Sm-Nd problem set solution

Advanced Geochemistry: Tohoku University 2019

1 Answers to the questions

1. Given the following isotope evolution diagram, what do points A, B, C, D, and E on the figure represent?

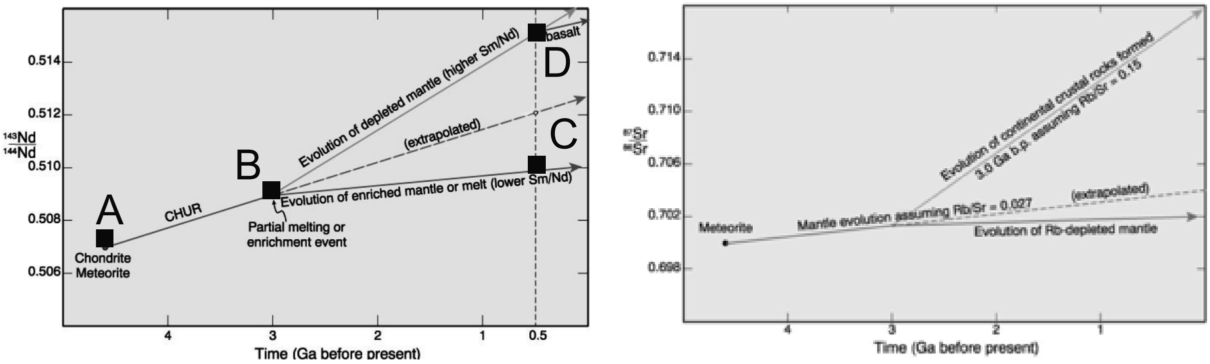

Figure 1: $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ evolution diagrams.

(a) $^{143}Nd/^{144}Nd$ of the bulk Earth at time of its accretion

(b) $^{143}Nd/^{144}Nd$ of bulk Earth at point of differentiation into a LREE depleted residue (residual mantle) and a LREE enriched melt (igneous rock).

(c) present-day $^{143}Nd/^{144}Nd$ of igneous rock that differentiated at point B (it has a negative epsilon value)

(d) present-day $^{143}Nd/^{144}Nd$ of residual mantle that differentiated from the chondritic mantle at point B (it has a positive epsilon value)

Given the following two isotope evolution diagrams, explain the differences in the two isotope systems? How might these systems differ if one used the evolution of the Depleted Mantle as the reference frame (instead of the CHUR reference frame)?

i. The top diagram shows the Nd isotopic evolution in which the Earth starts out with a *chondritic* $^{143}Nd/^{144}Nd$ and $^{147}Sm/^{144}Nd$ composition. Subsequent to accretion, the Earth differentiates a crust and mantle with the latter having a *superchondritic* Sm/Nd value (i.e., on average a LREE-depleted composition; high Sm/Nd relative to CHUR, point D) and the former having a *subchondritic* Sm/Nd value (i.e., on average a LREE-enriched composition low Sm/Nd relative to CHUR, point C). The bulk Earth continues to have a chondritic composition (i.e., extrapolation from point B, which marks the point in time for the differentiation event(s).

ii. The bottom diagram shows the Sr isotopic evolution in which the Earth starts out with a *chondritic* $^{87}Sr/^{86}Sr$ and *non-chondritic* $^{87}Rb/^{86}Sr$ composition. The Earth has chondritic relative abundances of refractory elements (including Sr), but is volatile element depleted (e.g., much lower concentrations of elements like Rb, K, Na) and consequently the Earth does not have chondritic proportions of Rb/Sr. On average crustal rocks have high Rb/Sr values and therefore evolve to high $^{87}Sr/^{86}Sr$ values, whereas the Depleted Mantle has, on average, a low Rb/Sr value and low $^{87}Sr/^{86}Sr$ values.

iii. Using a Depleted Mantle reference frame for both diagrams will still begin with the same starting point, but its evolution would start at the first melting and differentiation event time. At that time you still have 3 components: Depleted Mantle (DM, the residue from melting), bulk silicate Earth (BSE, the total system) and Continental Crust (CC, the extract melt). These 3 components will evolve with their characteristics slopes depending on their Sm/Nd and Rb/Sr values.

Sketch a likely chondrite-normalized REE pattern for the residual Depleted Mantle, Continental Crust, MORB, and CHUR (chondrite) in part a

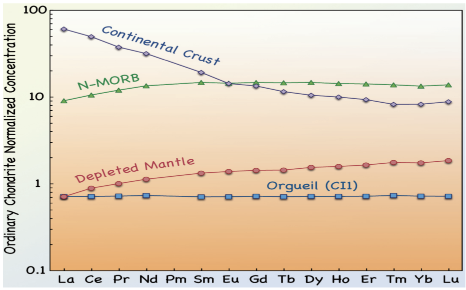

Figure 2: chondrite-normalized REE diagram. Figure from Bill White (Cornell University).

2. Calculate the $^{143}Nd/^{144}Nd$ ratio of CHUR (chondritic uniform reservoir) at 2.5 Ga given that the present $^{143}Nd/^{144}Nd$ for CHUR is 0.512638 and its $^{147}Sm/^{144}Nd$ is 0.1967. The half-life of ^{147}Sm is 106 Ga (i.e., λ is 6.539×10^{-12}).

   – The answer, using the isochron equation for CHUR at 2.5 Ga, is $[^{143}Nd/^{144}Nd]^{CHUR}_{@2.5Ga} = 0.509395$

3. Given a sample with an initial $^{143}Nd/^{144}Nd = 0.51100$ at 1.8 Ga, what is its ϵ_{Nd} relative to CHUR at that time? First you will need to calculate the $^{143}Nd/^{144}Nd$ of CHUR at 1.8 Ga using the isochron equation and the information provided in question 2 (see also the lecture notes), then calculate ϵ_{Nd} at 1.8 Ga.

   – The answer, using the isochron equation for CHUR at 1.8 Ga, is $[^{143}Nd/^{144}Nd]^{CHUR}_{@1.8Ga} = 0.510309$ and its ϵ_{Nd} is 13.5

4. (a) Calculate a model age relative to CHUR for a rock given the following data: Sm = 0.580 ppm, Nd = 1.539 ppm, $^{143}Nd/^{144}Nd = 0.513101$. The isotopic abundances for ^{147}Sm and ^{144}Nd are 15% and 23.9%, respectively.

   – $^{147}Sm/^{144}Nd = 0.2365$, model age is 1.77 Ga, and its present-day ϵ_{Nd} is 9.0

   (b) Plot the evolution lines for CHUR and the rock in part (a) in epsilon vs. age (time) space

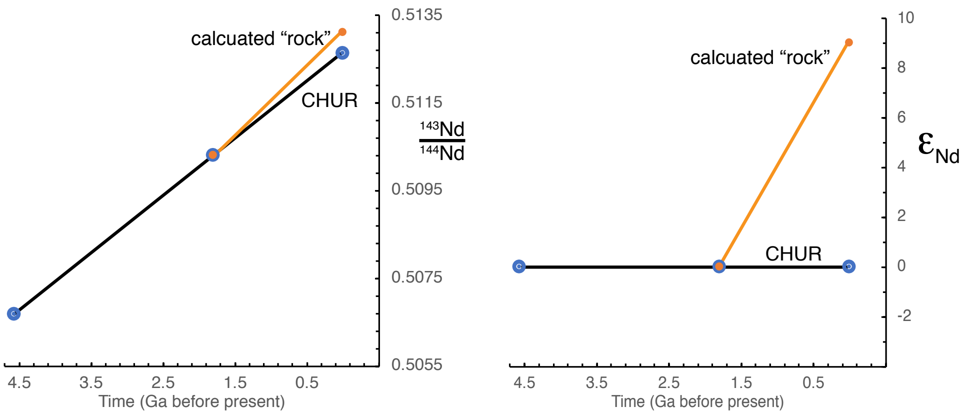

Figure 3: A $^{143}Nd/^{144}Nd$ evolution diagram.