Nov 16, 2010
C-T A LEE

more dating

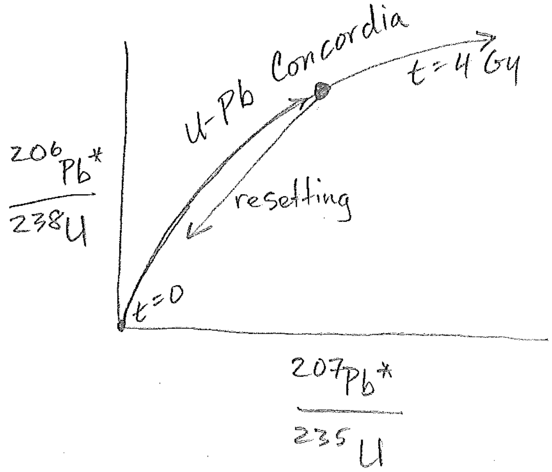
U-Pb concordia

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

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

$$\frac{^{206}Pb - {}^{206}Pb_o}{^{238}U} = e^{\lambda_{238} t} - 1$$

$$\frac{^{207}Pb - {}^{207}Pb_o}{^{235}U} = e^{\lambda_{235} t} - 1$$



$$^{206}Pb^* = {}^{206}Pb - {}^{206}Pb_o$$

$$^{207}Pb^* = {}^{207}Pb - {}^{207}Pb_o$$

This is particularly good for dating zircons which love to take in U, but not Pb. → zircons have hi U/Pb.

The Uranium system can also be used to date the galaxy.

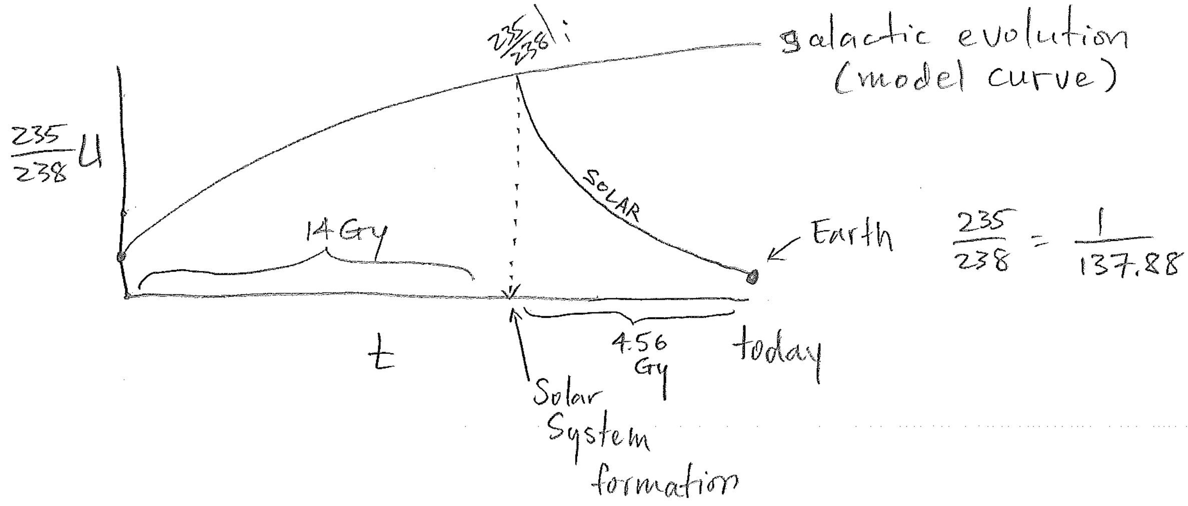
- ^{235}U and ^{238}U are produced by supernovas that have been ongoing since the Big Bang.
- the evolution of ^{235}U in the galaxy in bulk is ~

$$\frac{d\,^{235}U}{dt} = P_{235} - \lambda_{235}\,^{235}U$$

$$\frac{d\,^{238}U}{dt} = P_{238} - \lambda_{238}\,^{238}U$$

} GALACTIC EVOLUTION

- where P is a nucleosynthetic background production rate.



SOLAR EVOLUTION

SOLAR INITIAL

$$\frac{^{235}U}{^{238}U} = \frac{^{235}U_i}{^{238}U_i} e^{(\lambda_{238} - \lambda_{235}) t_{SOLAR}}$$

$t_{SOLAR} = 4.56$ Gy

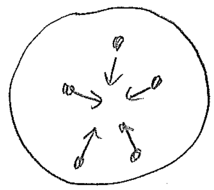
IF GALACTIC EVOLUTION model is known, and $\frac{^{235}U_i}{^{238}U_i}$ is known, THEN age of galaxy is known.

→ 14 Gy

EARTH DIFFERENTIATION.

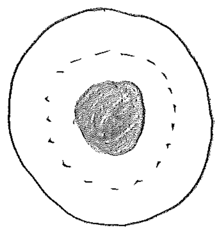
IDEALIZED SERIES OF EVENTS

STEP 1



~homogeneous Earth
- core-mantle segregation
  ~ 10 - 30 My

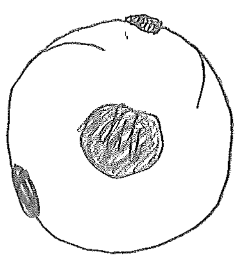
STEP 2



Homogenous mantle (BULK SILICATE EARTH)
PRIMITIVE MANTLE
↳ magma ocean
  ↳ crystallization → layering

FIRST 100 My

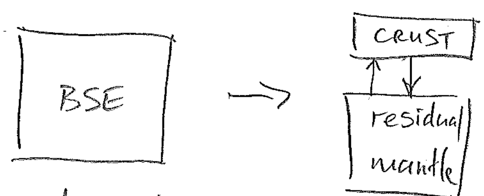
STEP 3



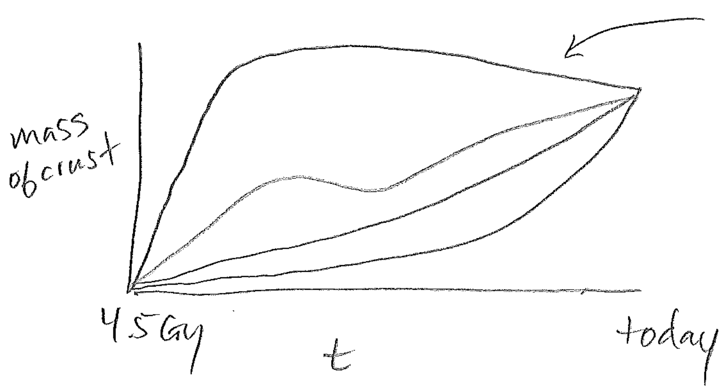
CRUST-MANTLE segregation

SILICATE DIFFERENTIATION
↳ throughout Earth's history.

- hallmark of silicate differentiation is formation of continental crust.



Stage 1

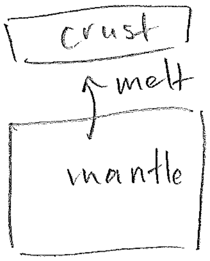


cumulative crustal growth curves.
which one is Earth?

Why is understanding growth of cont. crust important?

① continents don't subduct. (why?)
- therefore, they don't sink like typical TBLs
- they suppress convective heat loss from beneath continents.

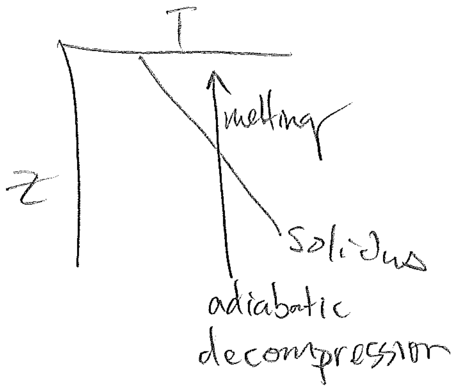
② Continents house the incompatible trace-elements, and this includes heat-producing elements (U, Th, K



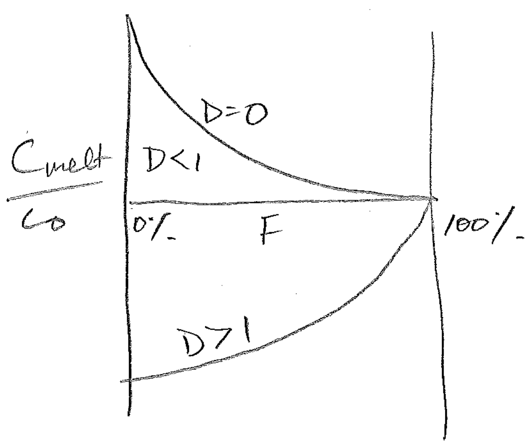
During melting, concentration of an element C:

$$D = \frac{C_{min}}{C_{melt}} < 1 \quad \text{INCOMPATIBLE}$$

$$D = \frac{C_{min}}{C_{melt}} > 1 \quad \text{compatible}$$



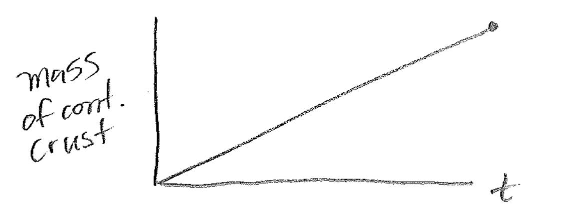
melts enriched in incompatible elements

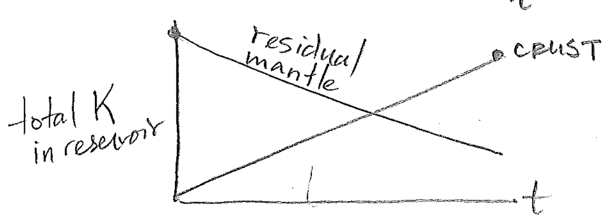


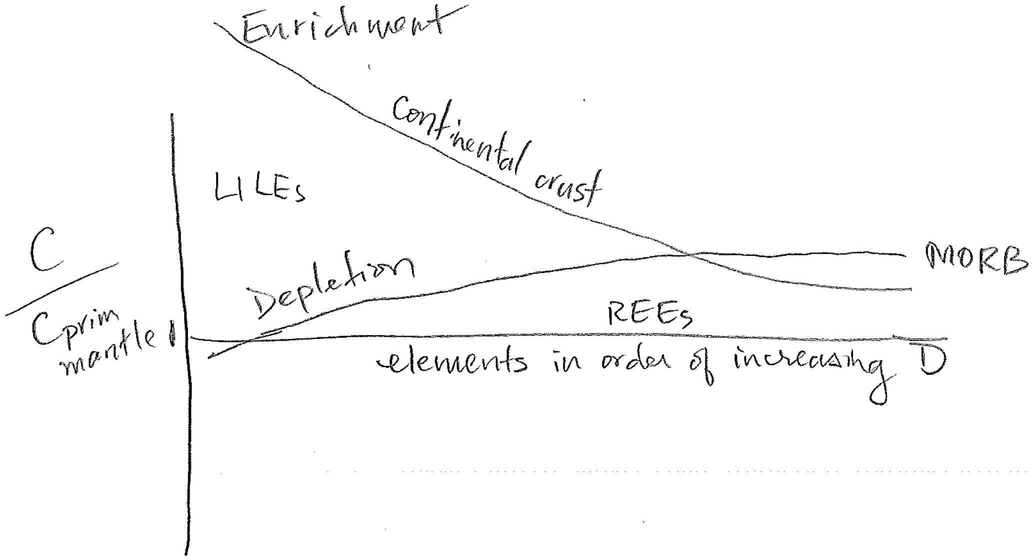
$$\frac{C_{melt}}{C_{o\,source}} = \frac{1}{D + F(1-D)}$$

F is melting degree

C_o is C in unmelted source





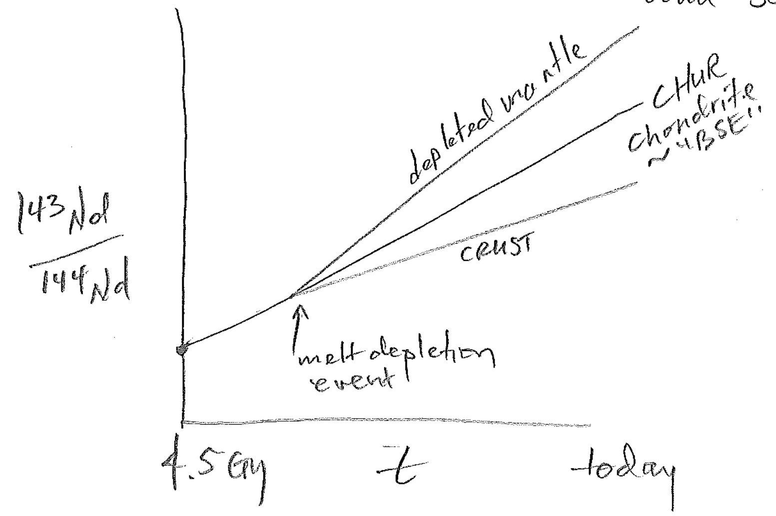


- CONTINENTAL CRUST HOUSES ~50% OF THE EARTH'S BUDGET OF HIGHLY INCOMPATIBLE ELEMENTS LIKE U, Th, K.
- THE UPPER MANTLE IS DEPLETED IN THESE SAME elements as evidenced by THE FACT THAT MORBS SHOW AN <u>INHERITED</u> DEPLETED SIGNATURE.

What is the effect on isotopic systems

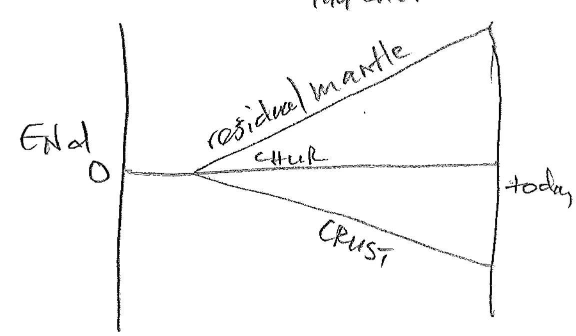
Sm + Nd (Sm parent, Nd daughter) } both are incompatible but $D_{Nd} < D_{Sm} < 1$.

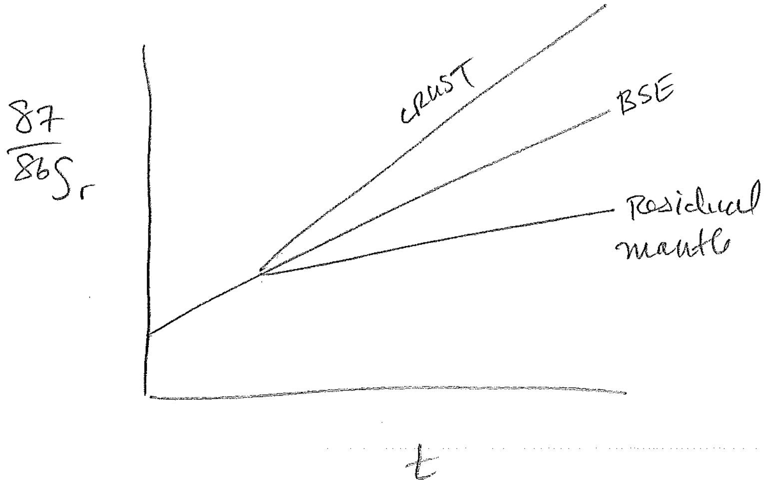
∴ melts have low Sm/Nd and solid residues have high $\frac{Sm}{Nd}$



in εNd

$$\varepsilon Nd = \frac{\frac{143}{144}_{SA} - \frac{143}{144}_{CHUR}}{\frac{143}{144}_{CHUR}} \times 10^4$$





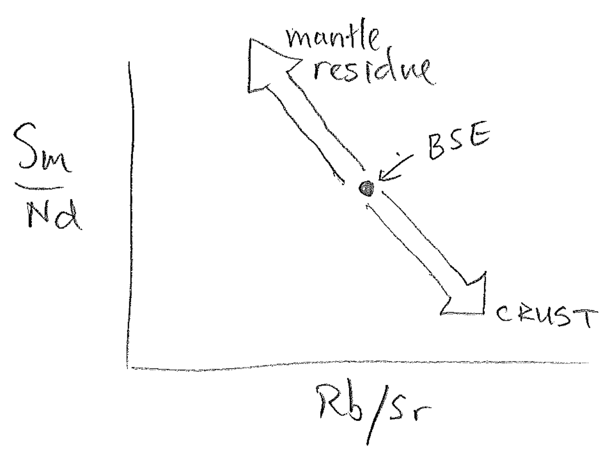
parent → daughter

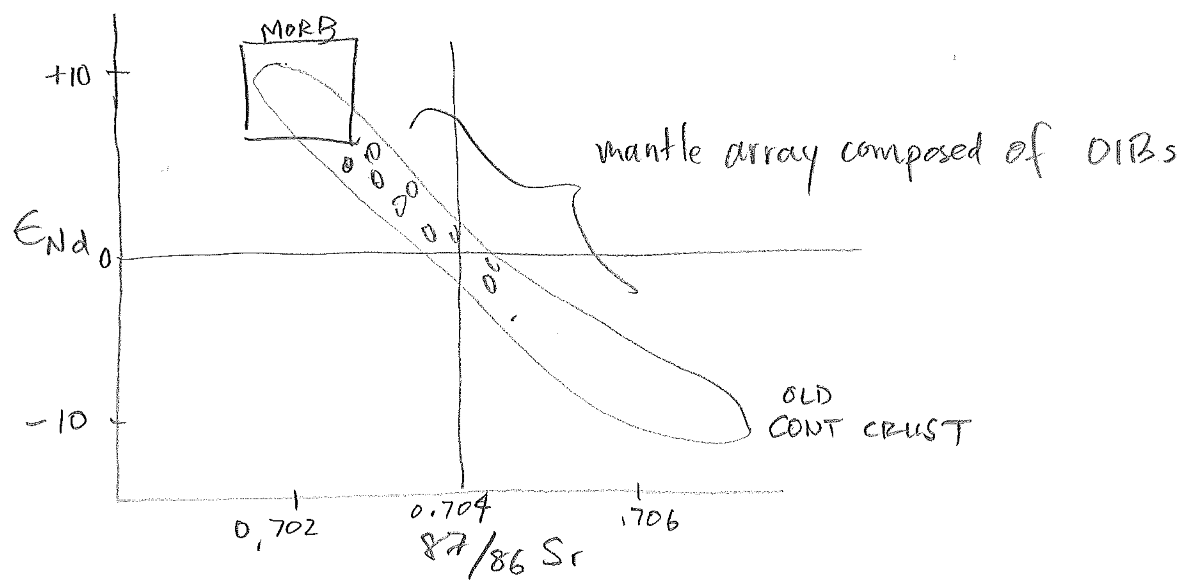
For Rb → Sr

$^{87/86}Sr$ is reverse of $^{143}Nd/^{144}Nd$

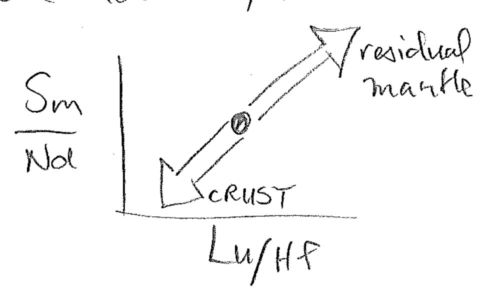
because

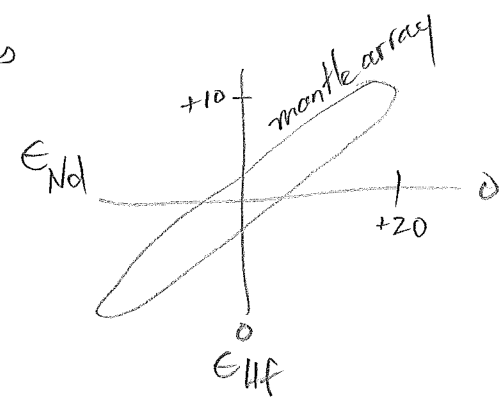
$D_{Rb} < D_{Sr}$





note for Lu/Hf similar trends





MORBS have ε_{Nd} +10
- which means they tap a mantle that is depleted in incompatible trace elements.

Is the entire mantle depleted?
probably not...

mass of element in BSE $\overset{?}{=}$ mass of element cont. crust + mass of ele. in mantle

$$C_{BSE} \cdot M_{BSE} > C_{cc} M_{cc} + C_{DM} M_{M}$$

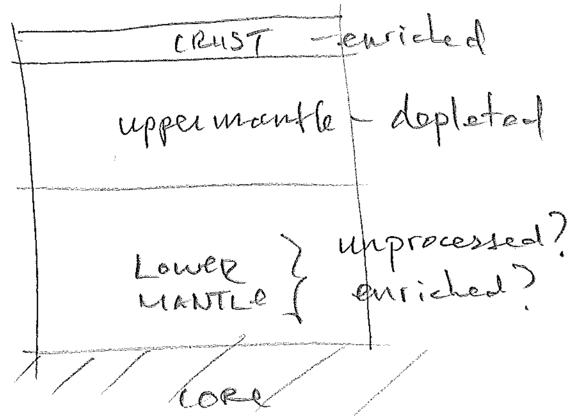
This means we have not accounted for all the elements in the mass balance.

- If we are confident about C_{cc}, M_{cc} and M_m it means that C of the mantle is larger than that of the depleted mantle source to MORB.

$$C_{BSE} \cdot M_{BSE} = C_{cc} M_{cc} + C_{DM} M_{UM} + \underbrace{C_{PM} M_{PM}}$$

∴ There is a component in the mantle that is enriched or has never been depleted.

⟶ this led to the LAYERED MANTLE MODEL

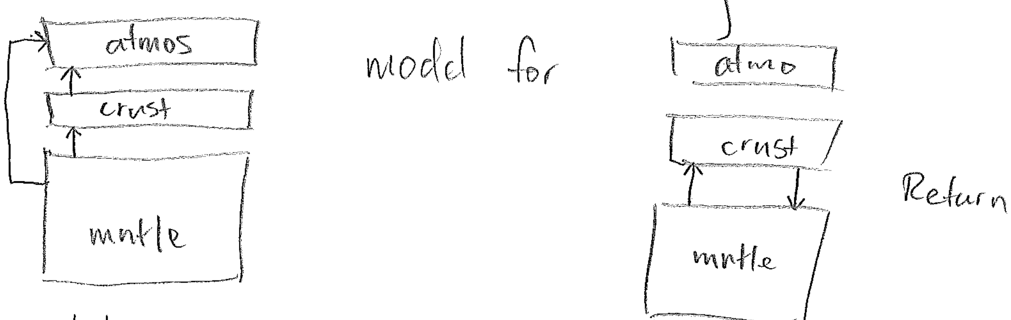


The notion of a primitive, untapped (or less tapped) Lower mantle is supported by $^3He/^4He$

^3He is a primordial gas, leftover from solar nebula accretion. It is not generated after Earth forms.

^4He is a product of ^{235}U, ^{238}U, ^{232}Th α decay. It grows w/ time.

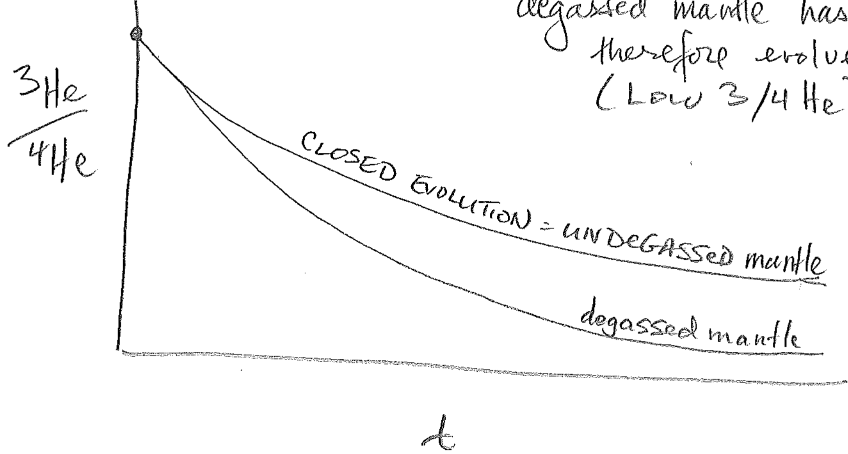
^3He and ^4He are gases, so are thought to escape to atmosphere during mantle melting. They are not thought to be recycled back into the mantle. One way ticket out

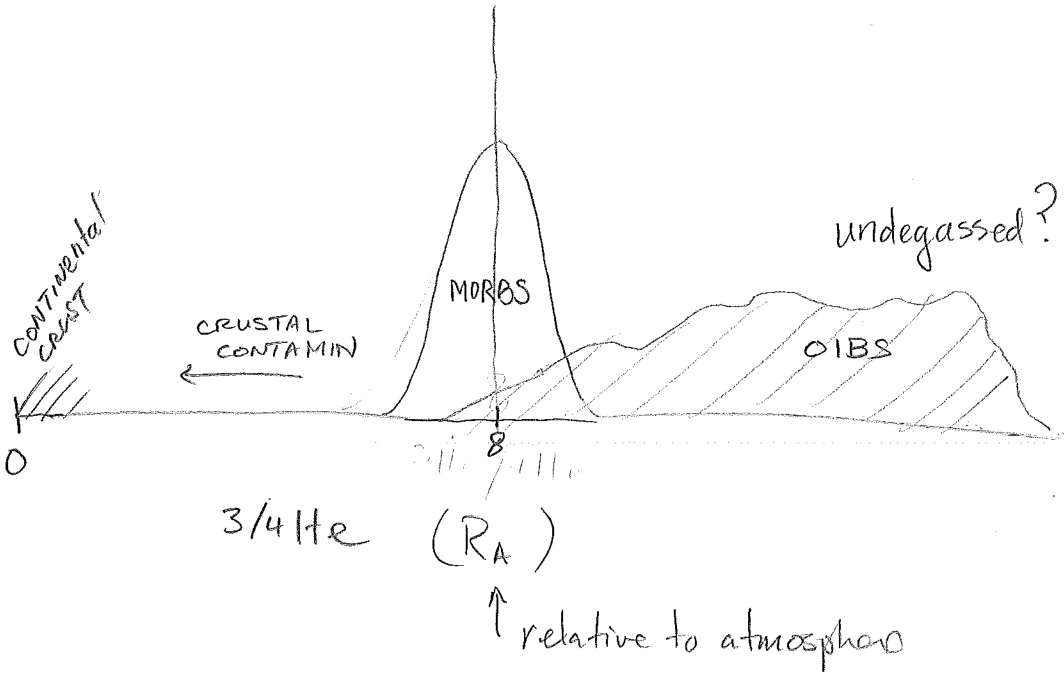


Helium
no return to mantle

Uranium

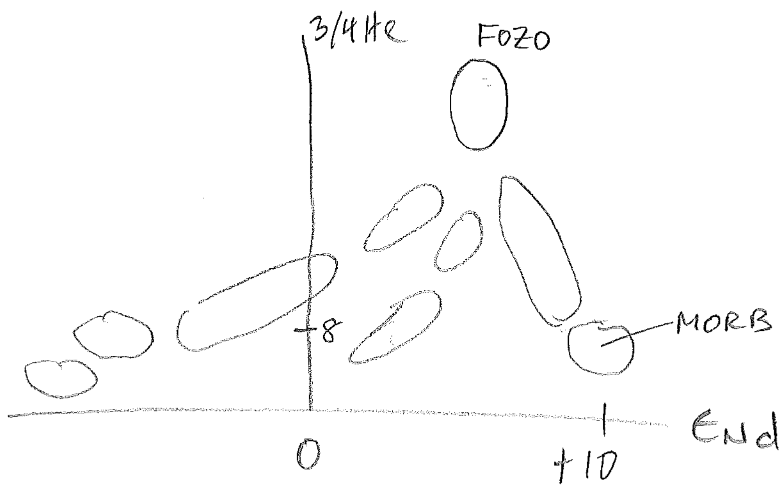
degassed mantle has high U/He and therefore evolves to radiogenic (Low 3/4 He)





Since OIBs have undegassed signature, it's always been assumed that they tap deep, primitive reservoirs whereas MORBs tap the depleted upper mantle.

<u>However</u>

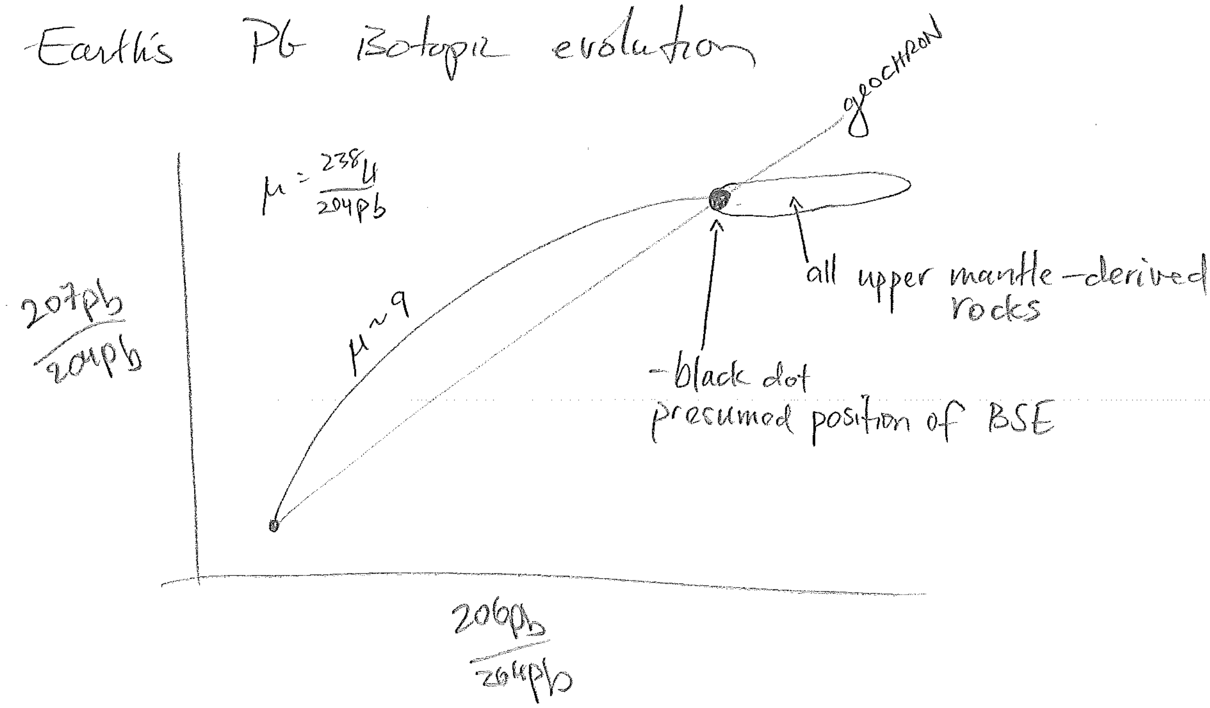


seems like all mantle rocks in ENd - 3/4 He space converge. This convergent point is called FOZO (Stan Hart)

Paradox FOZO = hi 3/4 He → primitive undegassed
BUT FOZO ENd > 0 → melt-depleted.

- possible SOLUTIONS
  1. He doesn't escape efficiently to atmosphere, and gets recycled back into mantle
  2. $D_U < D_{He}$ (controversial)

Earth's Pb isotopic evolution



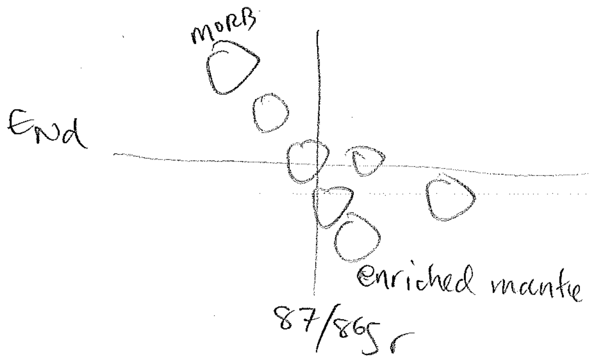
Pb-paradox = all upper mantle-derived rocks lie to the right of the geochron. To mass balance with BSE, a low U/Pb reservoir is needed (LOMU)

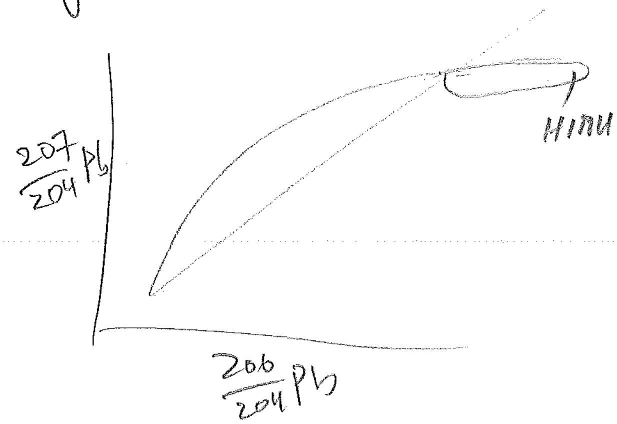
What is LOMU?

possible ideas

- Pb segregated to core
- Pb in sulfides that segregate to core
- Pb in lower crust (plagioclase)

Mantle heterogeneity as sampled by oceanic basalts



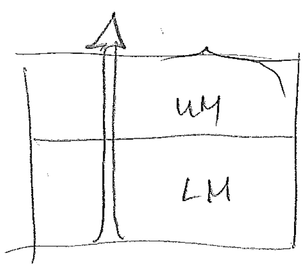


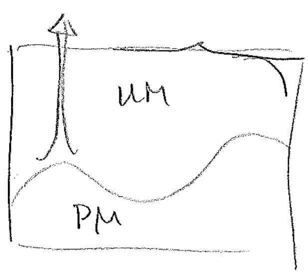
and $^3He/^4He$

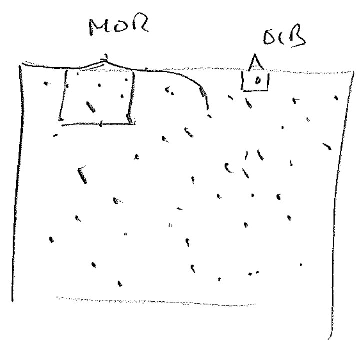
What are these recycled lithologies?

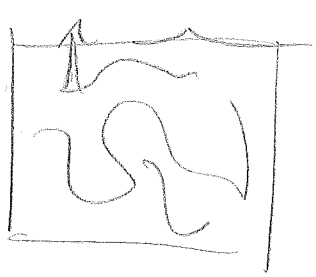
recycled oceanic crust, continental crust, shit

What is the spatial distribution of these heterogeneities









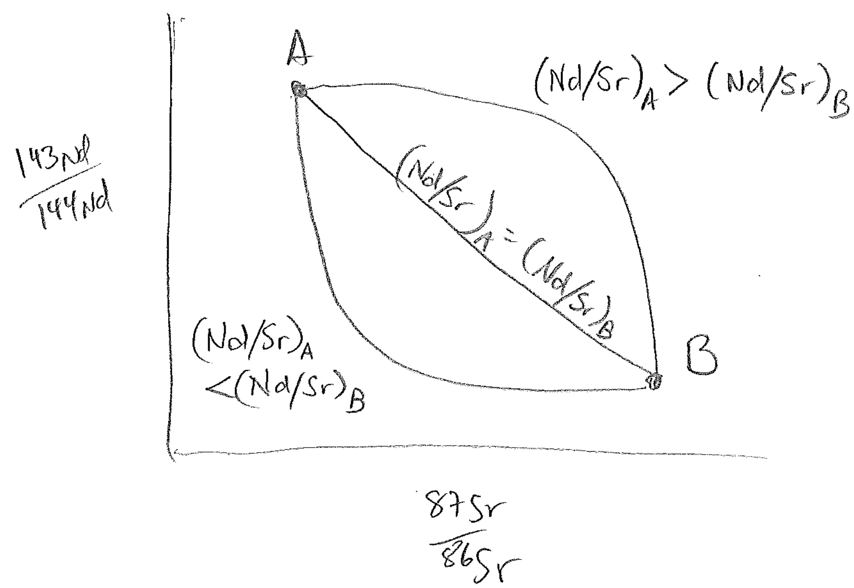
Some Notes on Isotope mixing

R = isotopic ratio, e.g. $^{143}Nd/^{144}Nd$

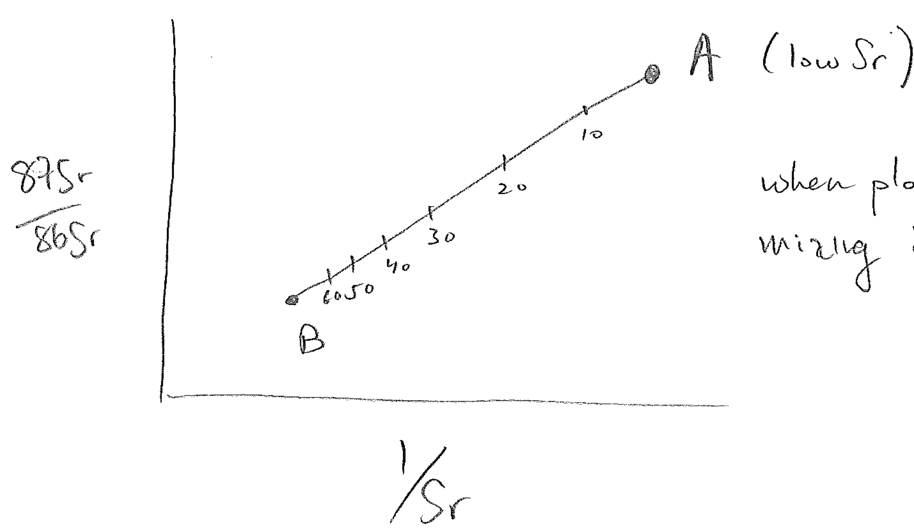
C = elemental concentration (we ignore atomic wt. differences of isotopes)

two-comp. mixing

$$M_{mix} R_{mix} = R_A C_A M_A + R_B C_B M_B$$ simple mass balance



binary mixing is hyperbolic



when plotted vs 1/element mixing is <u>linear</u>.