

Figure of rare earth elemental abundances removed due to copyright restrictions.

See figure 3.1 on page 26 of Tolstikhin, Igor and Jan Kramers. "The Evolution of Matter: From the Big Bang to the Present Day." Cambridge University Press, 2008.

Given that the r-process nucleosynthetic production ratio for $^{235}\text{U}/^{238}\text{U}$ is roughly 1.35 ± 0.3 , use the present-day terrestrial isotope ratio to estimate the “age of the elements” assuming a one-time production event for these isotopes.

Figures of recession velocity vs. distance removed due to copyright restrictions.

See figure 4.4 on page 50 of Tolstikhin, Igor and Jan Kramers. "The Evolution of Matter: From the Big Bang to the Present Day." Cambridge University Press, 2008.

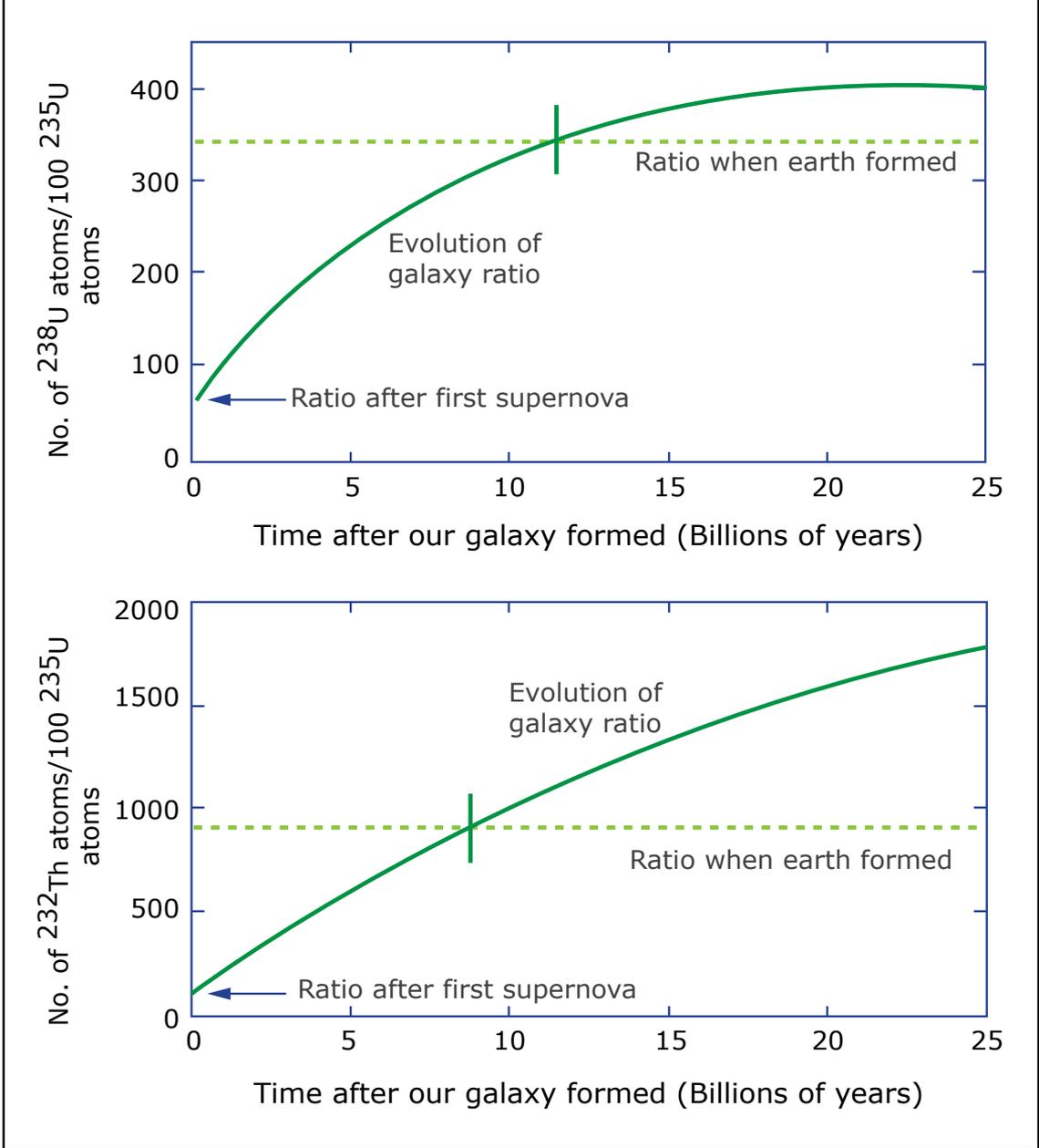


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Figure of uranium and thorium ratios vs. time and age removed due to copyright restrictions.

See figure 7.1 on page 81 of Tolstikhin, Igor and Jan Kramers. "The Evolution of Matter: From the Big Bang to the Present Day." Cambridge University Press, 2008.

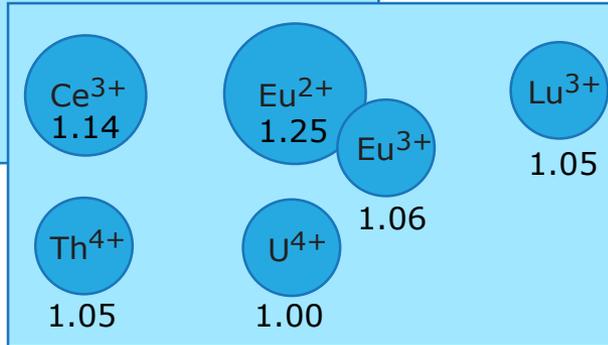
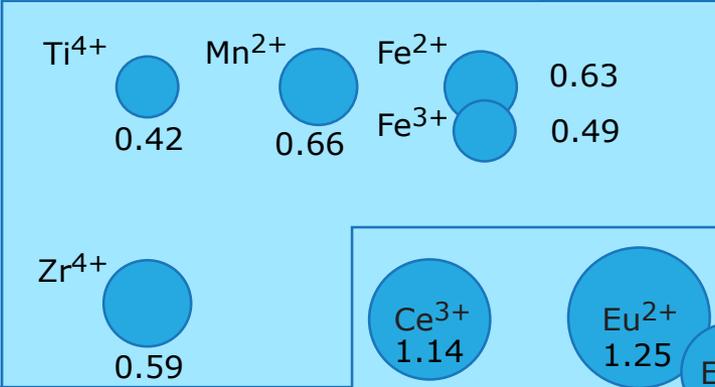
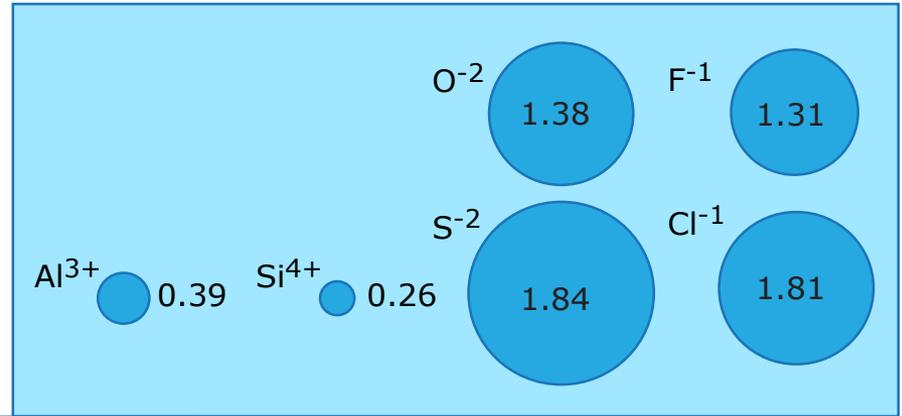
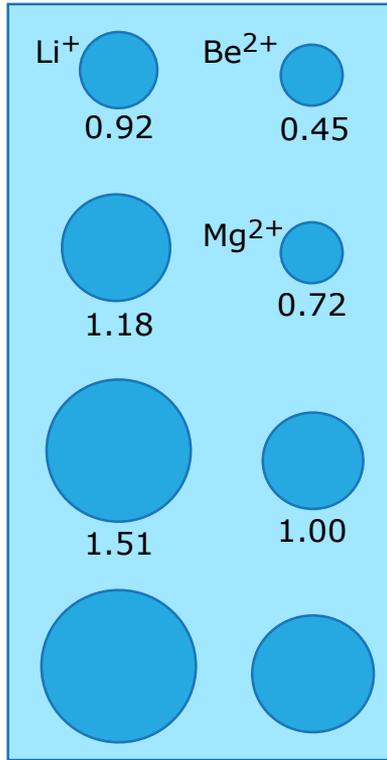
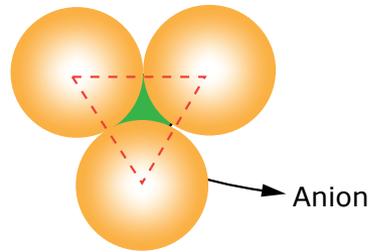


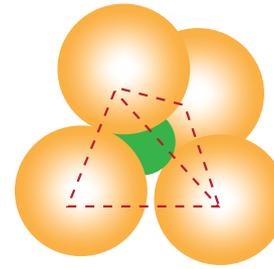
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Triangular coordination

$$0.15 < R_c / R_a < 0.22$$

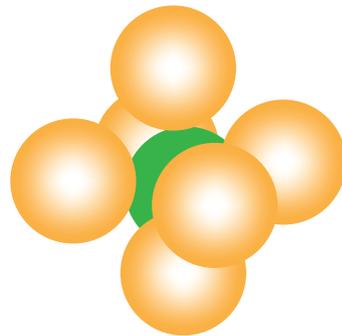
A



Tetrahedral coordination

$$0.22 < R_c / R_a < 0.41$$

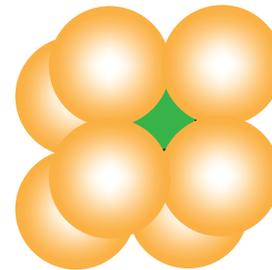
B



C

Octahedral coordination

$$0.41 < R_c / R_a < 0.73$$



D

Cubic coordination

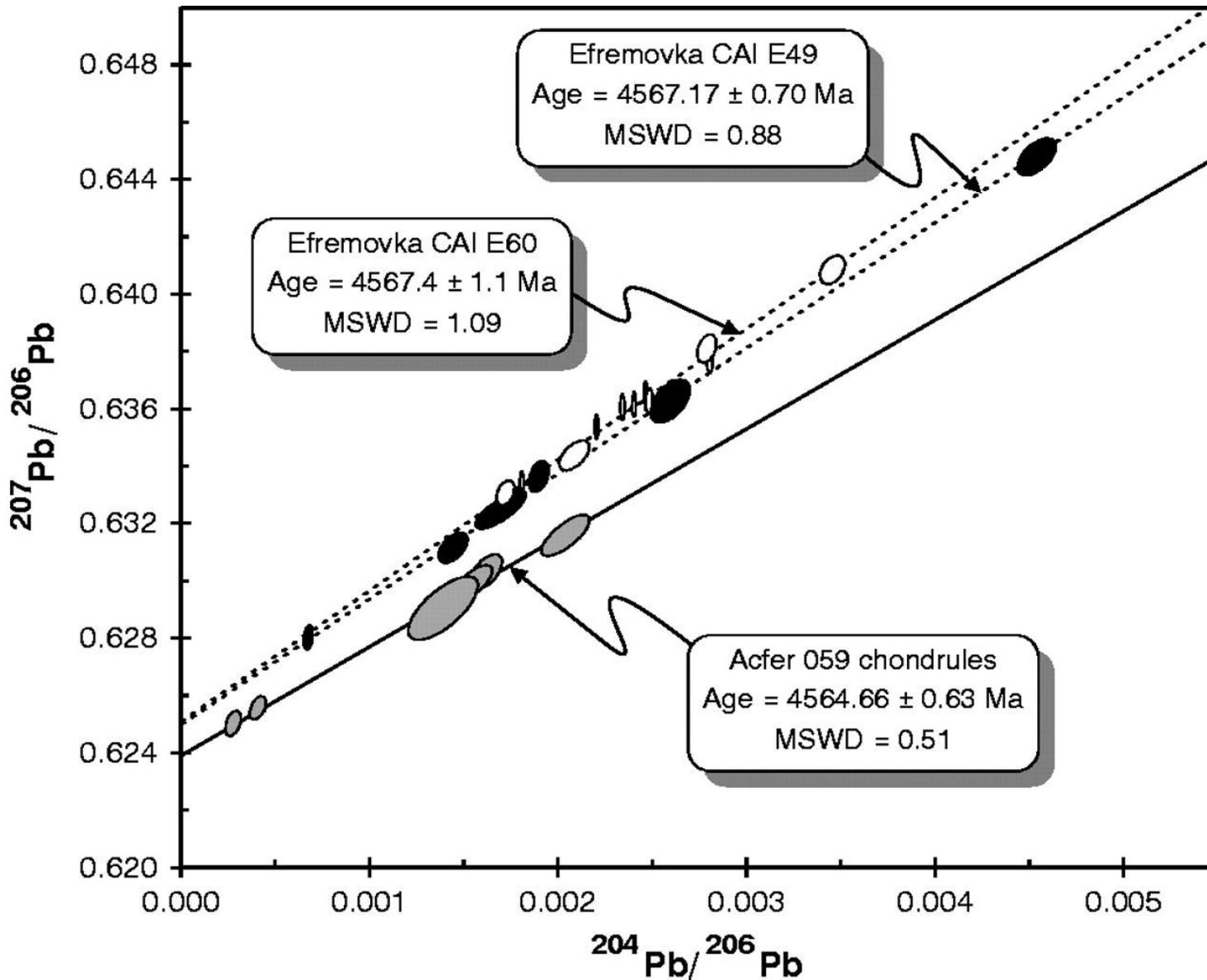
$$R_c / R_a > 0.73$$

 Cation

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Figure of $^{87}\text{Sr}/^{86}\text{Sr}$ vs. $^{87}\text{Rb}/^{86}\text{Sr}$ (atomic)
removed due to copyright restrictions.

See figure 12.7 on page 179 of Tolstikhin,
Igor and Jan Kramers. "The Evolution of
Matter: From the Big Bang to the Present
Day." Cambridge University Press, 2008.



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 Source: Amelin, Yuri, Alexander N. Krot, et al. "Lead Isotopic Ages of Chondrules and Calcium-Aluminum-Rich Inclusions." *Science* 297, no. 5587 (2002): 1678-83.

Figure of $^{207}\text{Pb}/^{204}\text{Pb}$ vs. $^{206}\text{Pb}/^{204}\text{Pb}$ with 4567 million year reference evolution line removed due to copyright restrictions.

See figure 10.3 on page 121 of Tolstikhin, Igor and Jan Kramers. "The Evolution of Matter: From the Big Bang to the Present Day." Cambridge University Press, 2008.

Figure of $(^{26}\text{Al}/^{27}\text{Al})_{\text{INI}} \times 10^{-5}$ and time relative to CAI formation ($\times 10^6$ years) vs. various meteorites removed due to copyright restrictions.

See figure 11.7 on page 153 of Tolstikhin, Igor and Jan Kramers. "The Evolution of Matter: From the Big Bang to the Present Day." Cambridge University Press, 2008.

Figure of ages of various meteorites with respect to solar system formation removed due to copyright restrictions.

See figure 13.1 on page 193 of Tolstikhin, Igor and Jan Kramers. "The Evolution of Matter: From the Big Bang to the Present Day." Cambridge University Press, 2008.

Figure of $^{107}\text{Ag}/^{109}\text{Ag}$ vs. $^{108}\text{Pd}/^{109}\text{Ag}$, $\times 10^5$
of Gibeon Metal and Normal Silver
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See figure 12.9 on page 182 of Tolstikhin,
Igor and Jan Kramers. "The Evolution of
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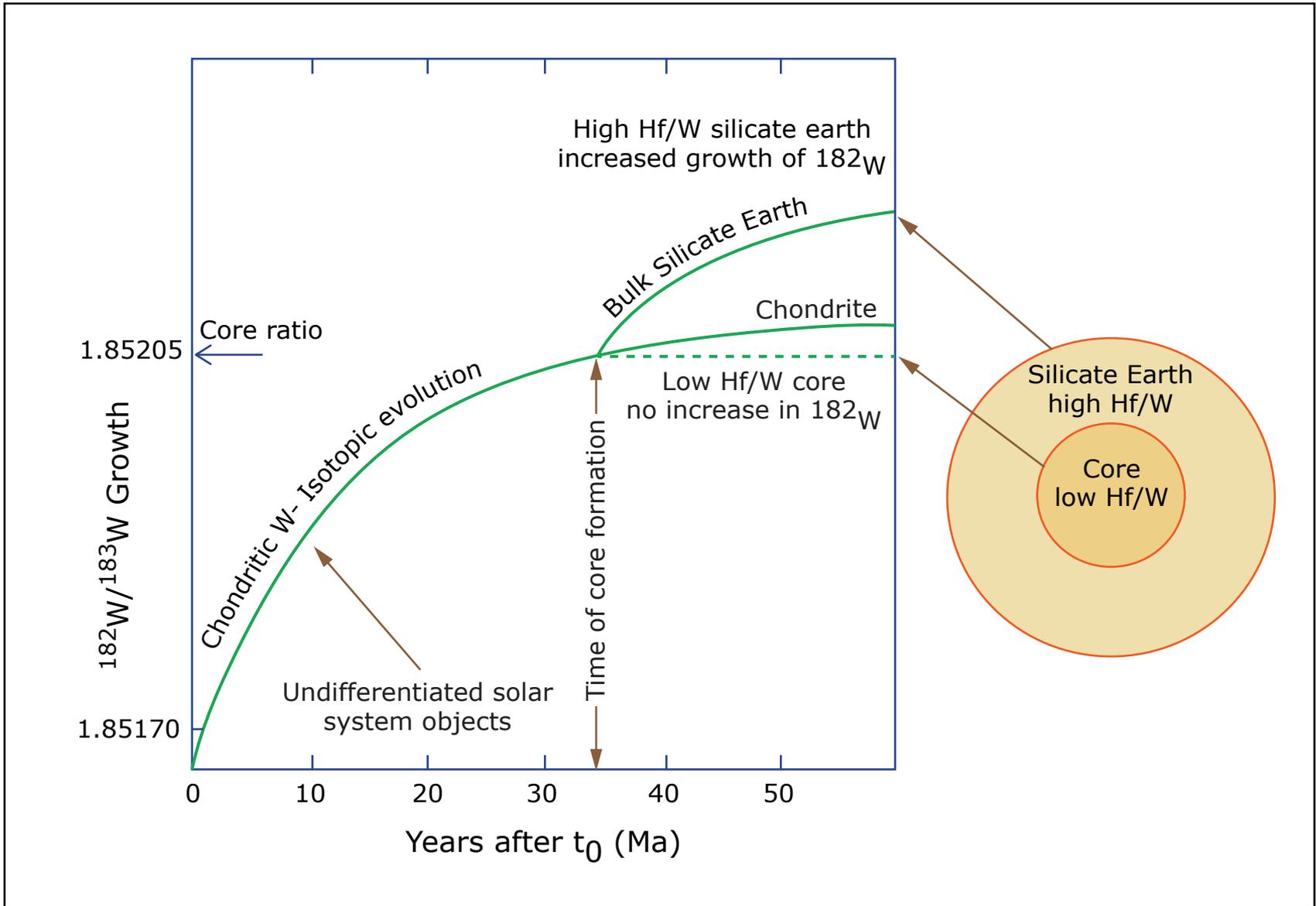


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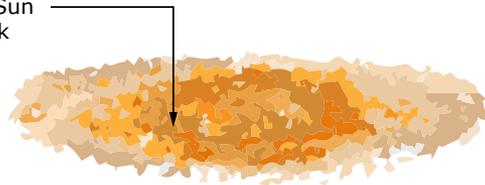
Figure of ϵ_{182} of Early Archaean samples and 3.8 billion year igneous mix with inset of ϵ_{182} vs. Cr/Ti for Early Archaean samples, Enstatite chondrites, Allende (C1), and Iron meteorites removed due to copyright restrictions.

See figure 19.1 on page 247 of Tolstikhin, Igor and Jan Kramers. "The Evolution of Matter: From the Big Bang to the Present Day." Cambridge University Press, 2008.

Figure of ϵ_{182} of carbonaceous chondrites, ordinary chondrites, and iron meteorites removed due to copyright restrictions.

See figure 11.8 on page 154 of Tolstikhin, Igor and Jan Kramers. "The Evolution of Matter: From the Big Bang to the Present Day." Cambridge University Press, 2008.

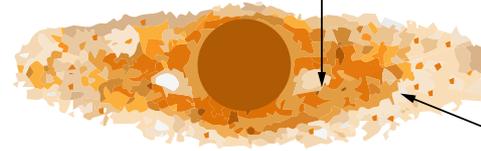
Solar nebula contracts and flattens into a single spinning disk. The Sun will form in the center of the disk containing all the elements, but mostly H and He.



(A)

H, He and other noble gases remain gas. Other elements condense according to their volatility.

Rock and metal condense in the hot inner solar system.



(B)

Rock, metal and ices condense in the outer solar system.

Accretion of planetesimals which will combine in giant impacts to form the planets.



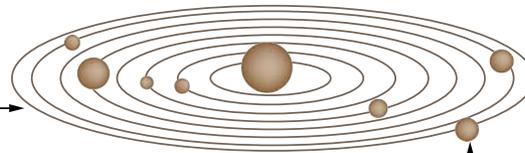
(C)



(D)

Solid particles stick together. Once larger objects have accreted, they are called planetesimals.

T-Tauri phases of the Sun creates large solar wind that ejects gas from between the planets.



(E)

Large outer planets have sufficient mass to accumulate vast atmosphere including H₂ and He.

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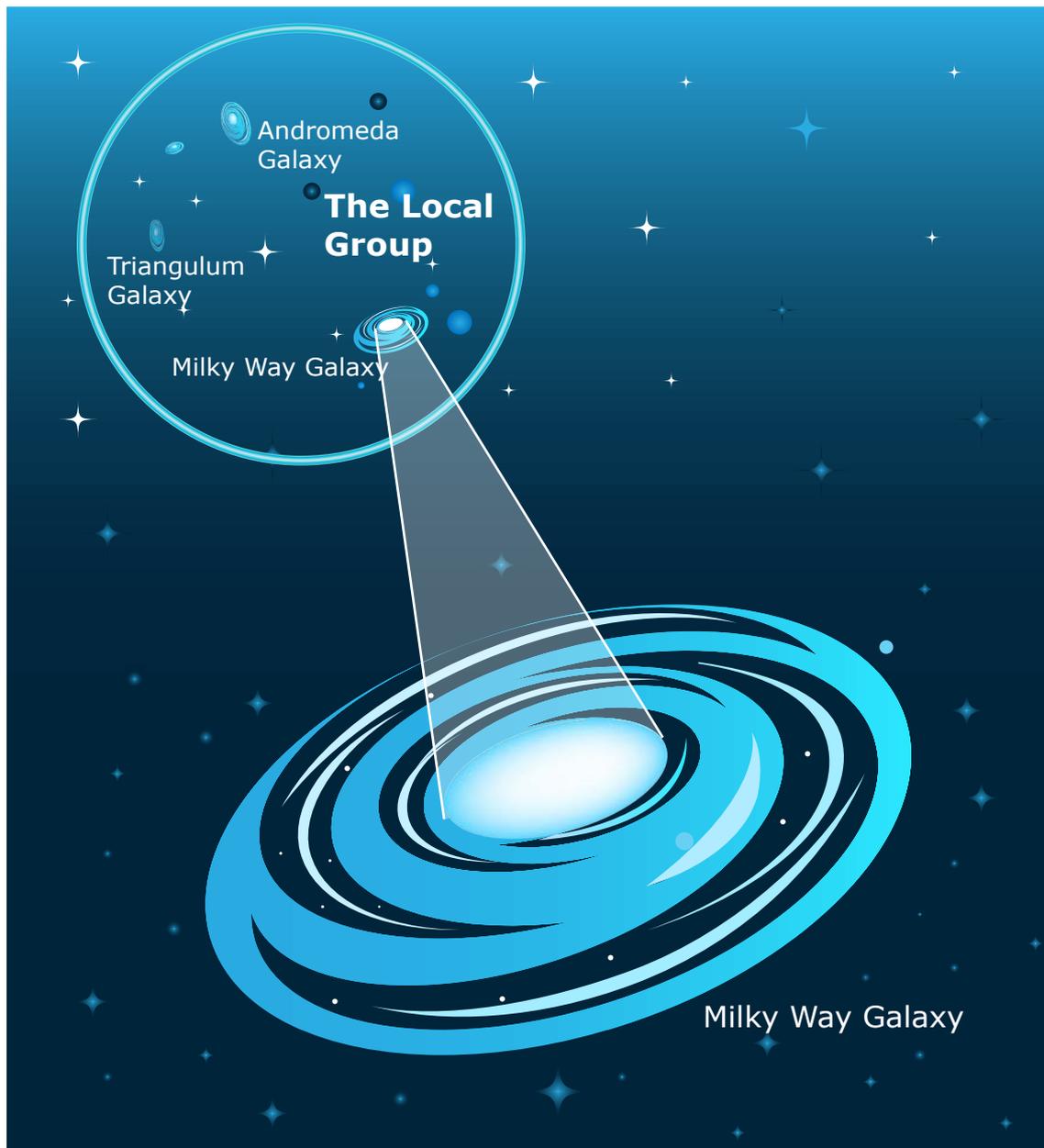


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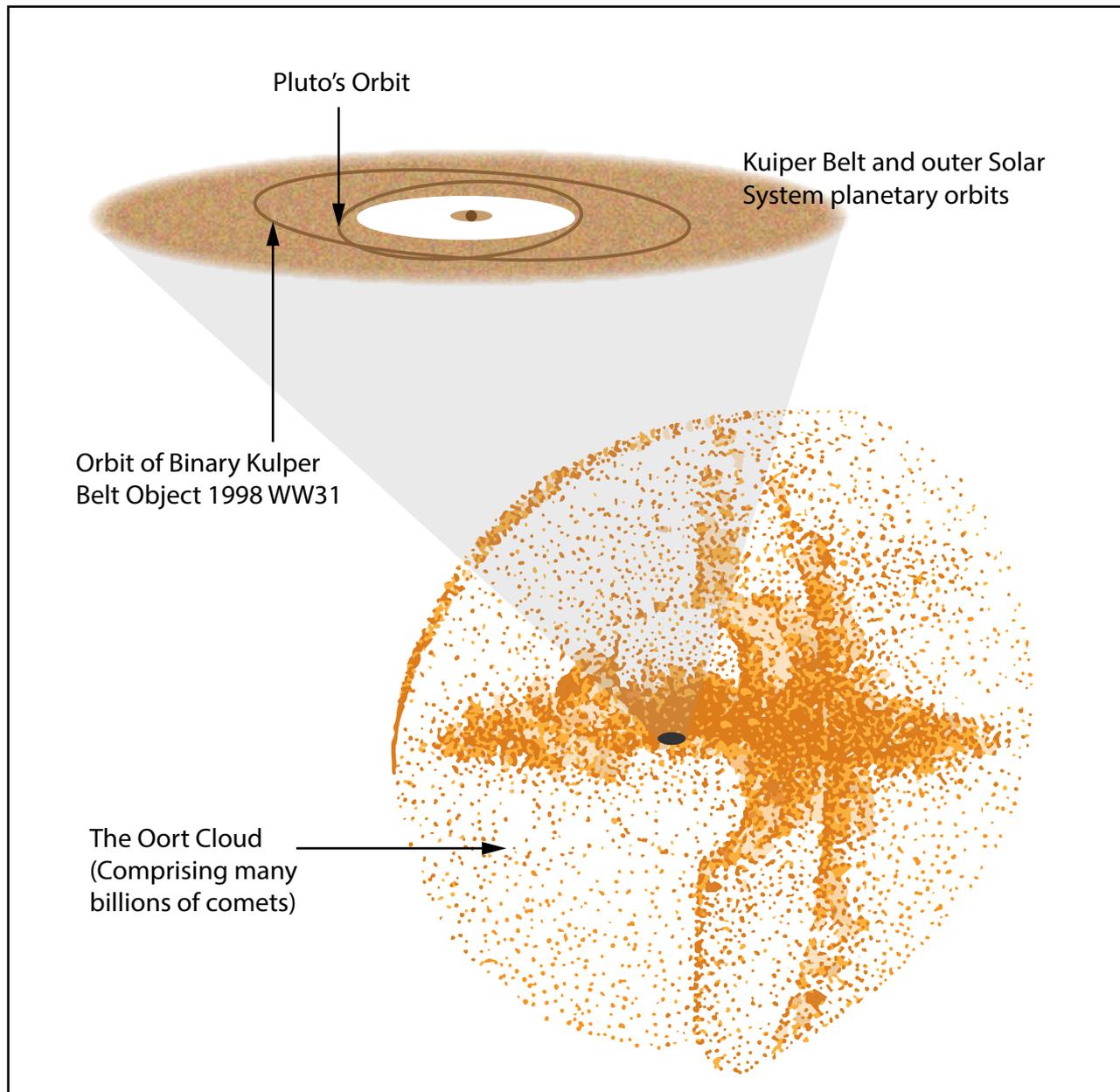


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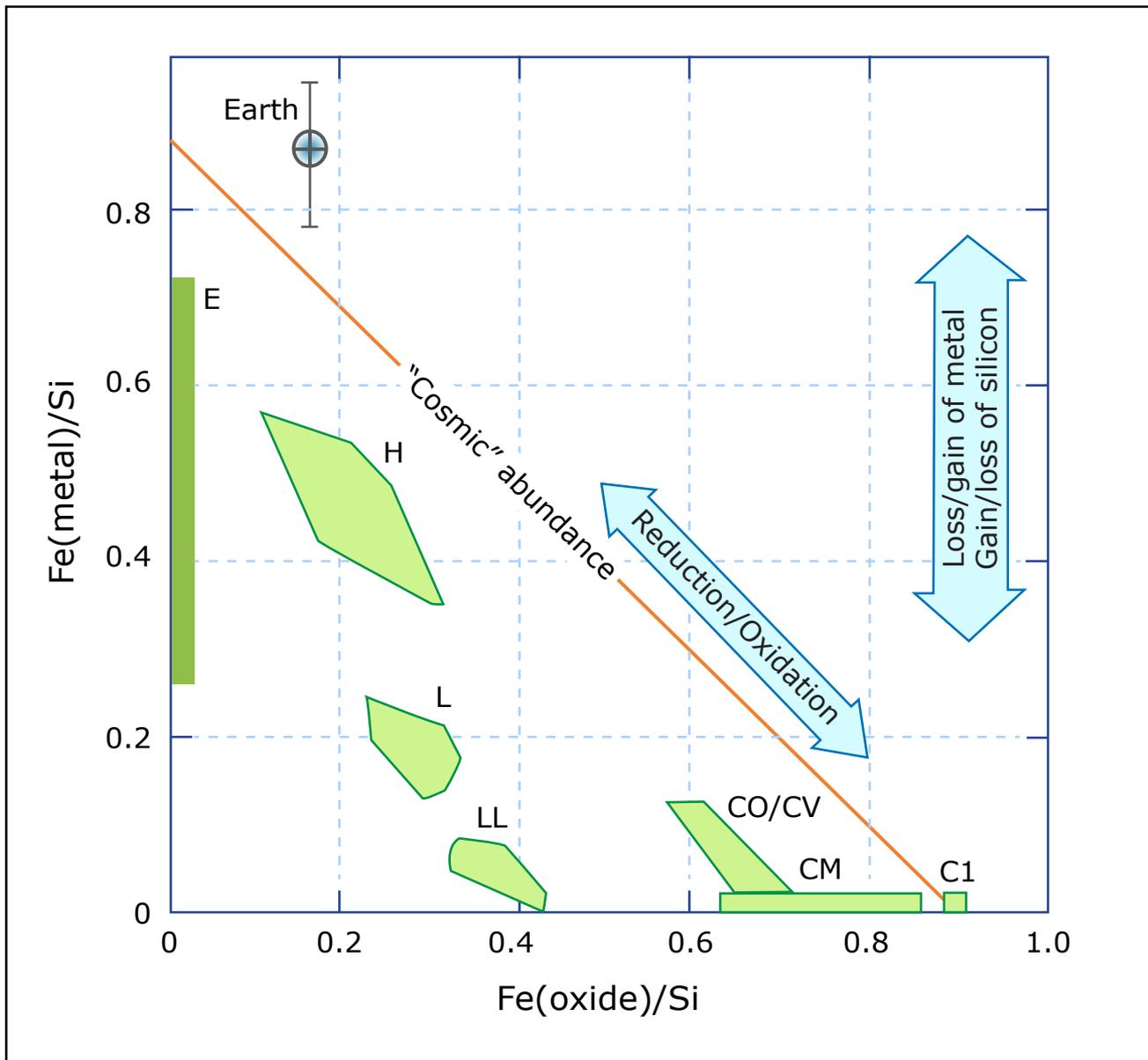


Image by MIT OpenCourseWare. After figure 11.1 in Tolstikhin, Igor and Jan Kramers. "The Evolution of Matter: From the Big Bang to the Present Day."

Figure of $\epsilon_{182}(\text{Earth}) - \epsilon_{182}(\text{initial})$ vs. time (millions of years) and Concentration/concentration in C1 vs. time (millions of years) removed due to copyright restrictions.

See figure 18.3 on page 241 of Tolstikhin, Igor and Jan Kramers. "The Evolution of Matter: From the Big Bang to the Present Day." Cambridge University Press, 2008.

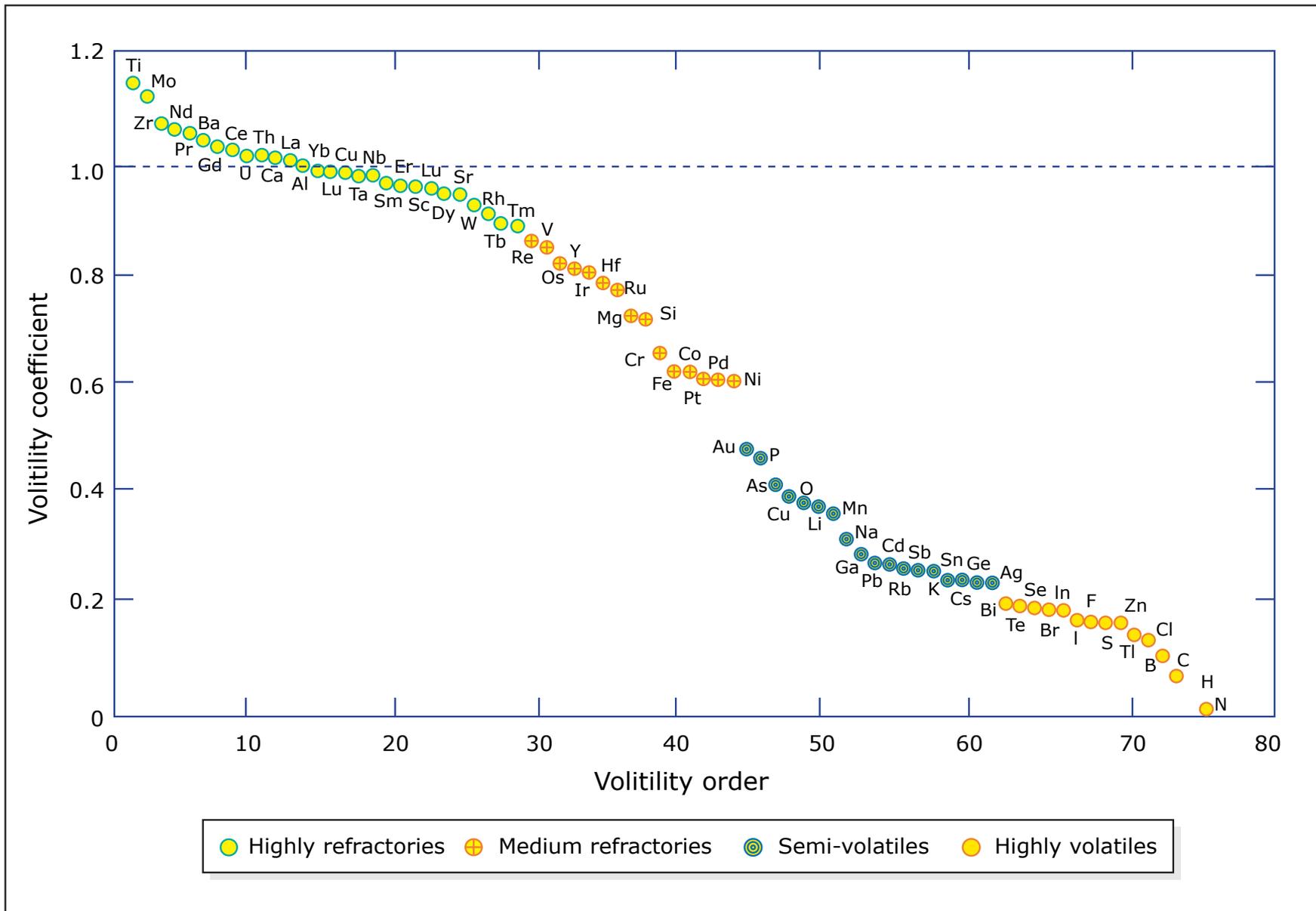


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Figure of Depletion relative to C1 and refractory element vs. Increasing siderophile behavior of refractory and transitional elements and volatile elements and low-pressure metal-silicate partition coefficients removed due to copyright restrictions.

See figure 18.1 on page 232 of Tolstikhin, Igor and Jan Kramers. "The Evolution of Matter: From the Big Bang to the Present Day." Cambridge University Press, 2008.

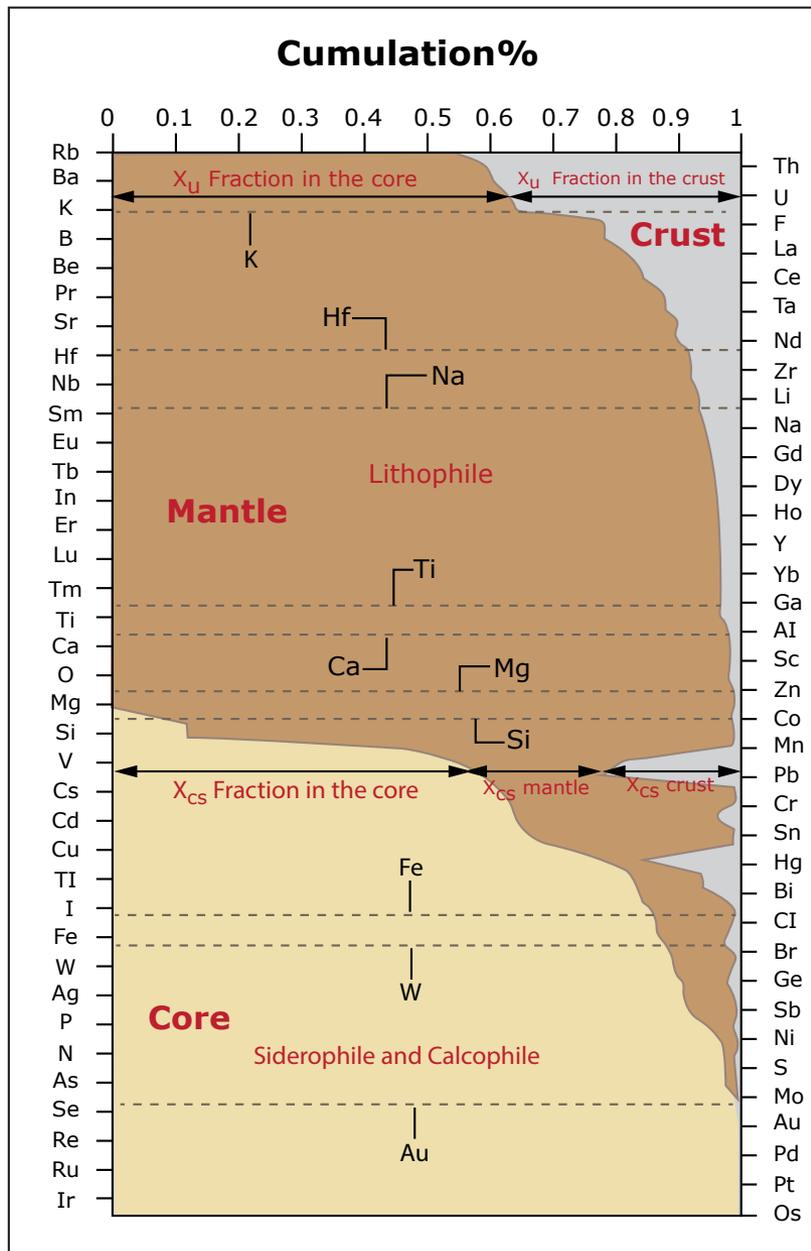


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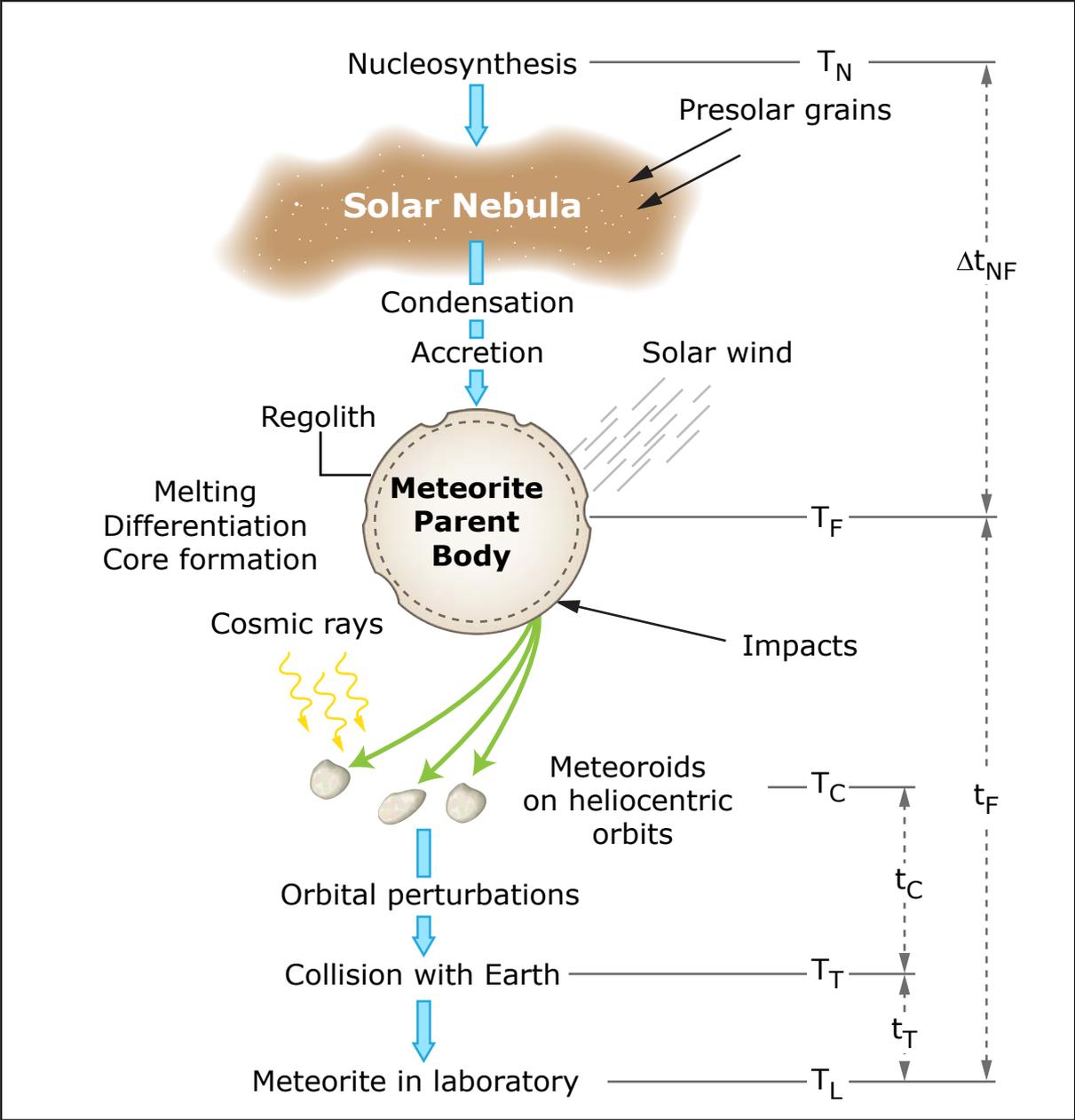


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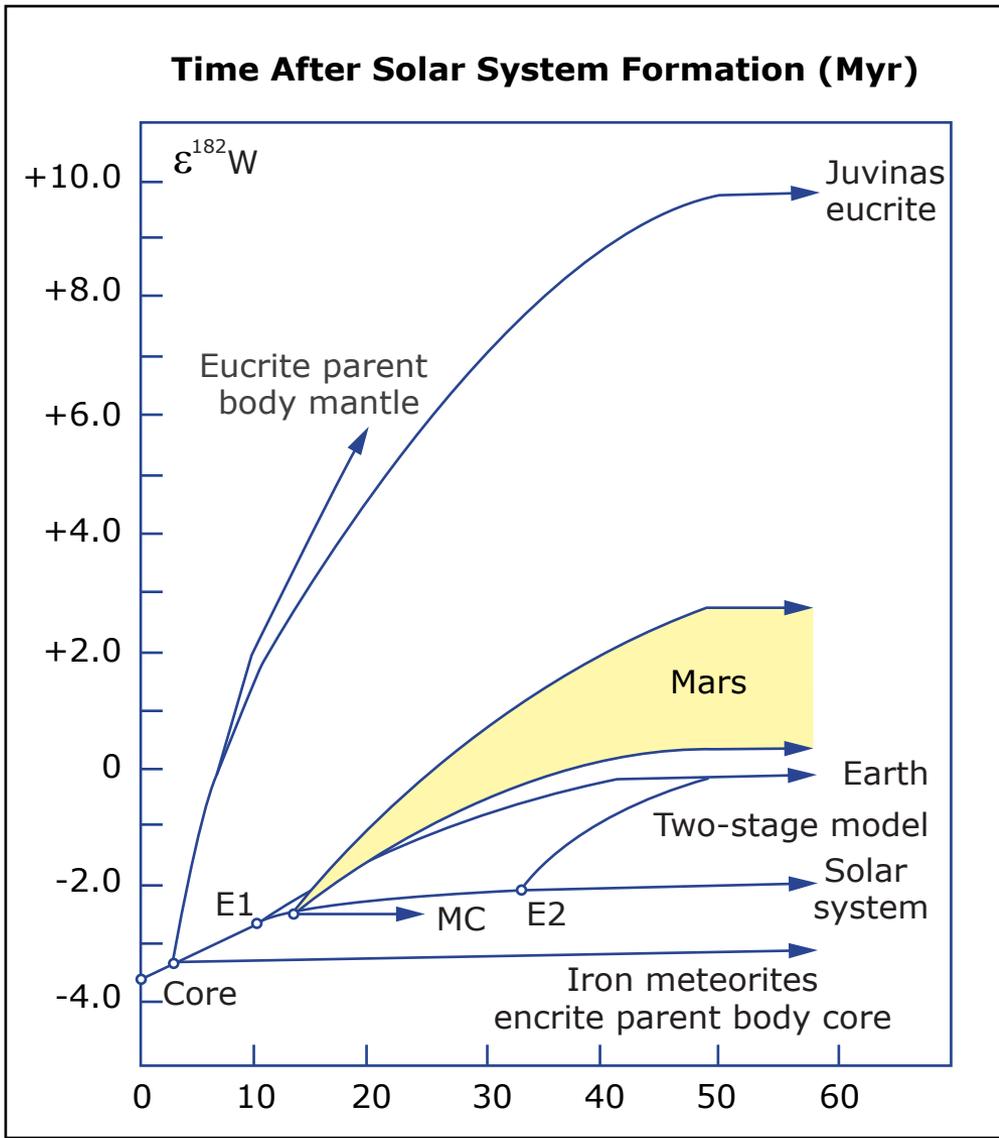


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Partition model

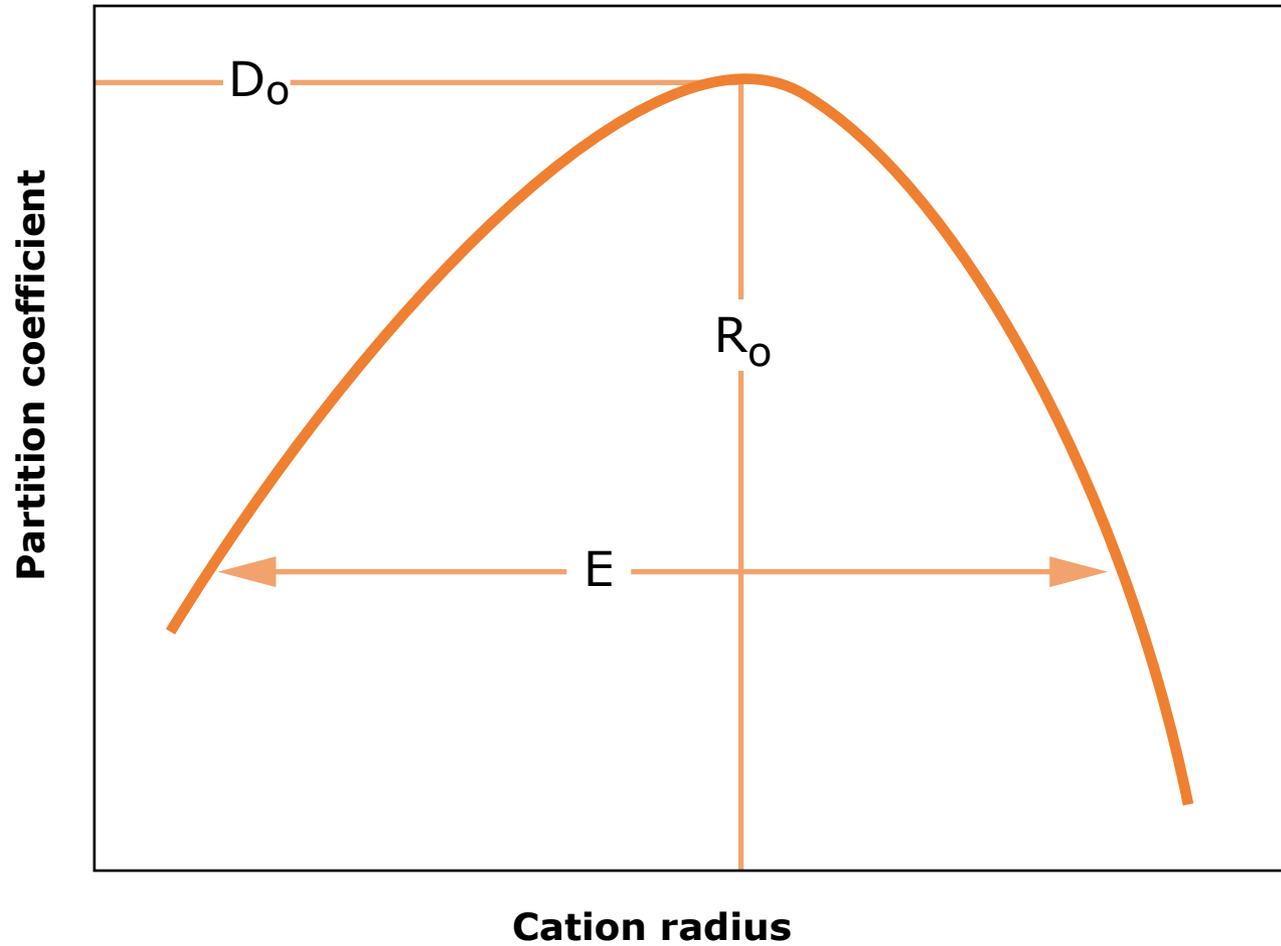
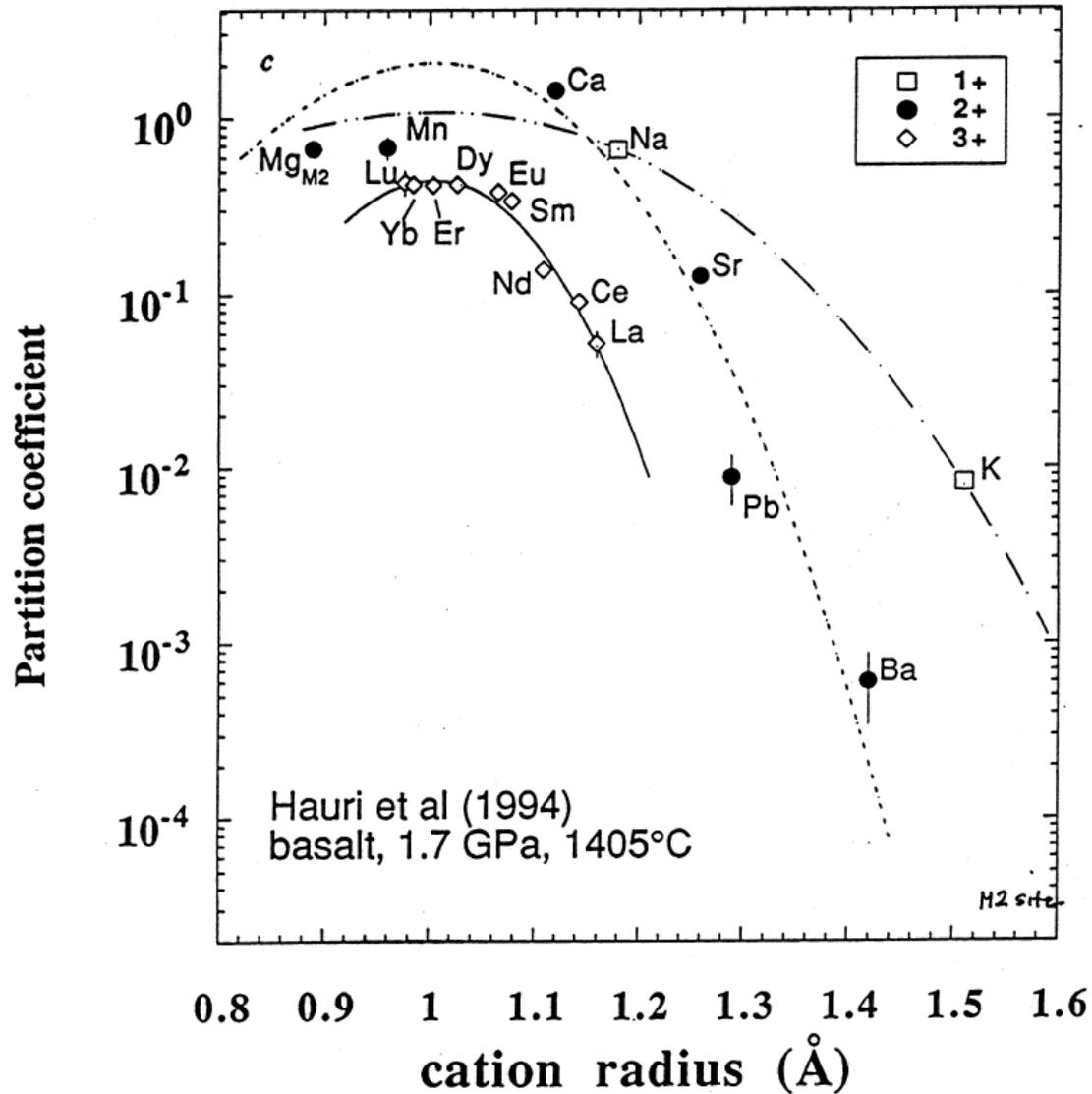


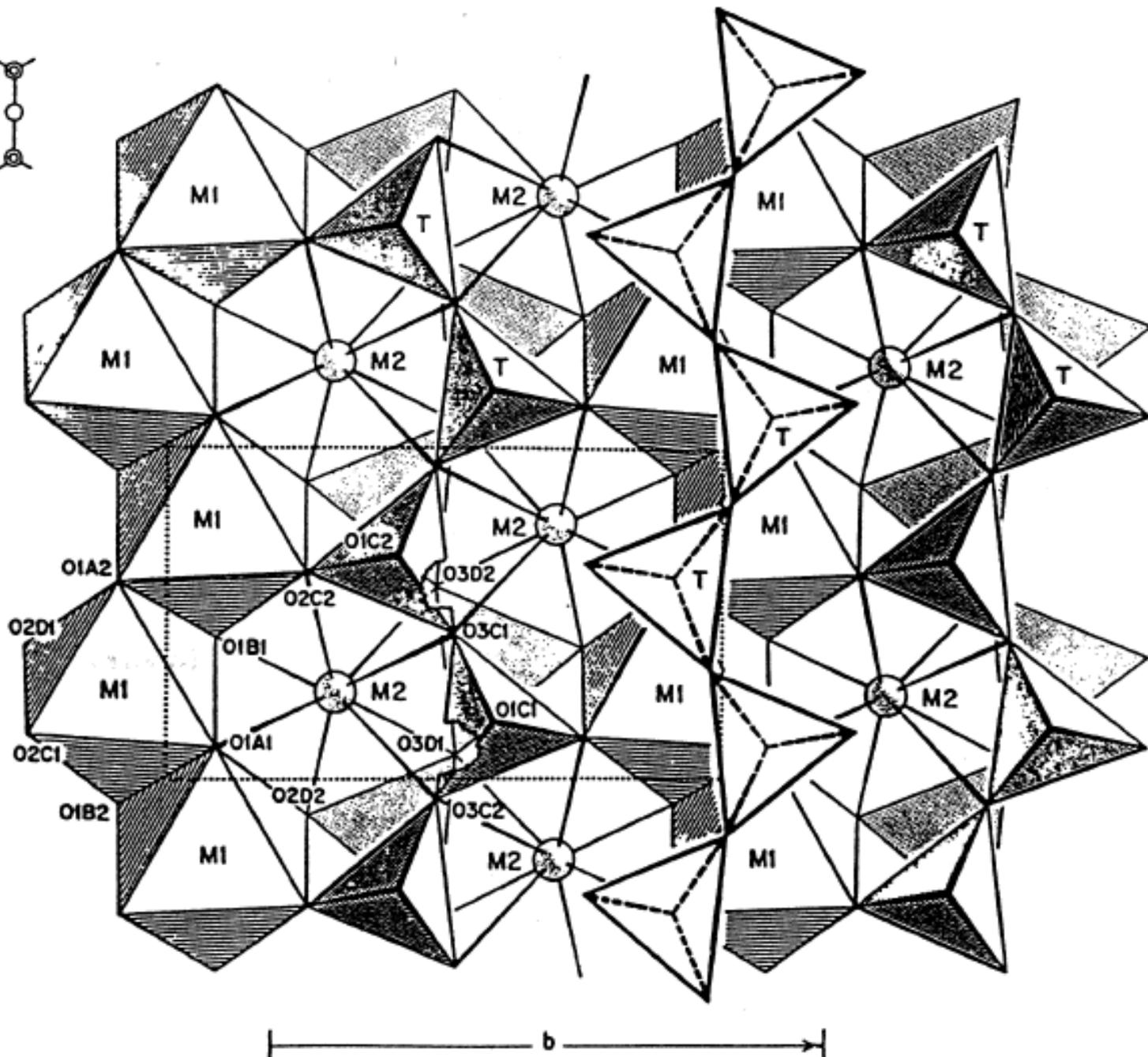
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Clinopyroxene



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Source: Blundy, Jon, and Bernard Wood. "Partitioning of Trace Elements between Crystals and Melts." *Earth and Planetary Science Letters* 210, no. 3 (2003): 383-97.



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12.744 Marine Isotope Chemistry
Fall 2012

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