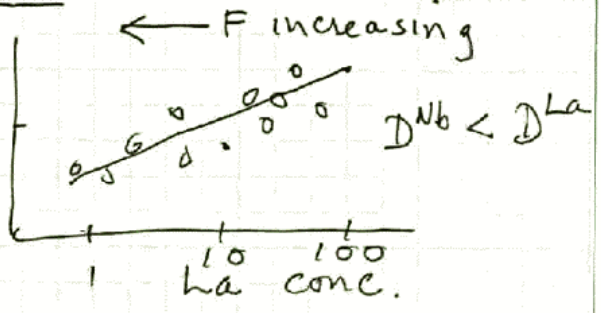
SPIDERGRAMS

- present ability to measure trace element concentrations to good precision (1-3%) for many elements (~40). How to classify and think about data?
- one method is to "normalize" each element concentration either to "chondritic" abundances, or our estimate of "Bulk Silicate Earth" abundances.
- Spidergram is just a plot of normalized concentrations against some order or sequence of elements
- How to "order" the elements?
- usually done in increasing order of "compatibility" (i.e. how happy an element is in crystal relative to melt - i.e. the partition coefficient)
  - problem here is elements have different K_D's in different minerals -
- Compromise - use "compatibility" order of actual melts from actual mantle.

The "Hofmann plot" approach

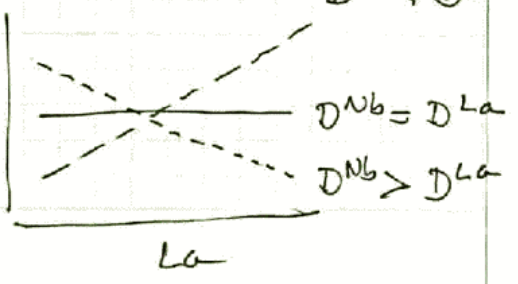
- take a cogenetic suite of basalts.
- plot any element ratio against absolute conc. of one element (proxy for F, degree of melting)



- Batch melting, small D:

$$\left[\frac{C_e^{Nb}}{C_e^{La}} = \frac{C_s^{Nb}}{C_s^{La}} \frac{(D^{La} + F)}{(D^{Nb} + F)}\right]$$

- From a matrix of such plots for all element ratios, can "order" the elements by compatibility

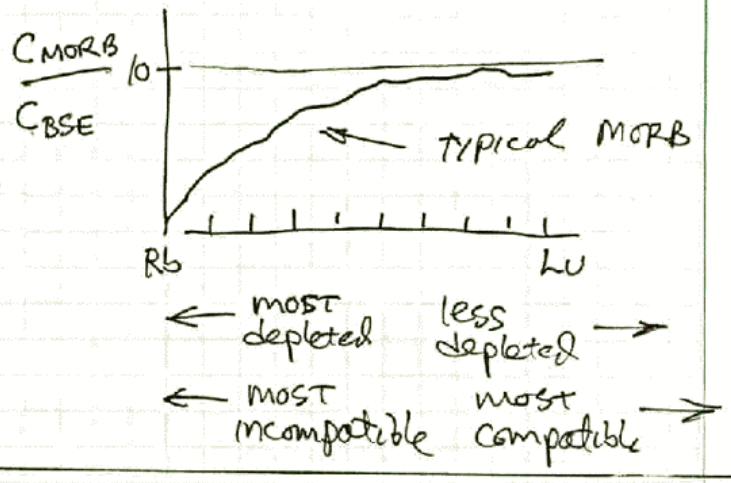


(2)

• The "MORB" approach

- Hypothesis is that the MORB mantle is JUST bulk earth mantle that has been somewhat depleted by melt extraction over earth history
- Thus the MORB source should have element concentrations that are variably depleted depending on the "compatibility" of the elements
  - so elements can be "ordered" simply in order of $\frac{\text{MORB concentration}}{\text{normalized to bulk earth}}$

- In practice, the community uses a "consensus" ordering based on both approaches
  { Hofmann method
  MORB method }



Element partitioning

- This data is key to almost all mantle melting studies

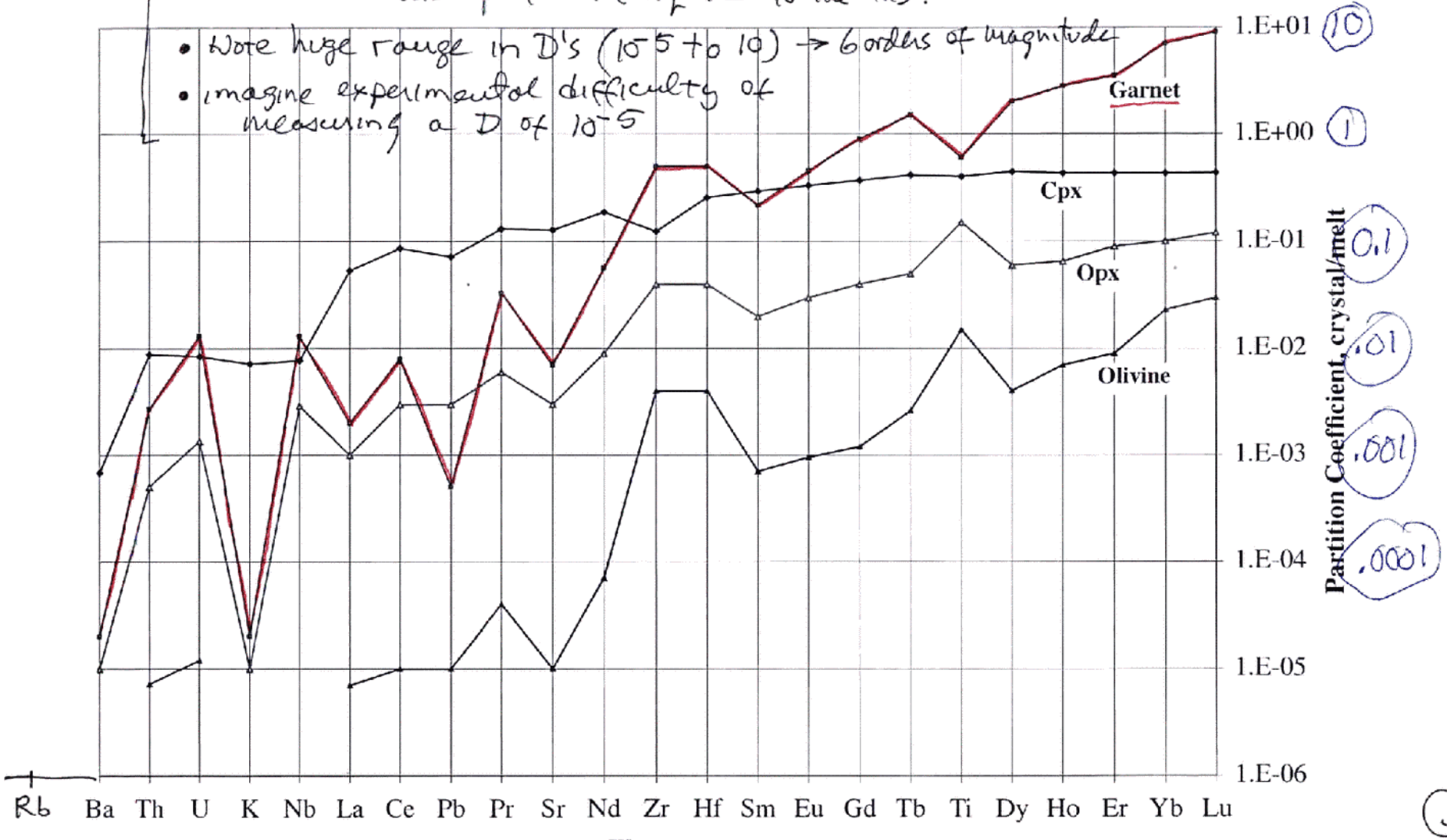
Technique - in the lab, "cook" a basalt (for example) containing mineral phenocrysts (at equilibrium) and measure the concentrations of an element in the melt and in the phenocrysts. The ratio of these is called the partition coefficient = $\frac{C_i \text{ in crystal}}{C_i \text{ in melt}} = D$ or K_D

- In practice, K_D's are functions of P, T, melt composition and mineral composition (so a lot of experiments are required!)

Results - we are concerned mostly about melting of mantle to produce basalts, and for a peridotite mantle, the minerals of interest are Cpx, Opx, garnet + olivine

← incompatible low K_D —— compatible, high K_D → Kelemen 2003 K_D's

- Note that except for heavy REE in garnet, all of these elements prefer the liquid to the Xls.
- Note huge range in D's (10^{-5} to 10) → 6 orders of magnitude
- imagine experimental difficulty of measuring a D of 10^{-5}



observations

- For mantle < 90 km (no garnet), $D^{cpx} > D^{opx} > D^{olivine}$
  + for peridotite with 15% Cpx, 25% opx, 60% olivine, the Cpx is the principal repository of these elements
- For mantle > 90 km (garnet), $D_i^{garnet} > D_i^{cpx}$ from Sm to the right, reversed to the left
- Note signature anomalies for some phases $(Zr-Hf)^{garnet}$, Nb/La Cpx vs Garnet

- The understanding of all isotope "tracer" systems clearly depends strongly on knowing how the parent/daughter elements are fractionated during (mineral/melt) processes.

  e.g. – Rb is much more "incompatible" than Sr.
  – melting will drastically lower Rb/Sr in the residue
  – after aging, will lead to low 87/86 Sr

- In converse Nd is more incompatible than Sm, so depleted residue will have low Nd/Sm, or high Sm/Nd ($^{147}Sm \rightarrow {}^{143}Nd$)
  – after aging, residue will have high 143/144 Nd, leading to the typical inverse correlation of Sr + Nd isotopes