Sarah Lambart - 2016

Lecture 16: Introduction to Radioactive Isotopes

Recap Lecture 14-15: Trace elements

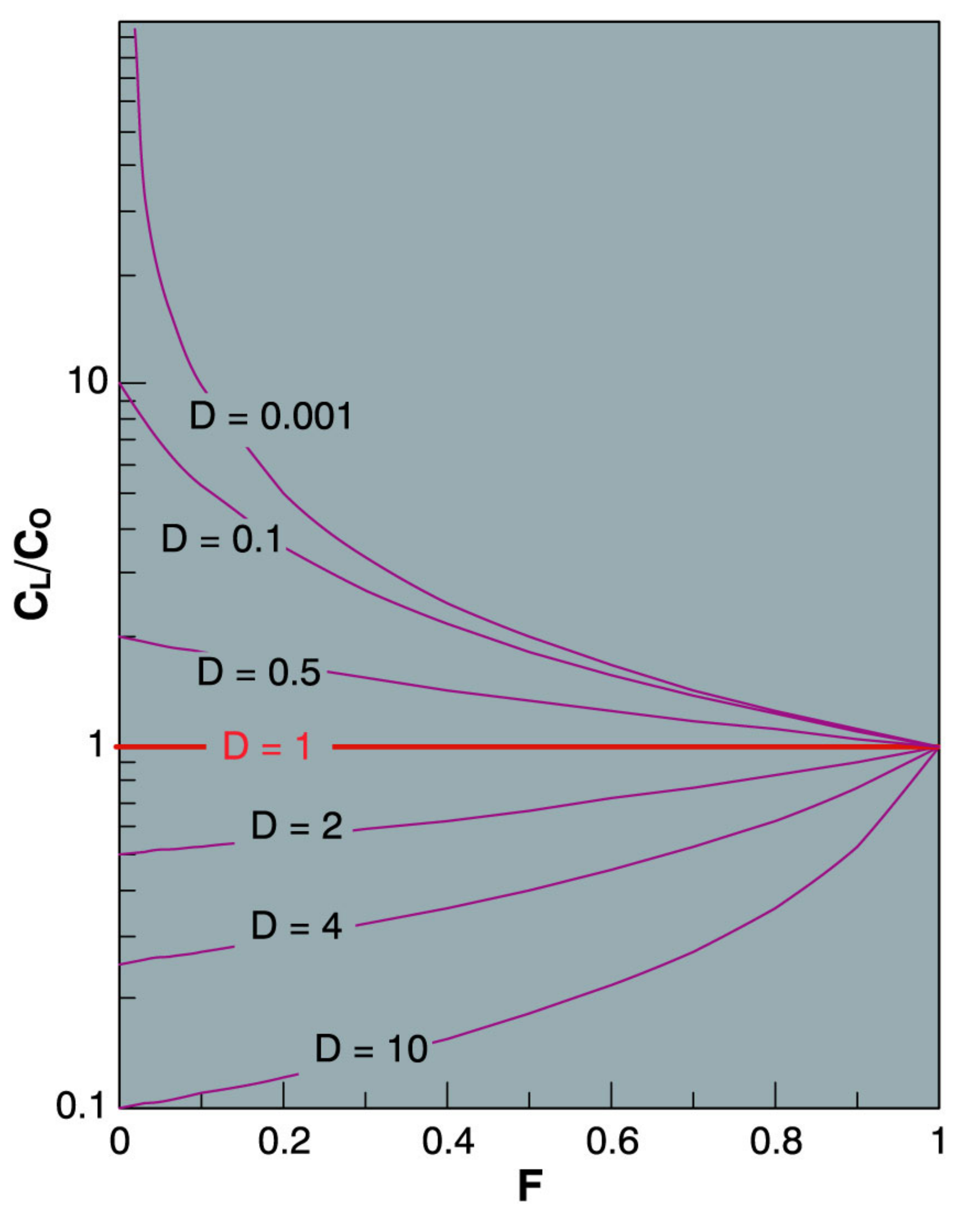
- Less than 1% in the bulk composition
- Much more sensitive to the igneous processes
- Potential tracers of the source composition

Recap Lecture 14-15: Trace elements

Batch Melting

C_0: Bulk composition
C_L: liquid composition
F: melt fraction
Bulk D = $\sum D_i X_i$

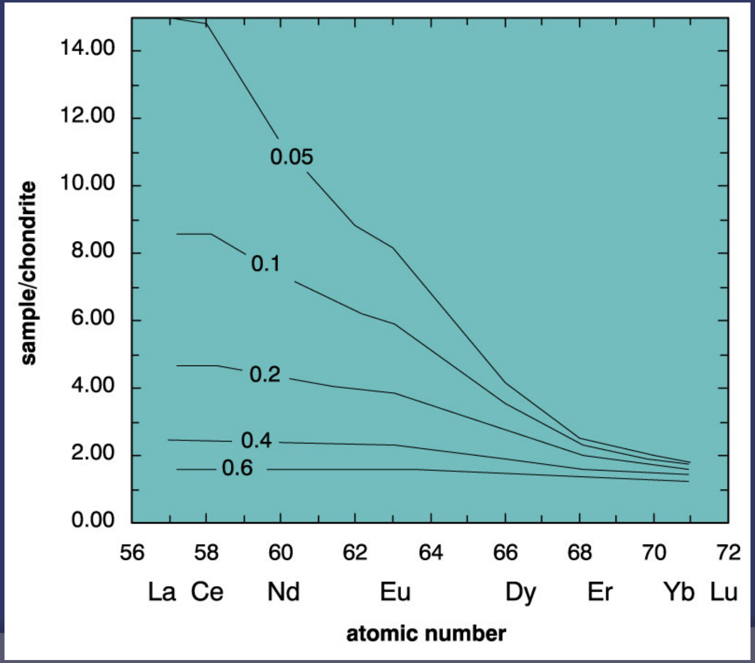
$$C_L/C_0 = 1/(F + D(1-F))$$



Recap Lecture 14-15: Trace elements

REE diagrams

- All incompatible (D<1)
- Continuous variation of the degree of incompatibility: $D_{LREE} < D_{MREE} < D_{HREE} < 1$



⇒negative slope

⇒higher slope for lower F

Recap Lecture 14-15: Trace elements

REE diagrams

- All incompatible (D<1)
- Continuous variation of the degree of incompatibility: $D_{LREE} < D_{MREE} < D_{HREE} < 1$

Application to igneous processes:

- Depth of melting (in the mantle):
  - $D_{Eu}^{plg} > 1 \Rightarrow$ negative anomaly in Eu
  - $D_{Yb}^{gt} >> 1 \Rightarrow$ stronger negative slope

Recap Lecture 14-15: Trace elements

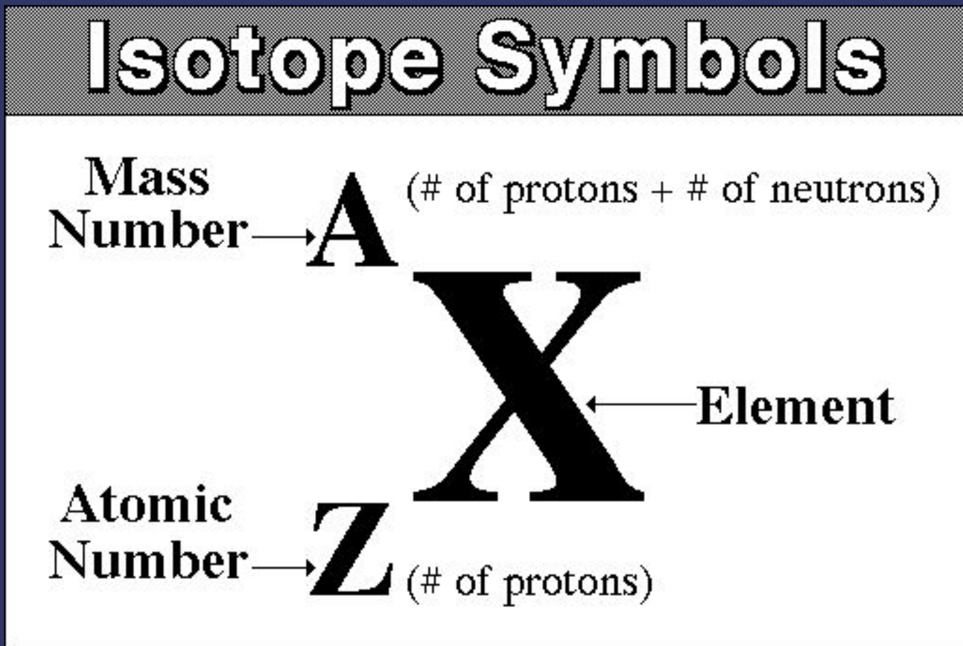
REE diagrams

- All incompatible (D<1)
- Continuous variation of the degree of incompatibility: $D_{LREE} < D_{MREE} < D_{HREE} < 1$

Application to igneous processes:

- Depth of melting (in the mantle):
- Source composition:
    - $D=1 \Rightarrow C_L$ (magma) $= C_0$ (source)
    - $D=0 \Rightarrow C_0 = F^*C_L$
    - $D_a = D_b \Rightarrow C_L^a/C_L^b = C_0^a/C_0^b$

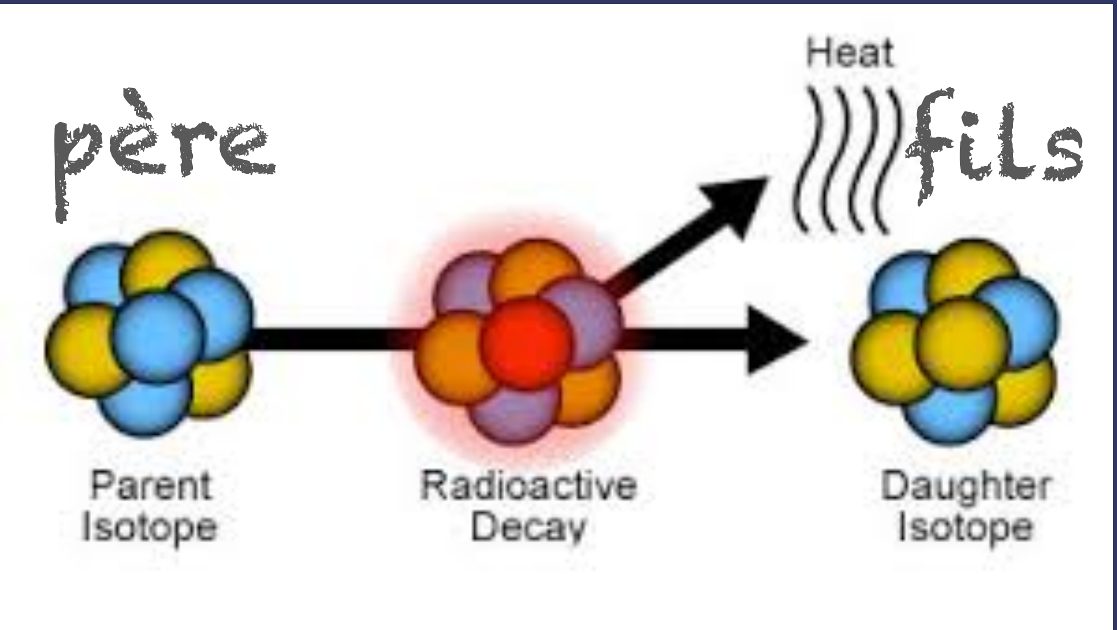
Isotopes: definition



Same # of protons (atomic number)

Different # of neutrons (protons + neutrons = elemental mass)

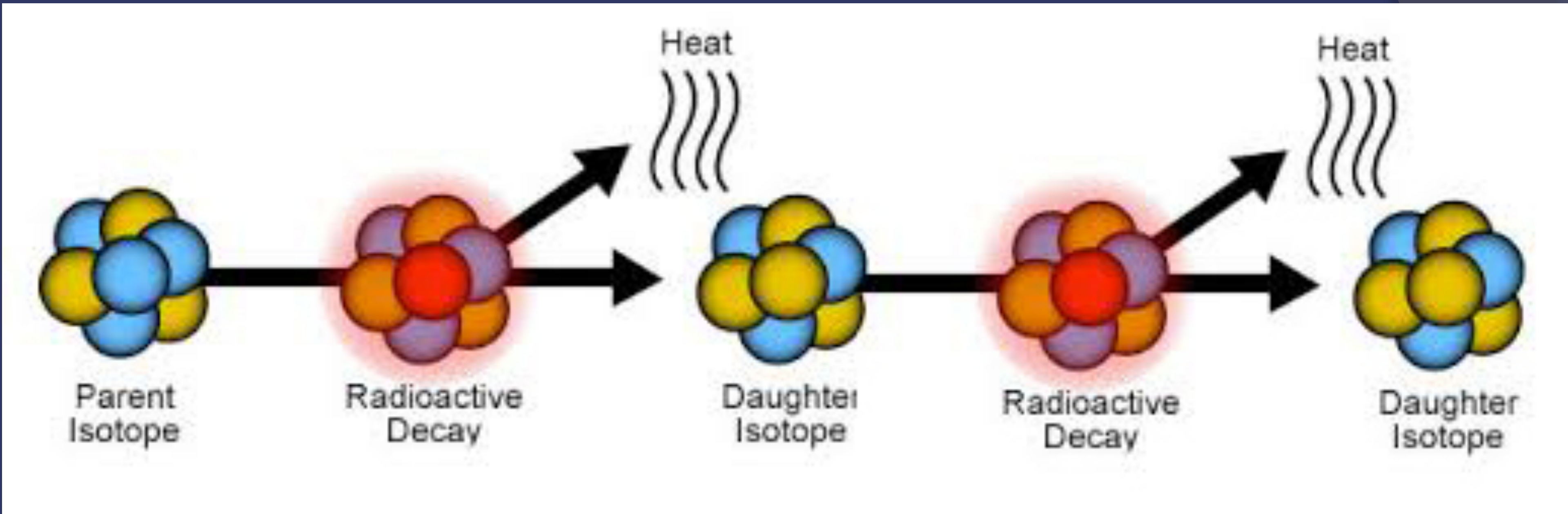
Radioactive and Radiogenic Isotopes



Radioactive isotope → Radiogenic isotope

Radioactive and Radiogenic Isotopes

Decay chain



Radioactive isotope → Radiogenic & Radioactive isotope → Radiogenic isotope

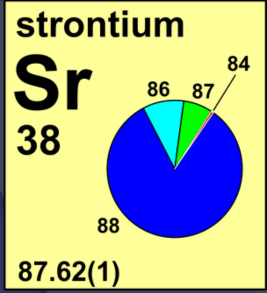
Isotopic systems

- Used for dating
  - K-Ar
  - Rb-Sr
  - Sm-Nd
  - U-Pb

Next Thursday

- Used as tracers
  - Sm-Nd
  - Rb-Sr
  - Pb-Pb
  - Lu-Hf
  - Re-Os

Example: the Rb-Sr system



- ^{87}Rb decays to ^{87}Sr ($t_{1/2} = 48.8 \times 10^9$ yr); both are referenced to ^{86}Sr, which is a stable isotope

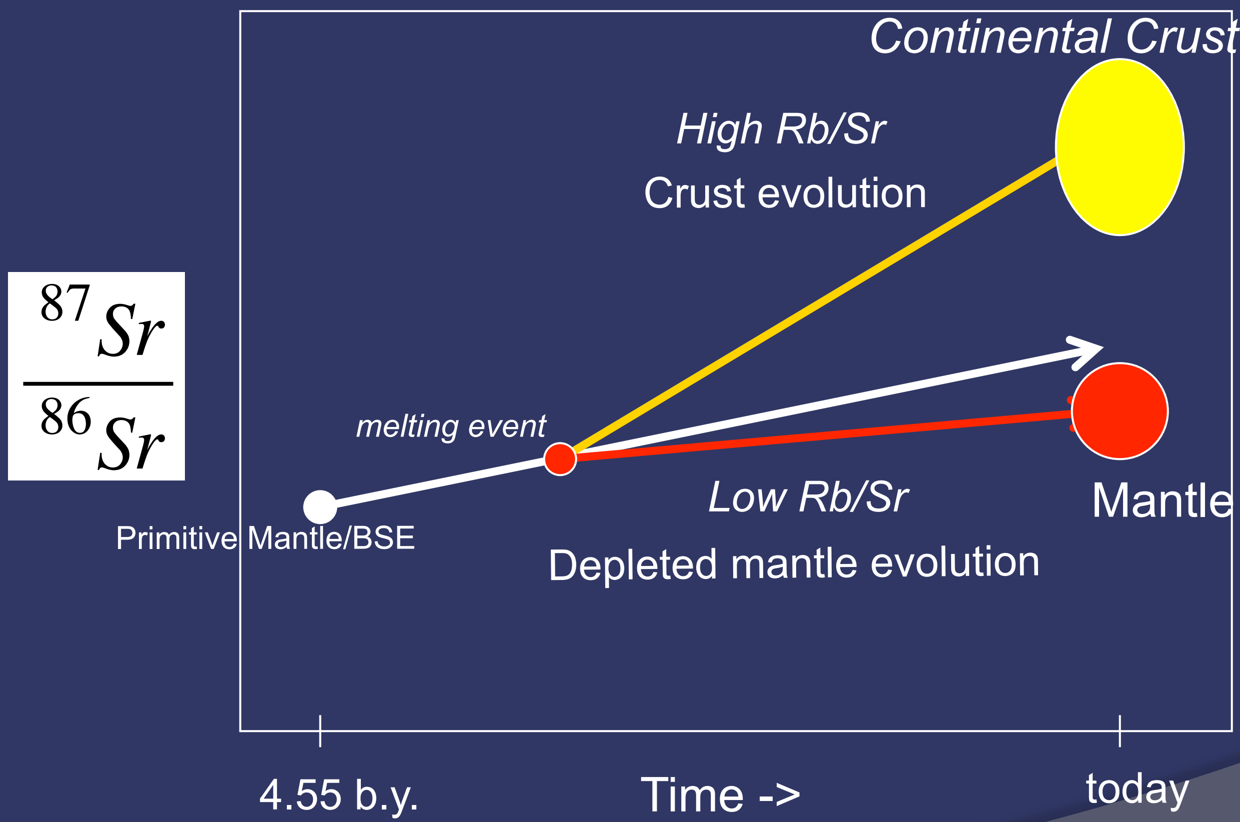
- ^{87}Sr/^{86}Sr ratio in present-day sample = initial ratio [(^{87}Sr/^{86}Sr)$_0$], plus any radiogenic ^{87}Sr that has formed since then

$$^{87}Sr = {}^{87}Sr_o + {}^{87}Rb\lambda t$$

$\lambda = 1/t_{1/2}$: decay constant

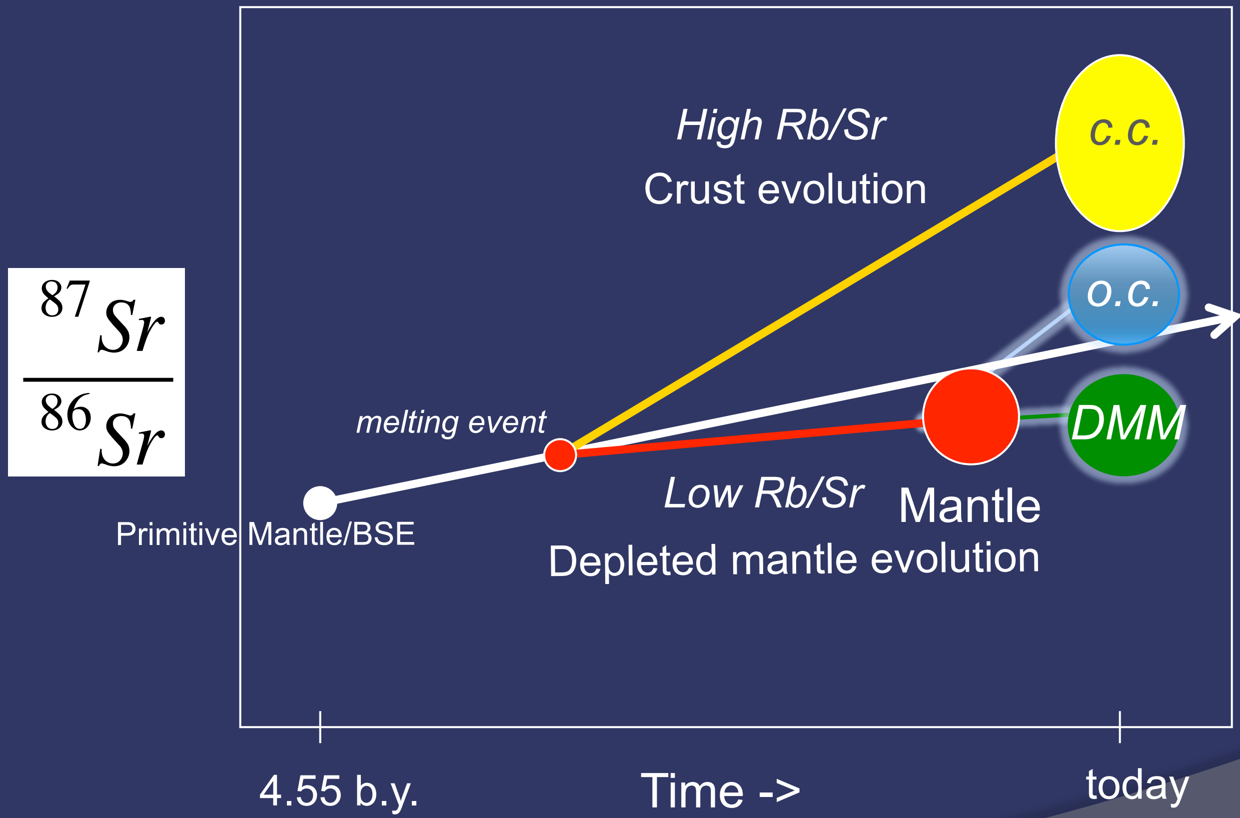
Example: the Rb-Sr system

- $D_{Rb} < 0 \quad \Rightarrow {}^{87}Sr/{}^{86}Sr_{cc} > {}^{87}Sr/{}^{86}Sr_{mantle}$

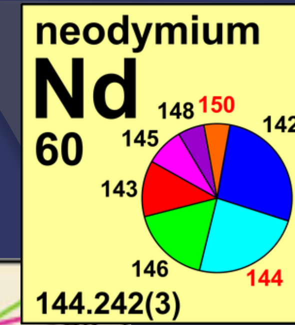


Example: the Rb-Sr system

- $D_{Rb}<0 \Rightarrow {}^{87}Sr/{}^{86}Sr_{cc} > {}^{87}Sr/{}^{86}Sr_{mantle}$
  $\Rightarrow {}^{87}Sr/{}^{86}Sr_{oc} > {}^{87}Sr/{}^{86}Sr_{mantle}$



Ex: $^{147}Sm \rightarrow {}^{143}Nd$ system



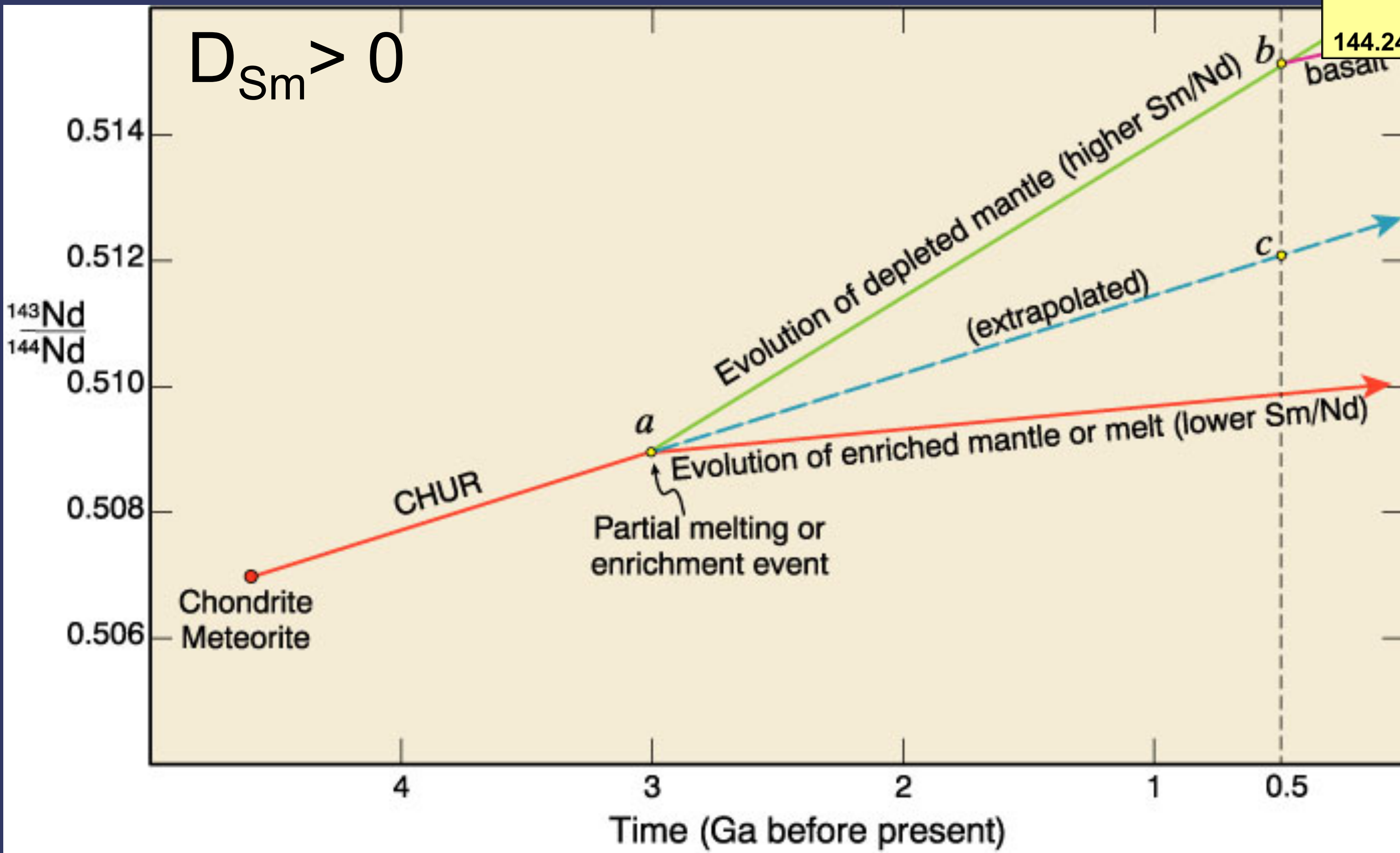
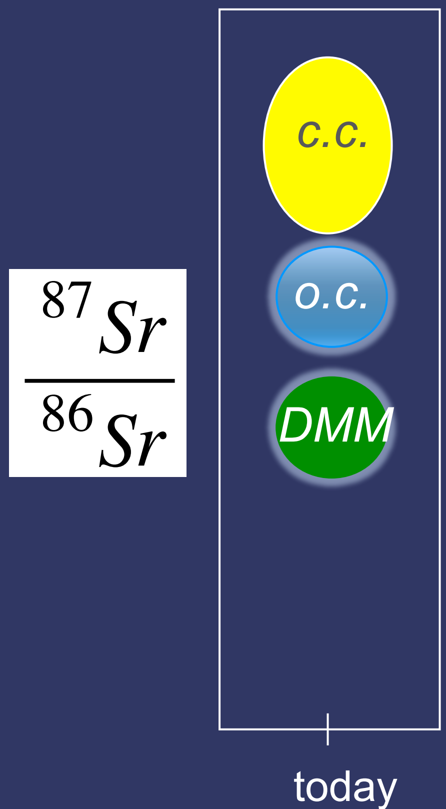


Fig. 9.15 in Winters

Today Mantle reservoirs

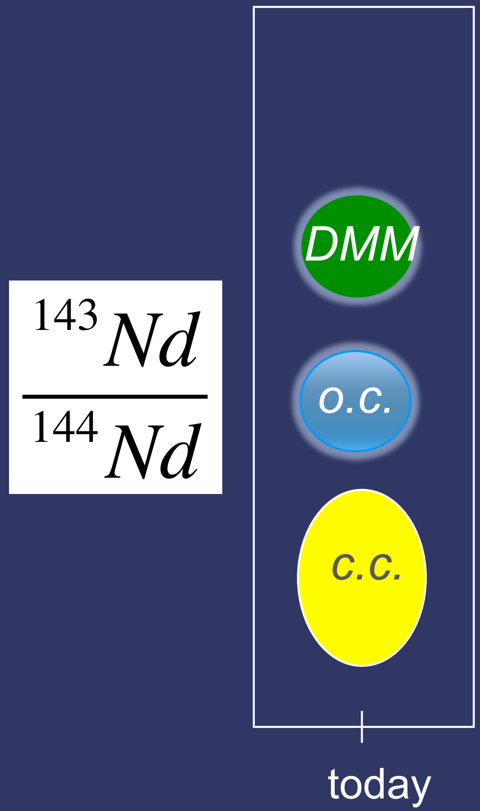


Isotopes do not fractionate during partial melting and crystallization processes!!!

Present day melting event:
$[^{87}Sr/^{86}Sr]_0 = [^{87}Sr]/[^{86}Sr]_L$

$[^{87}Sr/^{86}Sr]$: constant during melting/crystallization

Today Mantle reservoirs

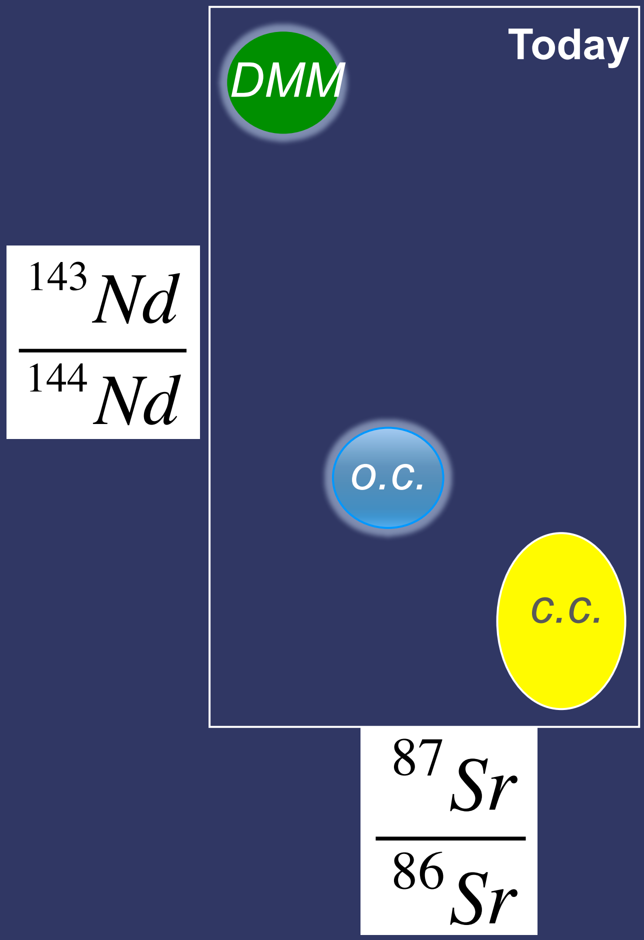


Isotopes do not fractionate during partial melting and crystallization processes!!!

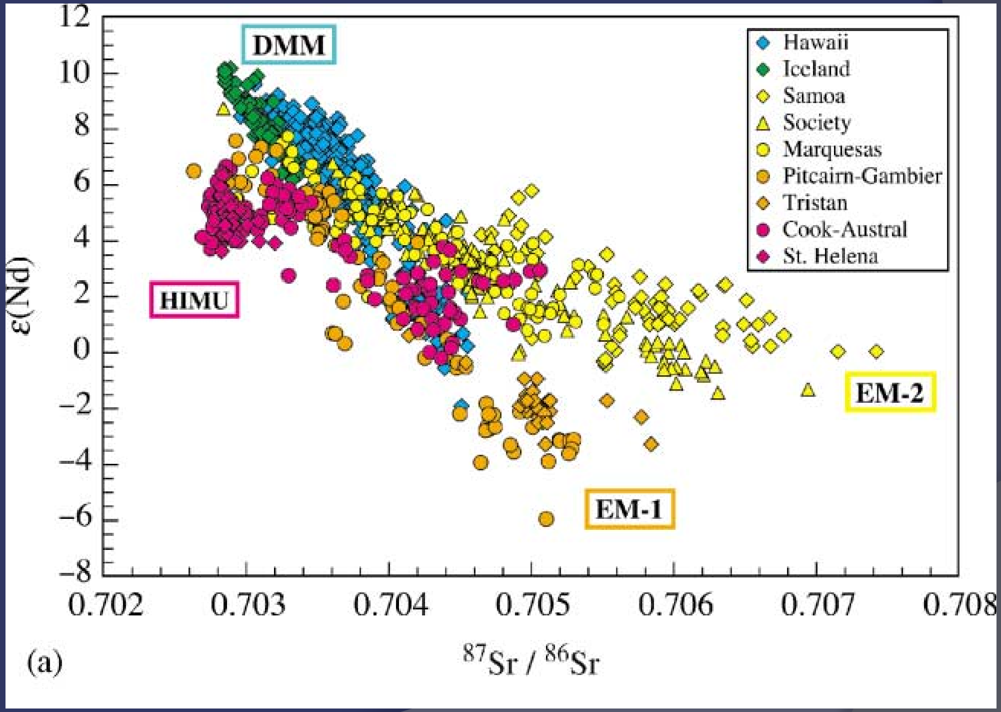
Present day melting event:
$[^{143}Nd/^{144}Nd]_0 = [^{143}Nd/^{144}Nd]_L$

$[^{143}Nd/^{144}Nd]$: constant during melting/crystallization

Today Mantle reservoirs

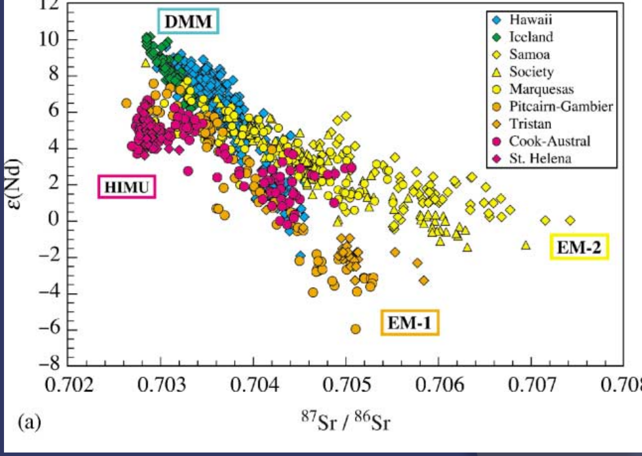


Isotopes do not fractionate during partial melting and crystallization processes!!!



OIB compilation: Hofmann, 2003

Mantle reservoirs flavors



OIB compilation: Hofmann, 2003

Isotopically enriched reservoirs (EM-1, EM-2, and HIMU): too enriched for mantle ⇒ crustal rocks and/or sediments

• HIMU – (enriched in ^{206}Pb/^{204}Pb, ^{207}Pb/^{204}Pb, ^{208}Pb/^{204}Pb, depleted in ^{87}Sr/^{86}Sr)
Origin: a) recycled oceanic crust, which has lost alkalis (Rb) during alteration and subduction b) metasomatically enriched oceanic lithosphere

• EM-1 (slightly enriched in ^{87}Sr/^{86}Sr, but not in Pb, very low ^{143}Nd/^{143}Nd)
Origin: a) recycling of delaminated subcontinental lithosphere b) recycling of subducted ancient pelagic sediment

• EM-2 (more enriched, especially in ^{87}Sr/^{86}Sr and radiogenic Pb
Origin: a) recycled ocean crust and small amount of subducted sediment b) recycling of melt-impregnated oceanic lithosphere

NEXT TIME

Oceanic basalts

TO READ:

Chapter 10

FIGURE PRESENTATION