Lecture 5: Making the Earth

1. Condensation temperatures
2. Goldschmidt classification
3. The primitive mantle

We acknowledge and respect the ləkʷ̓əŋən peoples on whose traditional territory the university stands and the Songhees, Esquimalt and W̱SÁNEĆ peoples whose historical relationships with the land continue to this day.

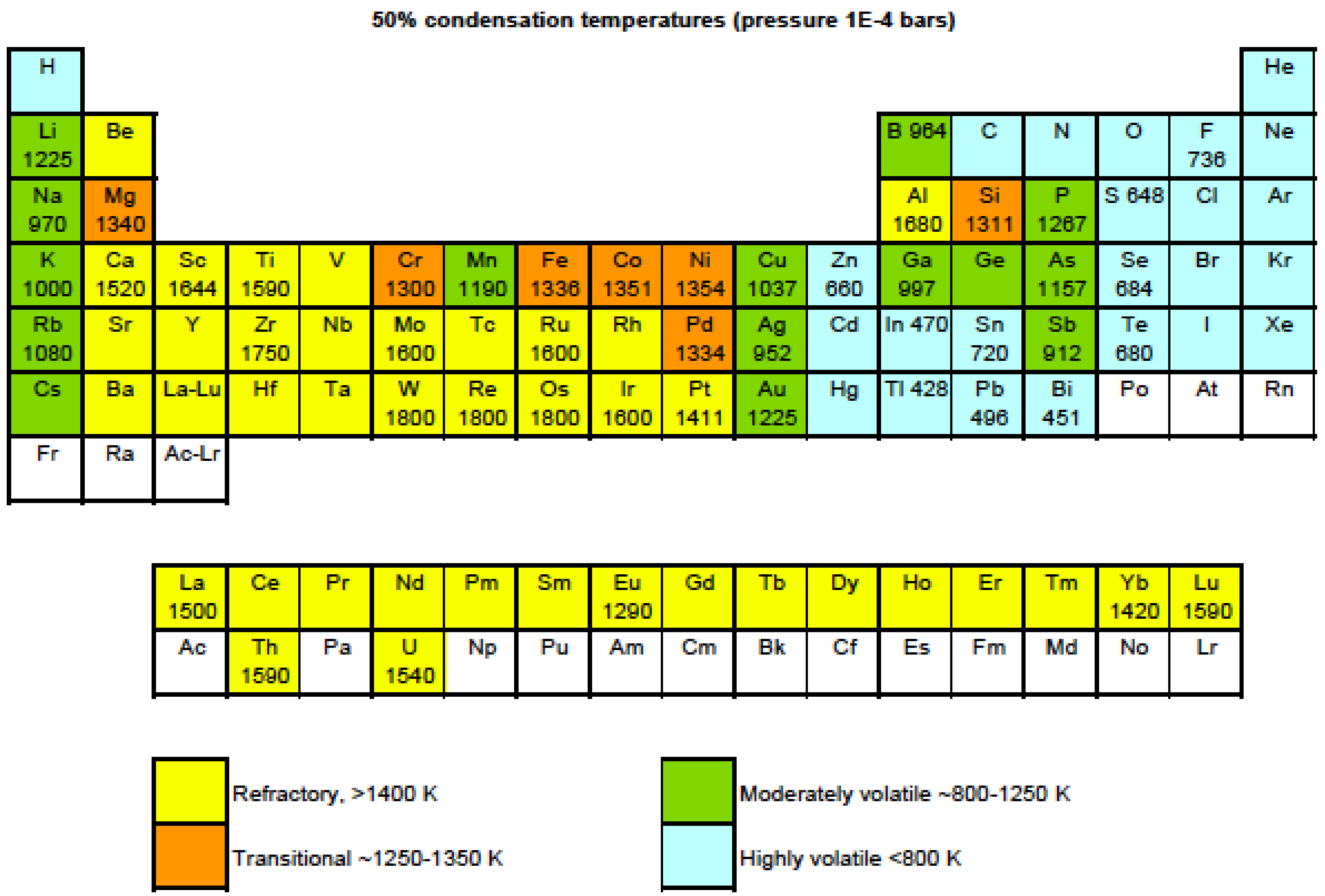


Figure 2.13. 50% condensation temperatures taken from [*Wasson*, 1985] and [*O'Neill and Palme*, 1998].

Which 6 elements make up most of Earth's mass?

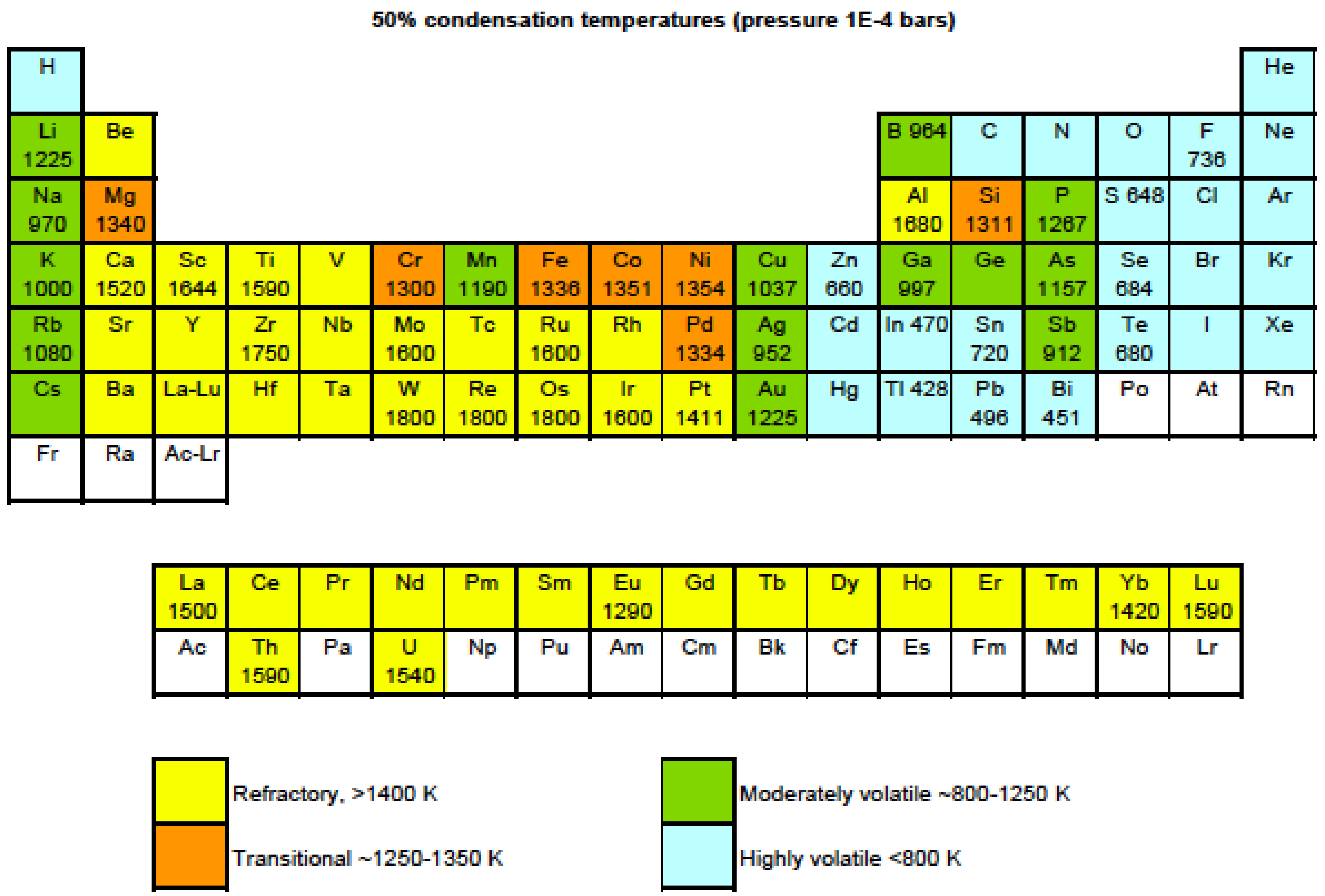
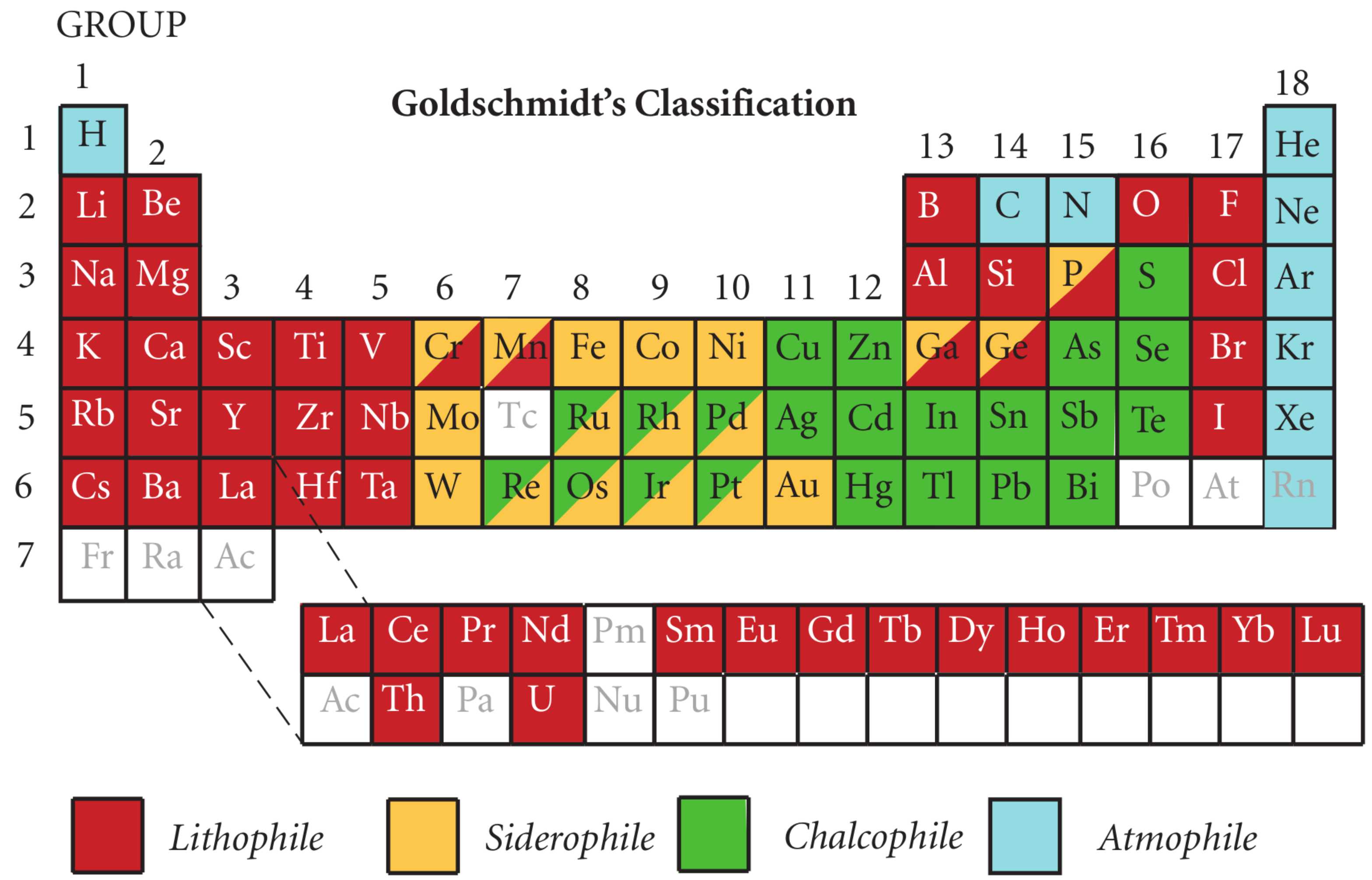


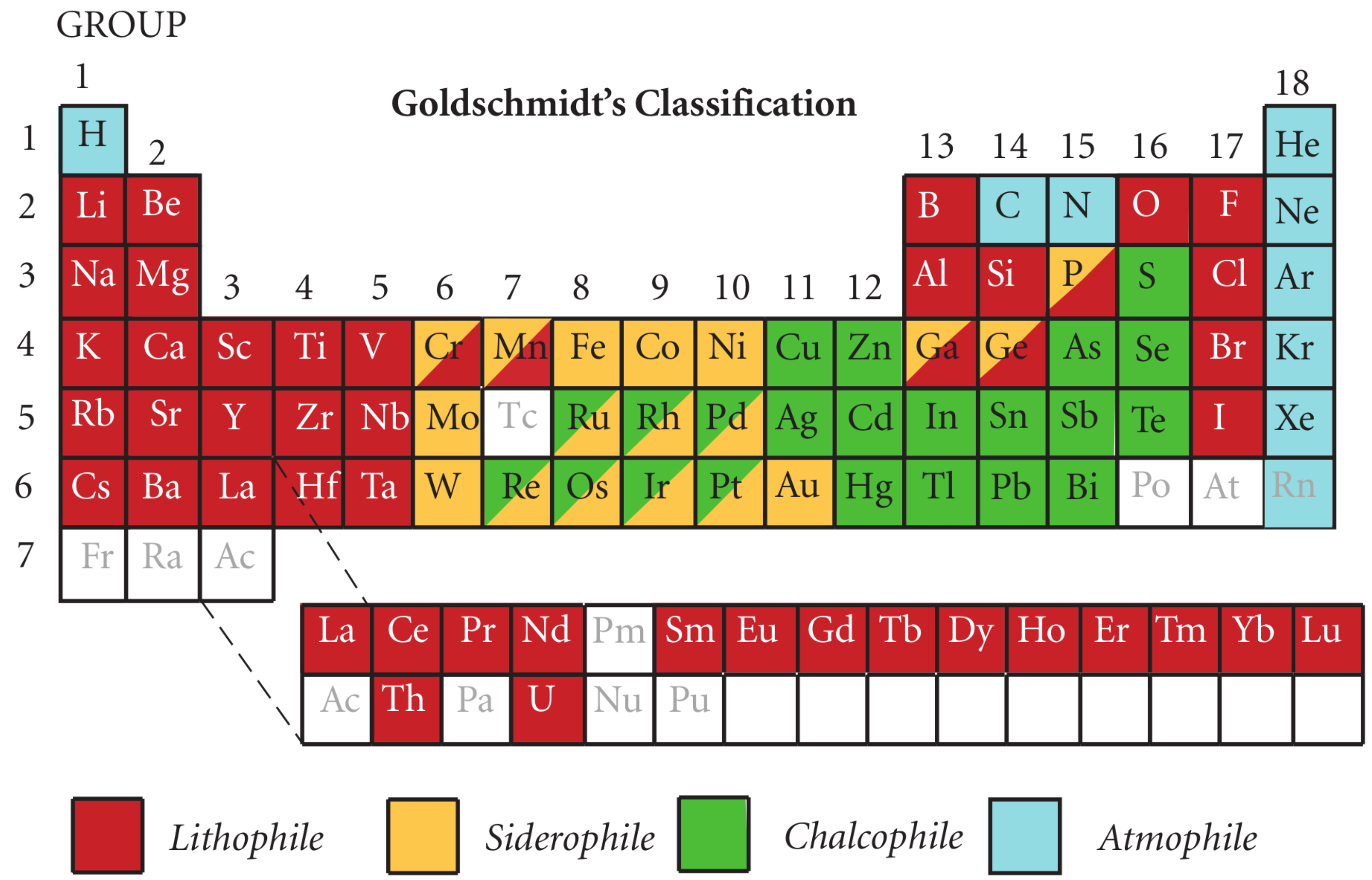
Figure 2.13. 50% condensation temperatures taken from [*Wasson*, 1985] and [*O'Neill and Palme*, 1998].

$$\text{Earth} \approx MgO + CaO + SiO_2 + Al_2O_3 + FeO$$

Define Goldschmidt classification.



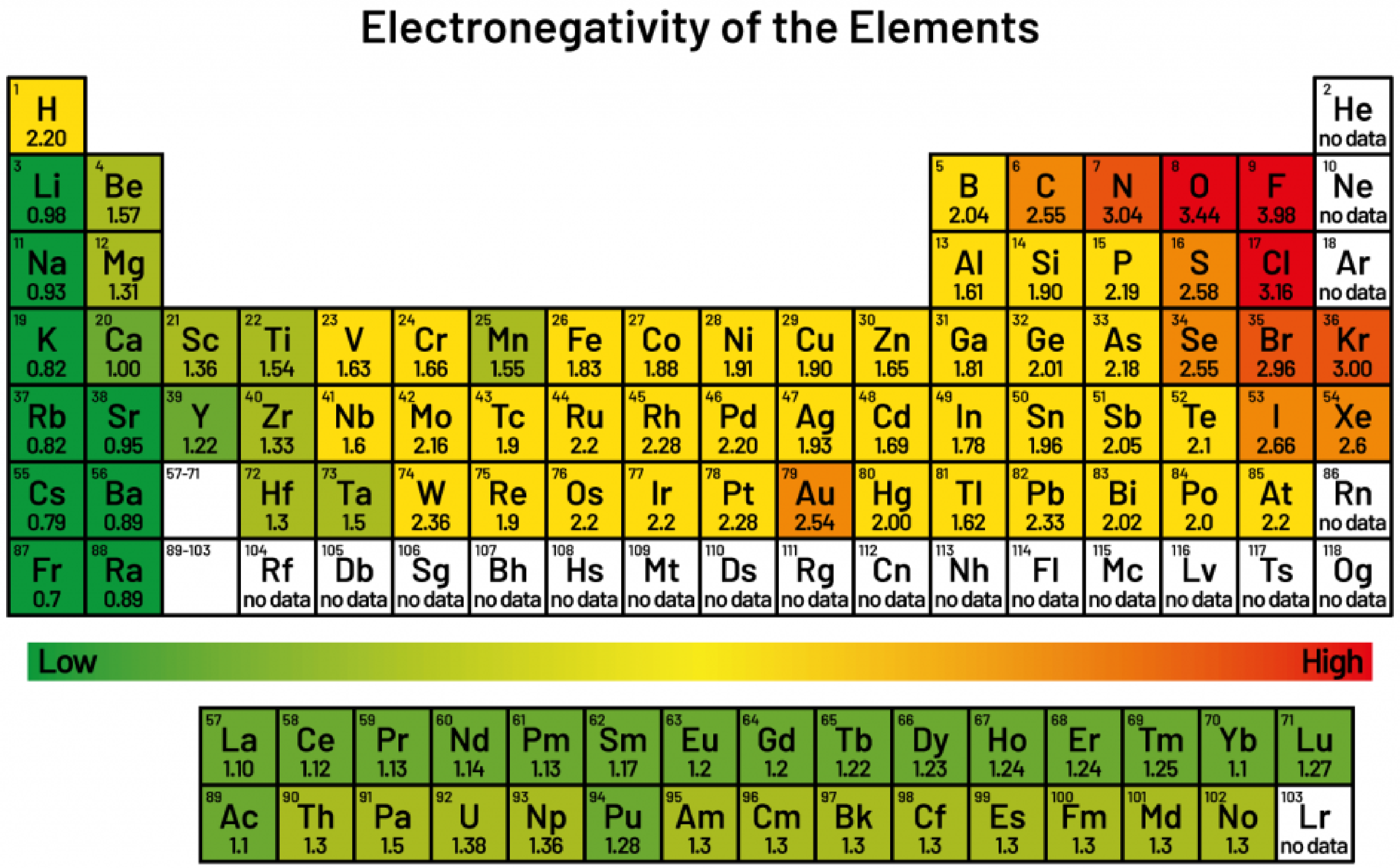
Define Goldschmidt classification.



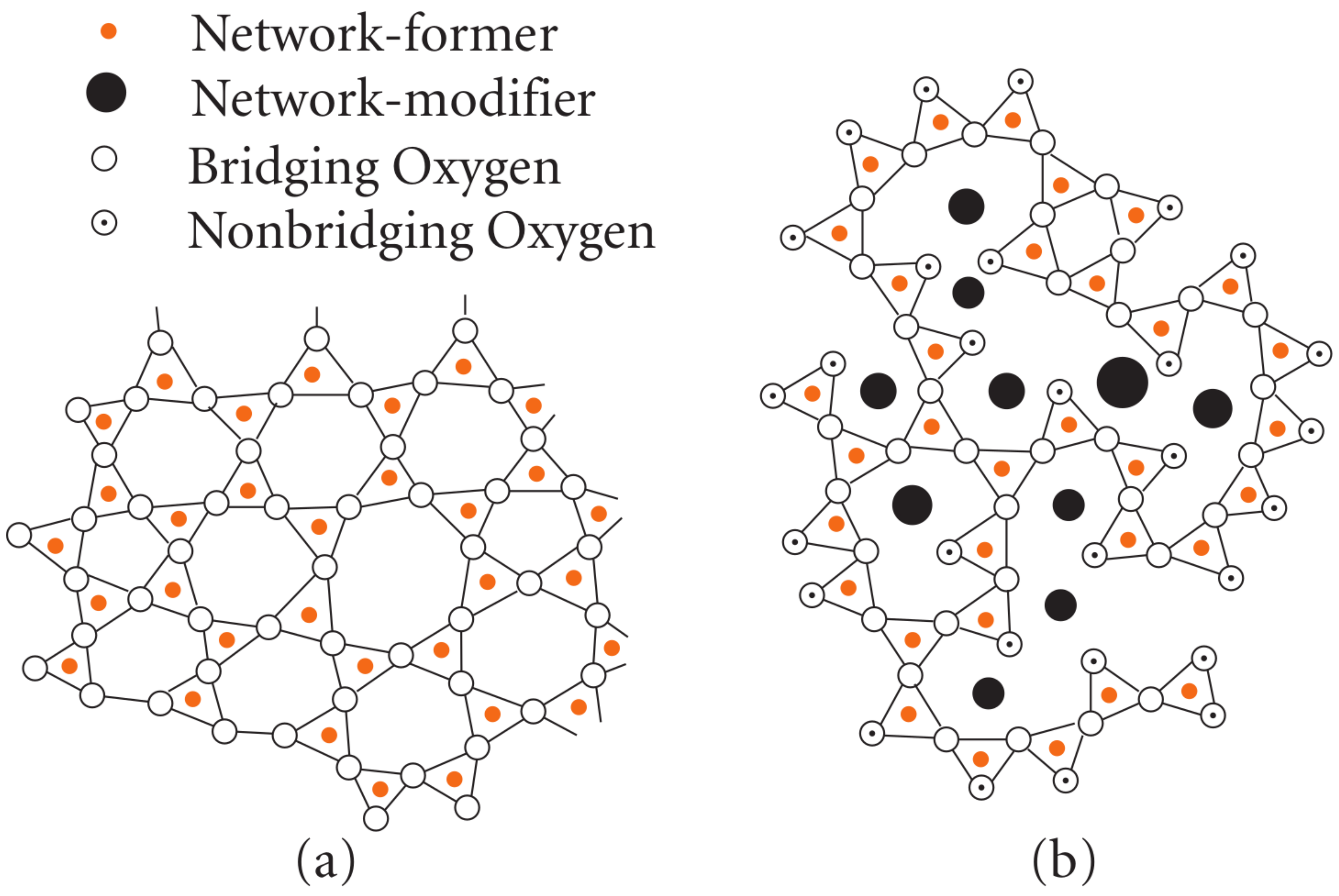
Describe the arrangement of Lithophile vs Siderophile elements in the periodic table. What might explain this arrangement?

Electronegativity

an atom's ability to attract shared electrons in a chemical bond



Silicate melt structure, is *oxyphile* a better word?



In Geochemistry, we often use the word **fractionate** to indicate that the original mass (*the nebula*) led to one or more smaller fractions of mass (*different planets*) that have compositional variations. Through our understanding of condensation temperatures and Goldschmidt's classification scheme, planet *formation* and planetary *differentiation* lead to predictable fractionations, and so the chemistry of a rock can tell us a lot about how it came to be.

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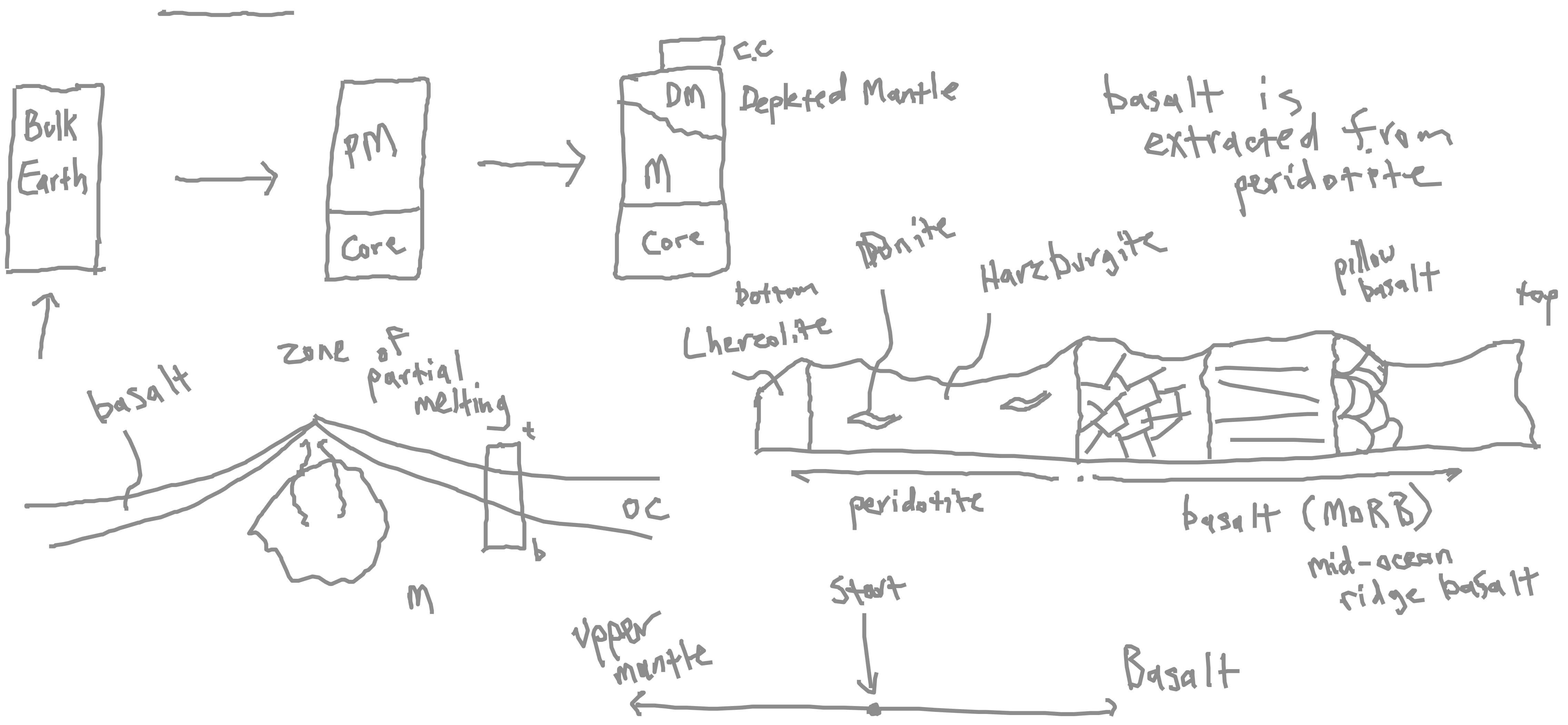
Some review questions to consider:

- **How does the Ca/Al ratio change from the inner solar system to the outer?** *(draw a figure showing this ratio vs distance from the Sun)*
- **How does the Na/Al ratio change from the inner solar system to the outer?** *(draw a figure showing this ratio vs distance from the Sun)*
- **Is the weight % of CaO of Bulk Earth higher or lower than the weight % of CaO of Bulk Jupiter?**
- **Is the Si/Fe ratio higher in an undifferentiated meteorite or the Earth's mantle?**

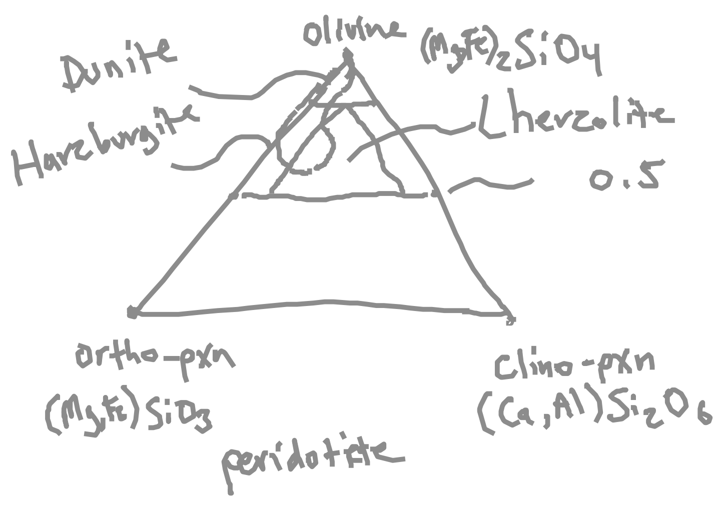
Define Primitive Mantle. What do we know about the modern mantle?

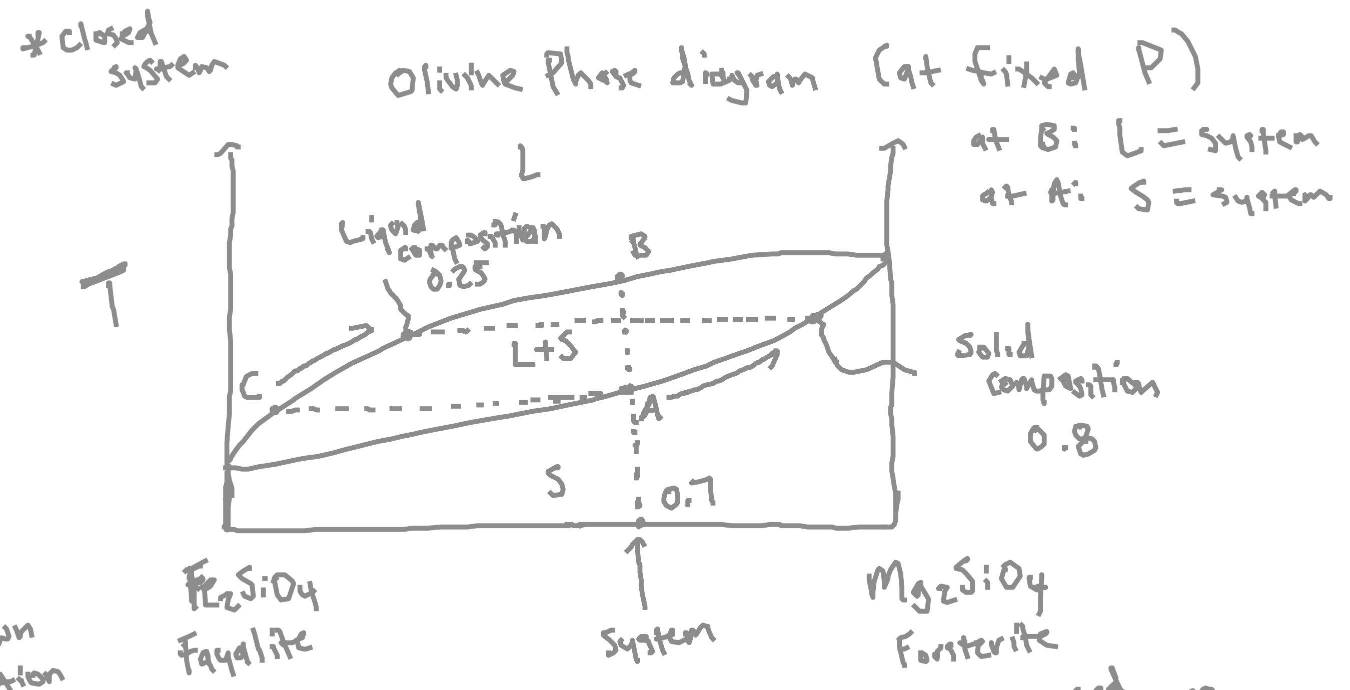


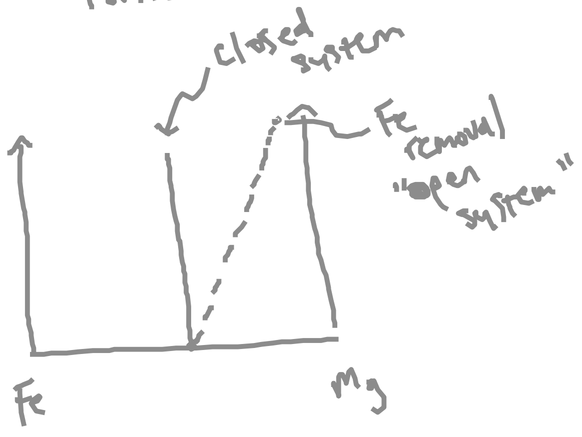
Peridotite: Ultramafic
Mg rich
olivine
clino-pyroxene
ortho-pyroxene

basalt is extracted from peridotite

Olivine Solid Solution Phase Diagram.







Lever Rule: (mass balance)

unknown fraction

$\underline{a} \cdot L + \underline{b}\, S = \text{system}$

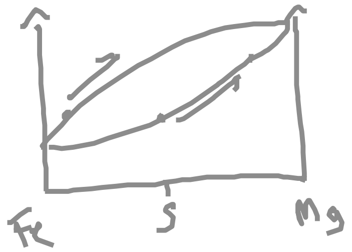
$a + b = 1$ mass balance

$b = 1 - a$

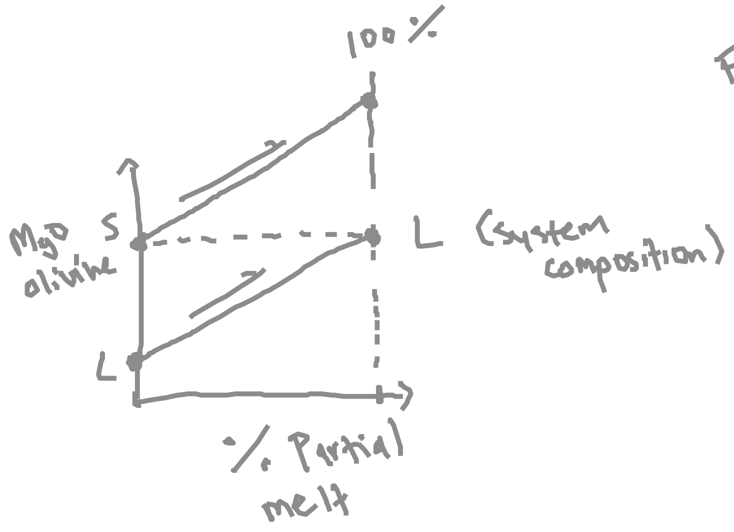
$a L + (1-a) S = \text{system}$

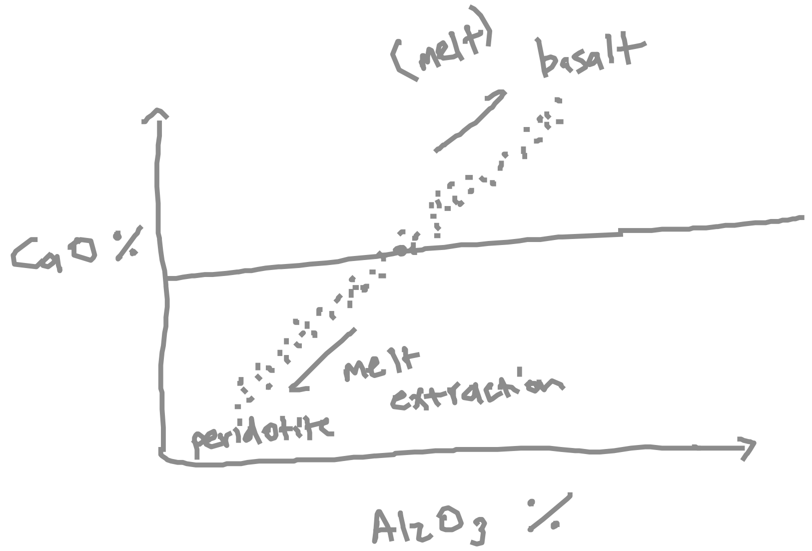
$a\, 0.25 + (1-a)\, 0.8 = 0.7$

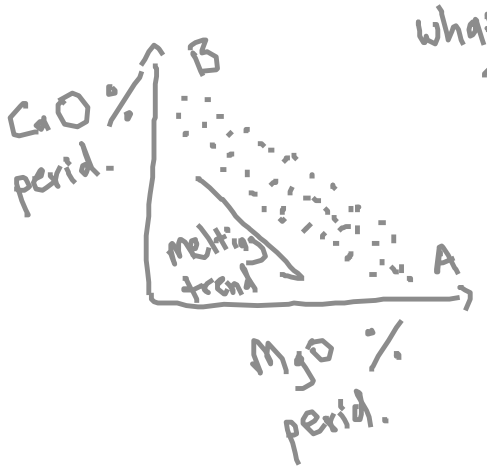
Melting trends.



RLE: Refractory lithophile element





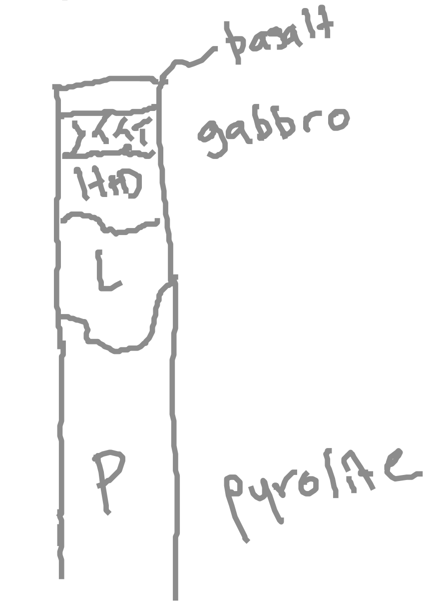


what is the melting trend?

more partial melt in A

Pyrolite Model: Ringwood, A.E., 1962. **A model for the upper mantle**. *Journal of Geophysical Research*.

Pyrolite Model

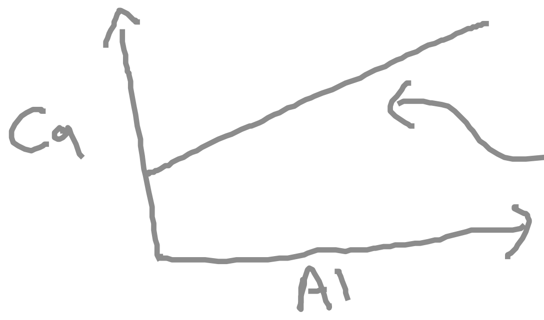


how can we estimate these coefficients

$$\text{pyrolite} = \underline{a}\ \text{MORB} + \underline{b}\ \text{DUNITE}$$

$$a + b = 1 \quad (\text{mass balance})$$

1. make an assumption about pyrolite

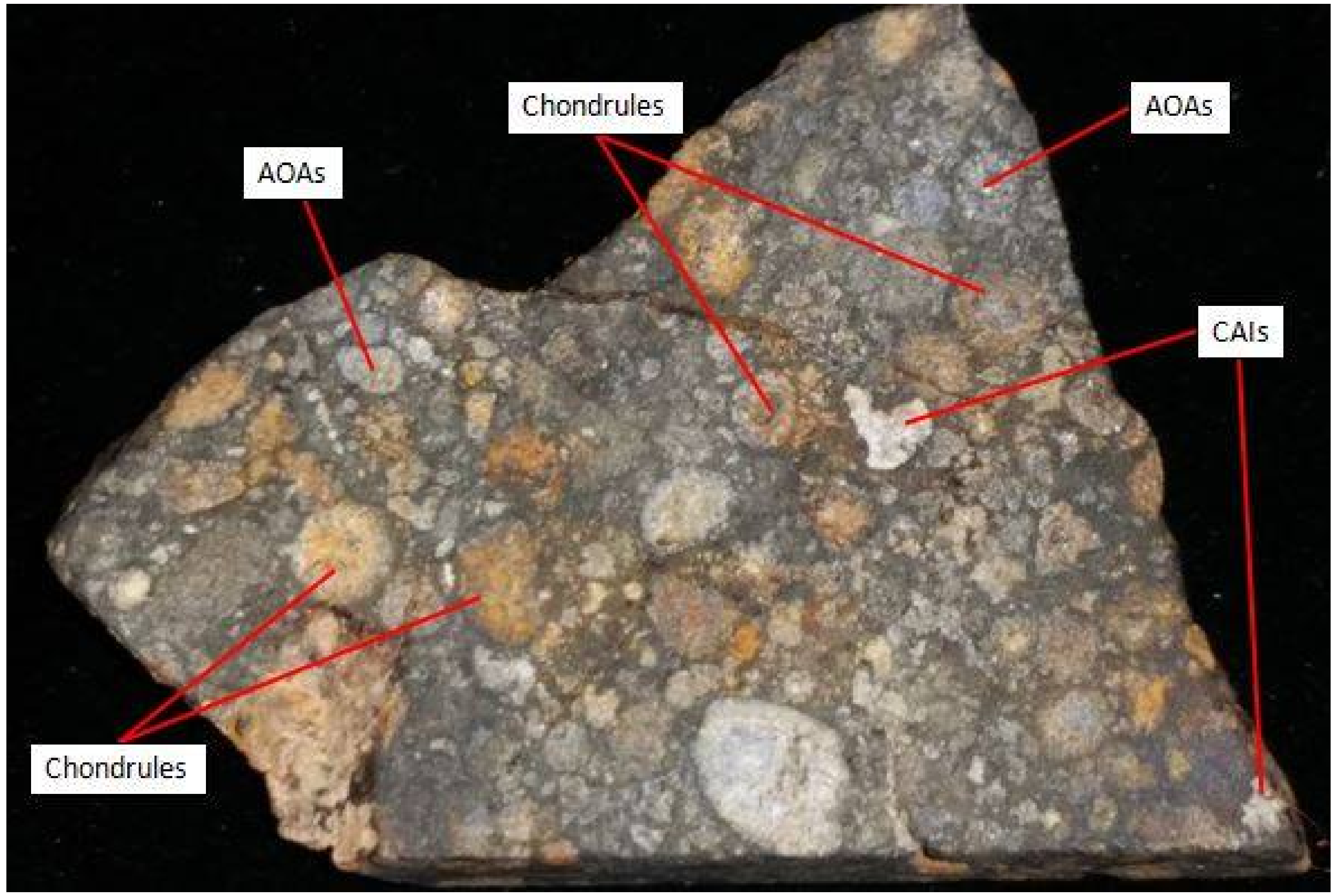


Ca:Al ratio of the solar system

why Ca:Al?
- Refractory
- Lithophile
- Major elements

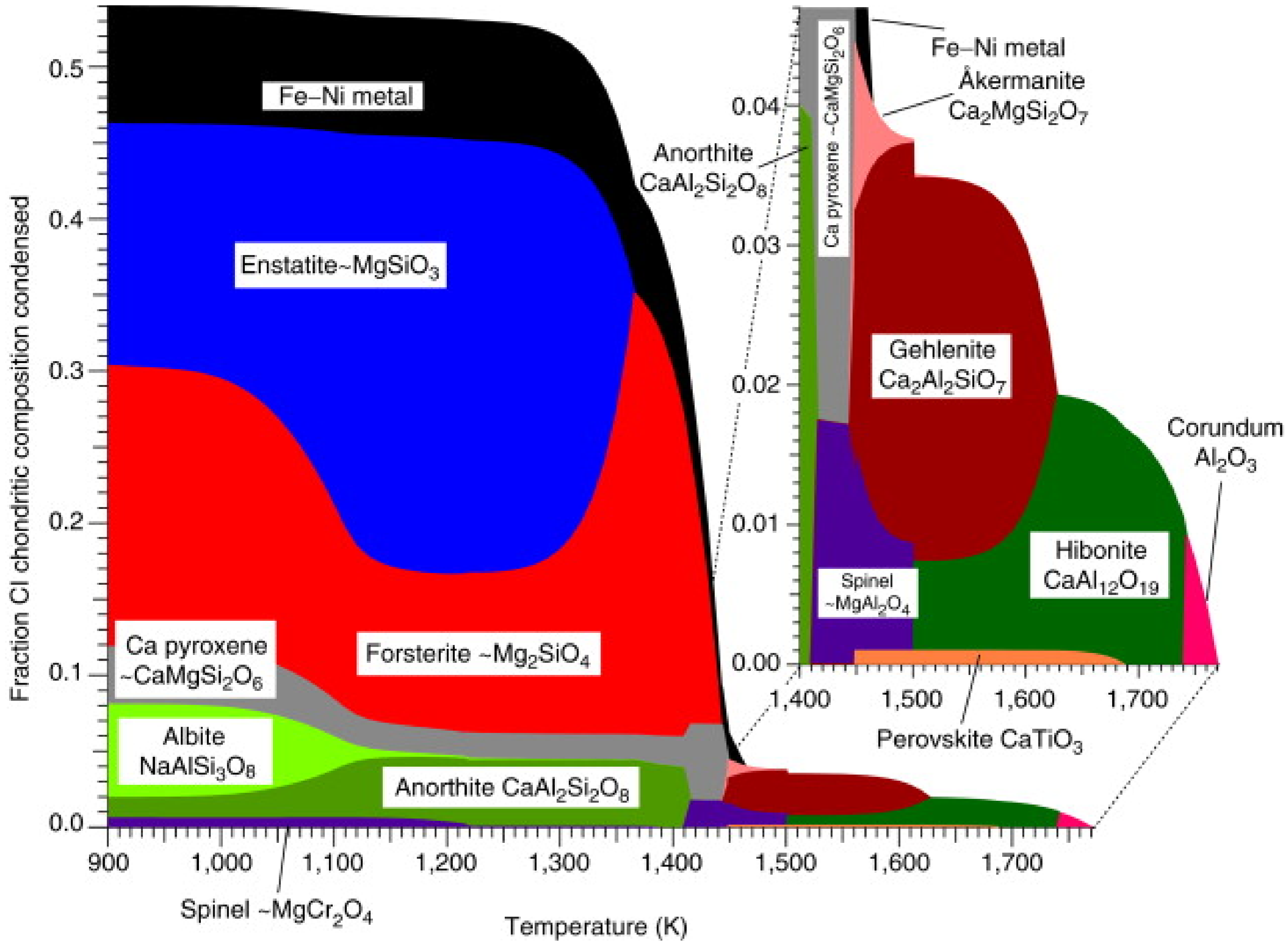
Pyrolite Model: Ringwood, A.E., 1962. **A model for the upper mantle**. *Journal of Geophysical Research*.

Chondrites

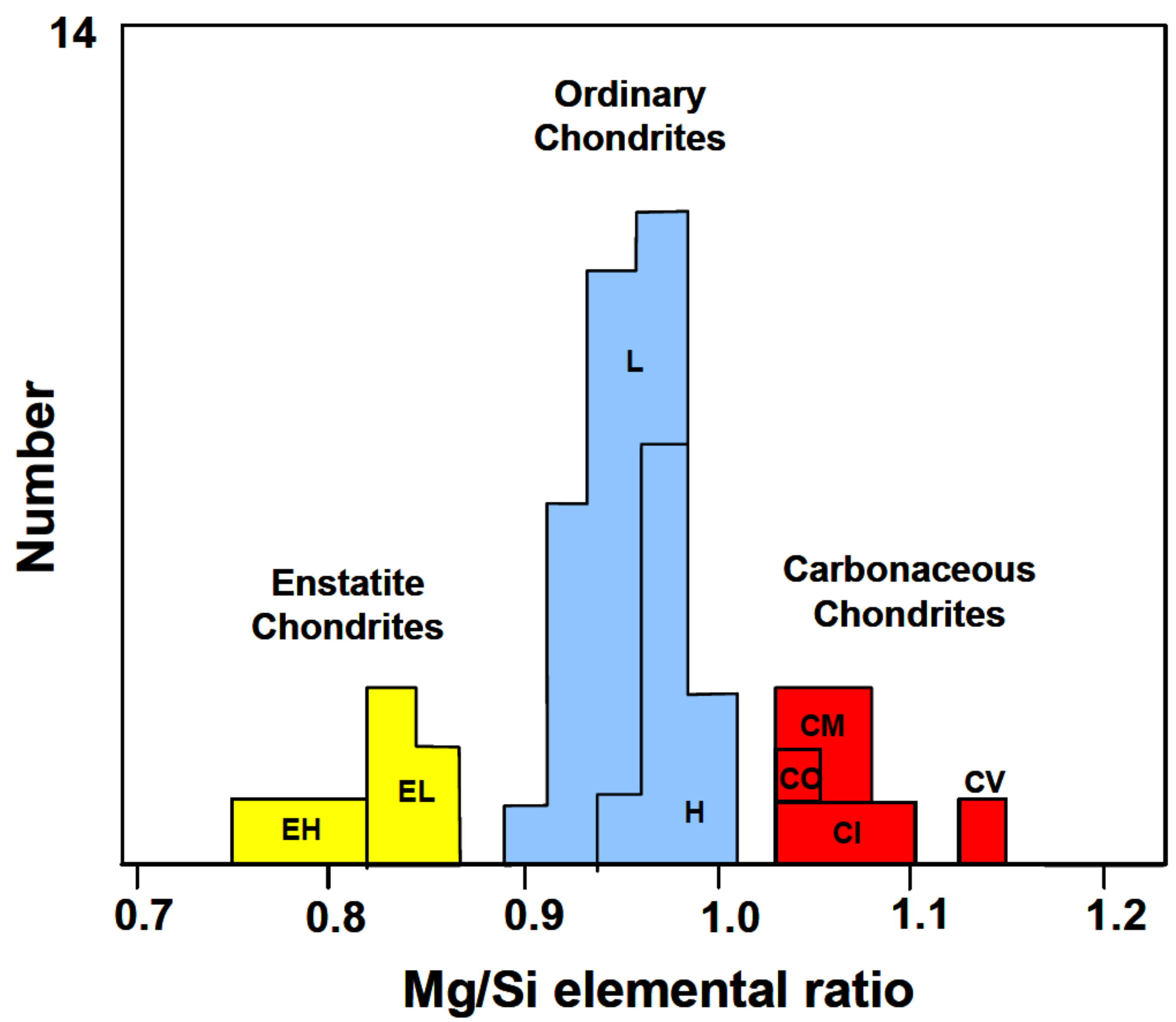


Chondrules: molten 'droplets' of nebular dust
AOAs: Ameboidal Olivine Aggregates ~100% olivine
CAIs: Calcium Aluminum Inclusions are the first condensates

Mineralogy of Chondrite phases



Chondrites have variable composition



Practice problem

The observed chondritic mass abundances for Calcium and Aluminum are:

Element	wt % in Chondrite	Atomic Mass
Ca	0.92	40.1
Al	0.85	27

The average wt % of CaO and Al_2O_3 in Basalt and Harzburgite:

Oxide	wt % in Basalt	wt % in Harzburgite
CaO	11.3	6.1
Al_2O_3	15.1	5.1

What ratio do you need to mix basalt and harzburgite back together to get the composition of the mantle before melt was removed? Assumptions:

- Pyrolite is a combination of melt (basalt) and melted mantle (harzburgites)
- Earth has the same Refractory Lithophile Elemental (RLE) abundances as Chondrites