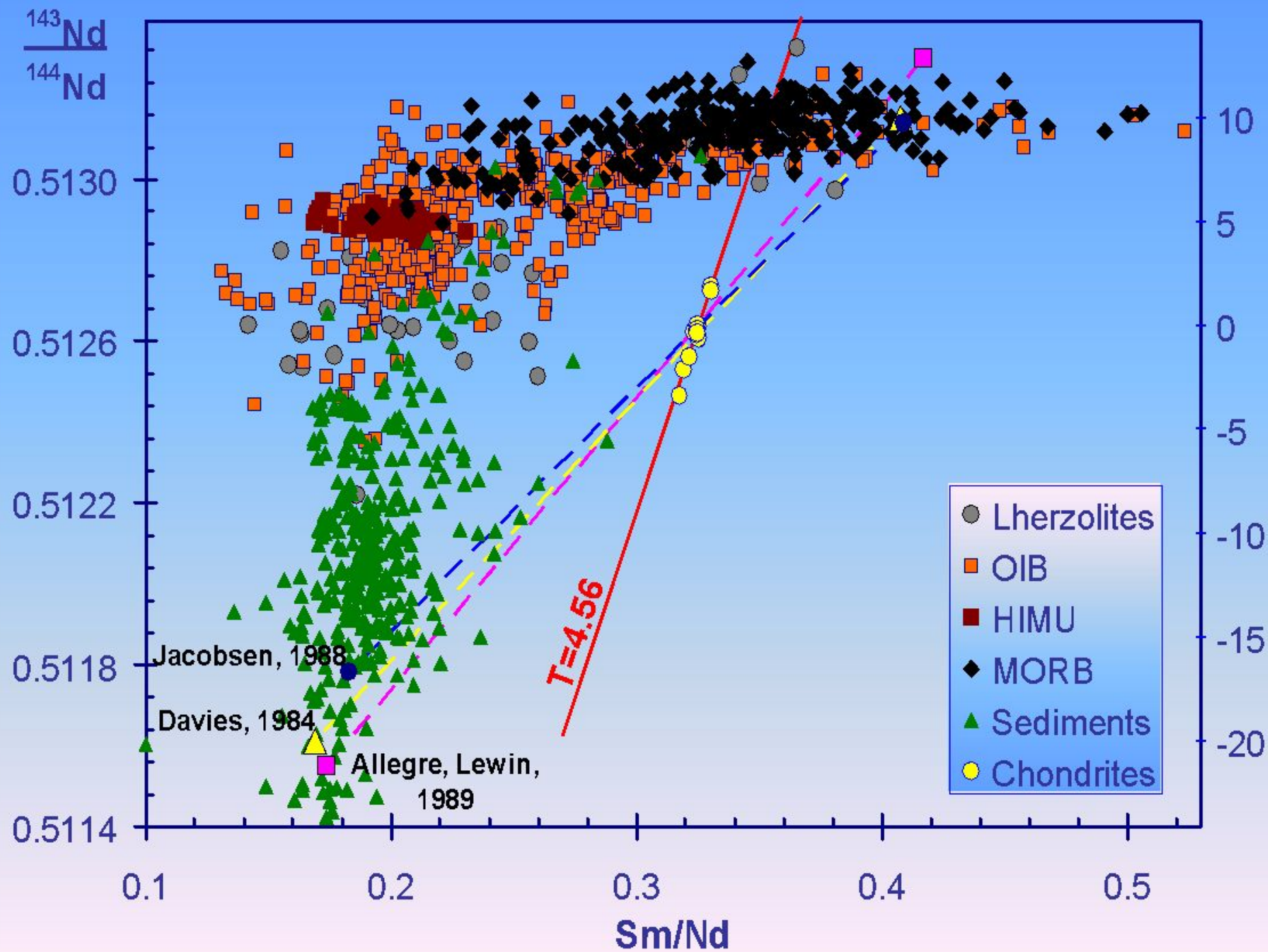
Partial melting

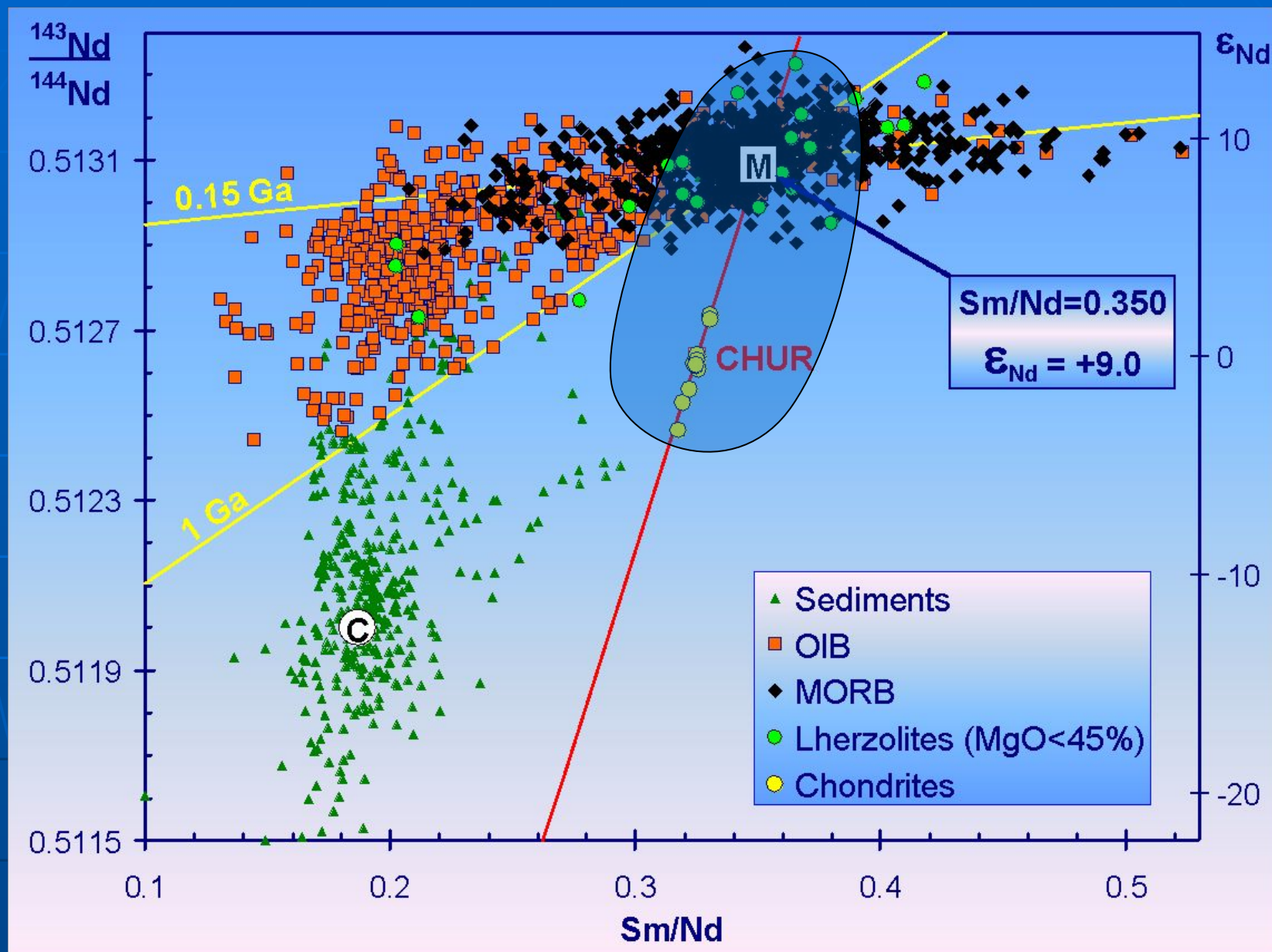


- Прямые выплавки (E) из примитивной мантии и рестит (D) должны иметь начальный изотопный состав этого источника и комплементарные отношения Sm/Nd
- Линии смешения обеднённого и обогащённого вещества в этих координатах – прямые, проходящие через исходный (примитивный) источник
- Прямые выплавки толеитов из CHUR должны иметь:

$$\begin{cases} \epsilon_{\text{Nd}} \approx 0 \\ \text{Sm/Nd} \approx 0.325 \end{cases}$$







Альтернатива:

- Мантия Земли в целом имеет отличное от хондритов Sm/Nd отношение

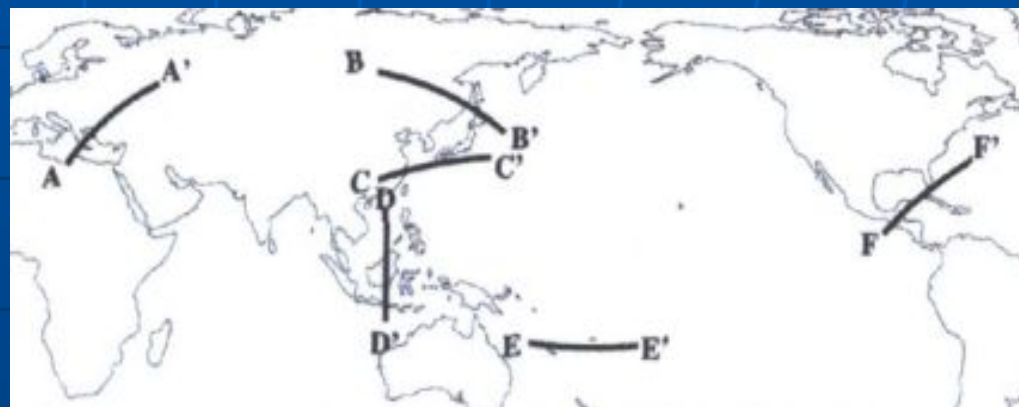
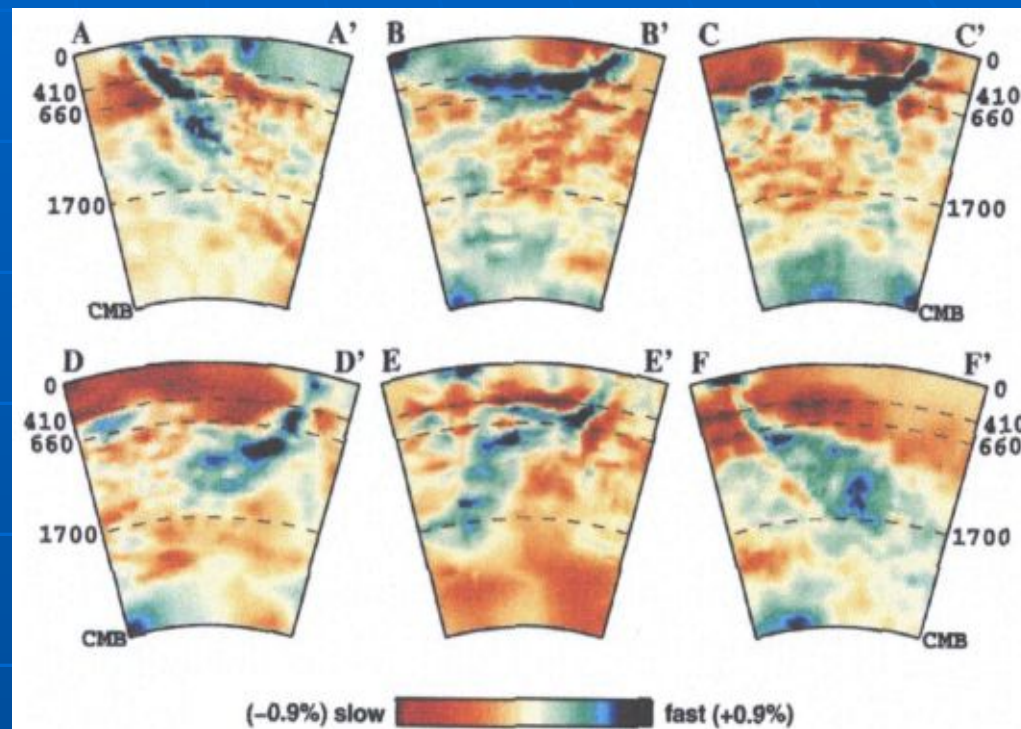
или

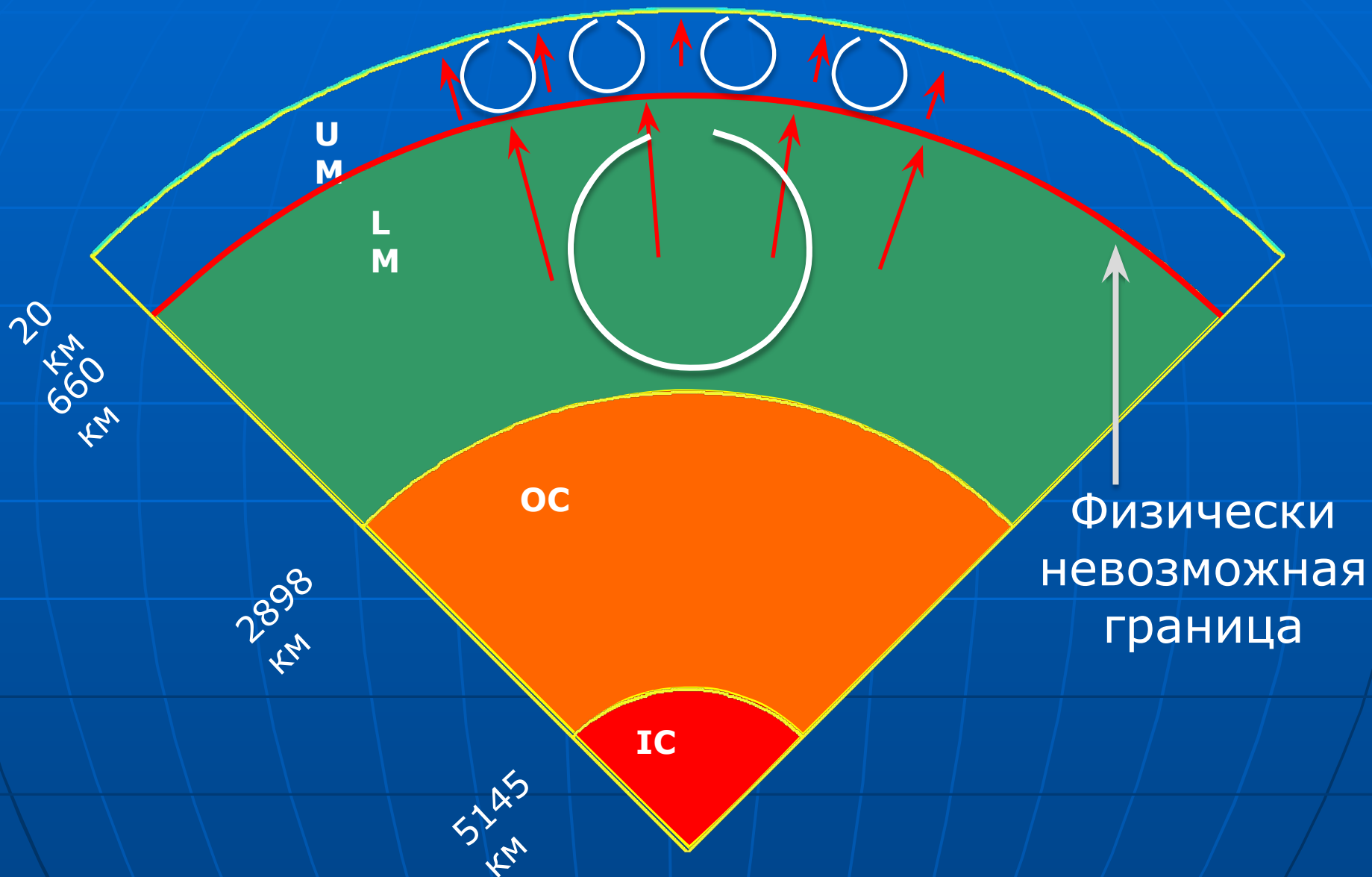
- Примитивное (необеднённое) вещество, в объёме нижней мантии, полностью изолировано на глубине

D.C.Rubie, R.D. van der Hilst,
Physics of the Earth and Planetary Interiors.
2001. V.127. P. 1-7.

Поток вещества в
нижнюю мантию
фиксируется
сейсмотомографией.

Значит есть и
обратный поток – из
нижней мантии к
поверхности Земли

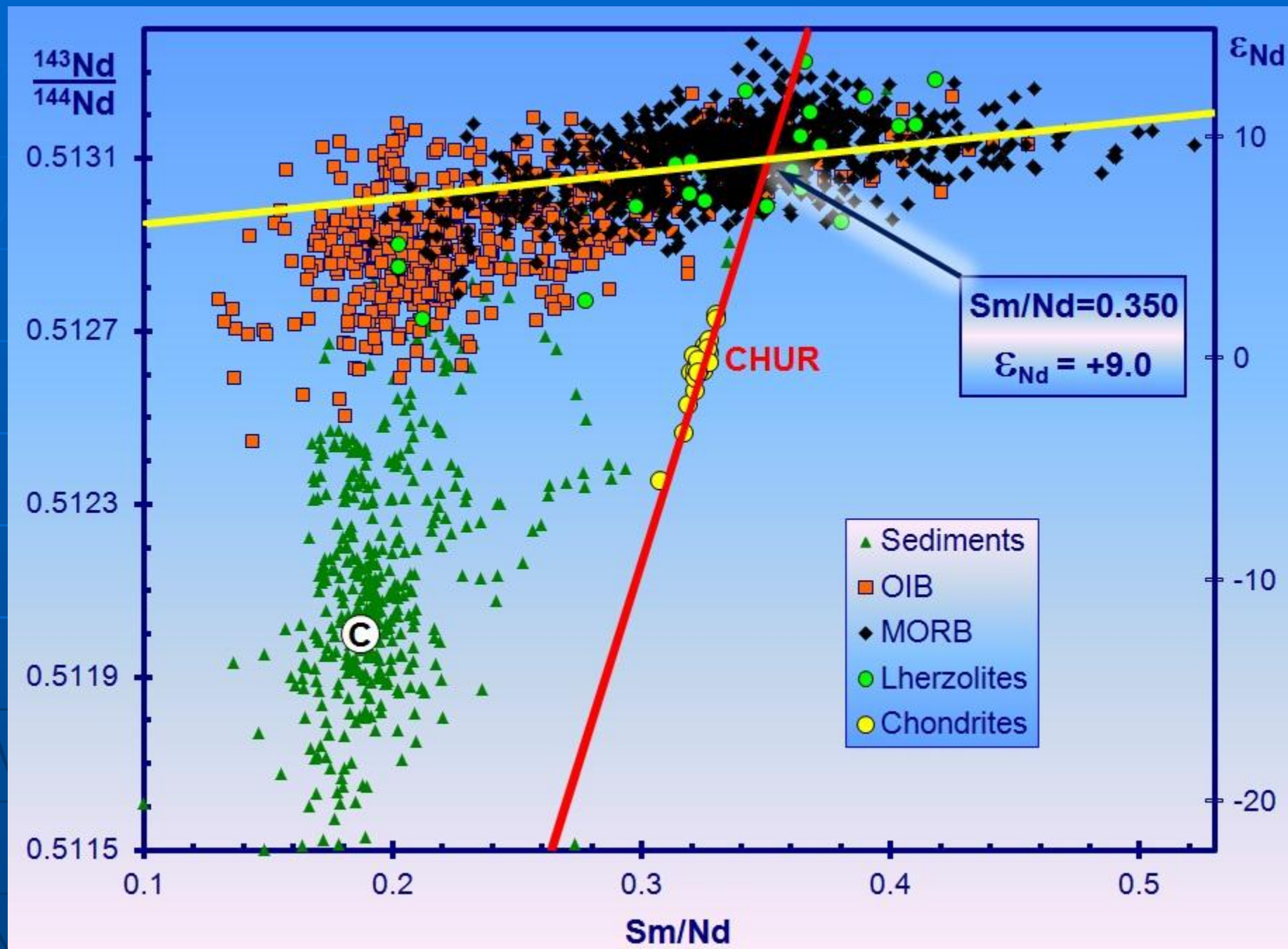




Вывод:

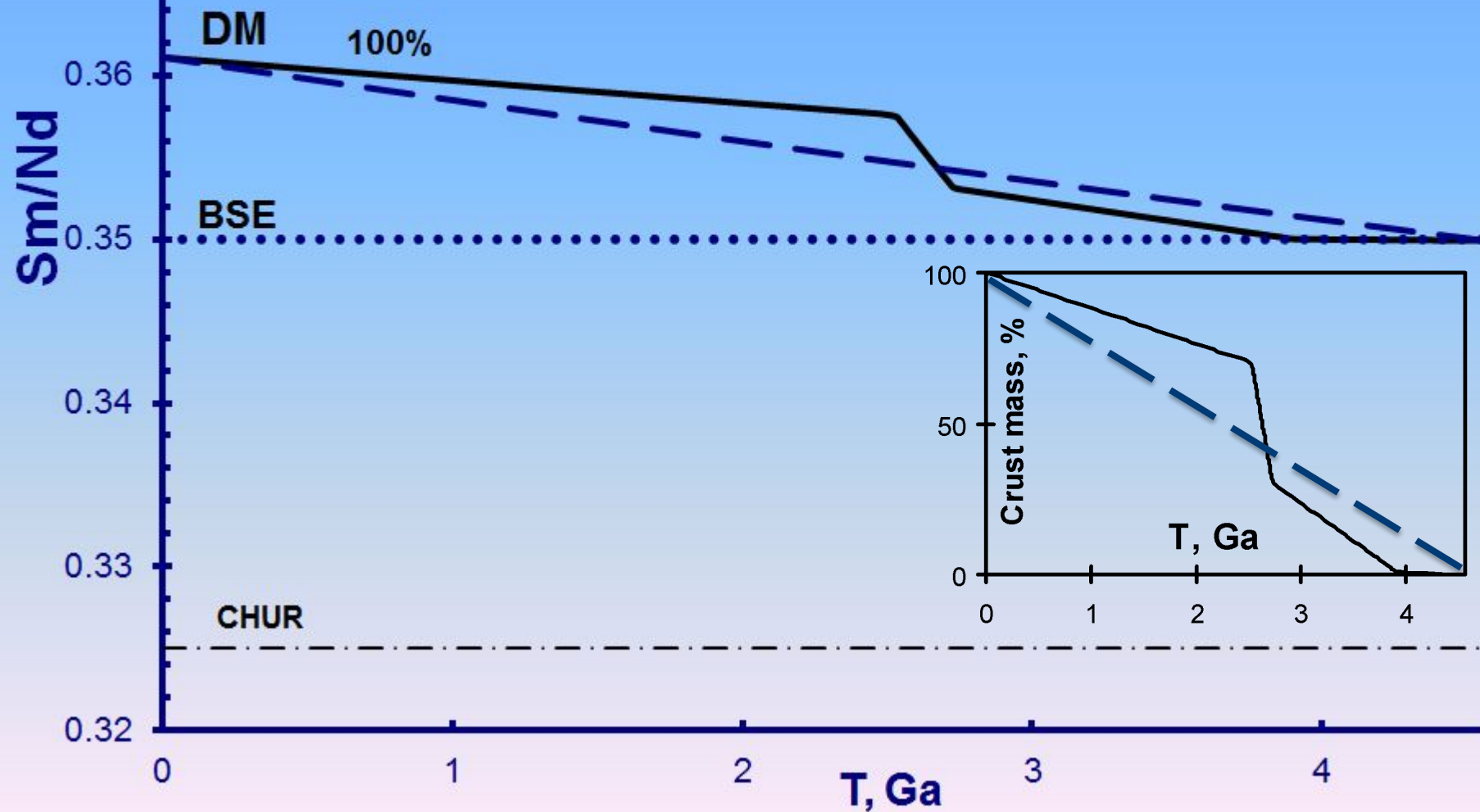
- Мантия Земли имеет отличное от хондритов Sm/Nd отношение

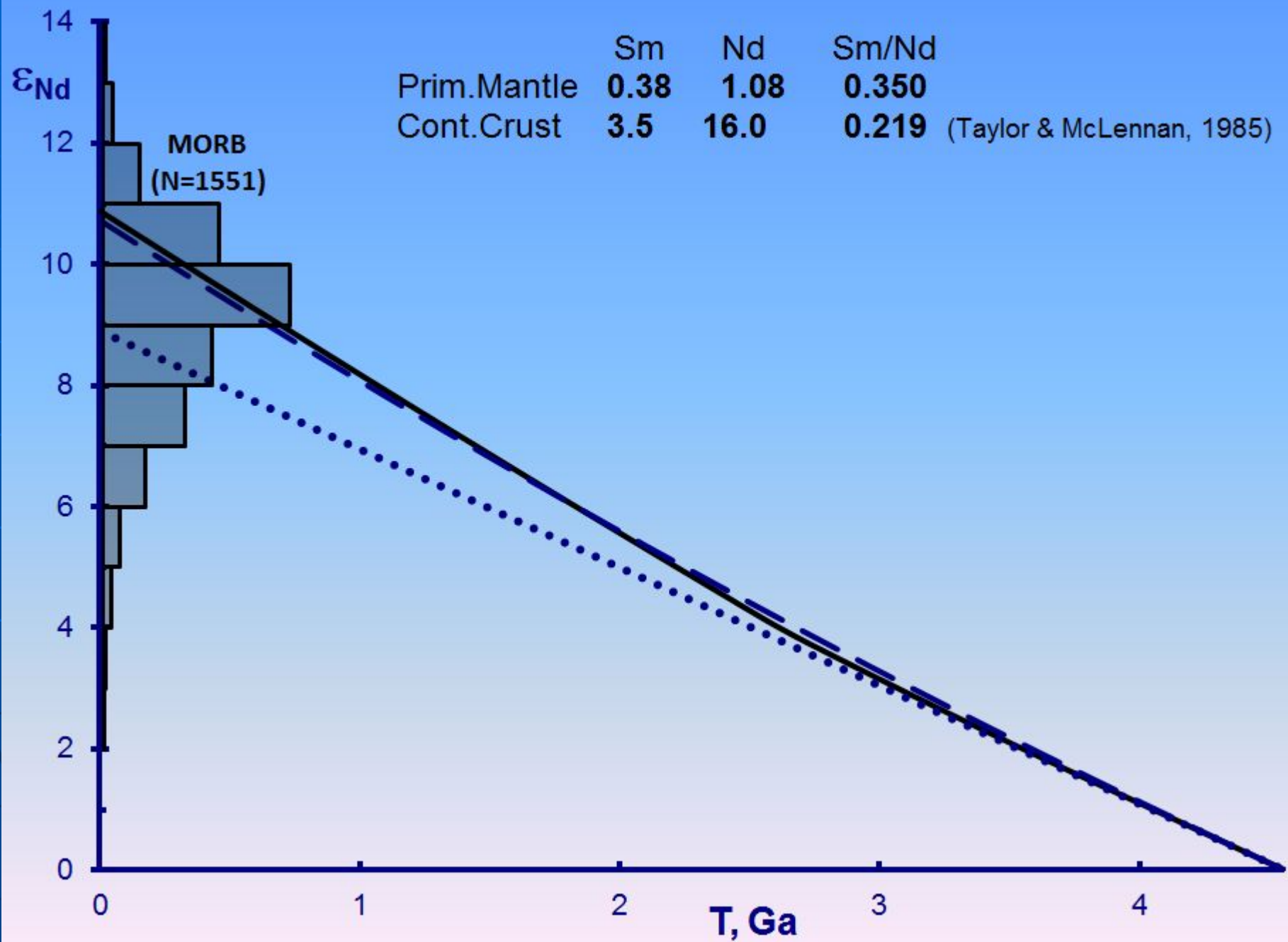
Какое?



	Sm	Nd	Sm/Nd
Prim.Mantle	0.38	1.08	0.350
Cont.Crust	3.5	16.0	0.219

(Taylor & McLennan, 1985)





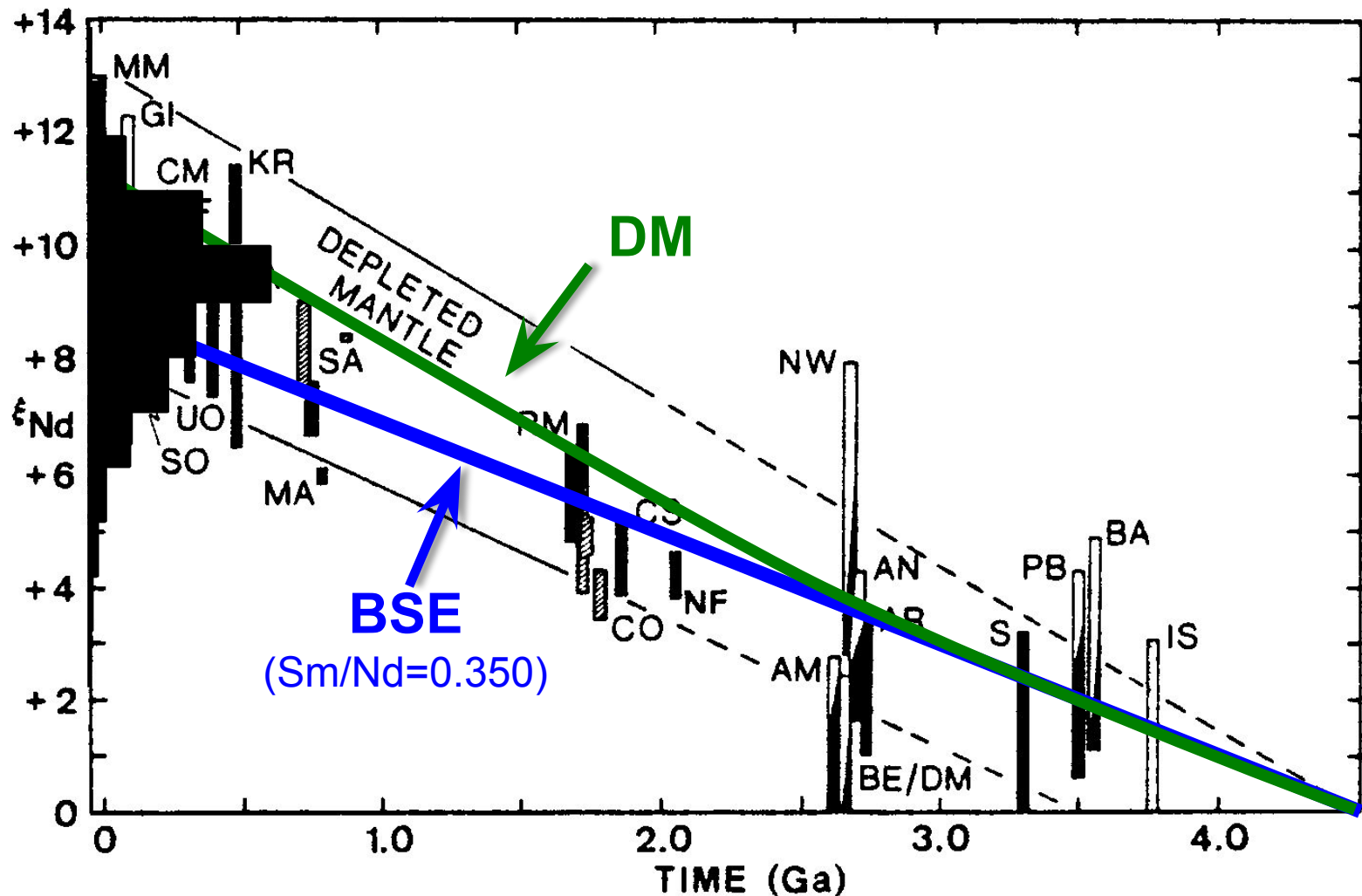


Fig. 3. Variation in ϵ_{Nd} with time for mantle-derived rocks (unshaded: komatiites; shaded: tholeiites; hatched: primitive island arc volcanics) and sediments (stippled).

ПЕТРОЛОГИЯ, 2004, том 12, № 5, с. 451–466

УДК 550.42

Sm-Nd И Lu-Hf ИЗОТОПНЫЕ СИСТЕМЫ ЗЕМЛИ: ОТВЕЧАЮТ ЛИ ОНИ ХОНДРИТАМ?

© 2004 г. Ю. А. Костицын

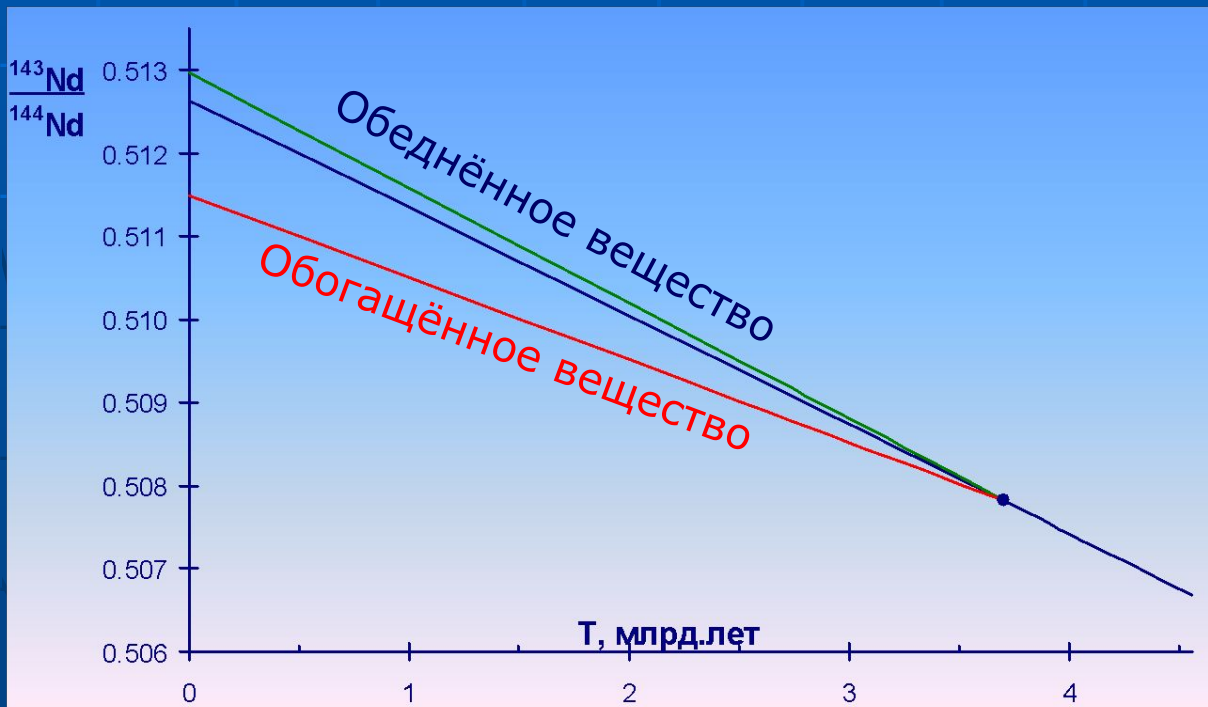
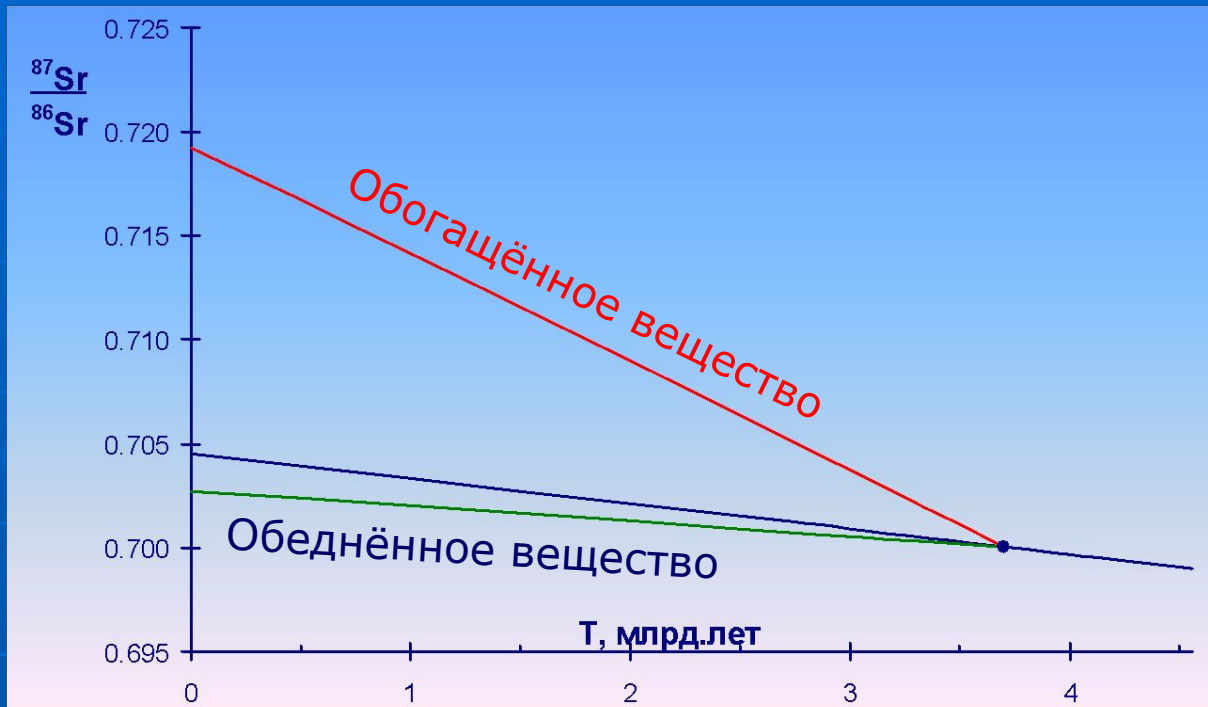
*Институт геохимии и аналитической химии им. В.И. Вернадского РАН
119991 Москва, ул. Косыгина, 19, Россия; e-mail: kostitsyn@geokhi.ru*

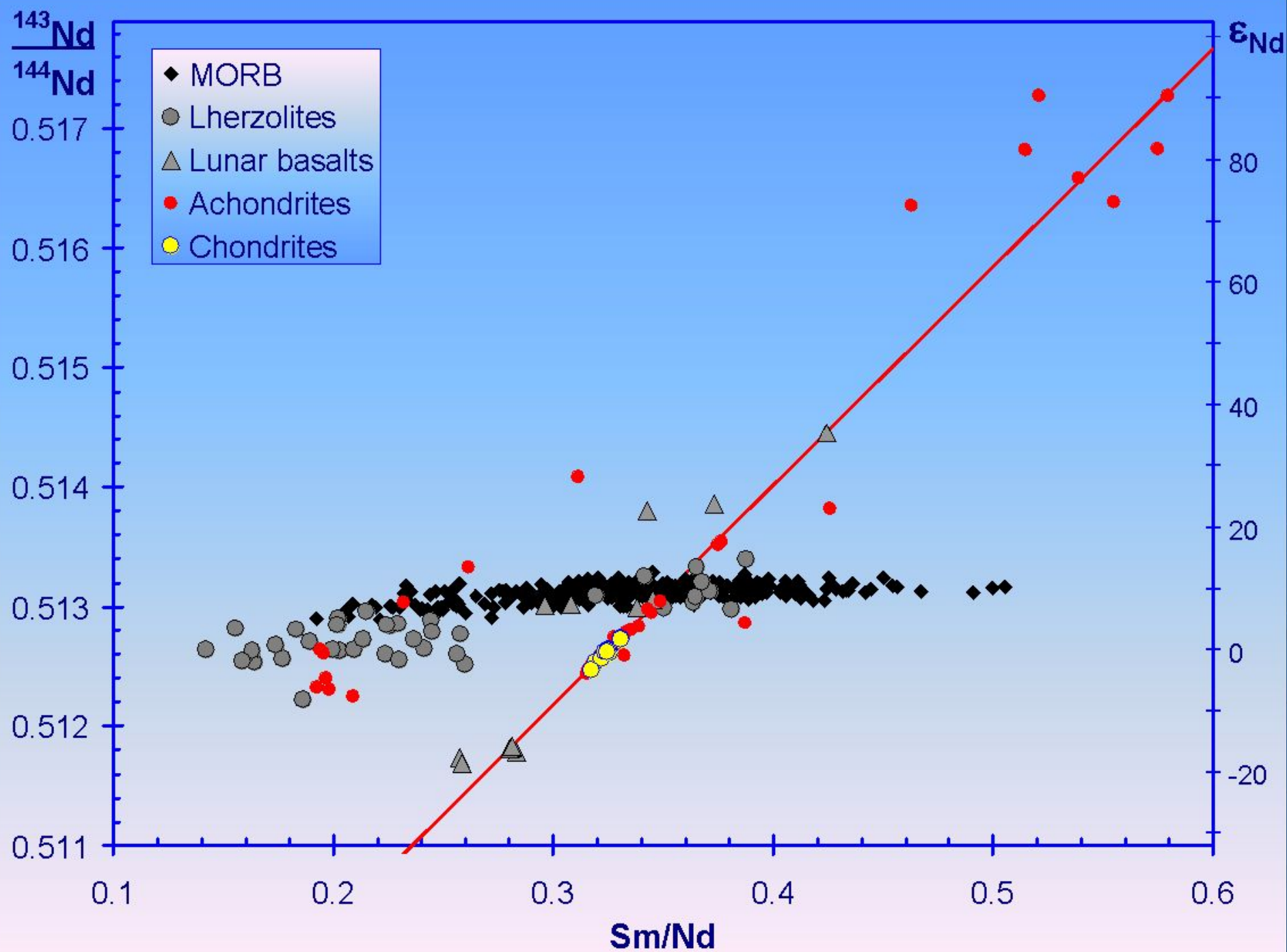
Поступила в редакцию 26.01.2004 г.

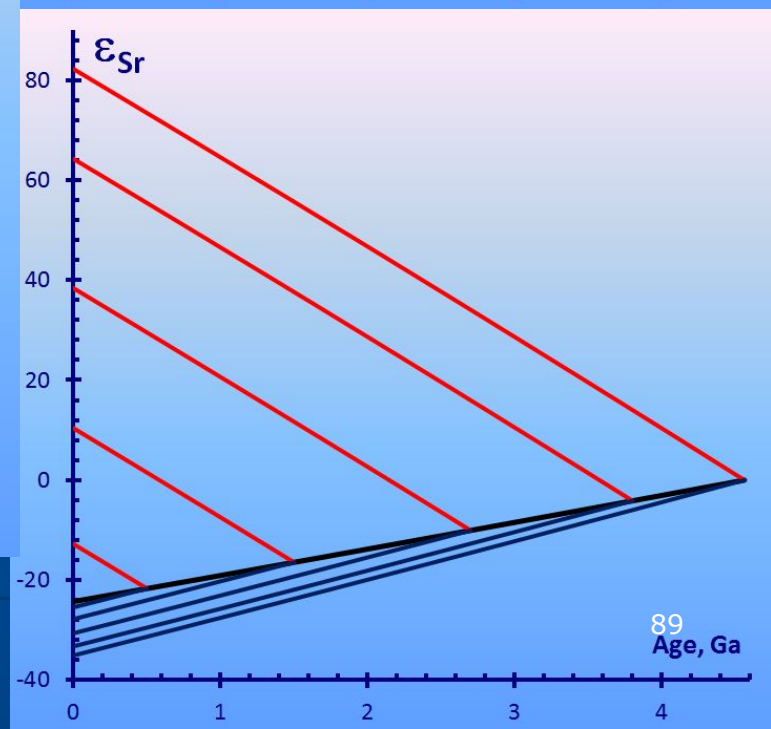
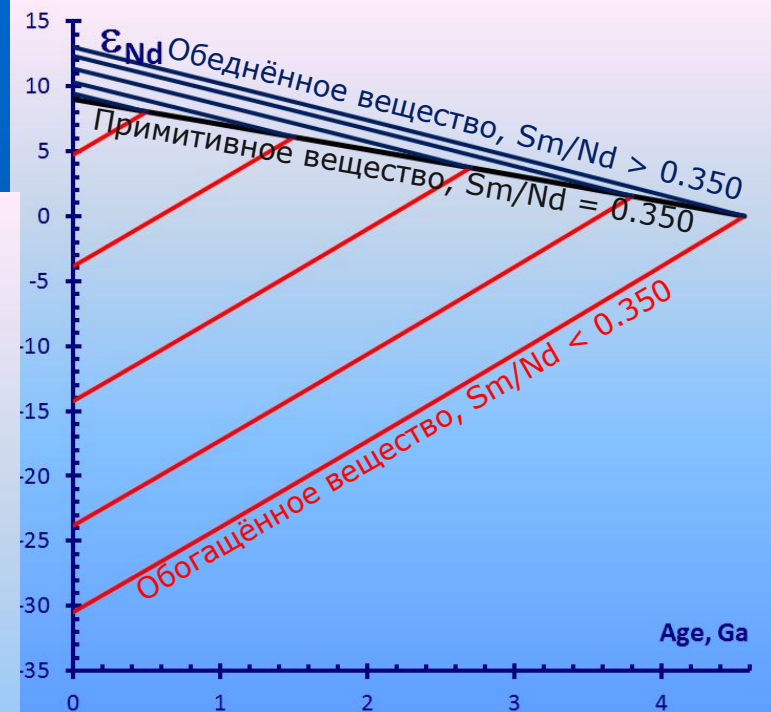
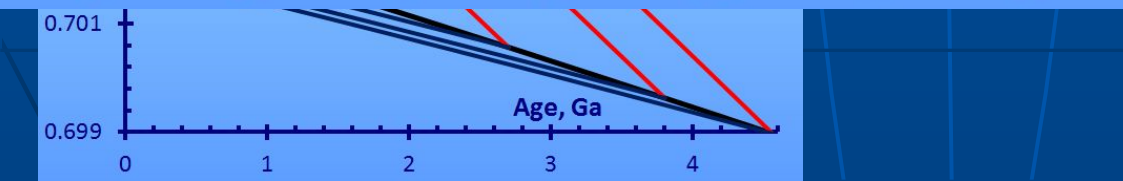
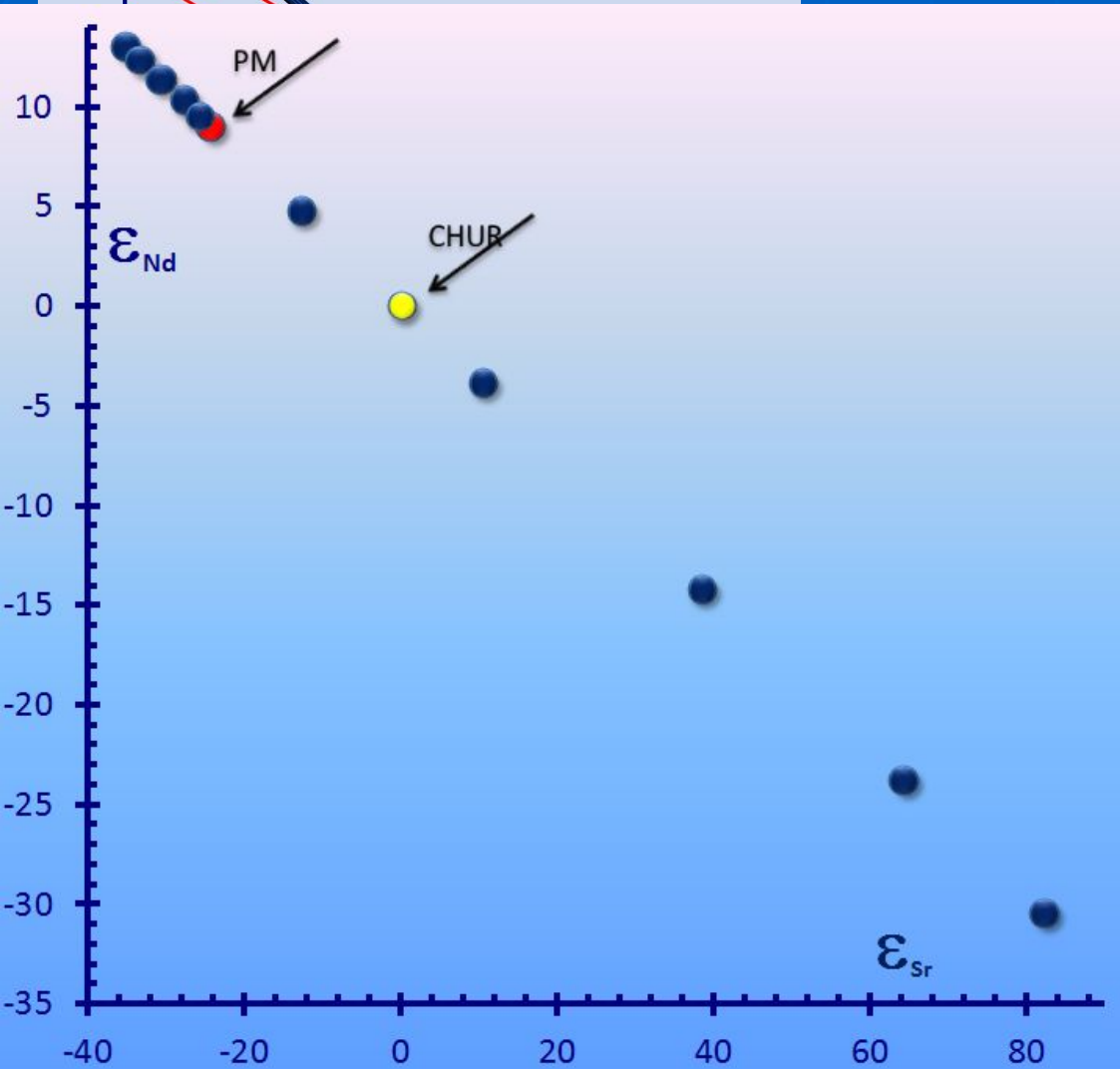
Задача 14

- Рассчитать изотопный состав обеднённой мантии (DM) при следующих допущениях:
 - DM образовалась в результате отделения вещества континентальной коры от примитивной мантии (а) хондритового и (б) нехондритового состава
 - средний возраст коры – по вариантам (файл Ex14.xlsx)
- Рассмотреть два случая:
 - 1) источник коры – вся мантия
 - 2) источник коры – верхняя мантия
- Сформулировать выводы ...

	Примитивная мантия		Конт. кора	DM	
	Хондритовая (CHUR/UR)	Нехондритовая		(а)	(б)
Rb, ppm	0.55	0.34	32		
Sr, ppm	19.25	17.2	260		
$^{87}\text{Rb}/^{86}\text{Sr}$	0.0827	0.0574			
$^{87}\text{Sr}/^{86}\text{Sr}$	0.7045	0.7028			
ϵ_{Sr}	0.0	-24		?	?
Sm, ppm	0.347	0.38	3.5		
Nd, ppm	1.067	1.08	16		
$^{147}\text{Sm}/^{144}\text{Nd}$	0.1967	0.2119			
$^{143}\text{Nd}/^{144}\text{Nd}$	0.512638	0.513099			
ϵ_{Nd}	0.0	9		?	?





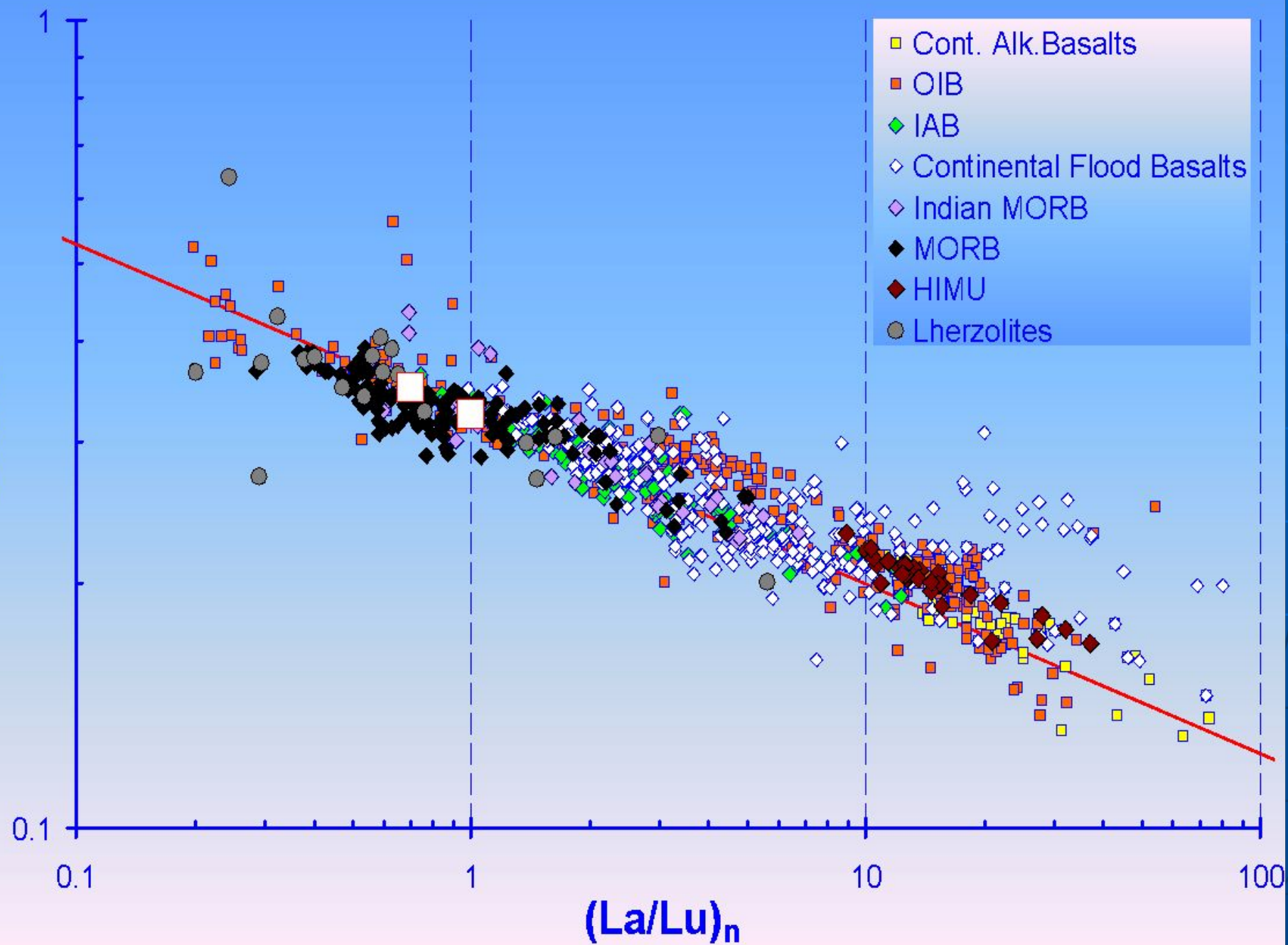


Состав примитивной мантии

- $\text{Sm/Nd} = 0.350$ и $^{143}\text{Nd}/^{144}\text{Nd} = 0.51310$ $\epsilon_{\text{Nd}} = 9$

- $\text{Rb/Sr} = 0.020$  $^{87}\text{Sr}/^{86}\text{Sr} = 0.7028$ $\epsilon_{\text{Sr}} = -24$
 $(^{87}\text{Sr}/^{86}\text{Sr})_{\text{BABI}} = 0.699$

Sm/Nd



10

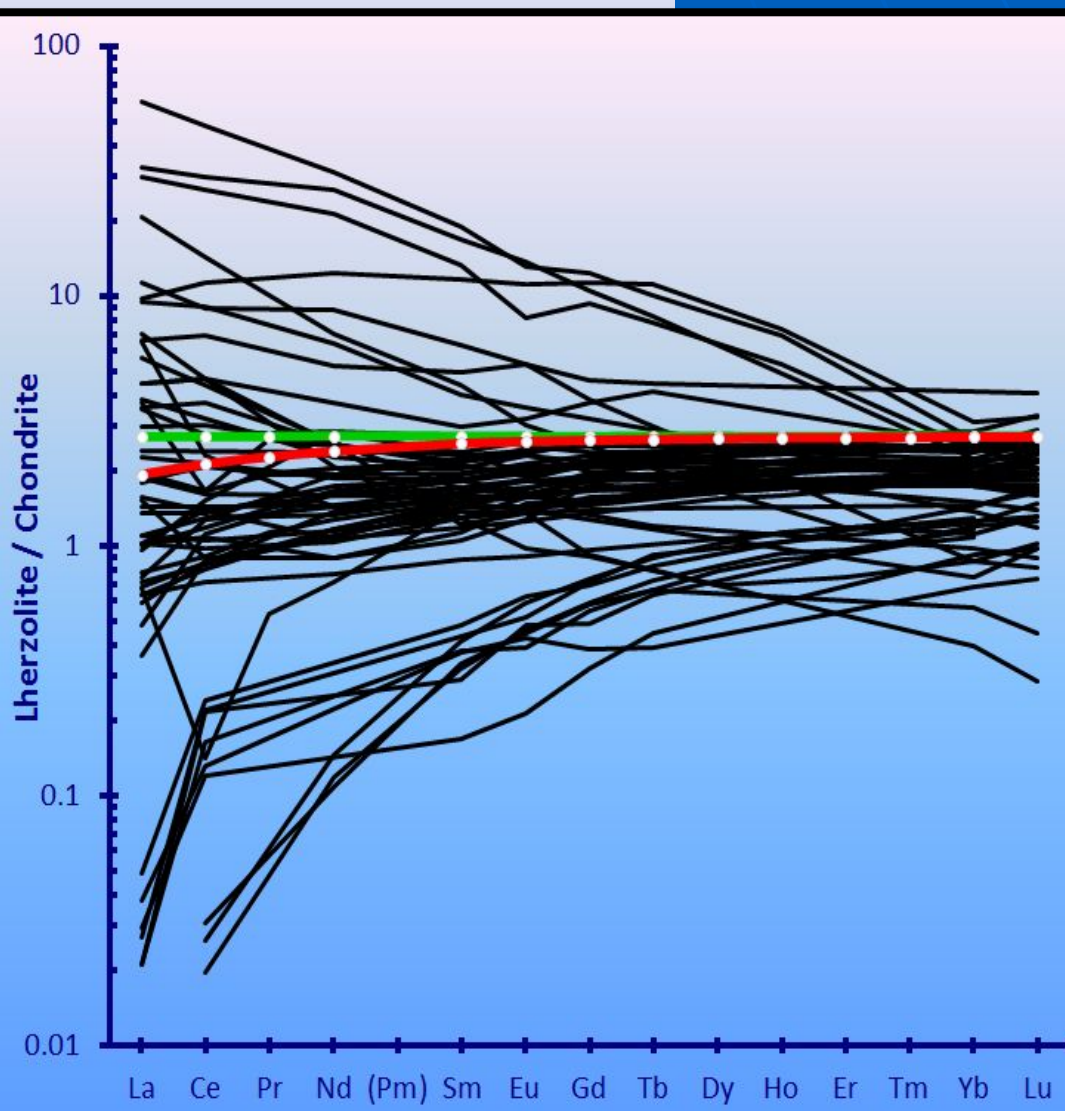
Norm.
to CI

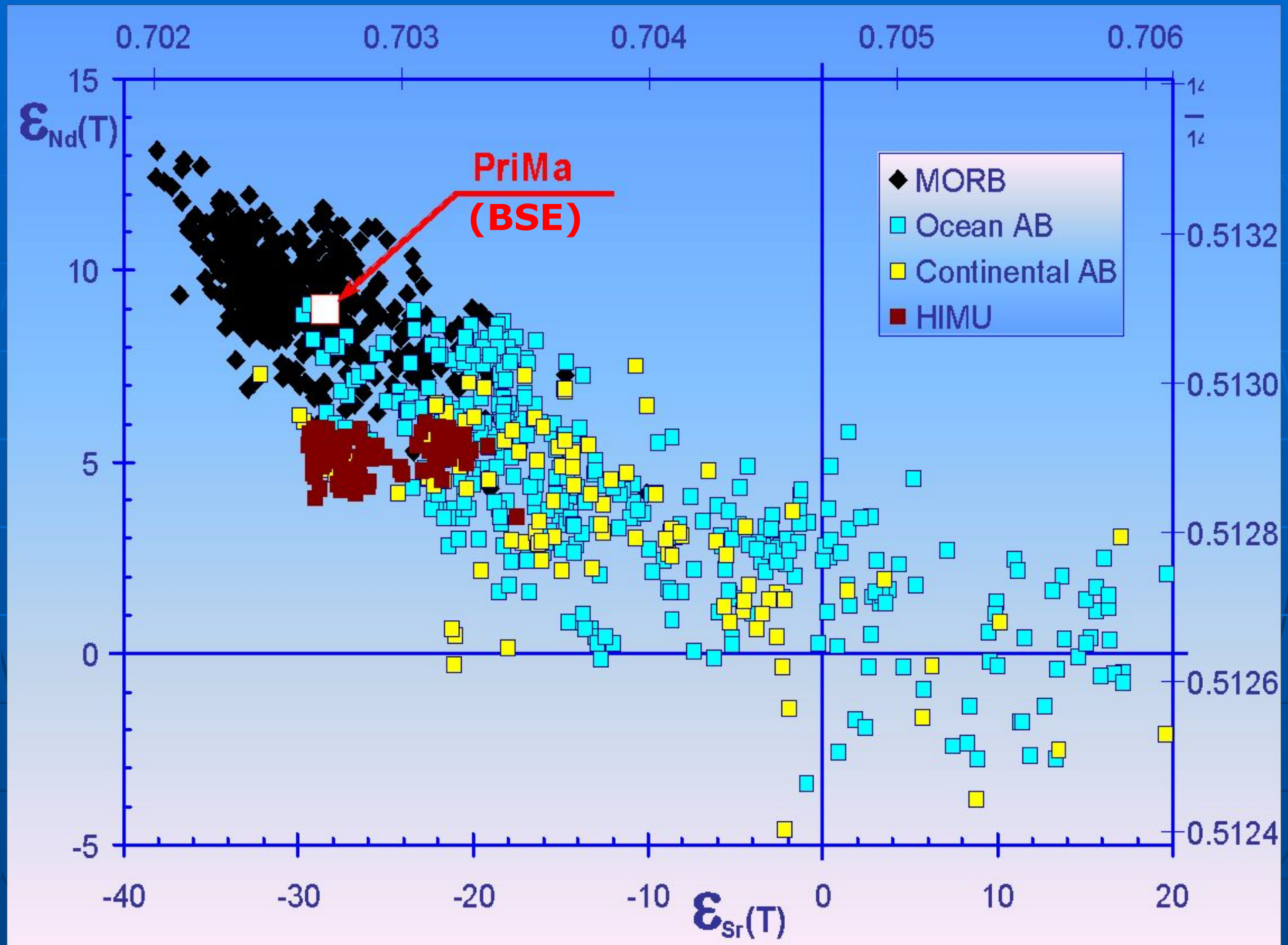
- Pyrolith (McDonugh & Sun, 1995)
- Primitive Mantle (Kostitsyn, 2004)

 $(La/Lu)_n = 1.0$ $(La/Lu)_n = 0.7$

1

La Ce Pr Nd (Pm) Sm Eu Gd Tb Dy Ho Er Tm Yb Lu







$$\lambda = 6.74 \times 10^{-9} \text{ год}^{-1}$$

$$T_{1/2} = 103 \text{ млн. лет}$$

$$N_0 = N \exp(\lambda t)$$

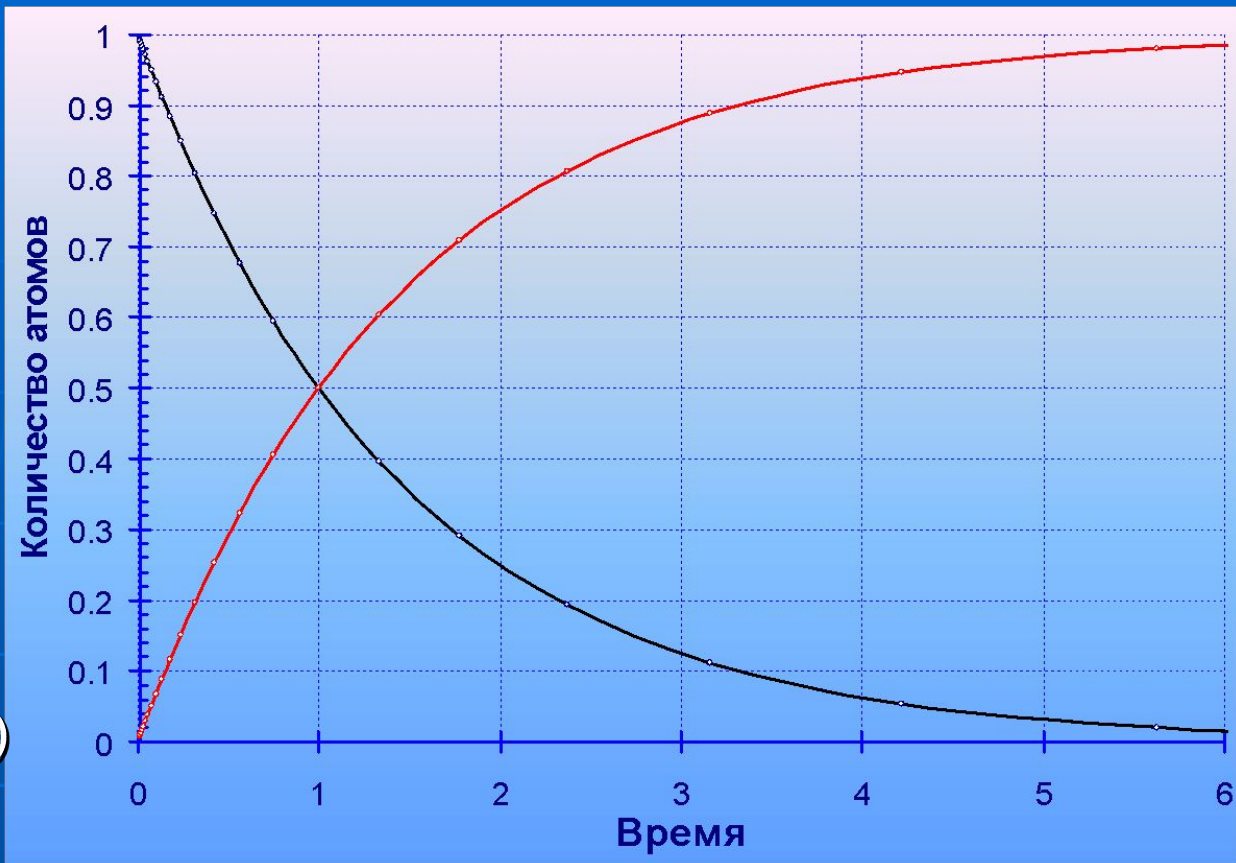
$$N = N_0 \exp(-\lambda t)$$

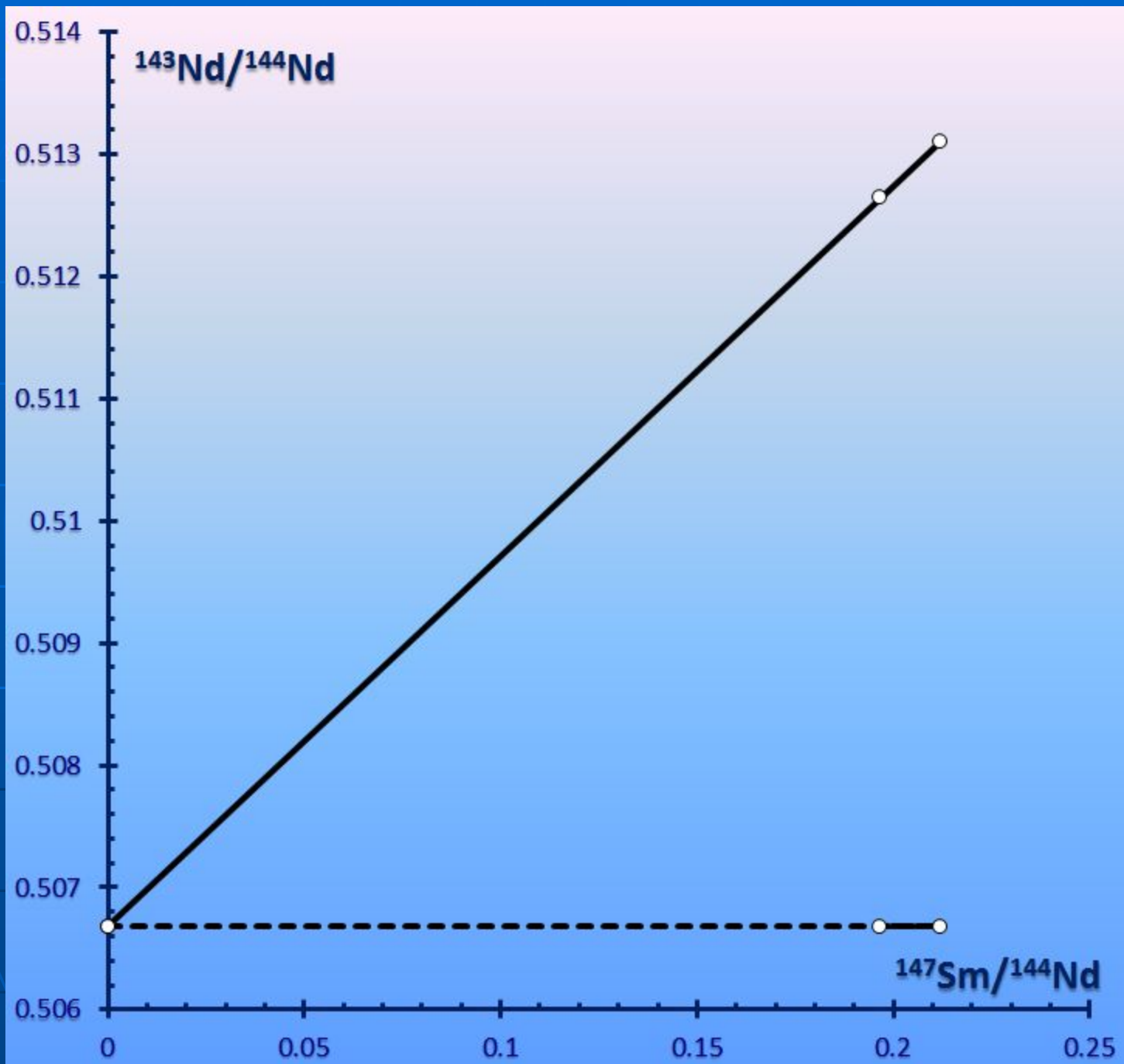
$$^{146}\text{Sm} = ^{146}\text{Sm}_0 \cdot \exp(-\lambda t)$$

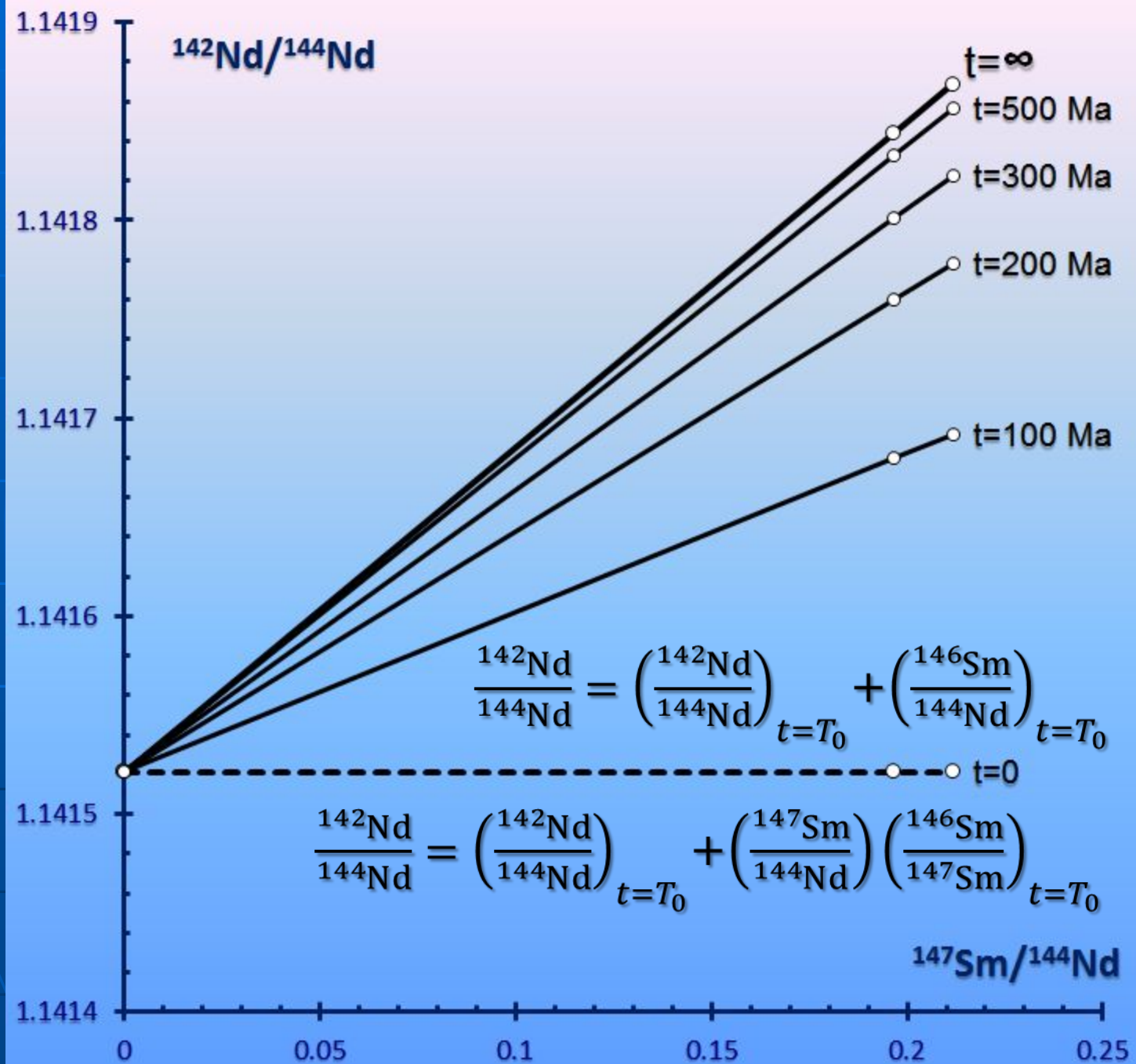
когда $t \gg T_{1/2}$

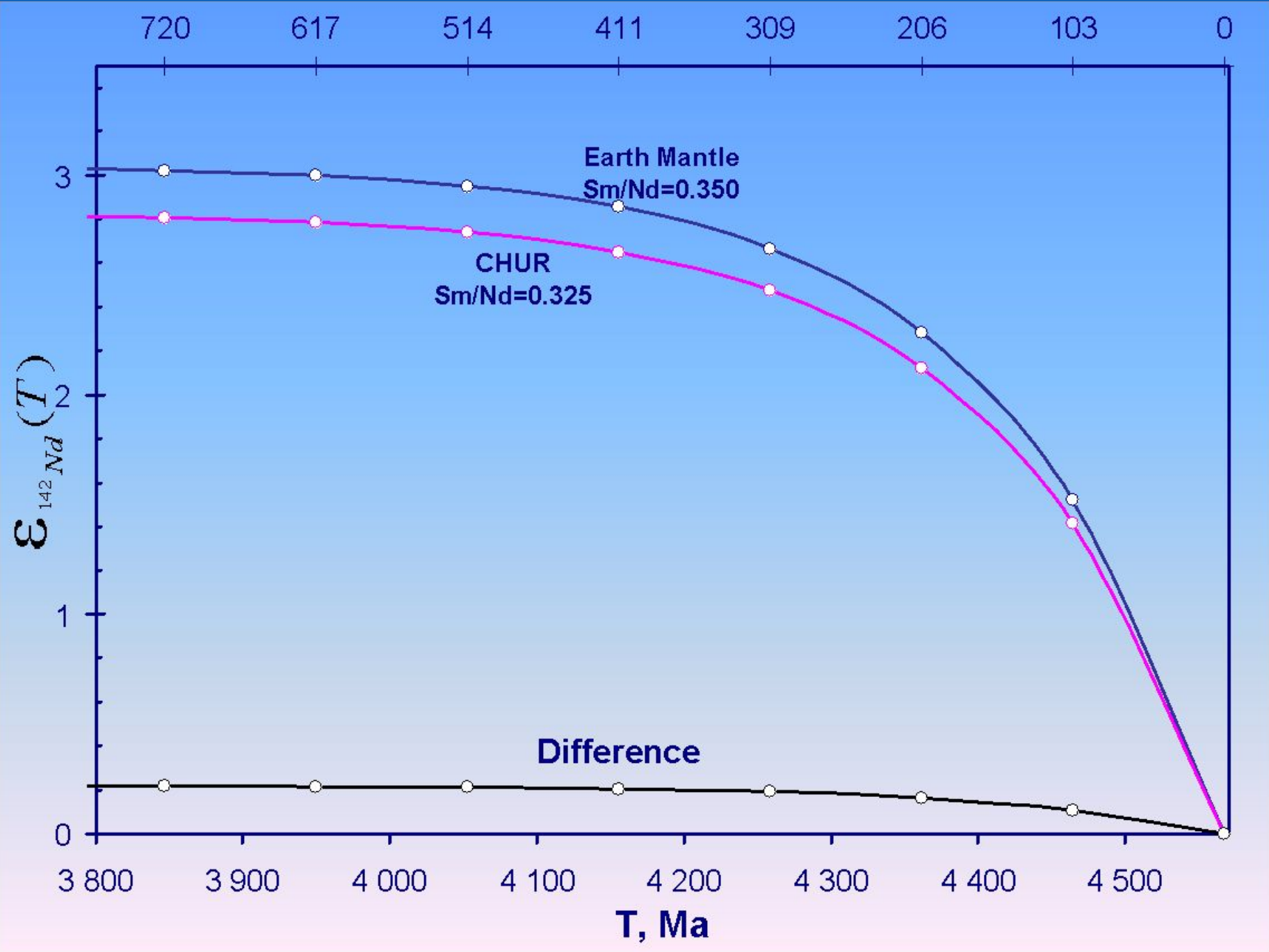
$$^{142}\text{Nd}_{\text{rad}} = ^{146}\text{Sm}_0$$

$$\left(\frac{^{142}\text{Nd}}{^{144}\text{Nd}} \right) = \left(\frac{^{142}\text{Nd}}{^{144}\text{Nd}} \right)_{t=T_0} + \left(\frac{^{146}\text{Sm}}{^{144}\text{Nd}} \right)_{t=T_0}$$









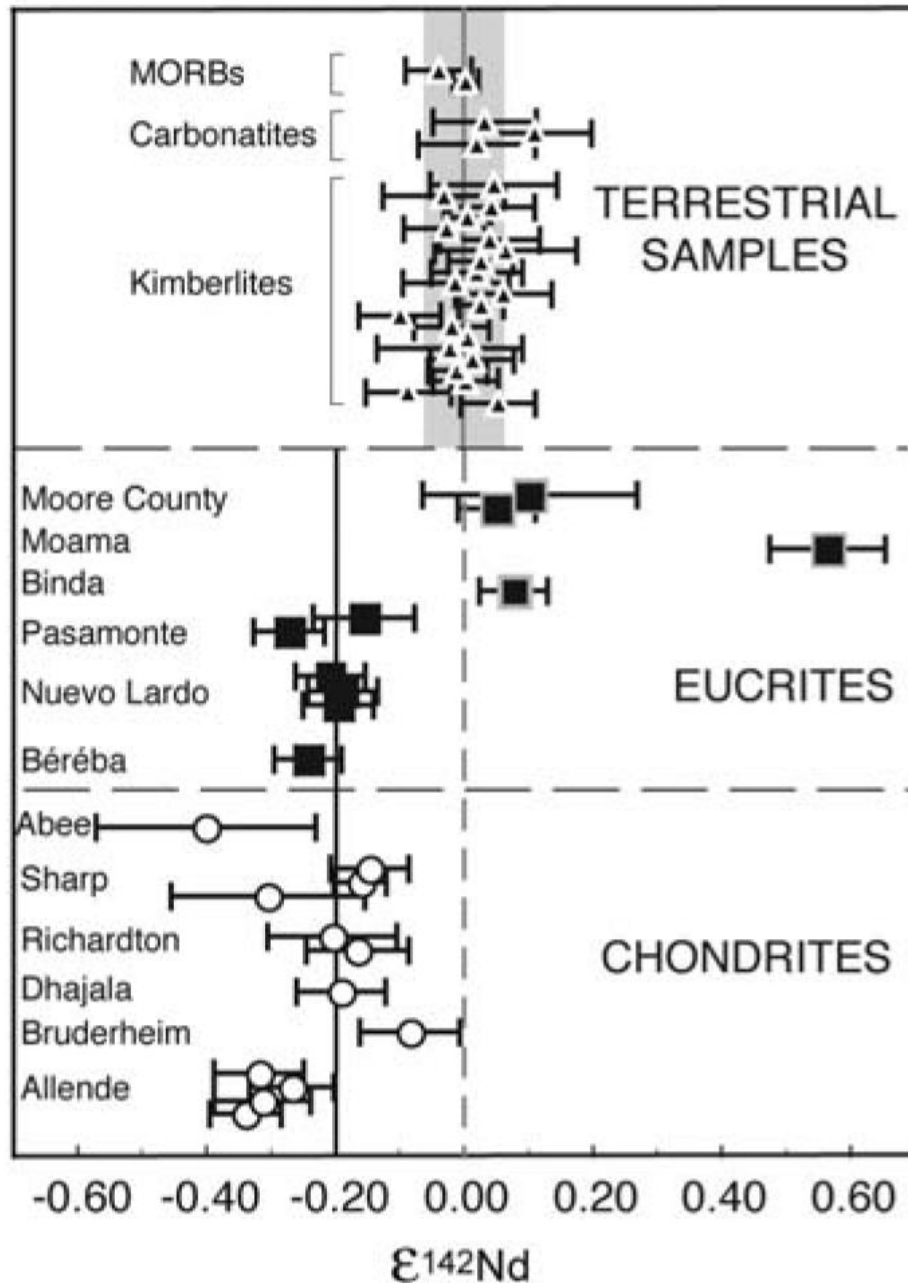
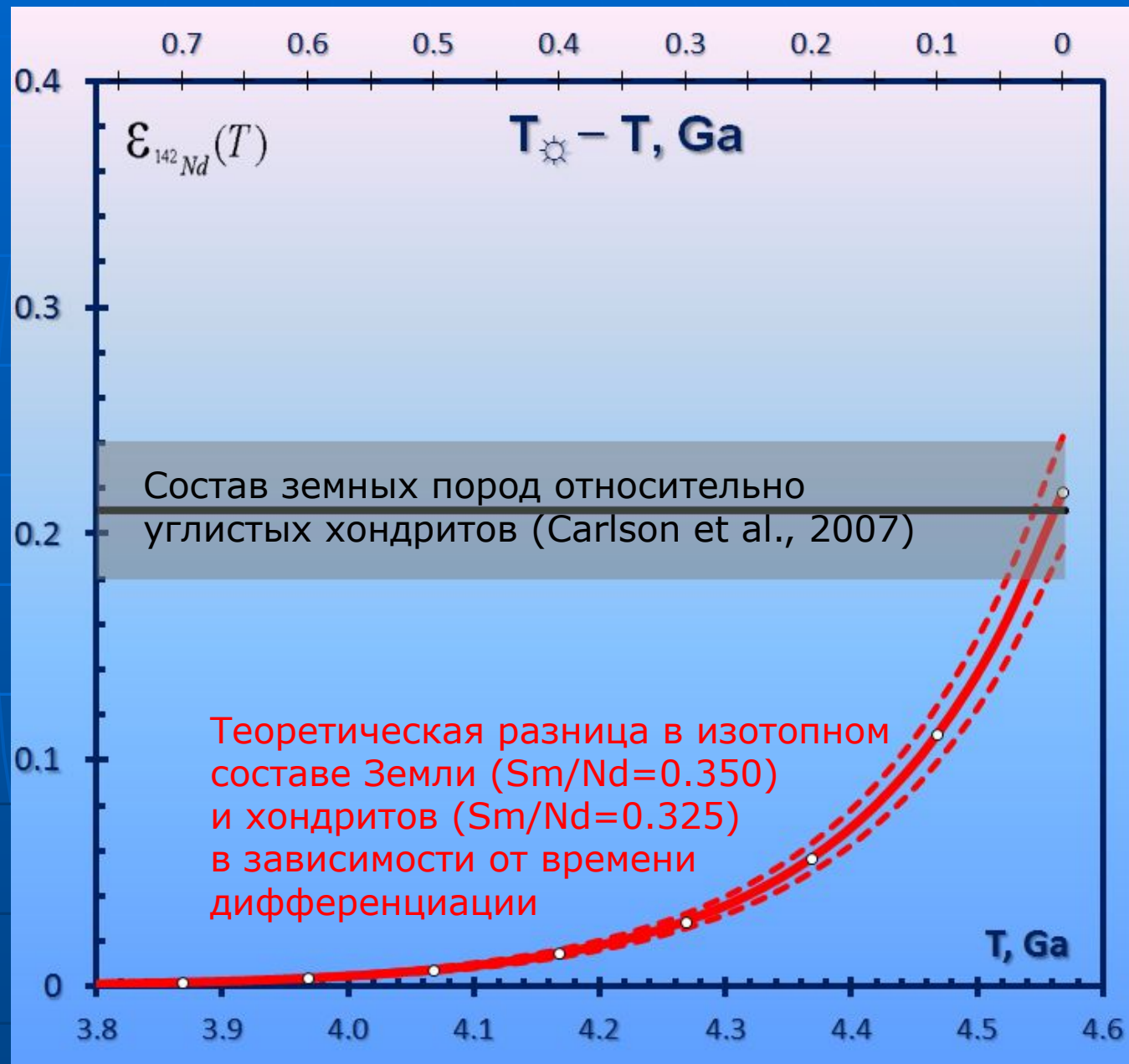


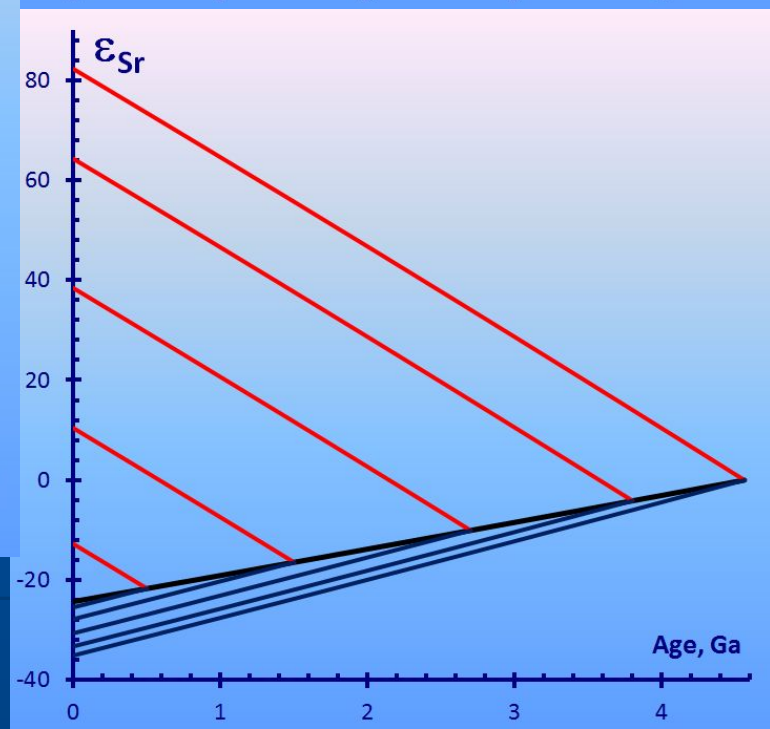
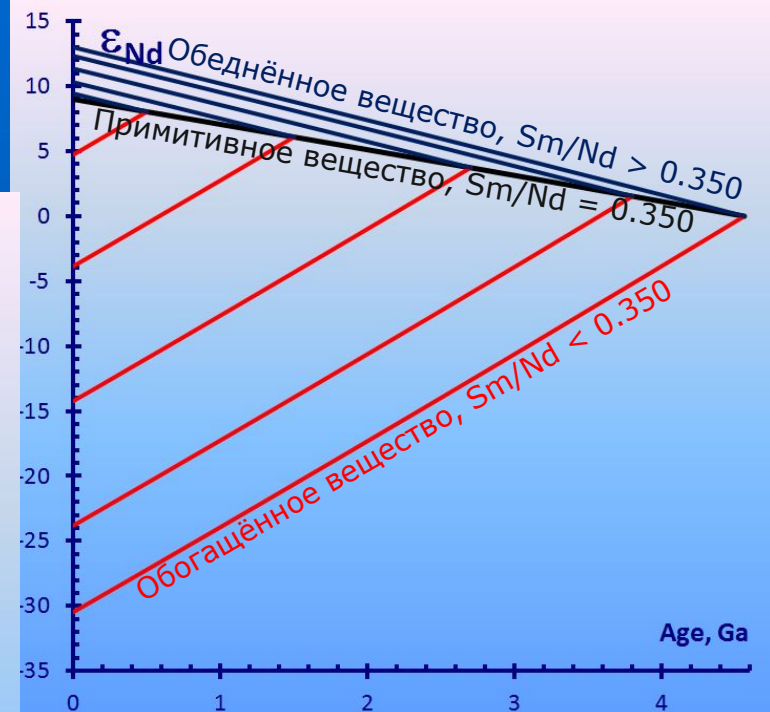
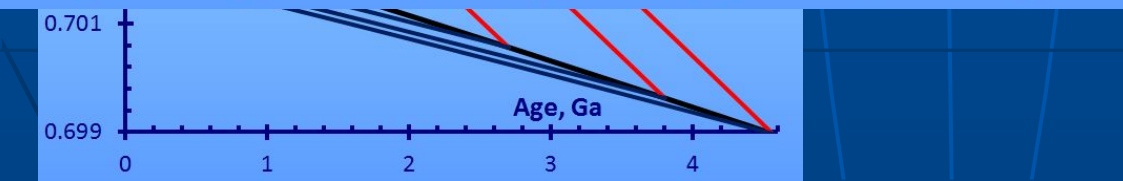
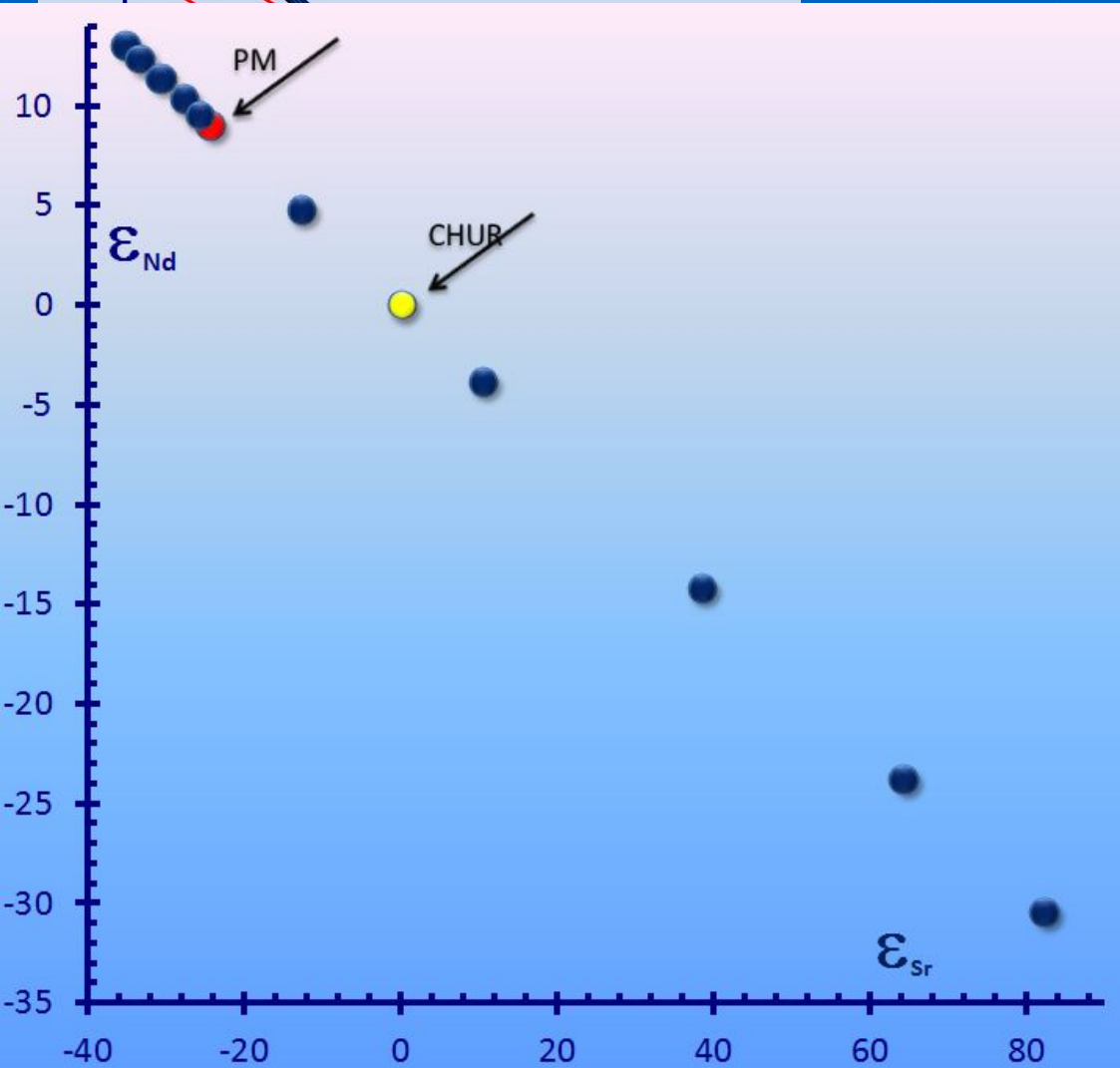
Fig. 1. $^{142}\text{Nd}/^{144}\text{Nd}$ ratios measured for chondrites and eucrites compared to the La Jolla terrestrial Nd standard ($\epsilon^{142}\text{Nd}$). All chondrites and basaltic eucrites have negative $\epsilon^{142}\text{Nd}$ values outside the external analytical error of $\pm 0.07 \epsilon$ units (2σ) (shaded area). Cumulate eucrites have positive $\epsilon^{142}\text{Nd}$ values in agreement with their high Sm/Nd, resulting from igneous processes on their parent body. The error bars correspond to the internal precision ($2\sigma_{\text{mean}}$). Terrestrial samples (MORBs, kimberlites, and carbonatites of different ages and collected in diverse locations) measured using the same procedure (27) have been added to demonstrate the significant excess of 0.2 ϵ units in all the terrestrial material (samples and standard) relative to the mean chondritic value. All terrestrial samples were measured several times using the same procedures as were used for the chondrites. The uncertainties reported on the mean are 2σ .

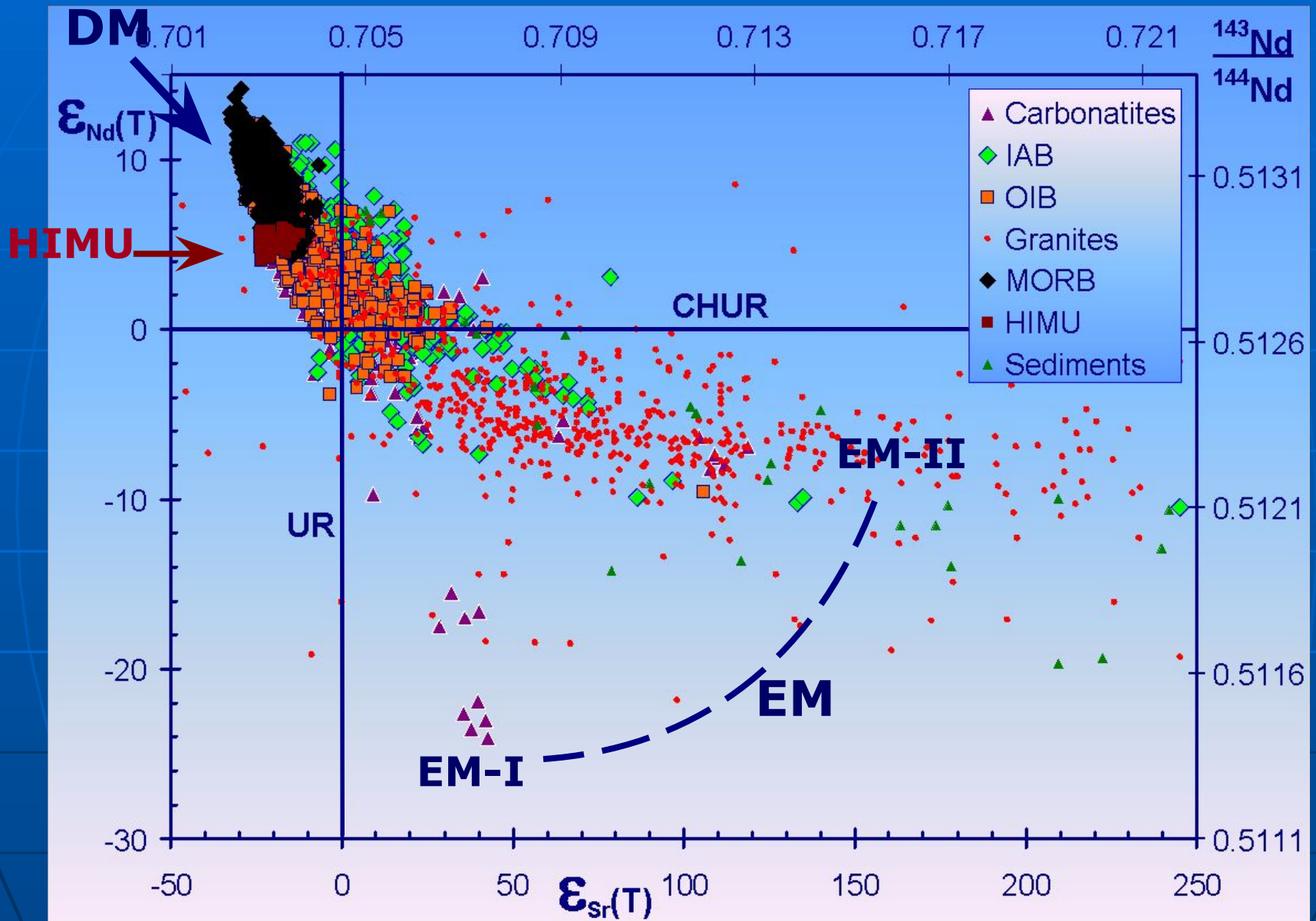
Различия в Sm/Nd
отношениях Земли и
хондритов возникли
изначально.
Корообразование к
этому феномену
отношения не имеет

Обе пары:
и $^{146}\text{Sm}-^{142}\text{Nd}$
и $^{147}\text{Sm}-^{143}\text{Nd}$
приводят к
исключительно
согласованным
выводам

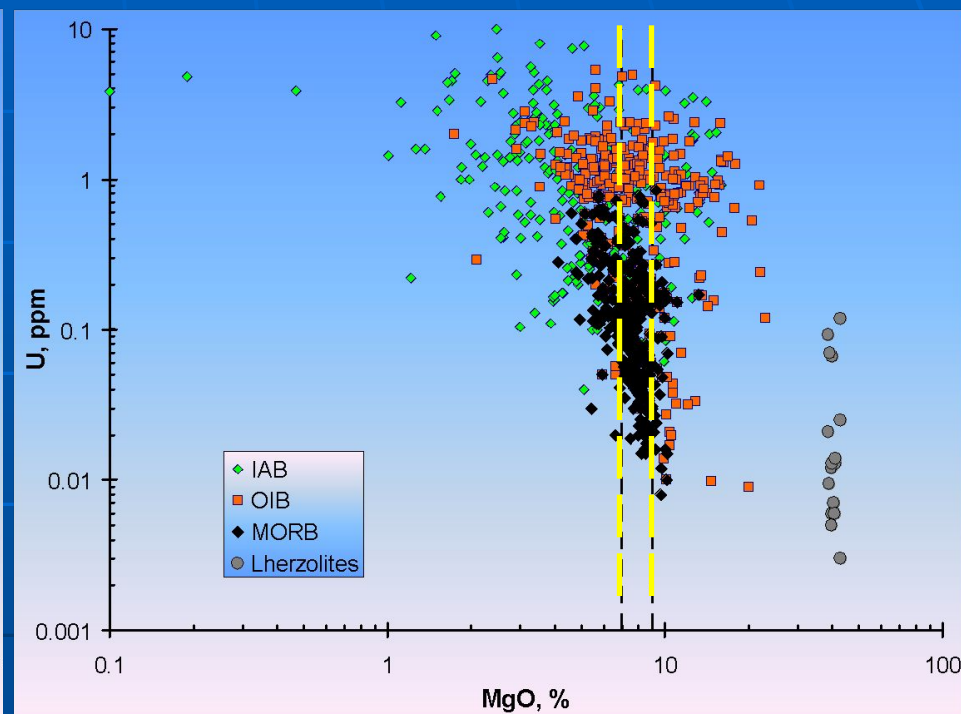
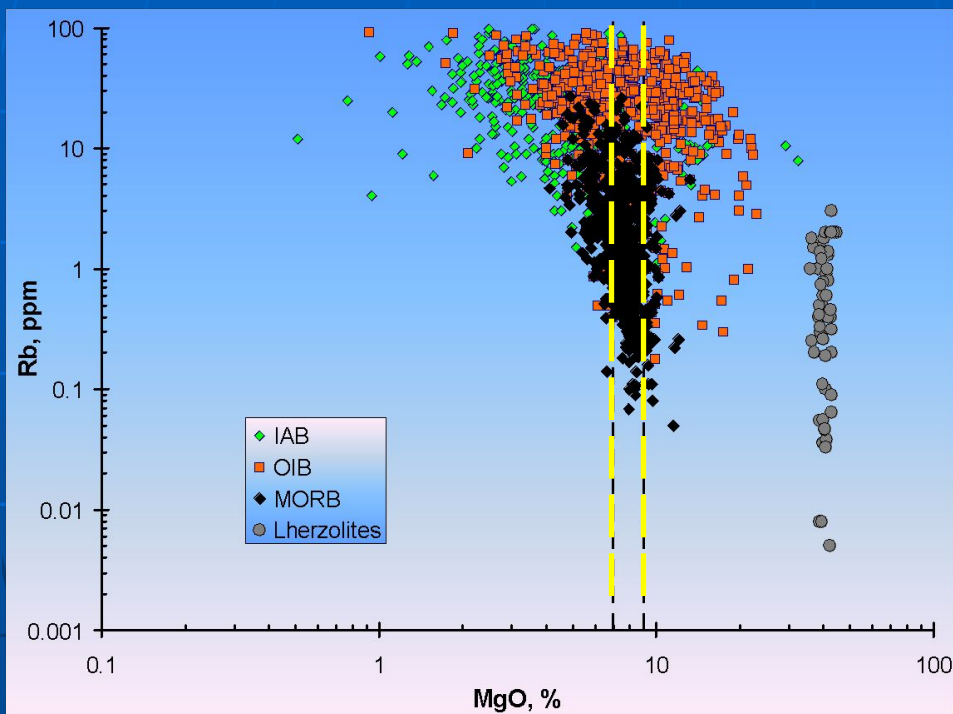


Причины изотопной гетерогенности мантии в Rb-Sr и Sm-Nd изотопных системах

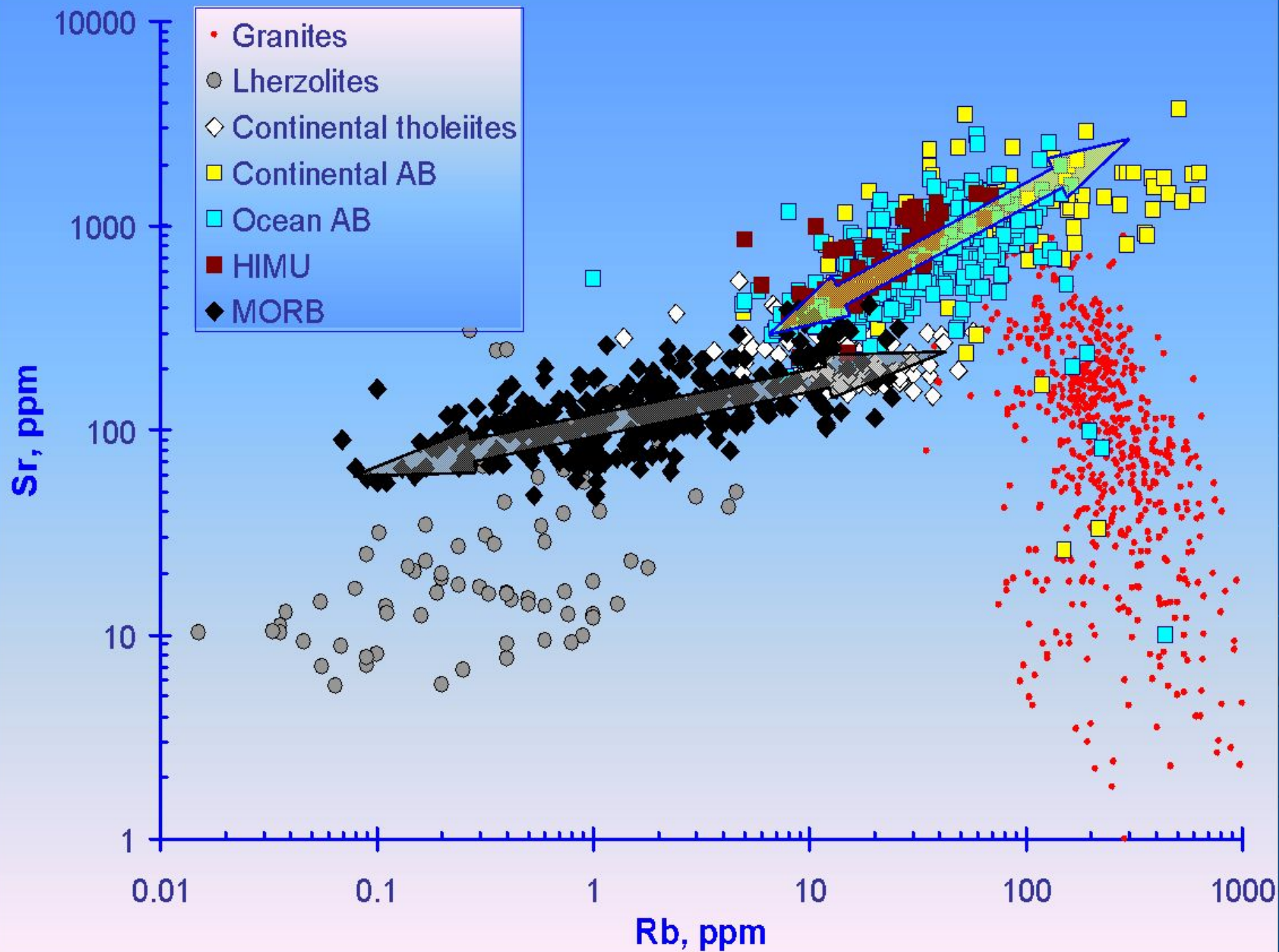


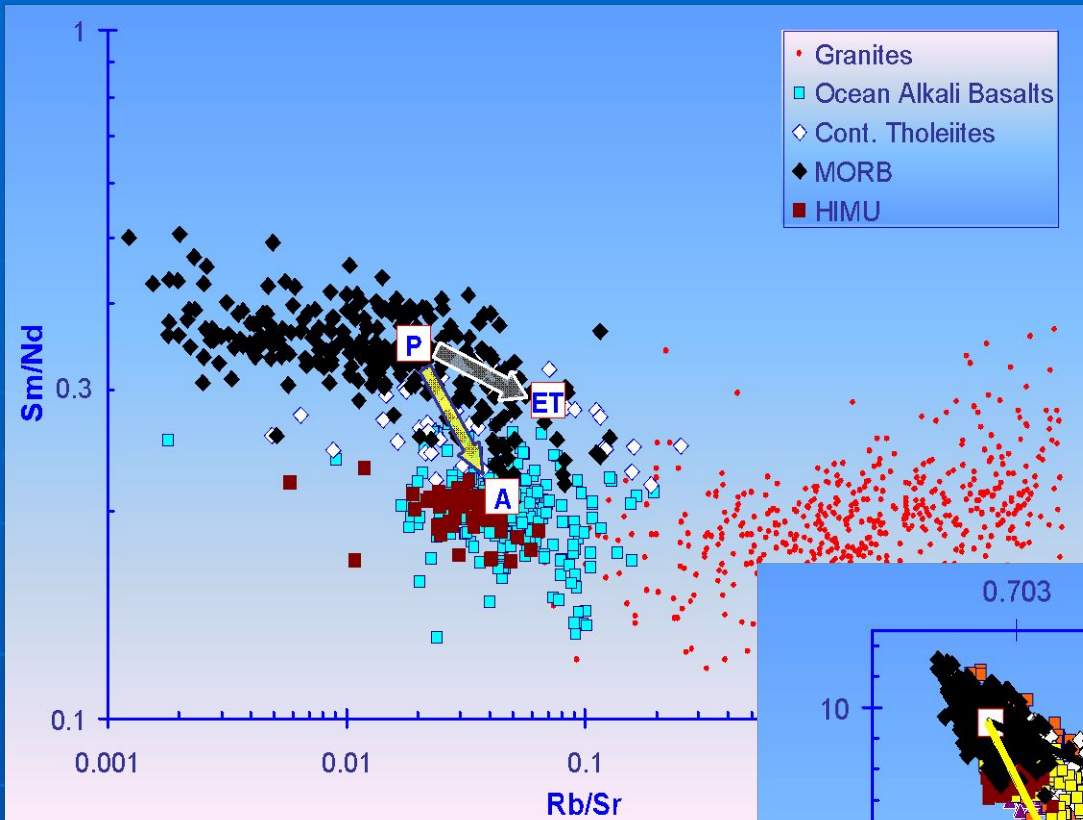


Насколько мантийный источник может быть гетерогенным в отношении элементов-примесей?



Если в мантии имеют место вариации Rb/Sr, Sm/Nd, U/Th/Pb, Lu/Hf отношений, то со временем это должно привести к изотопной гетерогенности Sr, Nd, Pb, Hf

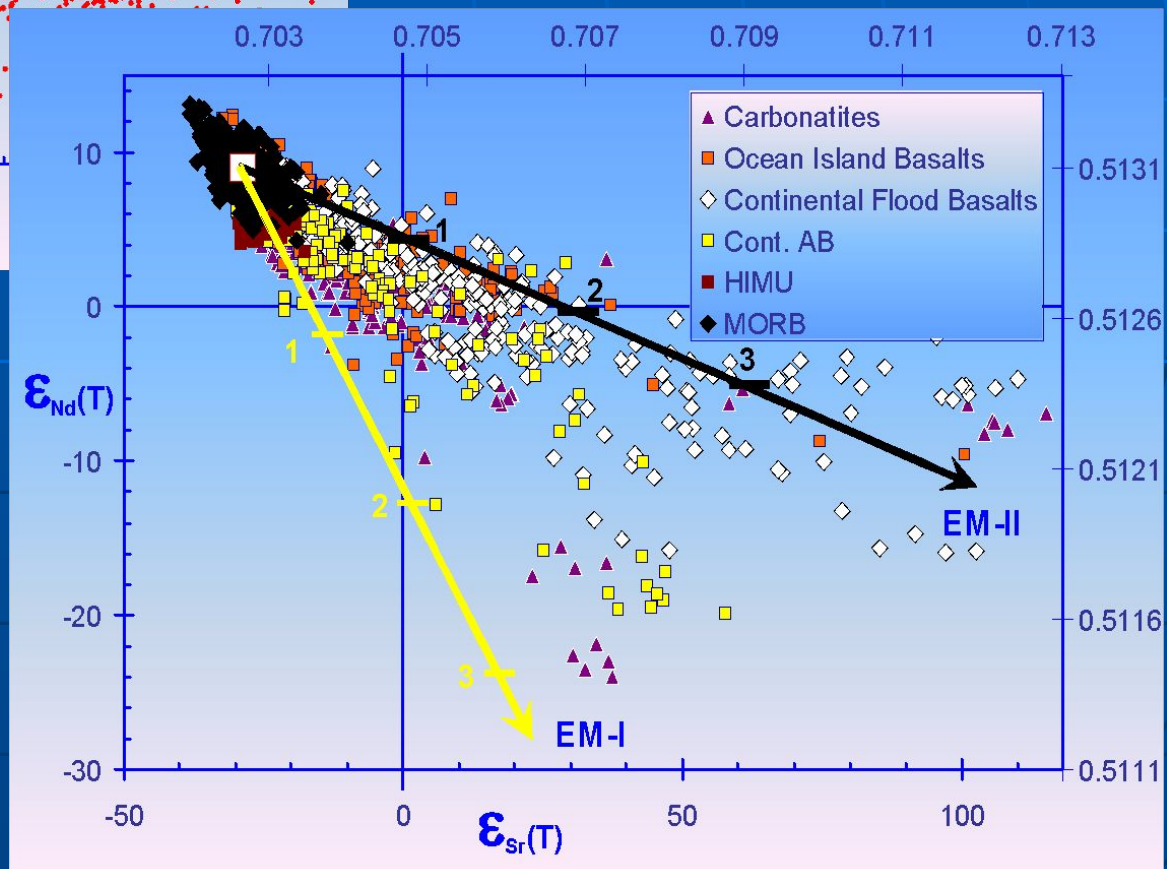




Изотопная гетерогенность мантии ($^{87}Sr/^{86}Sr$ и $^{143}Nd/^{144}Nd$) может быть следствием её химической гетерогенности (Rb/Sr и Sm/Nd)

Два главных типа мантийных магм с "обогащёнными" характеристиками:

- Щелочные базальты (A)
- Обогащённые толеиты (ET)



Relationships between the Chemical and Isotopic (Sr, Nd, Hf, and Pb) Heterogeneity of the Mantle

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