

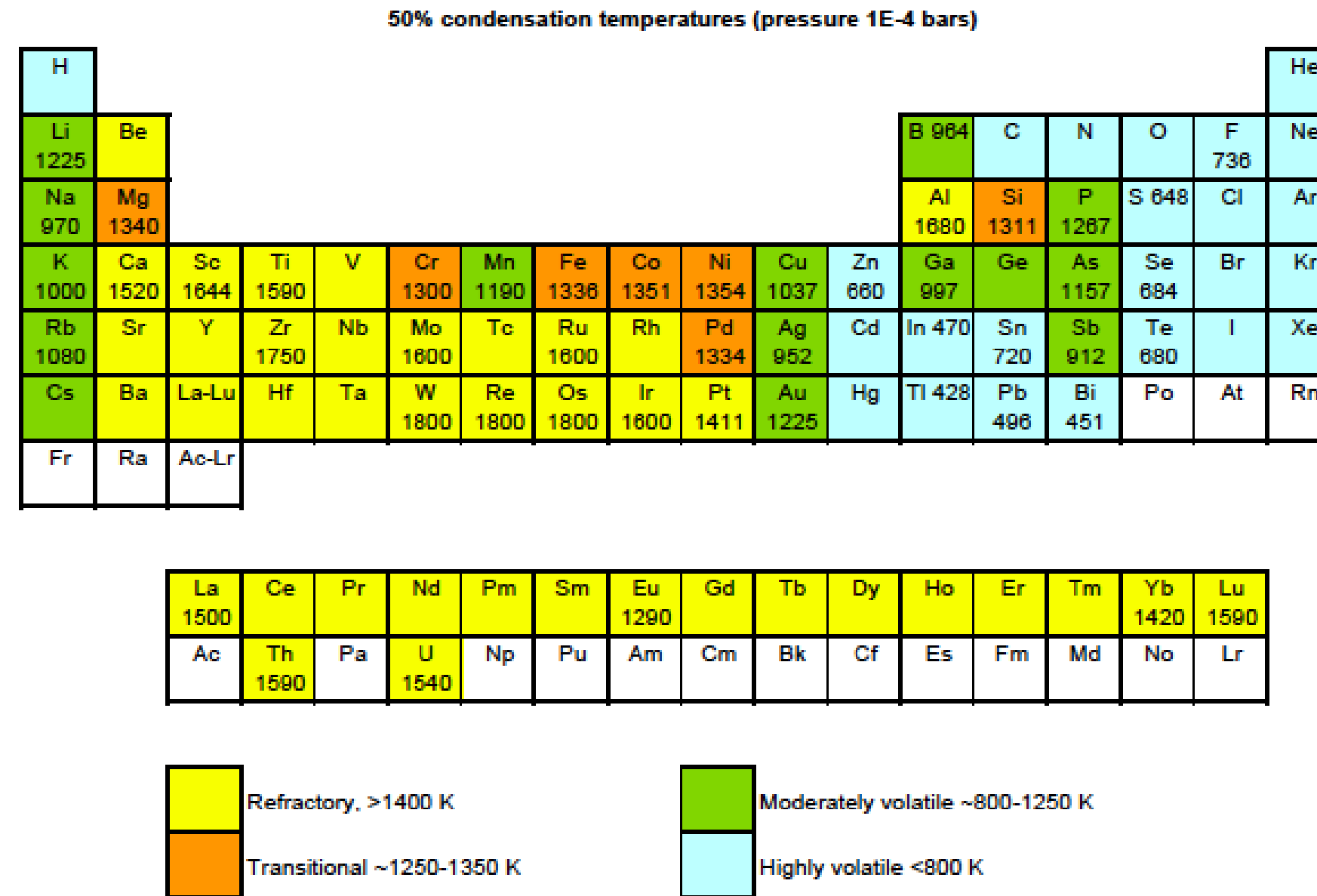


# Lecture 5: Making the Earth

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

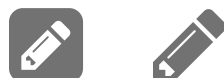
*We acknowledge and respect the lək̓ʷəŋən peoples on whose traditional territory the university stands and the Songhees, Esquimalt and W̱SÁNEĆ peoples whose historical relationships with the land continue to this day.*

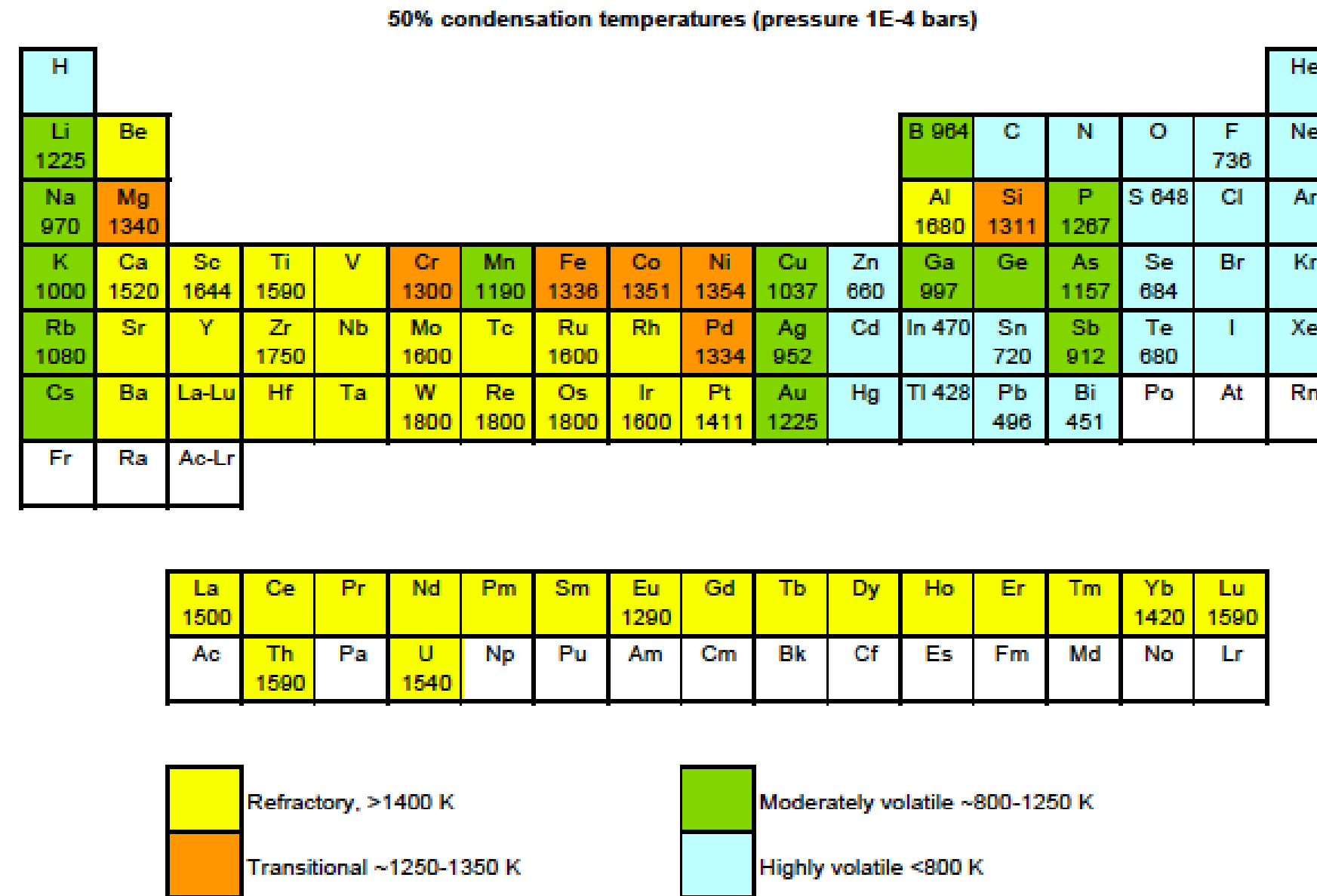




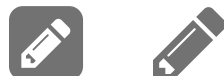
**Figure 2.13.** 50% condensation temperatures taken from [Wasson, 1985] and [O'Neill and Palme, 1998].

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

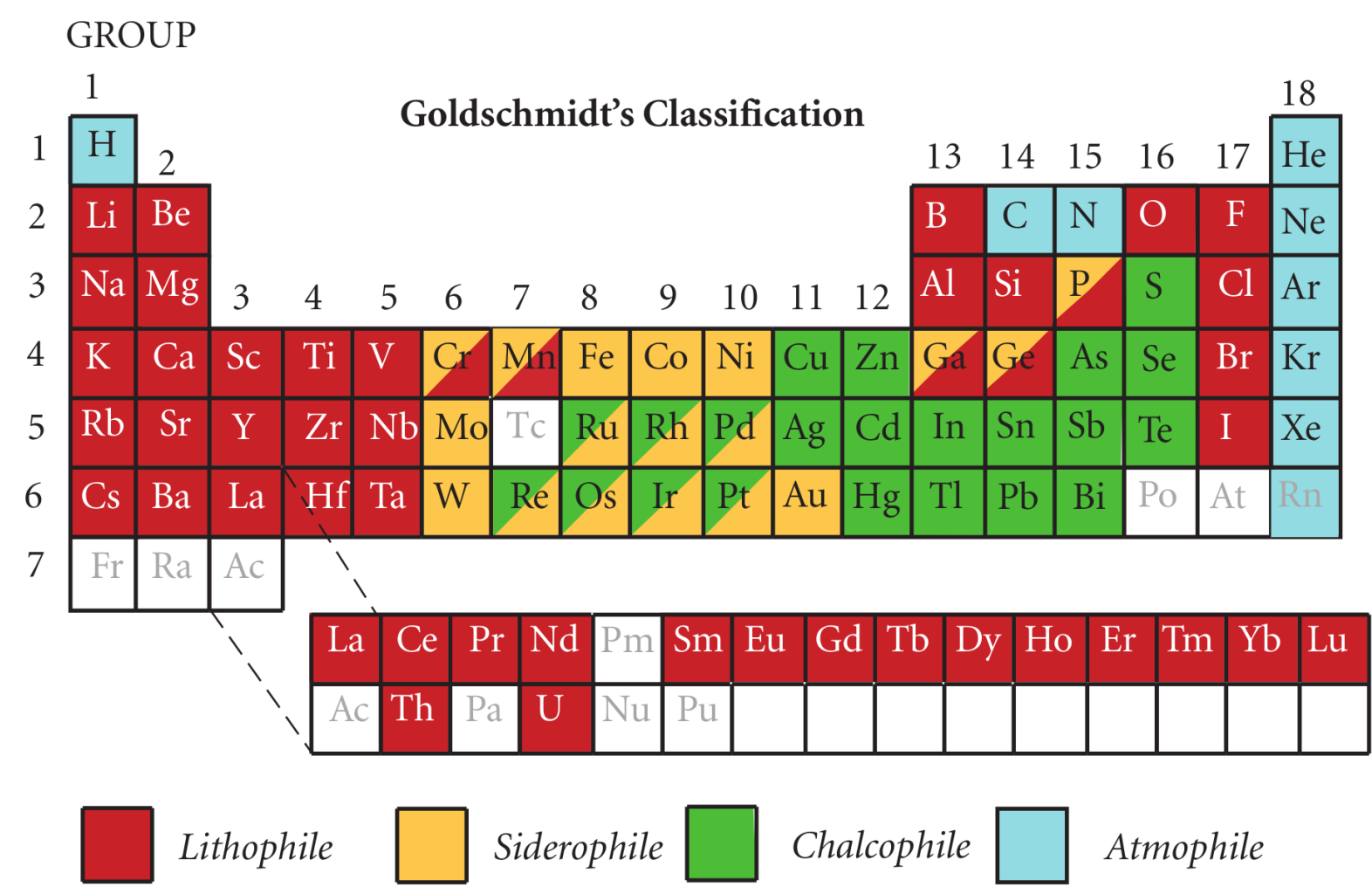




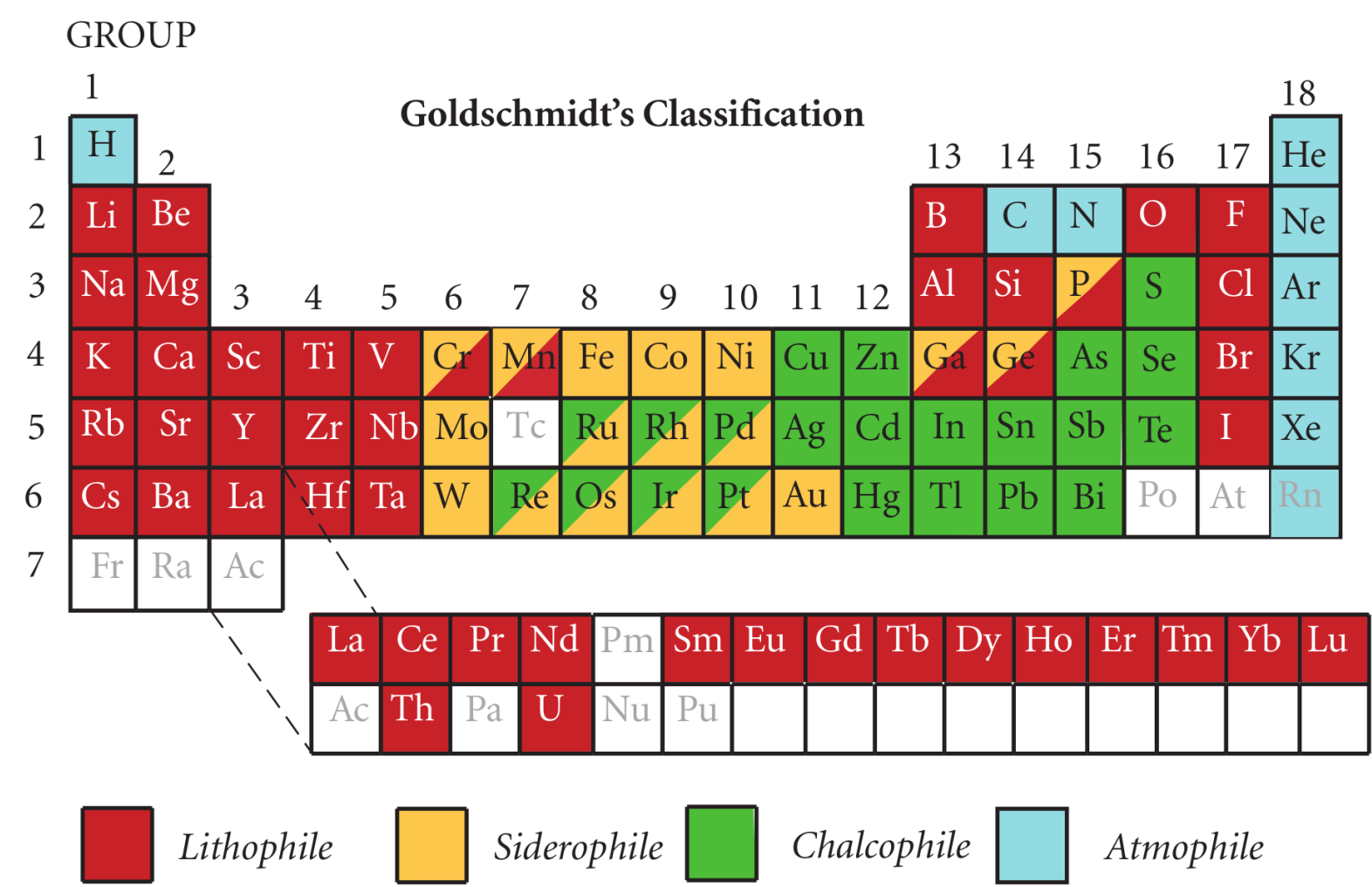
**Figure 2.13.** 50% condensation temperatures taken from [Wasson, 1985] and [O'Neill and Palme, 1998].



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*

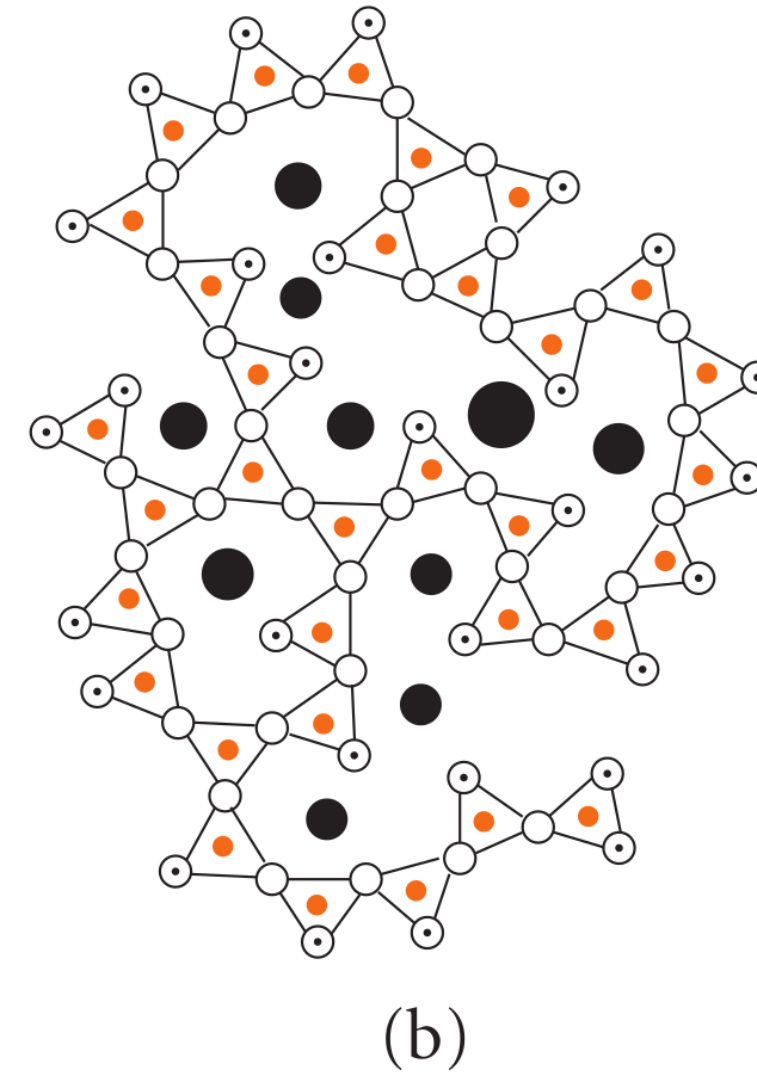
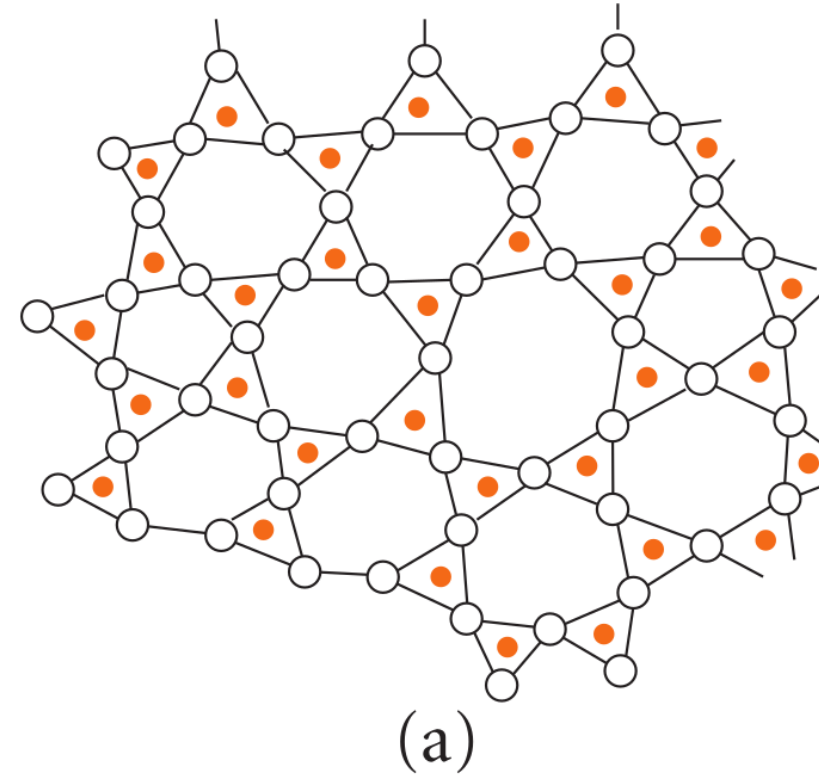
Electronegativity of the Elements

1 H 2.20																	2 He no data				
3 Li 0.98	4 Be 1.57															5 B 2.04	6 C 2.55	7 N 3.04	8 O 3.44	9 F 3.98	10 Ne no data
11 Na 0.93	12 Mg 1.31															13 Al 1.61	14 Si 1.90	15 P 2.19	16 S 2.58	17 Cl 3.16	18 Ar no data
19 K 0.82	20 Ca 1.00	21 Sc 1.36	22 Ti 1.54	23 V 1.63	24 Cr 1.66	25 Mn 1.55	26 Fe 1.83	27 Co 1.88	28 Ni 1.91	29 Cu 1.90	30 Zn 1.65	31 Ga 1.81	32 Ge 2.01	33 As 2.18	34 Se 2.55	35 Br 2.96	36 Kr 3.00				
37 Rb 0.82	38 Sr 0.95	39 Y 1.22	40 Zr 1.33	41 Nb 1.6	42 Mo 2.16	43 Tc 1.9	44 Ru 2.2	45 Rh 2.28	46 Pd 2.20	47 Ag 1.93	48 Cd 1.69	49 In 1.78	50 Sn 1.96	51 Sb 2.05	52 Te 2.1	53 I 2.66	54 Xe 2.6				
55 Cs 0.79	56 Ba 0.89	57-71	72 Hf 1.3	73 Ta 1.5	74 W 2.36	75 Re 1.9	76 Os 2.2	77 Ir 2.2	78 Pt 2.28	79 Au 2.54	80 Hg 2.00	81 Tl 1.62	82 Pb 2.33	83 Bi 2.02	84 Po 2.0	85 At 2.2	86 Rn no data				
87 Fr 0.7	88 Ra 0.89	89-103	104 Rf no data	105 Db no data	106 Sg no data	107 Bh no data	108 Hs no data	109 Mt no data	110 Ds no data	111 Rg no data	112 Cn no data	113 Nh no data	114 Fl no data	115 Mc no data	116 Lv no data	117 Ts no data	118 Og no data				
Low																			High		
57 La 1.10	58 Ce 1.12	59 Pr 1.13	60 Nd 1.14	61 Pm 1.13	62 Sm 1.17	63 Eu 1.2	64 Gd 1.2	65 Tb 1.22	66 Dy 1.23	67 Ho 1.24	68 Er 1.24	69 Tm 1.25	70 Yb 1.1	71 Lu 1.27							
89 Ac 1.1	90 Th 1.3	91 Pa 1.5	92 U 1.38	93 Np 1.36	94 Pu 1.28	95 Am 1.3	96 Cm 1.3	97 Bk 1.3	98 Cf 1.3	99 Es 1.3	100 Fm 1.3	101 Md 1.3	102 No 1.3	103 Lr no data							



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

- Network-former
- Network-modifier
- Bridging Oxygen
- ⊙ Nonbridging Oxygen



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.

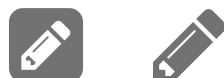




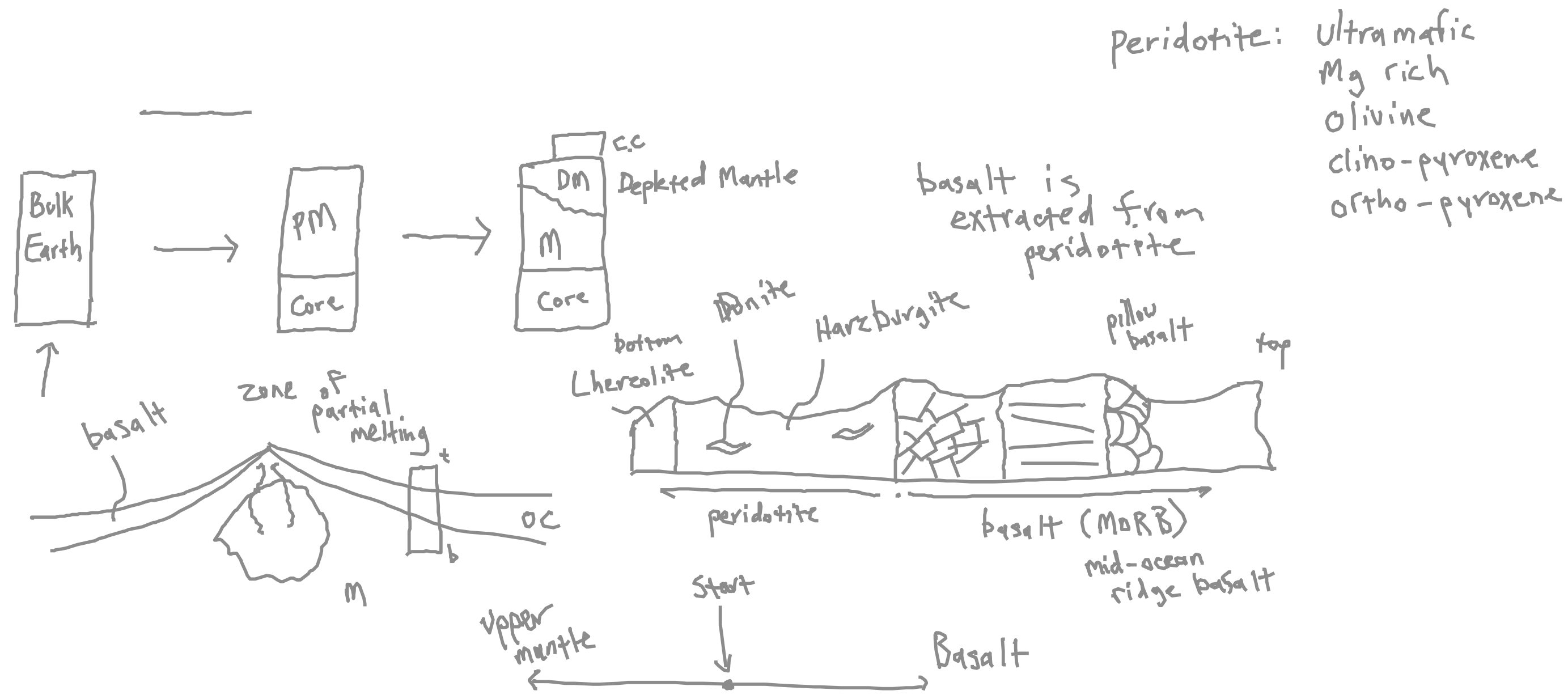
In Geochemistry, we often use the word **fractionate** to indicate that the original mass (*the nebula*) led to one or more smaller fractions of mass (*different planets*) that have compositional variations. Through our understanding of condensation temperatures and Goldschmidt's classification scheme, 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.

Some review questions to consider:

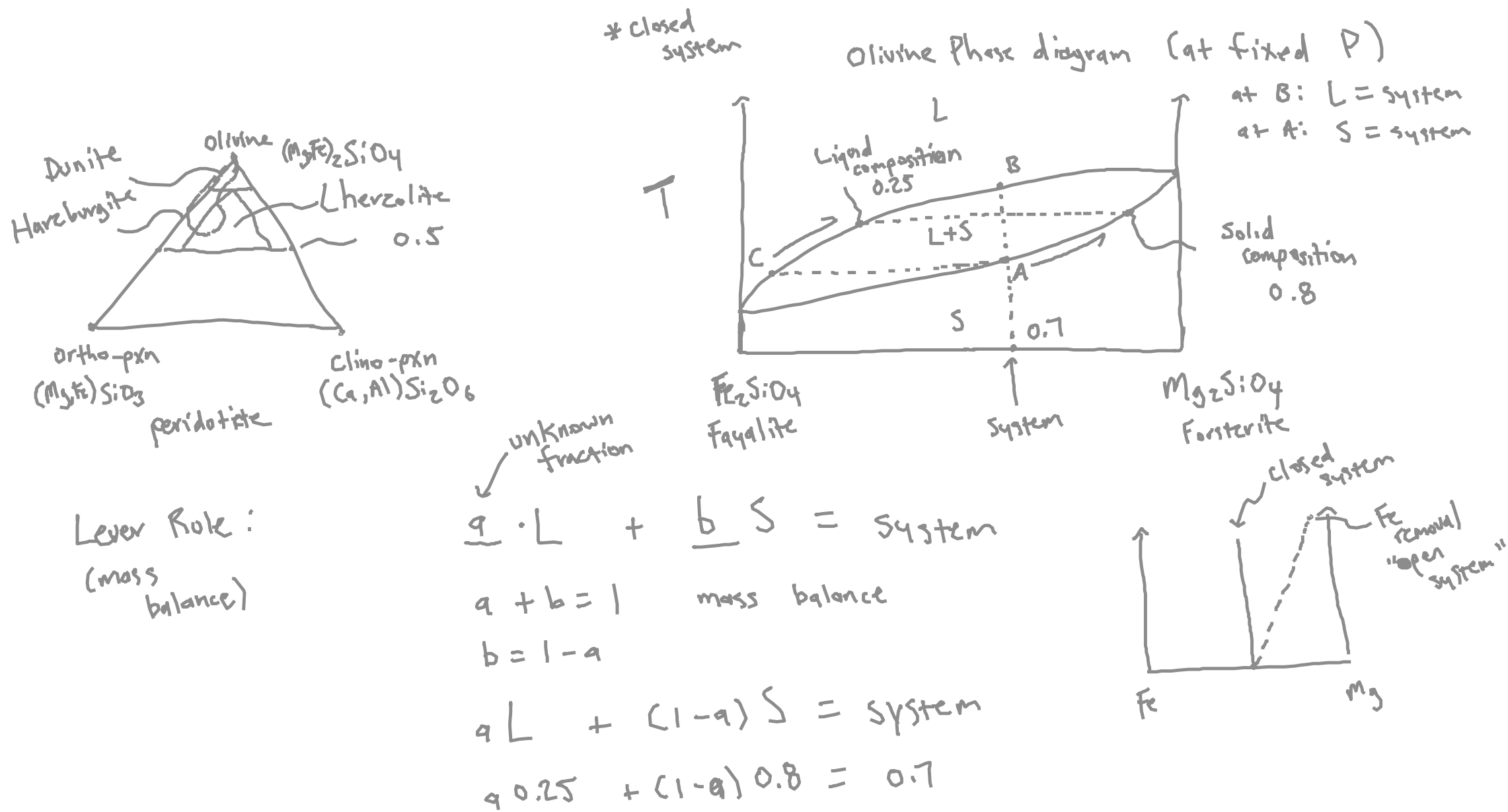
- **How does the Ca/Al ratio change from the inner solar system to the outer?** (*draw a figure showing this ratio vs distance from the Sun*)
- **How does the Na/Al ratio change from the inner solar system to the outer?** (*draw a figure showing this ratio vs distance from the Sun*)
- **Is the weight % 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?**



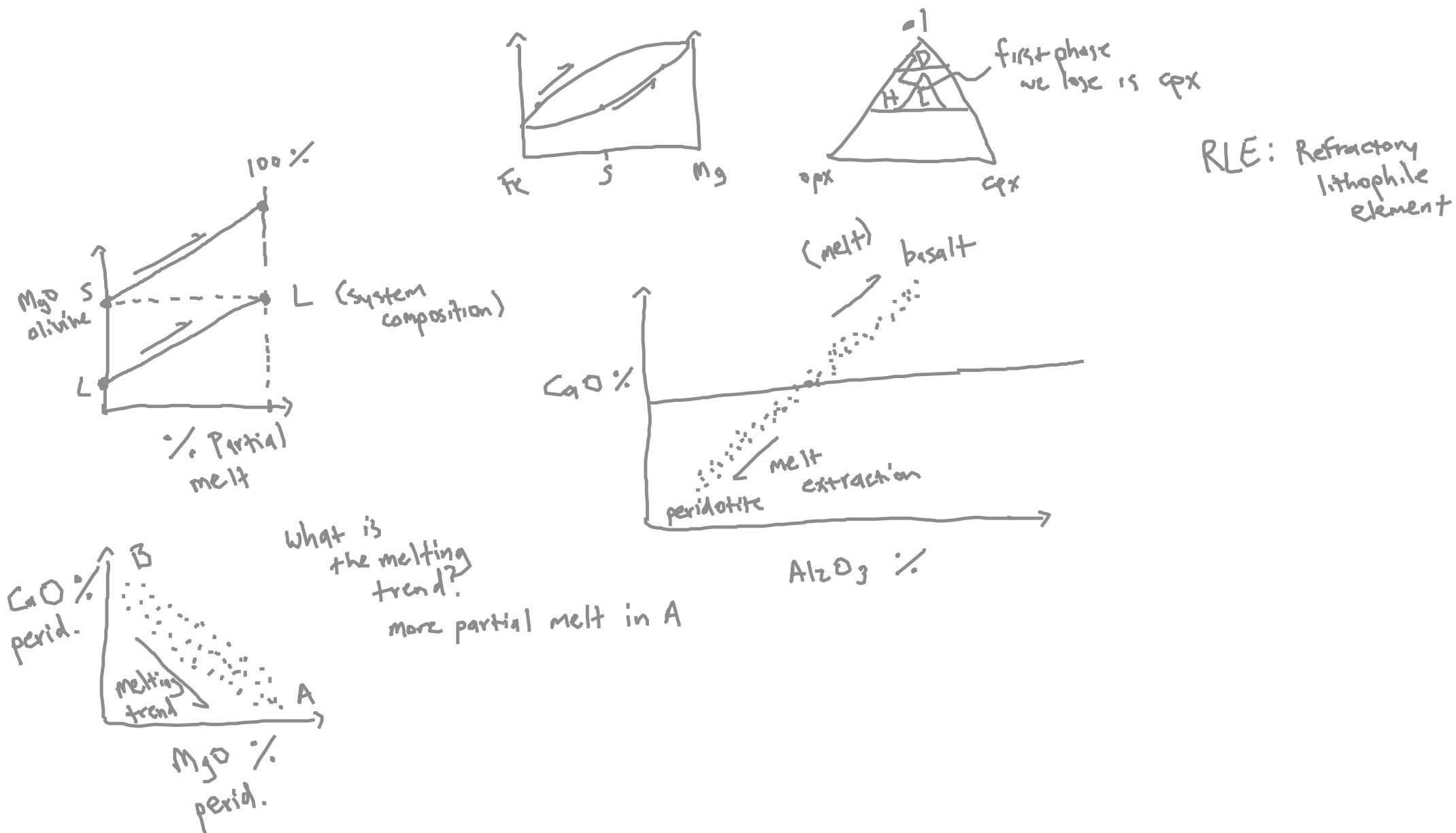
Define Primitive Mantle. What do we know about the modern mantle?



# Olivine Solid Solution Phase Diagram.



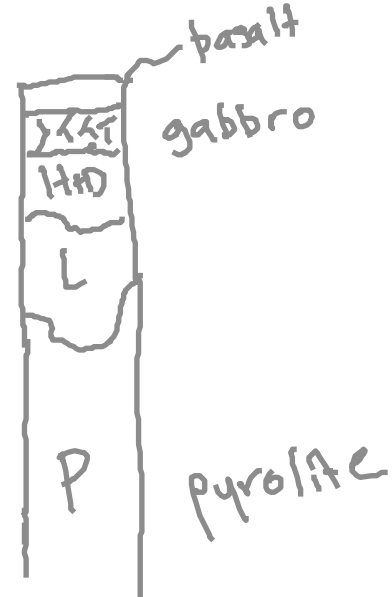
# Melting trends.



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



## Pyrolite Model

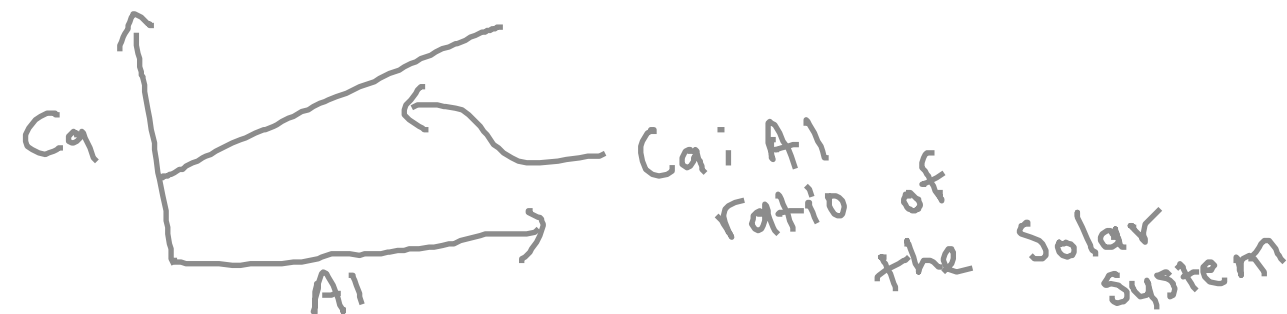


how can we  
estimate  
these coefficients

$$\text{pyrolite} = \alpha \text{ MORB} + b \text{ DUNITE}$$

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

1. Make an assumption about pyrolite



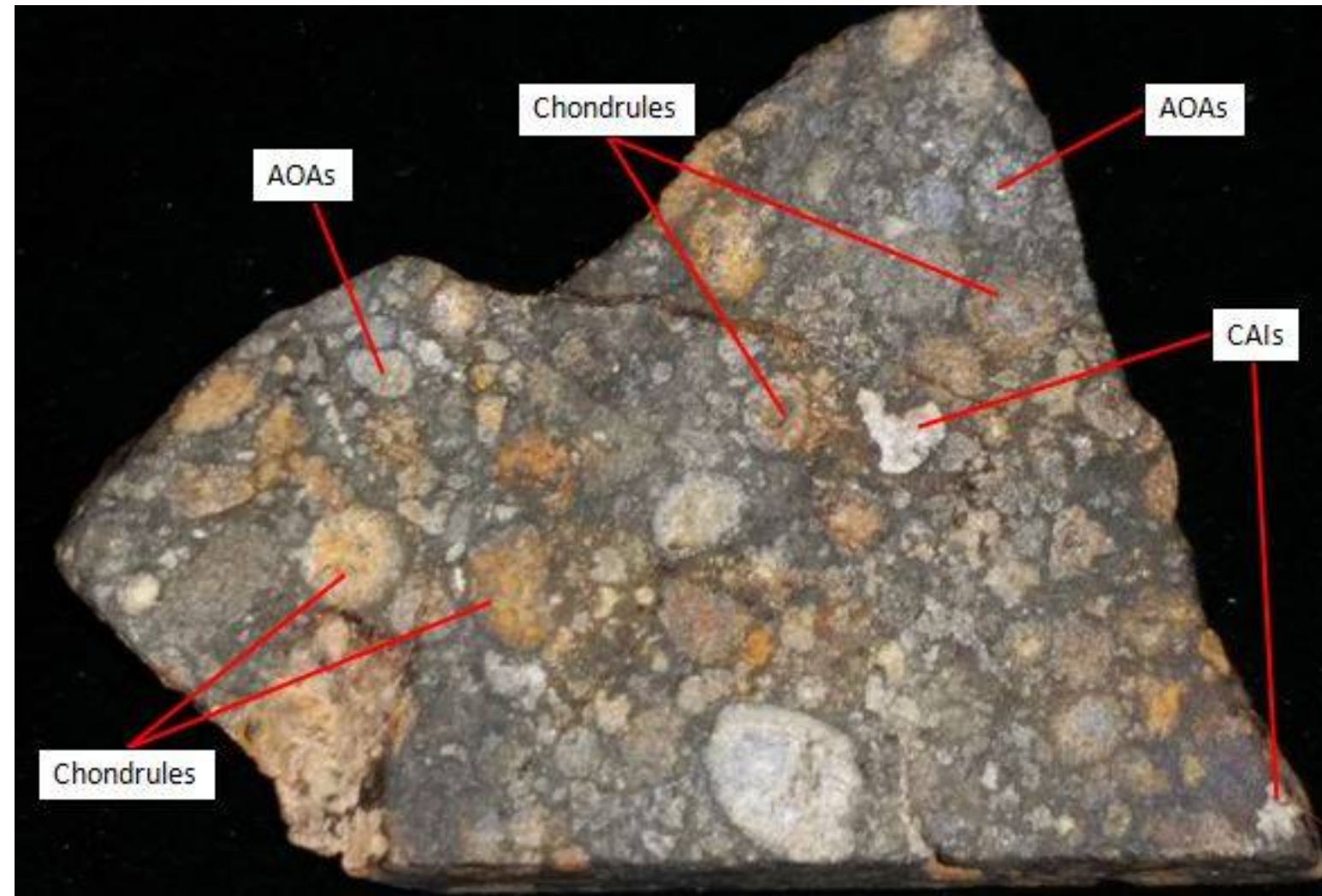
Why Ca:Al?

- Refractory
- Lithophile
- Major elements

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



# Chondrites

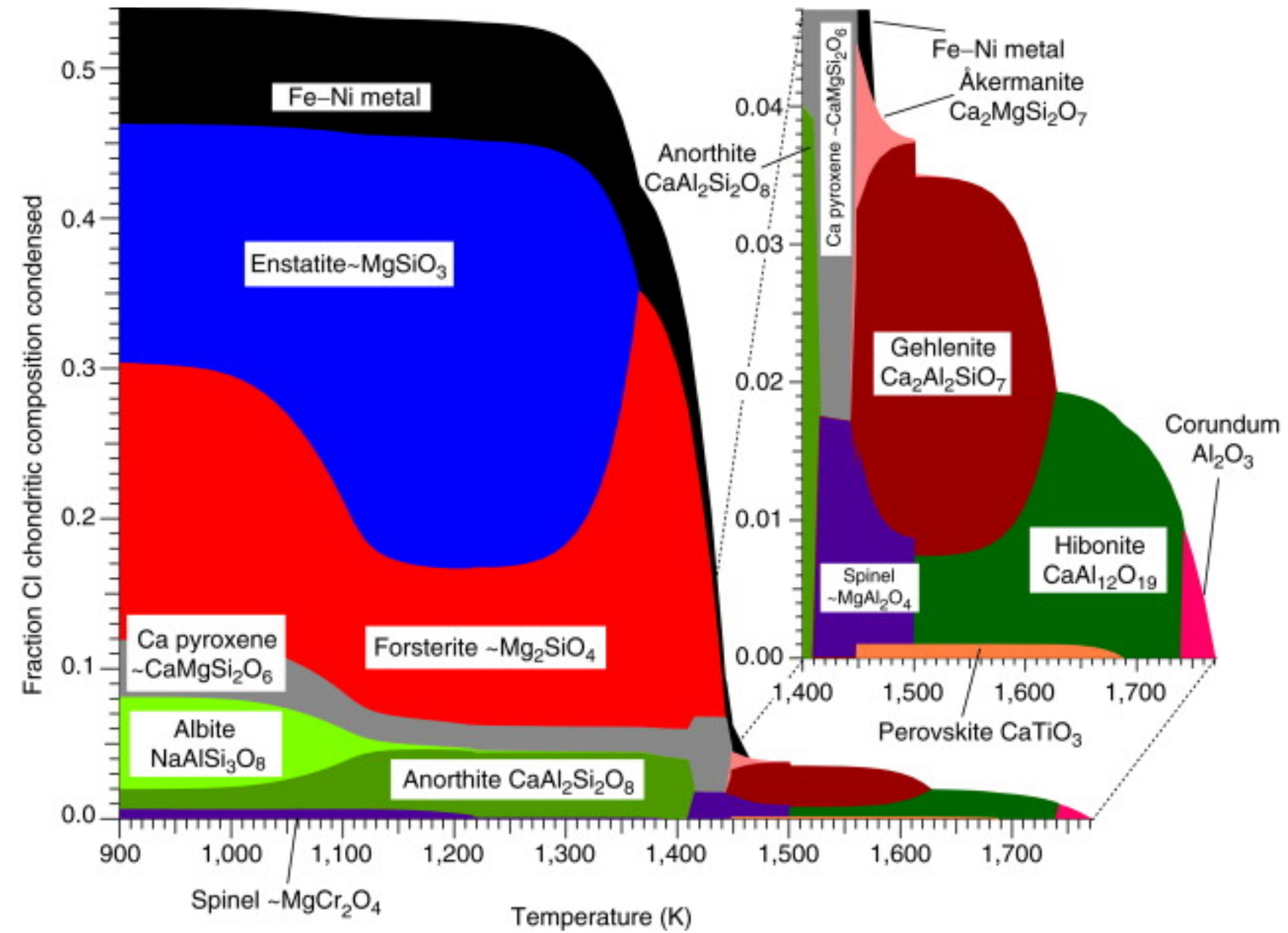


Chondrules: molten 'droplets' of nebular dust

AOAs: Ameboidal Olivine Aggregates ~100% olivine

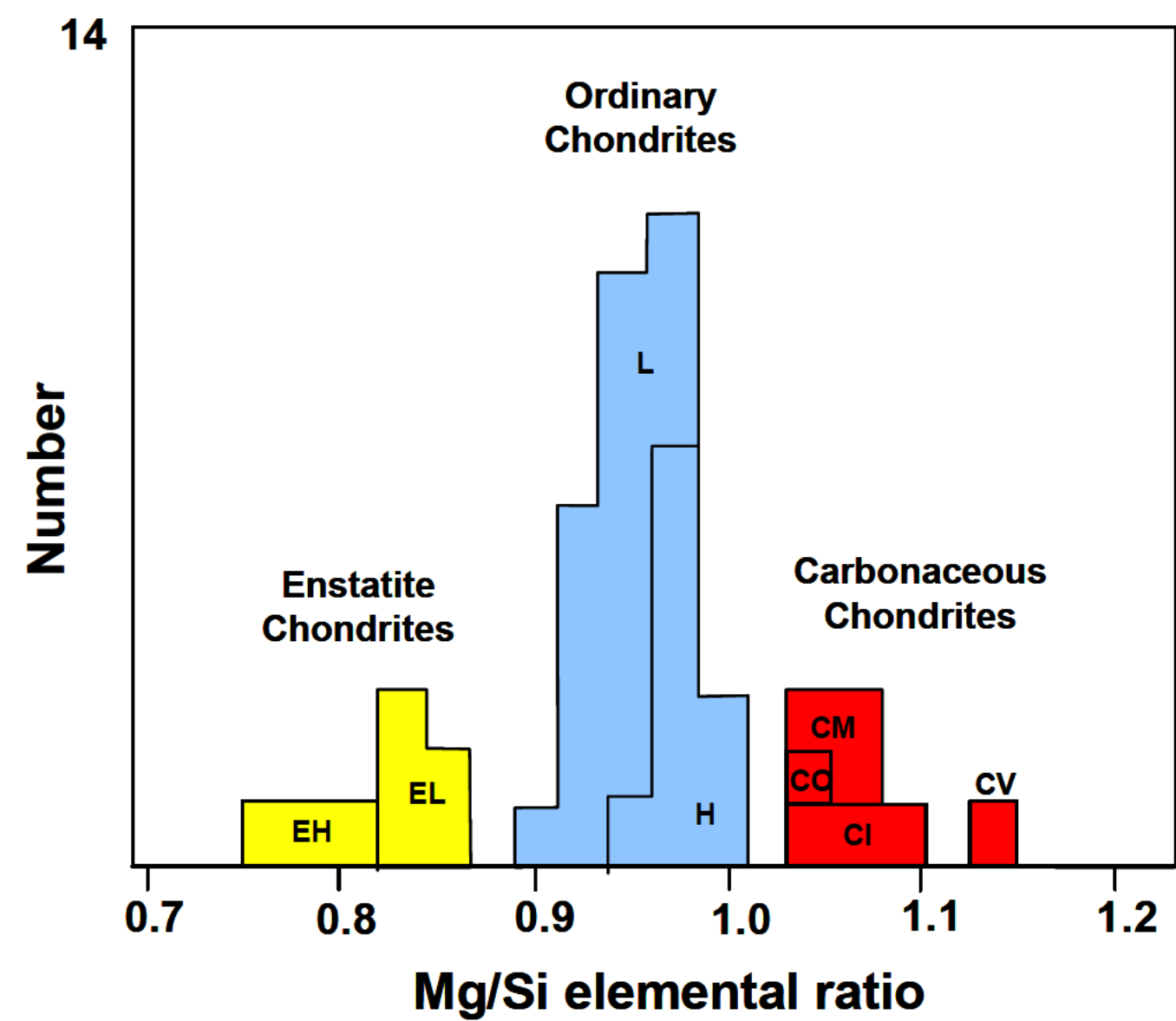
CAIs: Calcium Aluminum Inclusions are the first condensates

## 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<sub>2</sub>O<sub>3</sub> in Basalt and Harzburgite:

Oxide	wt % in Basalt	wt % in Harzburgite
CaO	11.3	6.1
Al <sub>2</sub> O <sub>3</sub>	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

