Lecture 7: Hot spots, seamounts, and ridges

The topography and geology of the seafloor offers some of the only clues we have to understanding the hidden workings of the mantle below. We have discussed some of the largest features of ocean basins, and today we consider the small seamounts and their critical role in this story.

- Axial depth and crustal thickness
    - Na_2O in MORB
- Spreading rate vs potential temperatures
- Trace elements and isotopes in MORB/OIB

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.

Review

What evidence do we have for mantle convection?

- Magnetic anomalies that are symmetric around MOR
- Elevation of seafloor fits diffusive cooling model (up to ~50 Ma)
- Constant crustal thickness in the oceanic crust
- Higher heatflow under MOR than far from MOR
- Ocean basins are young

What evidence do we have for plumes?

- Anomalously high elevation swell surrounding active mid-plate (usually) volcanism
- Often a monotonic age progression of volcanism the youngs in the plate-motion direction

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Today we will go into some of the geochemical properties of mid-ocean ridge and ocean island basalts to get a better understanding of how the mantle on Earth works.

Axial depth, crustal thickness, and melting

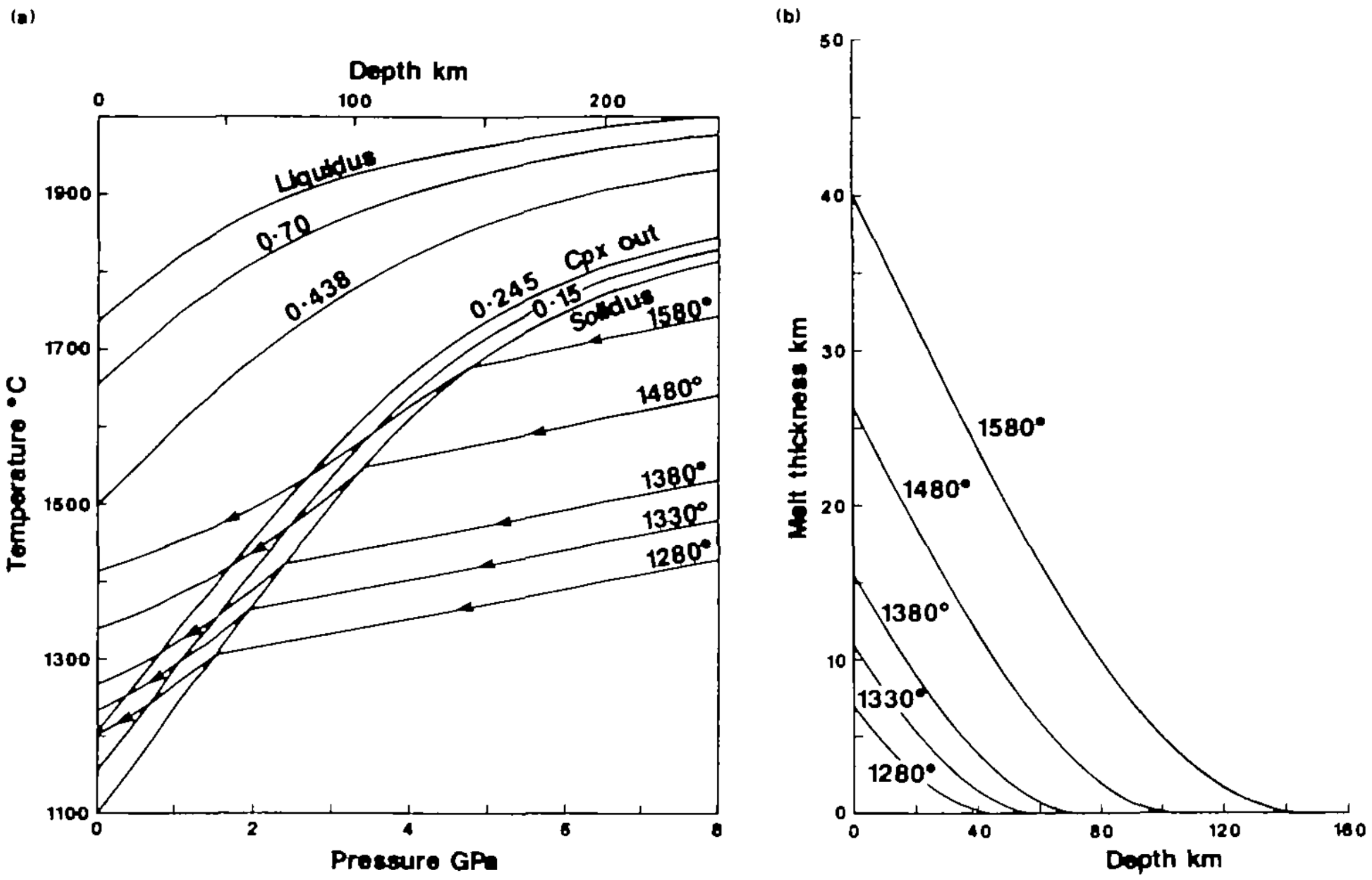
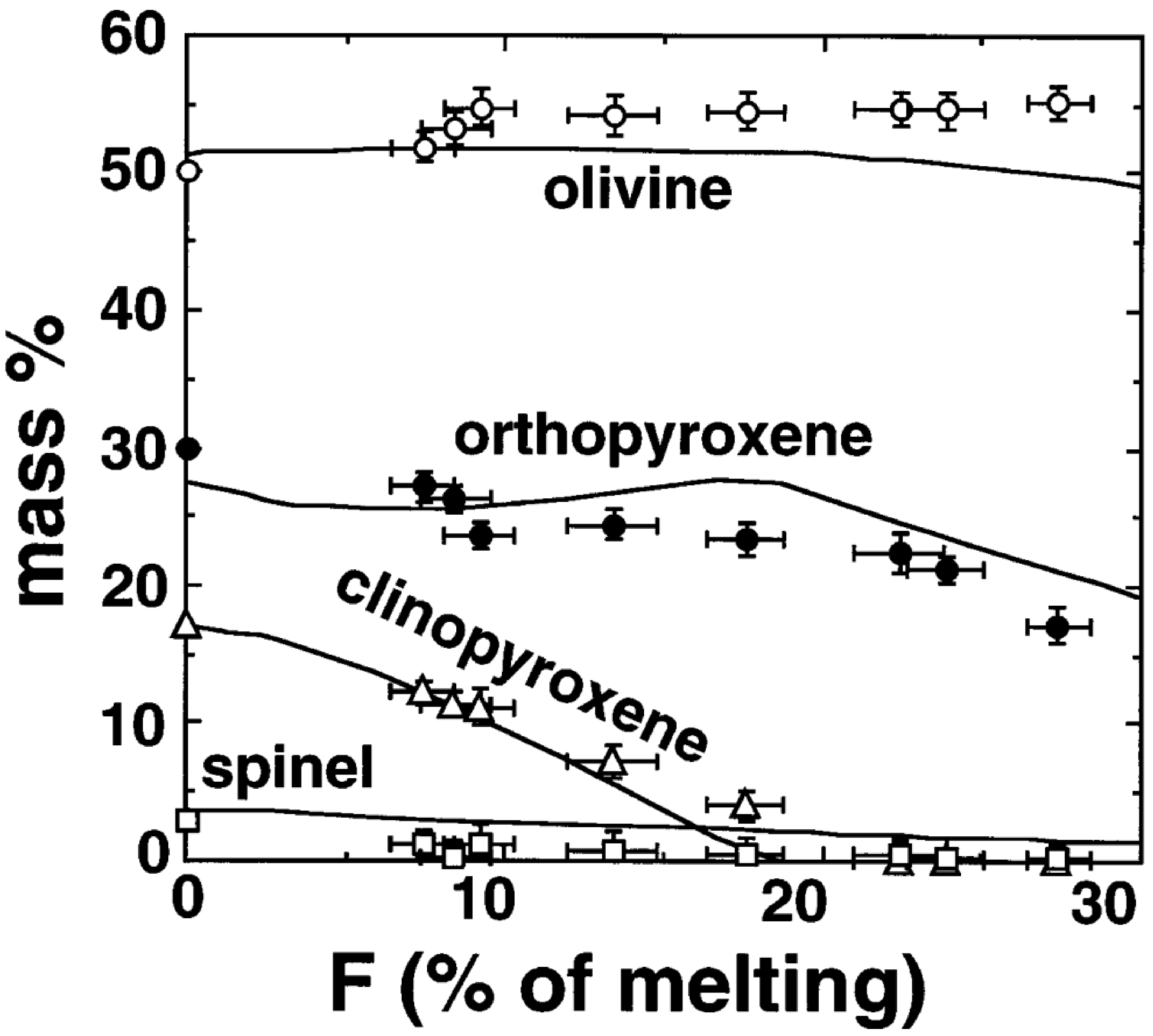


FIG 7 (a) Adiabatic decompression paths calculated using the equations given by McKenzie (1984*a*) Appendix D, a fourth order Runge–Kutta scheme and

$$\Delta S = 250 \text{ J kg}^{-1}\,{}^{\circ}\text{C}^{-1}.$$

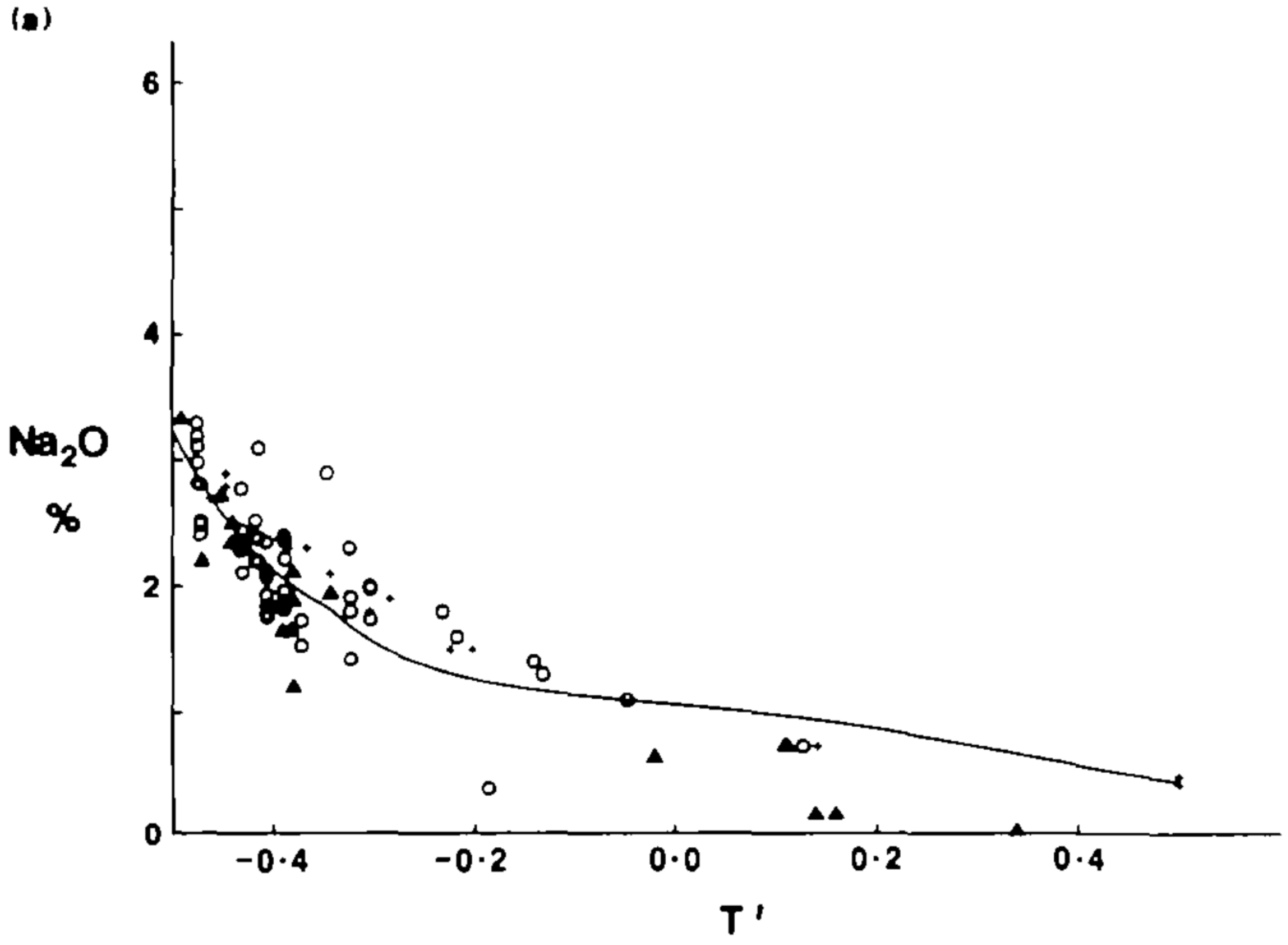
The curves are labelled with their potential temperatures, and entropy is conserved to 1 part in 10^4 during the numerical integration. The curves between the solidus and the liquidus are labelled with the melt fraction by weight. (b) The total thickness of melt present below a given depth plotted as a function of depth, calculated by integrating the volume of melt present in (a).

Melting peridotite



Peridotite melting experiments

(-0.5 is the solidus, 0.5 is the liquidus)



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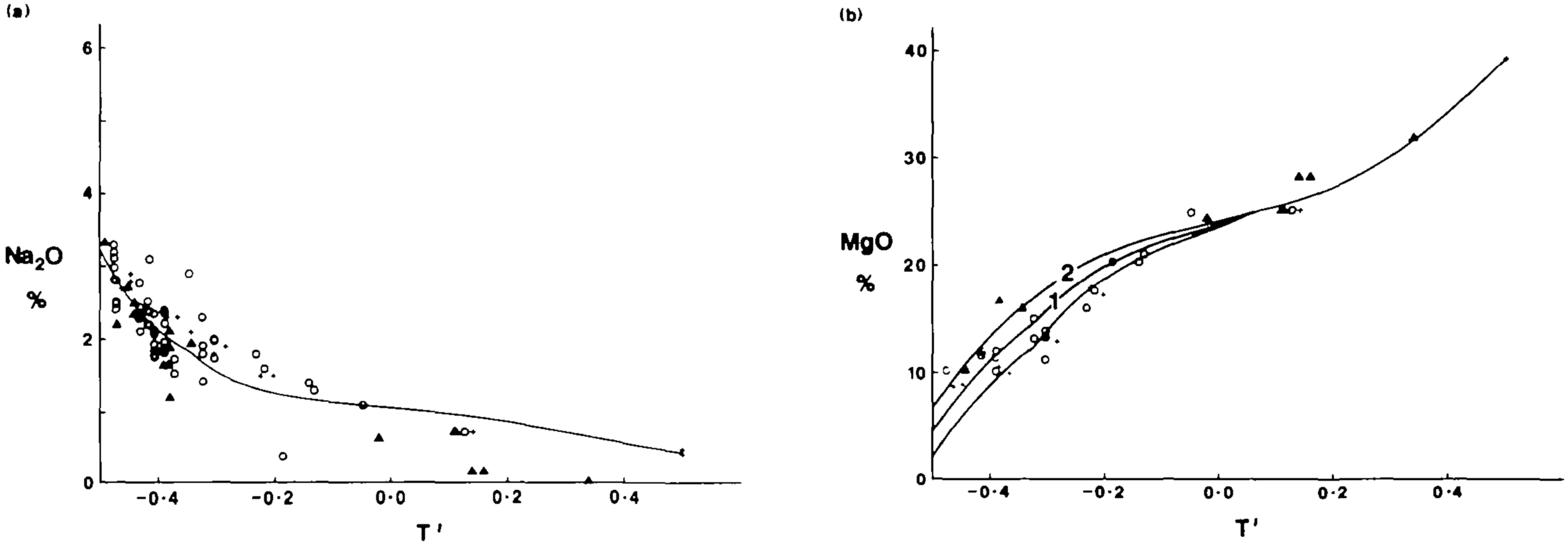
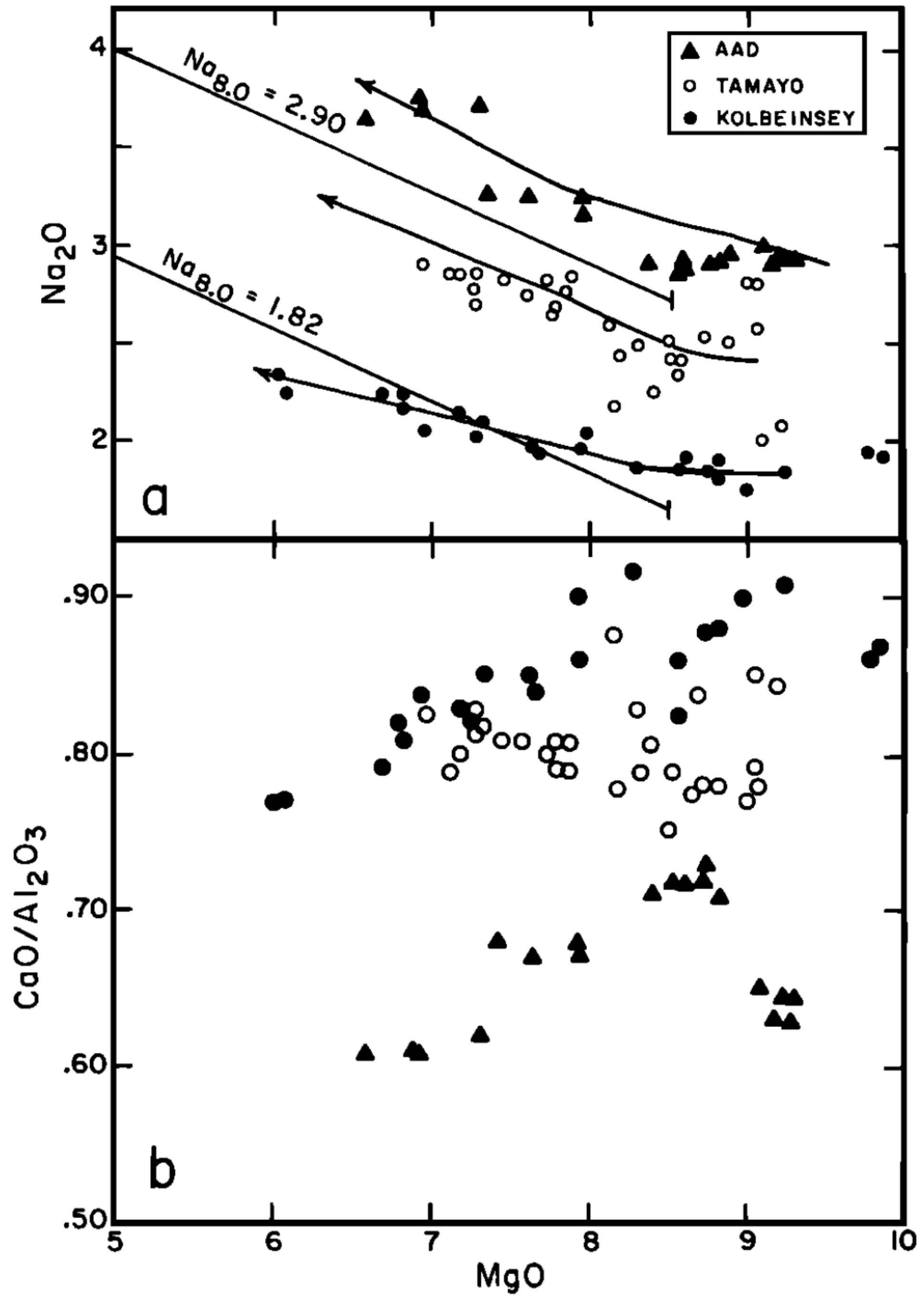
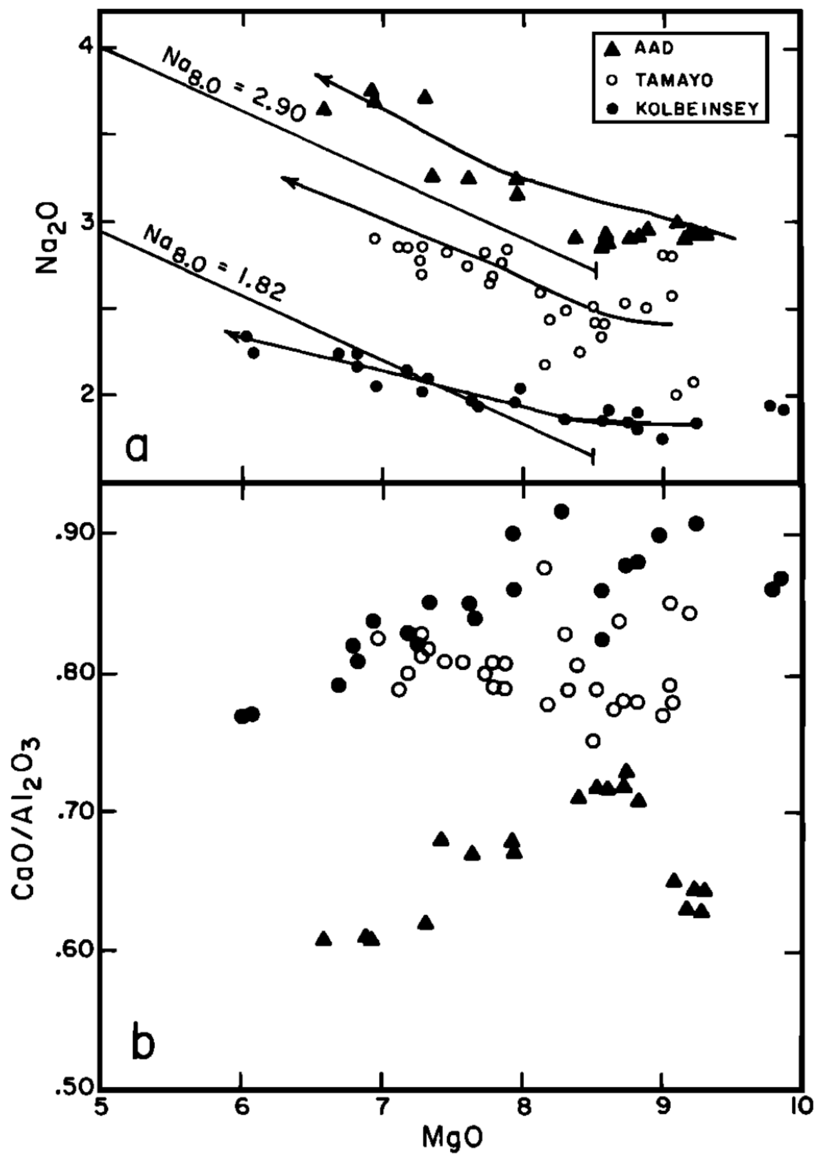


Na2O data from MORB



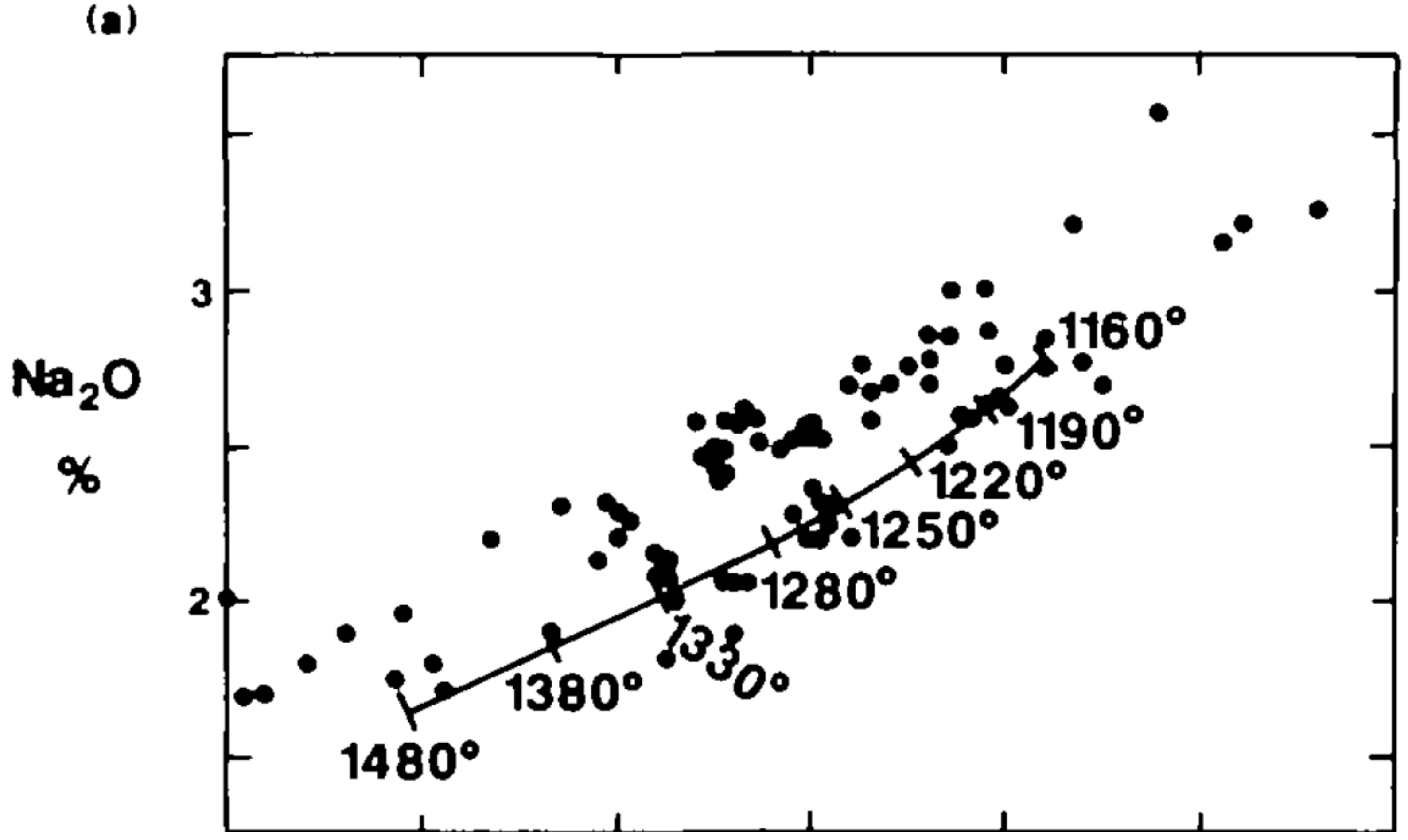
What is controlling the Na to Mg ratio?

Na2O data from MORB

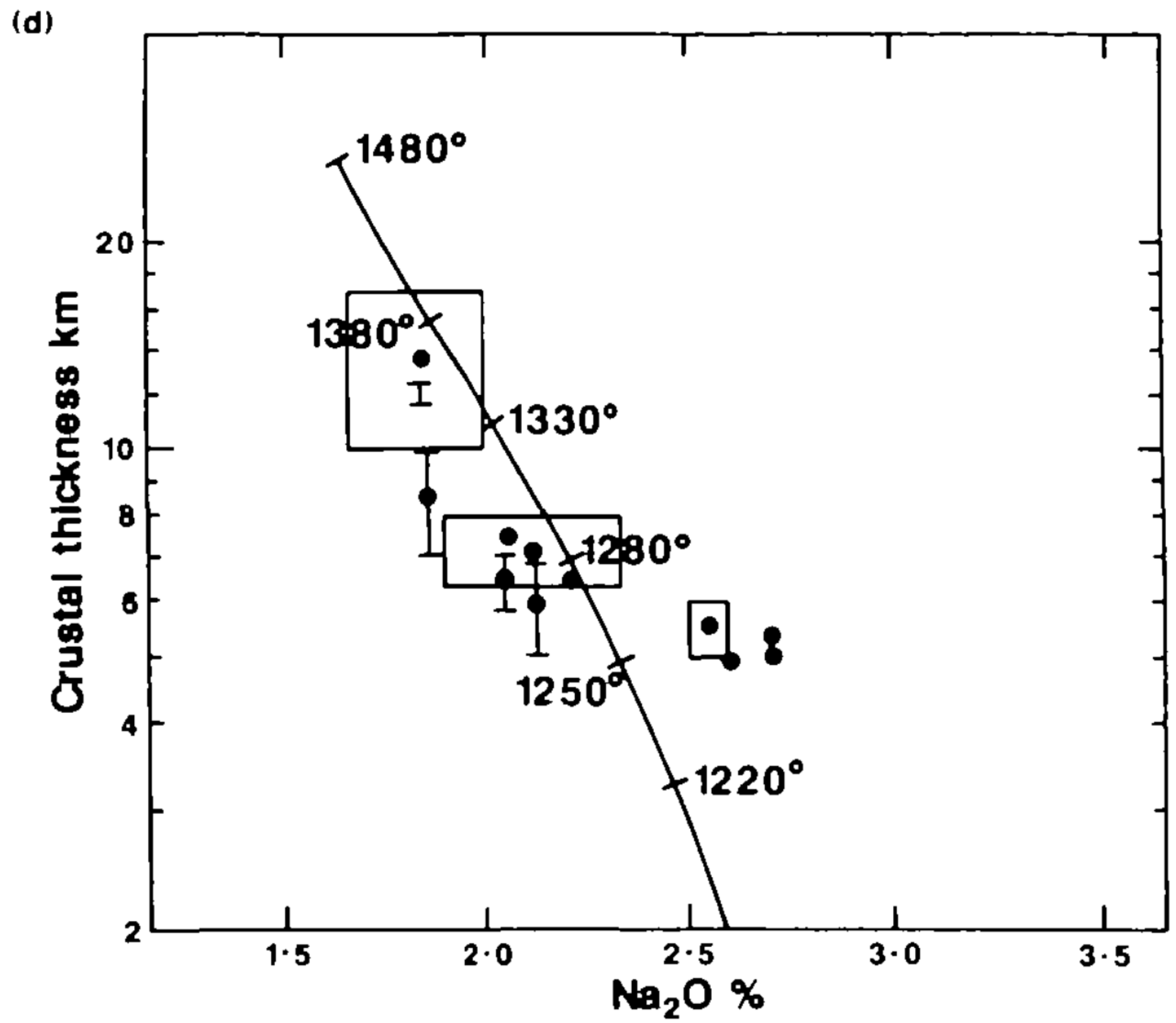


What is controlling the Na to Mg ratio? Percent melting AND differentiation. Na_2O is controlled by percent partial melting but the magmas can lose phases during ascent. Olivines or pyroxenes may literally *drop out* of the rising magma, changing the major element chemistry. By *normalizing* Na_2O data to a fixed MgO content, percent melting (potential temperature) can be isolated.

Normalized (MgO = 8%) Na_2O



0 Depth to the ridge axis (km) 6



Variations in spreading rate?

If melting is *passive*, what is the expected relationship between spreading rate and axial depth?

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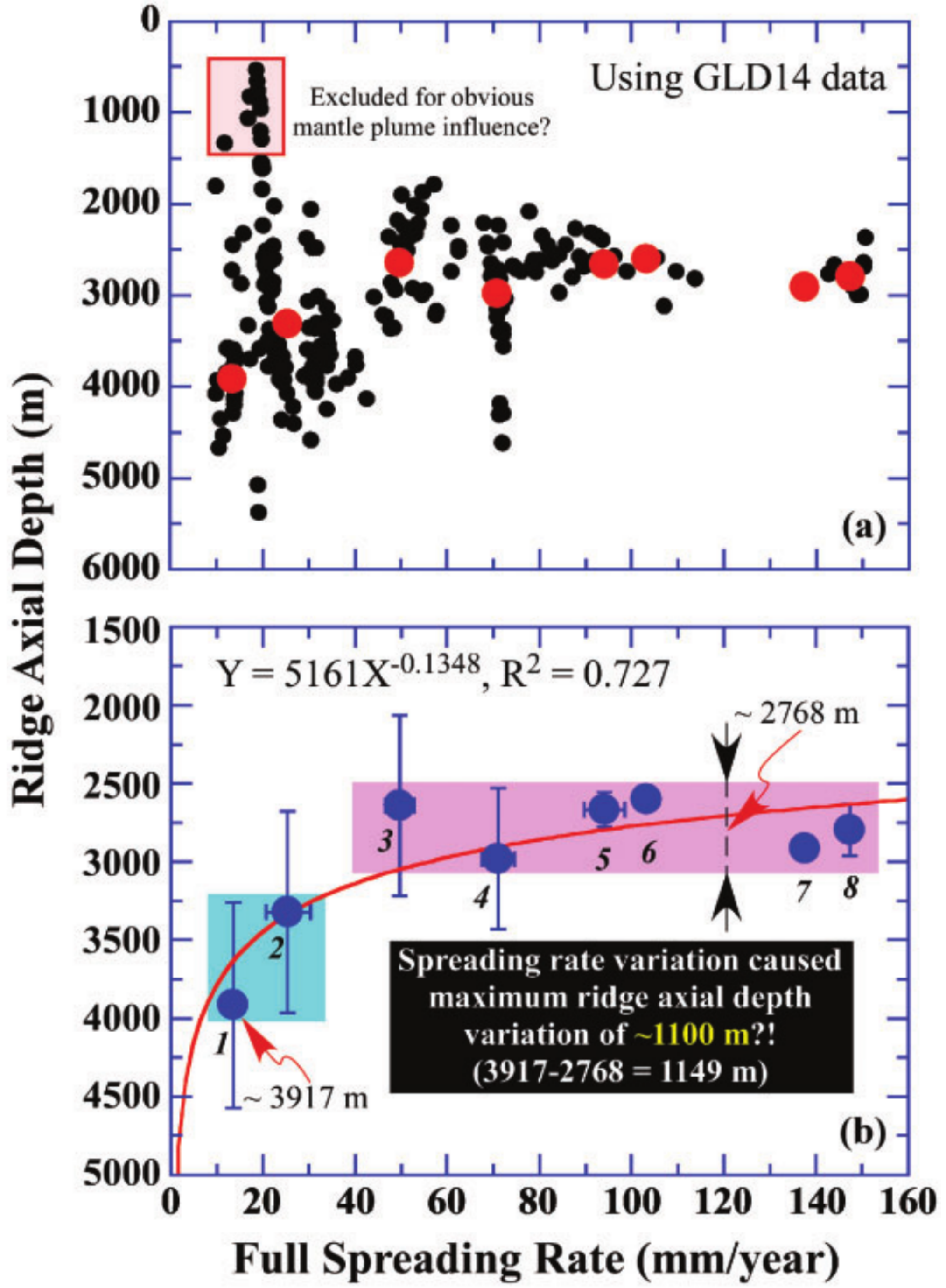
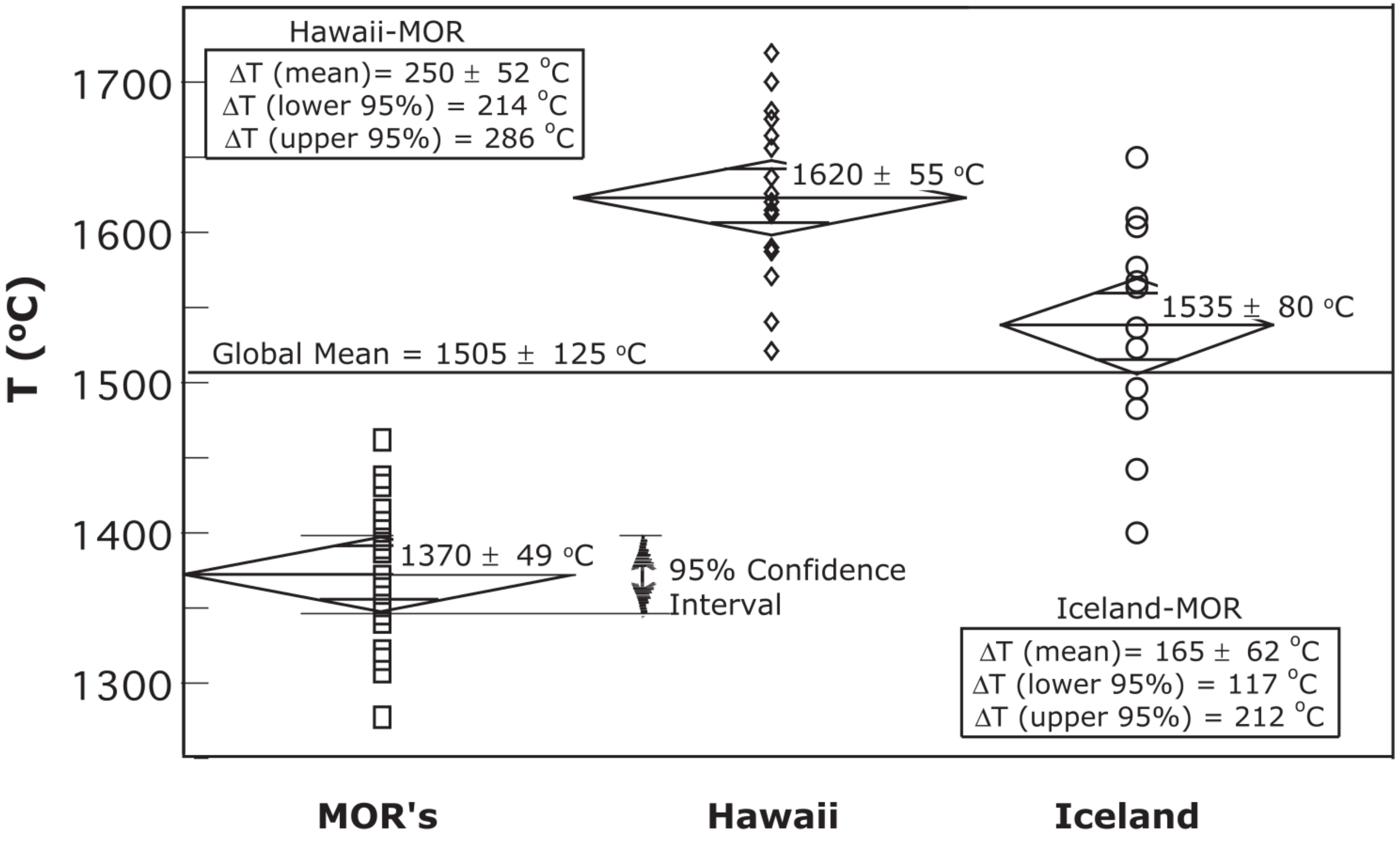


Potential temperatures beneath ridges and oceanic islands

The partitioning of Mg in Olivine is sensitive to temperature while the Fe/Mg partitioning is not



Strong geochemical evidence for the existence of thermally driven mantle plumes

Trace elements in MORB and OIB (review compatibility trends)

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Tristan, South Atlantic

Tubuai, French Polynesia

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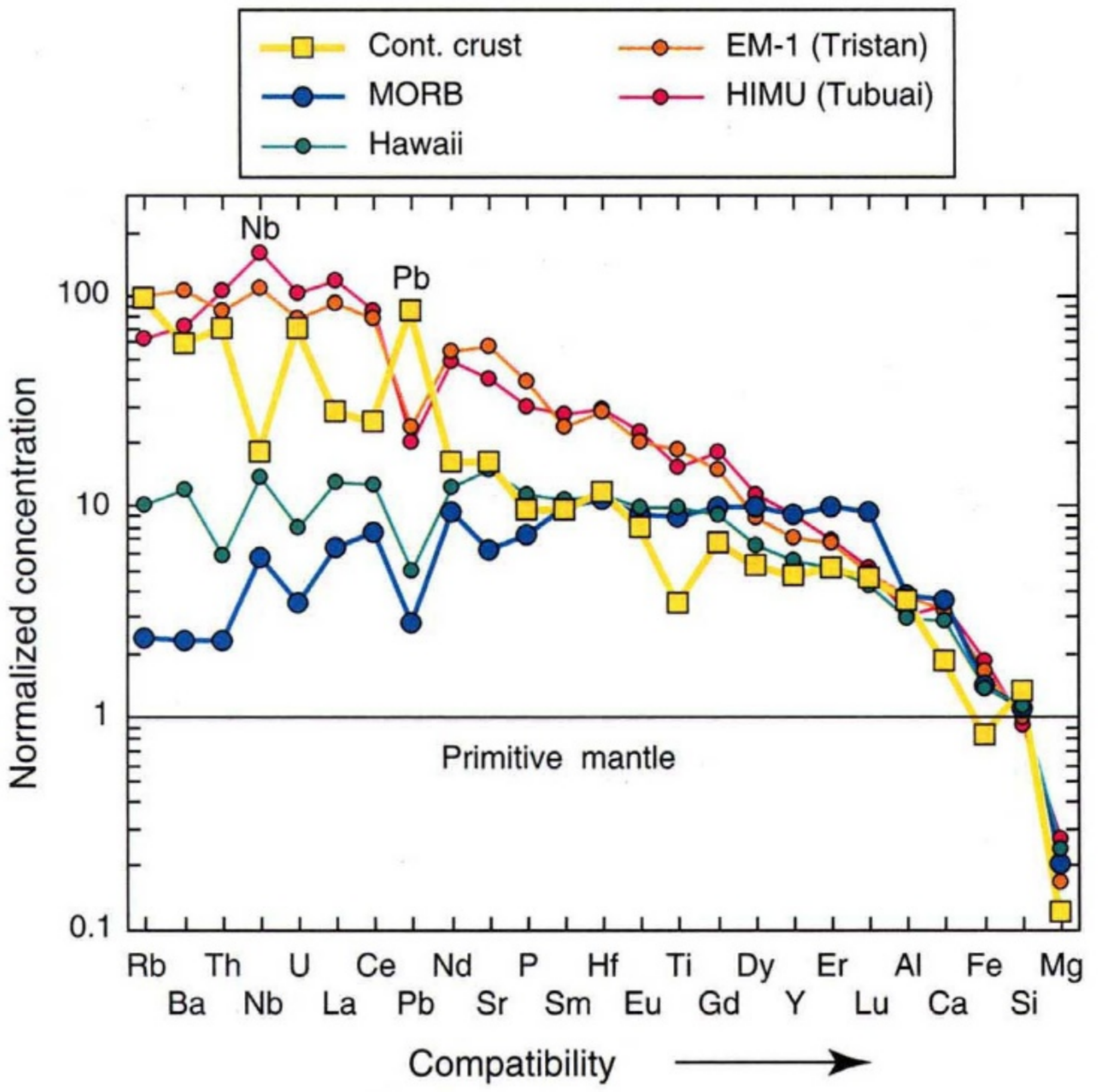
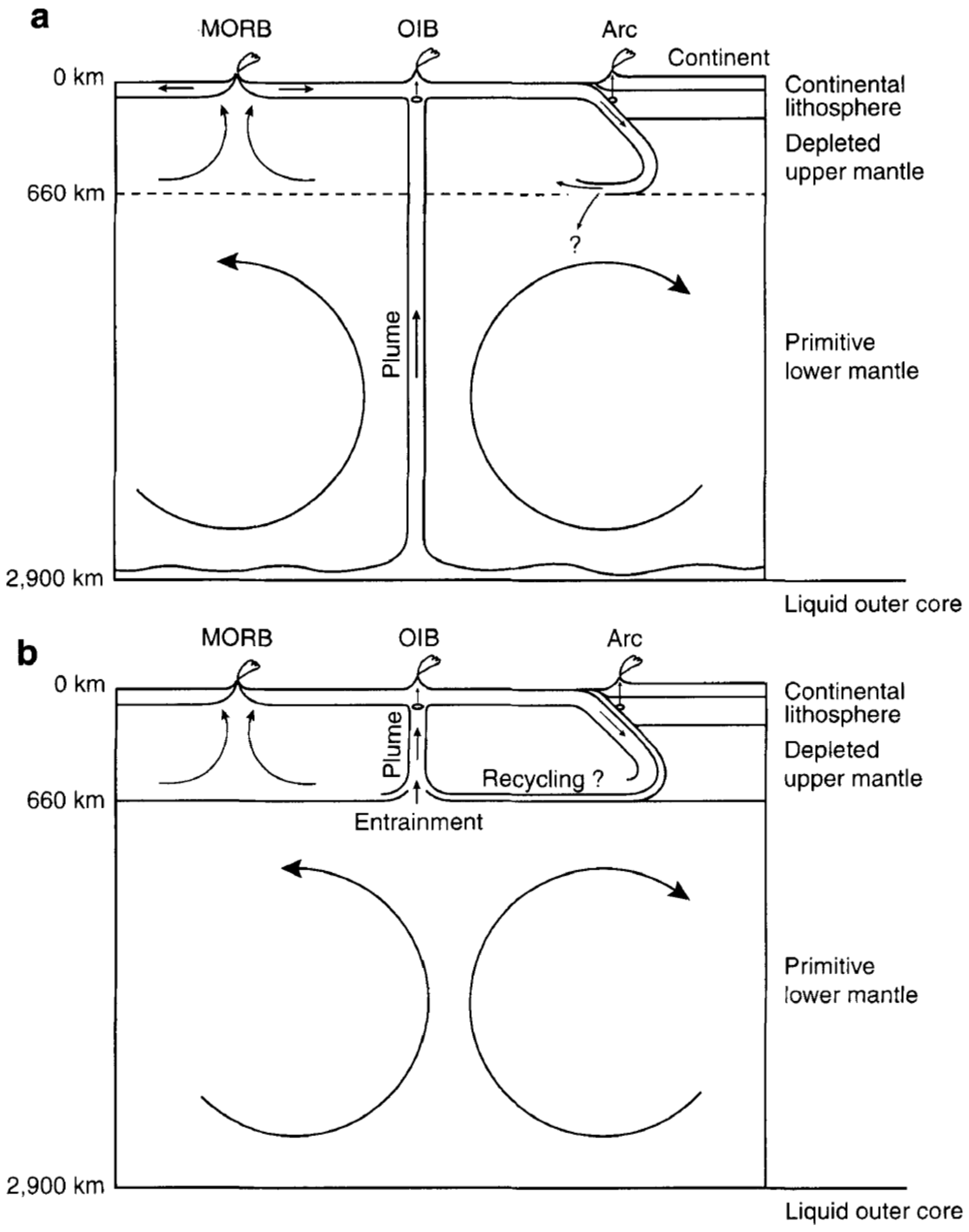


Models of the mantle



Sm and Rb

- ^{147}Sm$\rightarrow^{143}$Nd
  - Sm more **compatible** than Nd
- ^{87}Rb$\rightarrow^{87}$Sr
  - Rb highly **incompatible** (and more incompatible than Sr)

- What trends do you expect between primitive mantle, MORB, and continental crust?
  - If plumes sample primitive mantle, what should their radiogenic Nd and Sr look like?
  - *sketch:* $\frac{^{87}Sr}{^{86}Sr}$ *(x) vs* $\frac{^{143}Nd}{^{144}Nd}$ *(y)*