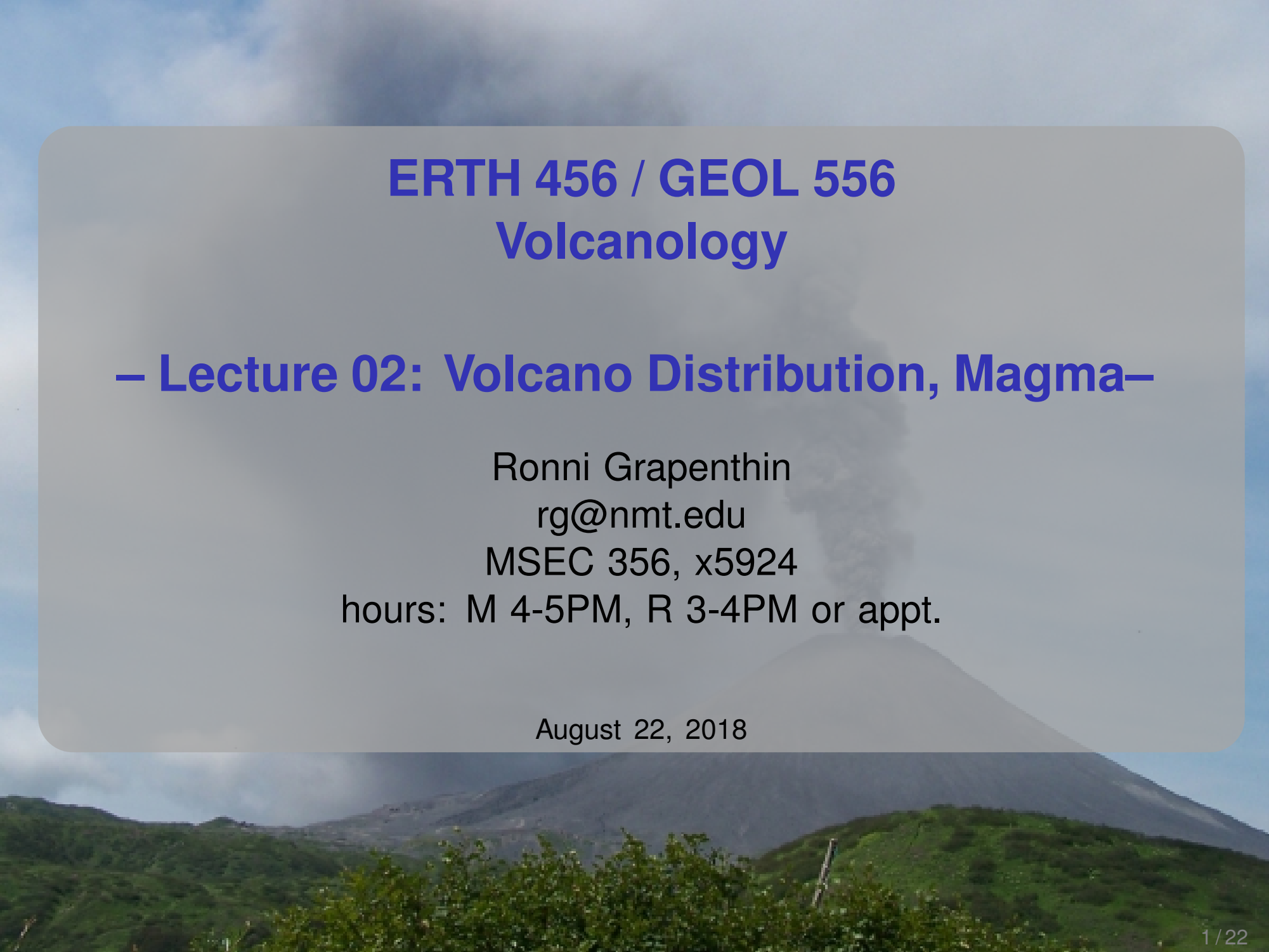

ERTH 456 / GEOL 556
Volcanology

– Lecture 02: Volcano Distribution, Magma–

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hours: M 4-5PM, R 3-4PM or appt.

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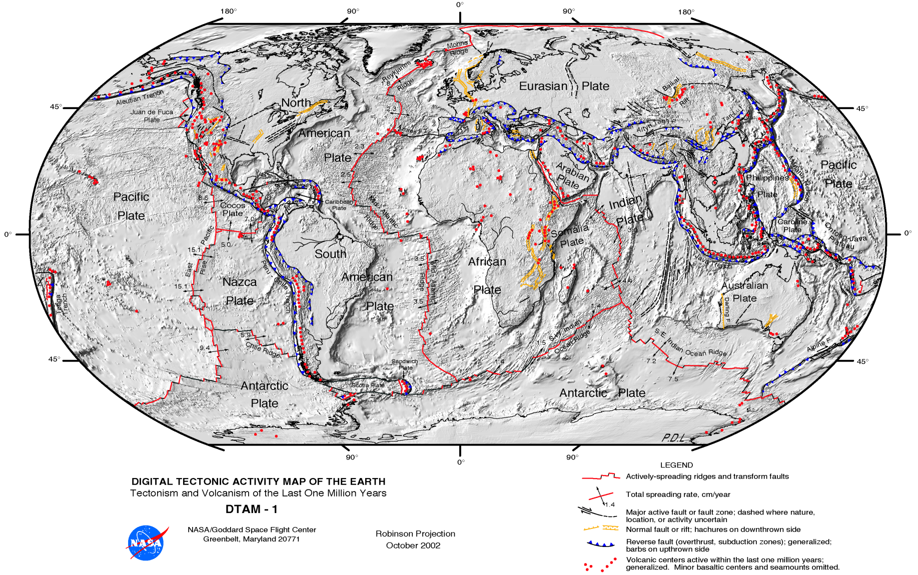
What is a volcano?

Where do we find volcanoes?

Where do we find volcanoes? . . . on Earth?

Volcano Distribution



NASA

What is magma?

What is magma?

Mixture of:

- melt (liquid rock)
- crystals (solids)
- volatiles (gases)

Melt

- silicate molecules + other elements (aluminium, magnesium, iron, sodium, potassium, calcium, . . .)
- no free molecules, but polymerized
  - repeated linking of same molecule groups
  - due to strong linking of atoms in SiO_2 molecule
- no clear cut freezing point

Factors on Melting Temperature

- **composition**: mafic $\rightarrow$ felsic composition, temperature drops
  - mafic (45-52 wt% SiO_2): 1000-1250$^\circ C$, rock type: basalt
  - intermediate (52-62 wt% SiO_2): 950-1200$^\circ C$, rock type: andesite
  - felsic (low Si) (62-70 wt% SiO_2) : 800-1100$^\circ C$, rock type: dacite
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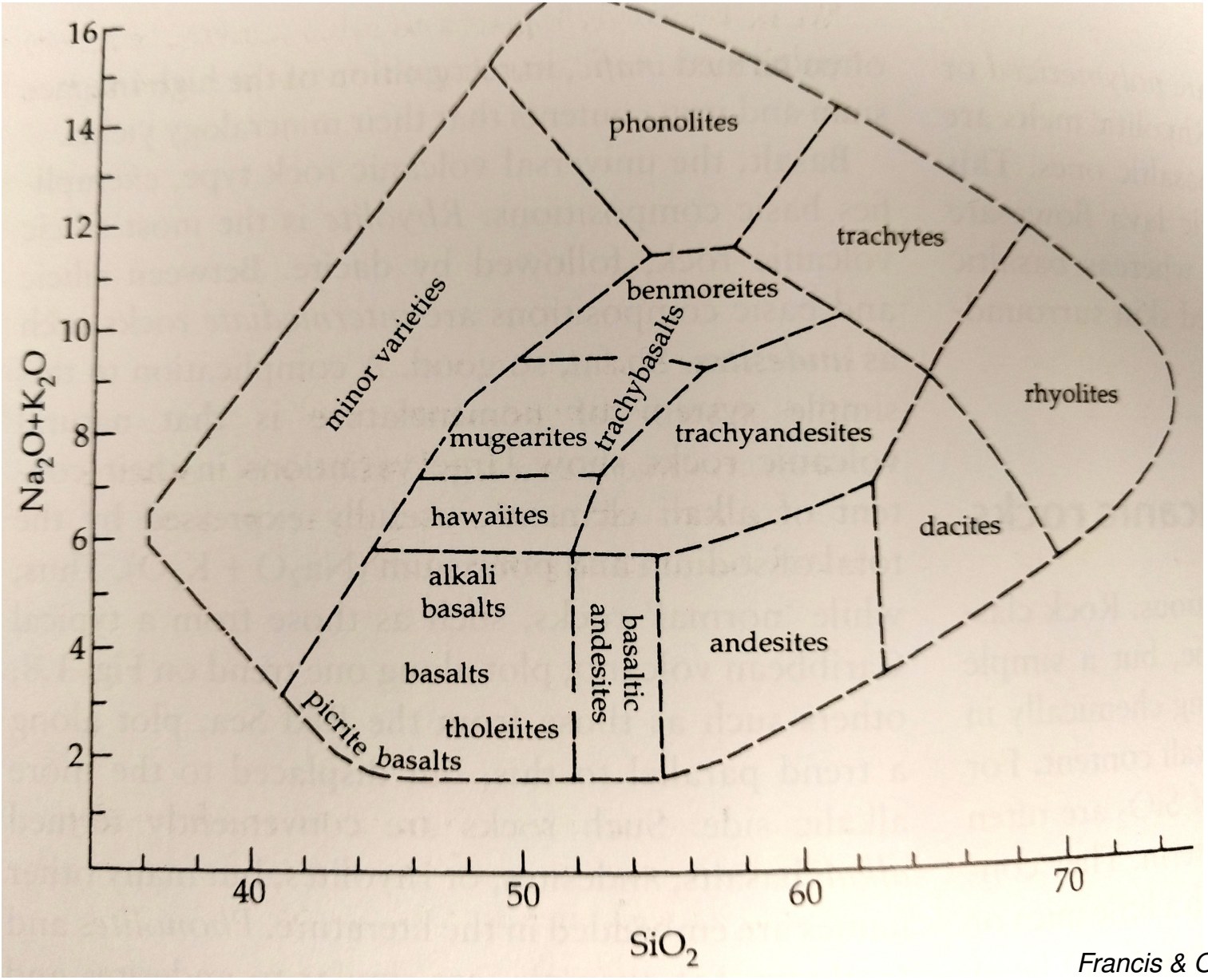
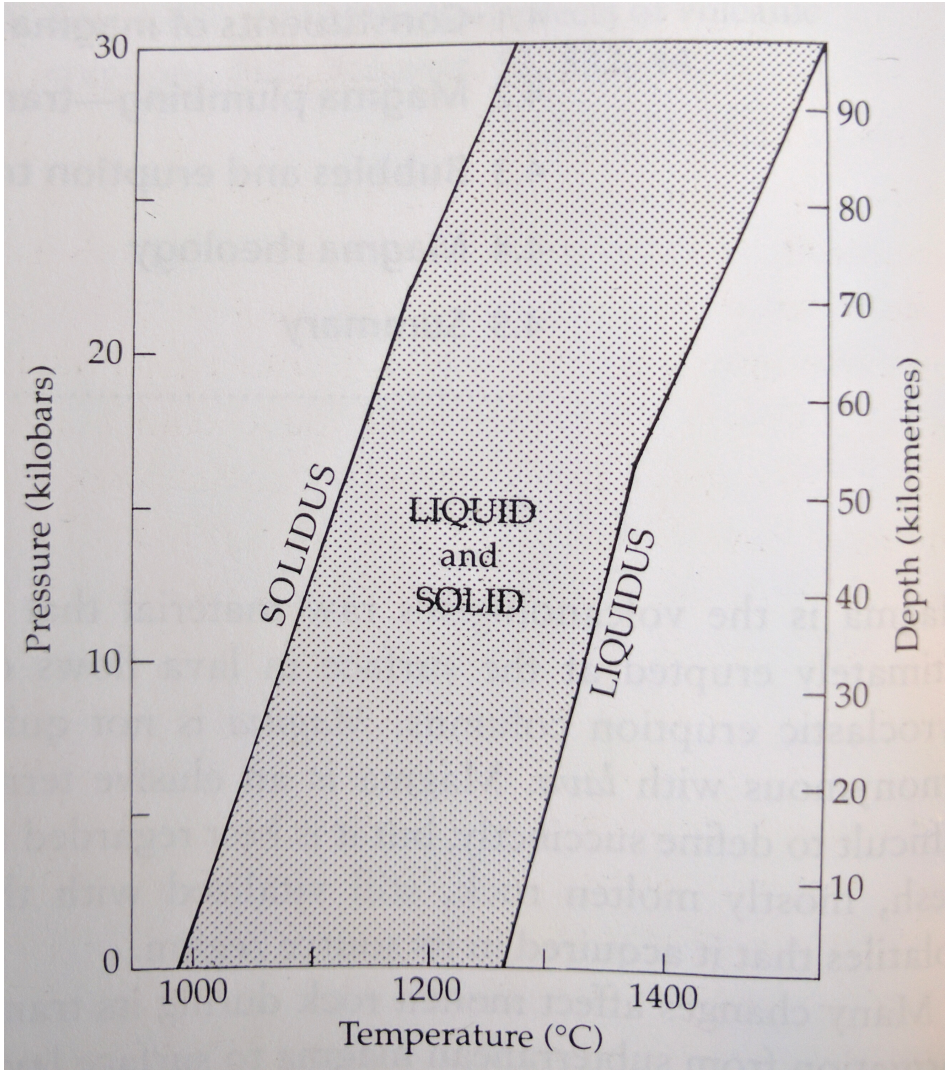
- **pressure**: fixed composition at lower pressure melts at lower temperature
- **volatile content**: 'wet' silicate (lots of volatiles) melts at lower temperatures

Volcanic Rock Classification



Francis & Oppenheimer

Partial Melting: Liquidus - Solidus



Francis & Oppenheimer

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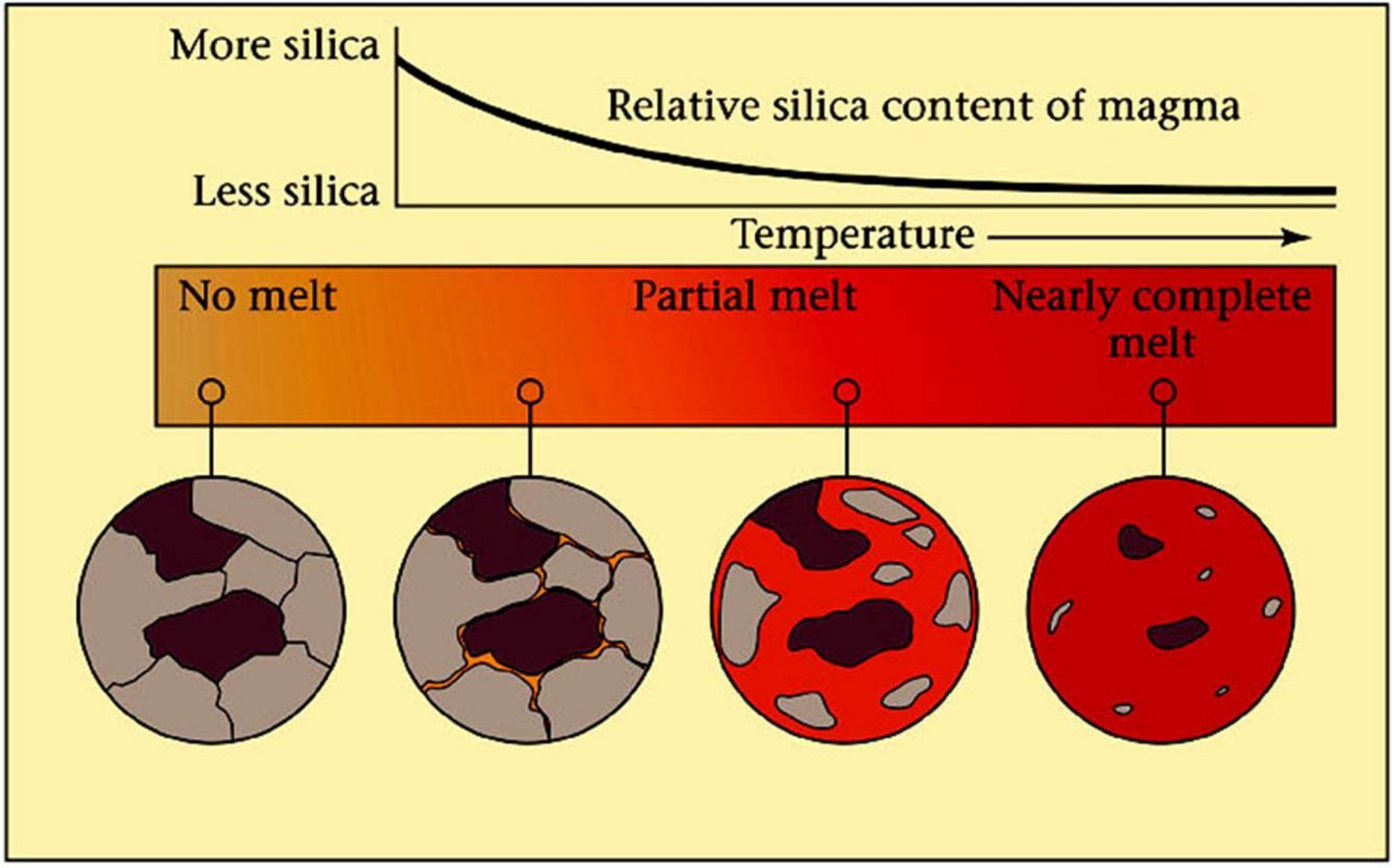
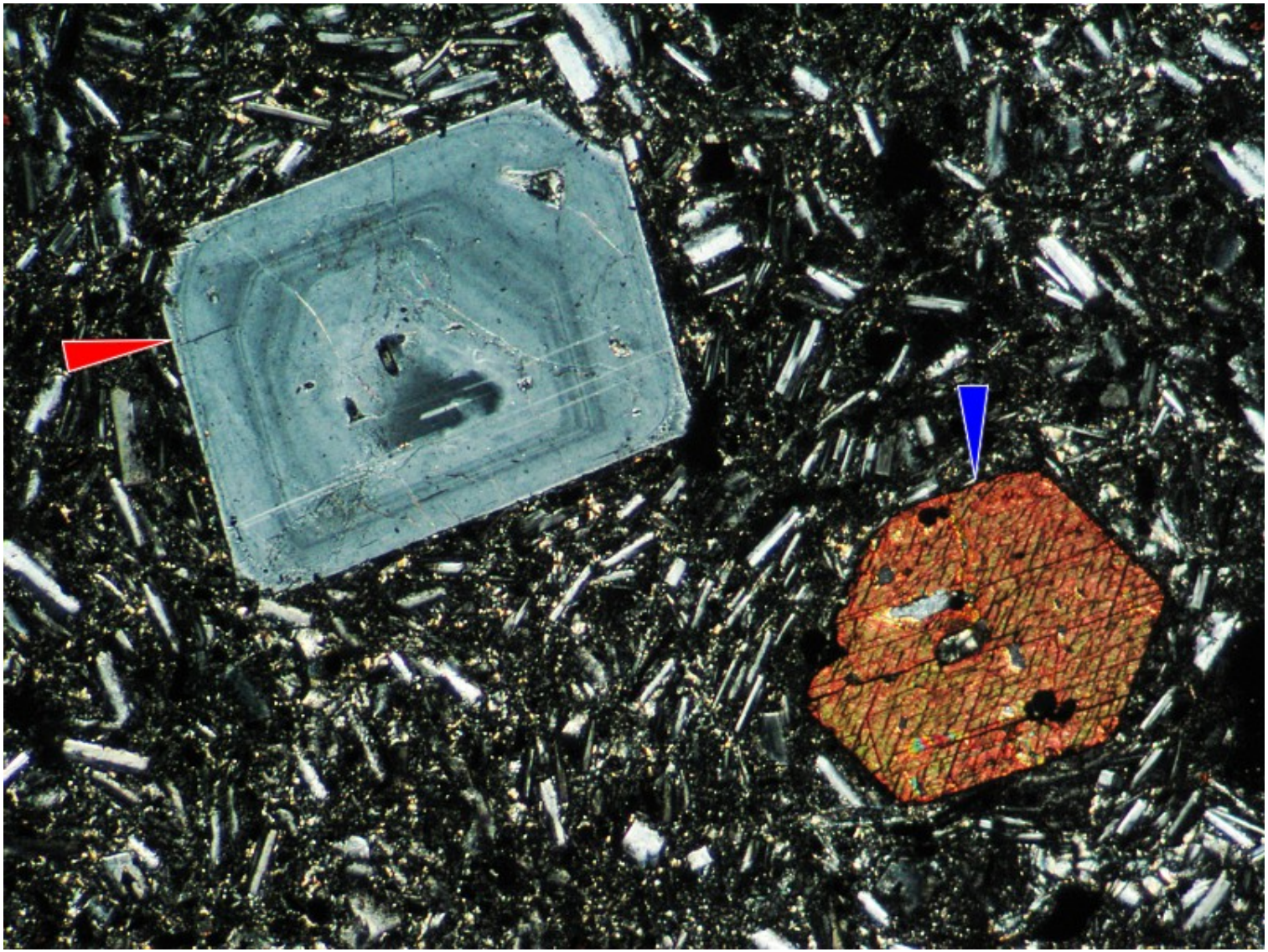


Internet

Crystals

- fractional crystallization: magmas commonly begin crystallizing before erupting
- often abundant phenocrysts (millimeters across), crystallize out at highest temperatures
- basalt: olivine & pyroxene
- phenocrysts may have complex histories:
  - plagioclase feldspar: compositional zoning (change in calcic to sodic)
  - e.g., normal zoning if more calcic in center to more sodic at edges
  - variations can be used to track evolution of conditions in magma chamber / ascend

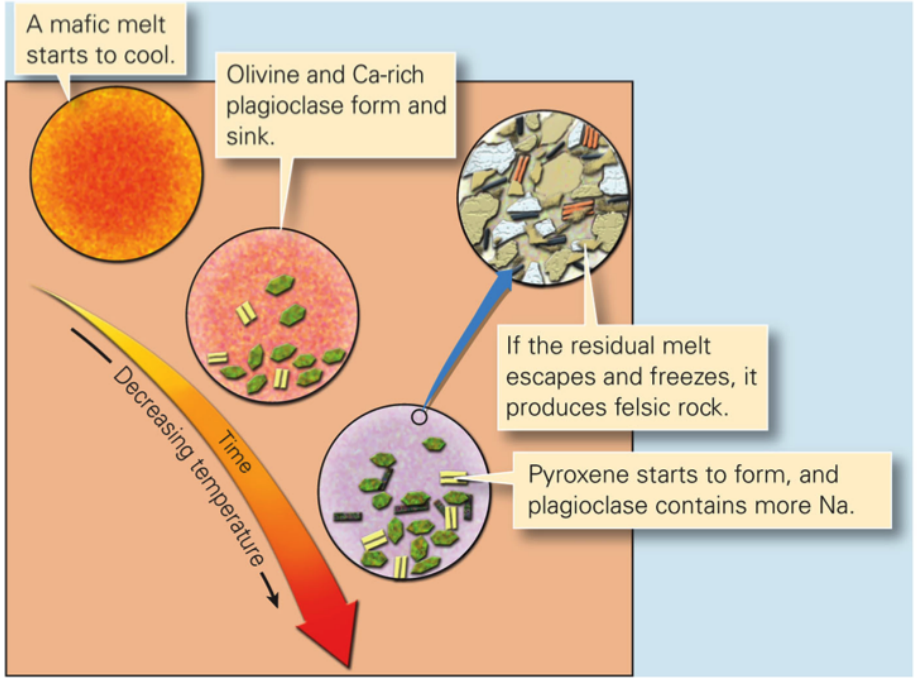
Zoned Feldspar

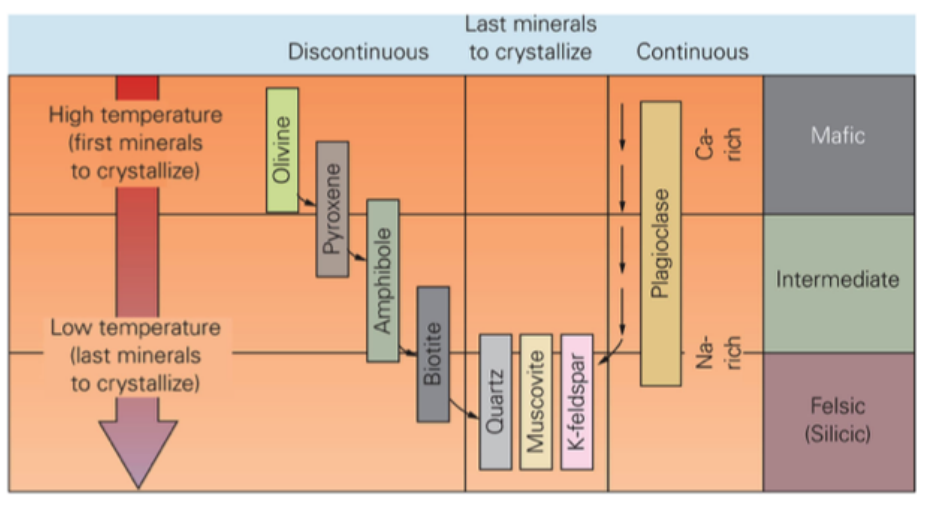


Alkali Feldspar oscillatory zoning (red); hornblende phenocryst (blue) *Imperial College Rock Library*

Fractional Crystallization

- magma cools (e.g.: rises to cooler environment)
- not all parts of melt solidify simultaneously





Internet

Volatiles

- vigorous degassing of volcanoes common in absence of eruptive activity (good!)
- Sulfur dioxide SO_2 most well recognized;
- water (steam), H_2O, & carbon dioxide CO_2 more abundant
- MORB $<$ 0.5 wt% water
- arc basalt / rhyolite 5 wt% water or more
- volcanic gas samples are a mix of elements from mantle, sea water, crust, atmosphere

Where does magma come from?

Where does magma come from?

- partial melting
- decompression melting

Where does magma come from? - 1. Partial Melting

NWA 869 chondrite, *Wikipedia*

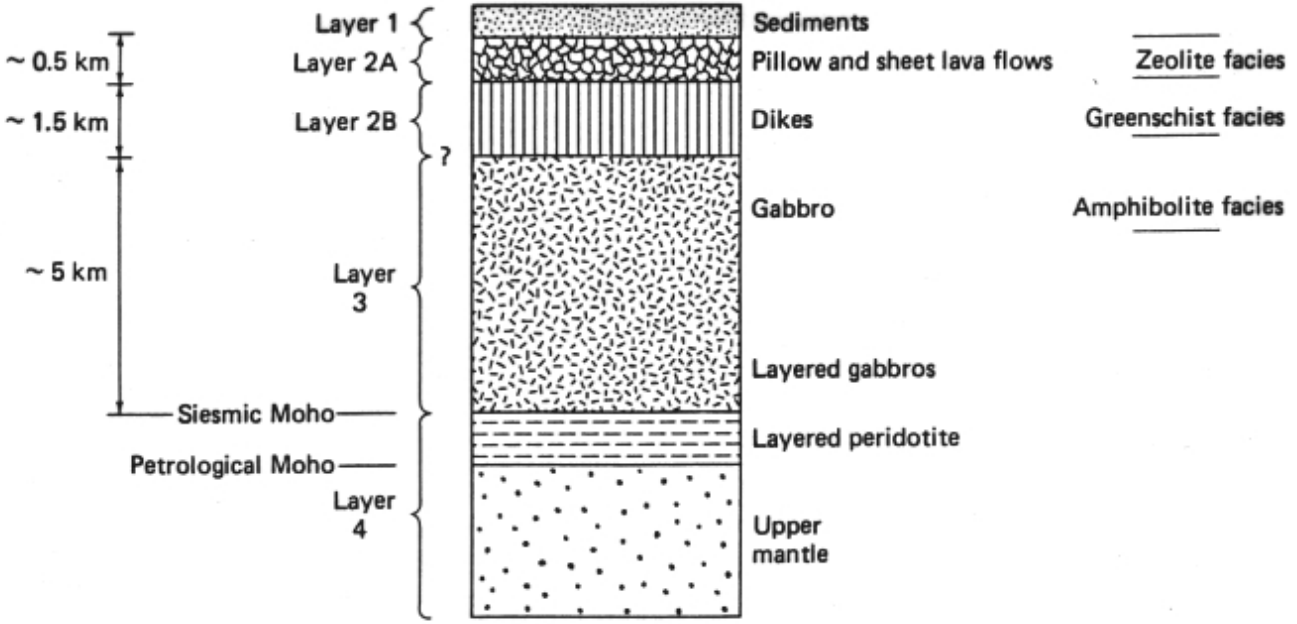
- heating (e.g., radioactive decay, primordial heat) of rock
- primitive basalt is result of **partial melting** of chondritic silicates
- “raw material of the solar system”
- Mid-Oceanic Ridge basalts (MORBs) were thought to be primitive
- MORBs really result of multi-stage process
- partial melting at lower temperatures: higher SiO_2 content

Where does magma come from? 1. Partial Melting

Komatiite lava, Komati Valley, South Africa, *Wikipedia*

- most primitive basalt formed at highest temperatures (mantle $> 200^{\circ} C$ hotter than today)
- early Earth higher temperatures allow for higher degree of partial melting
- komatiites - large blade like olivine crystals (centimeters long)
- up to 30% or more magnesium
- found (mostly) in Archean rocks: Canada, Australia, Southern Africa

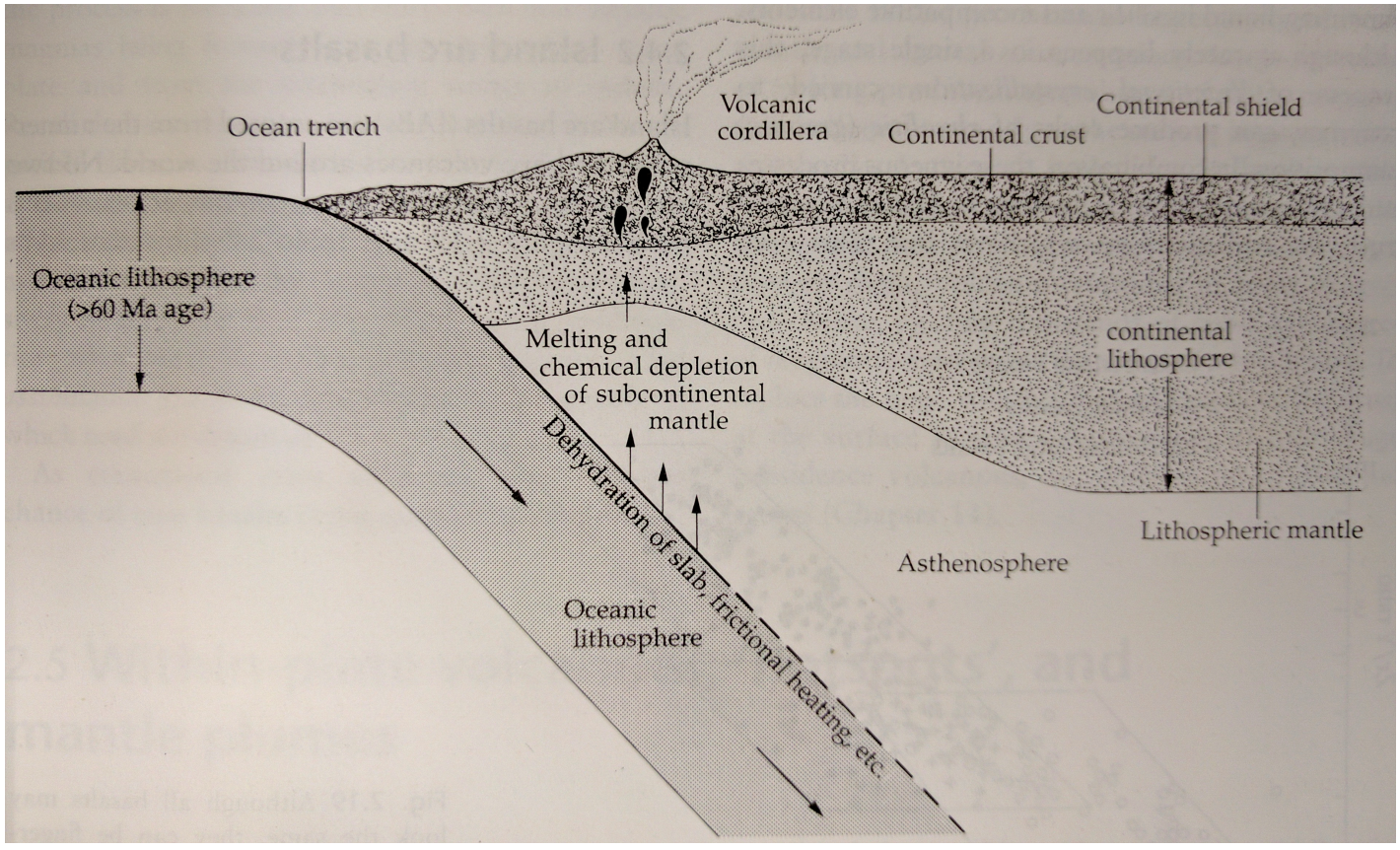
Oceanic Crust



Kennett, J.P. (1982), Marine Geology

- Made of melt from mantle, intruded into pre-existing crust / erupted on seafloor.
- Pillow and sheet lavas: rapidly cooled volcanics
- Gabbros: plutonic/intrusion products (slowly cooled)
- Dikes: feeder zones for magma to rise to surface.

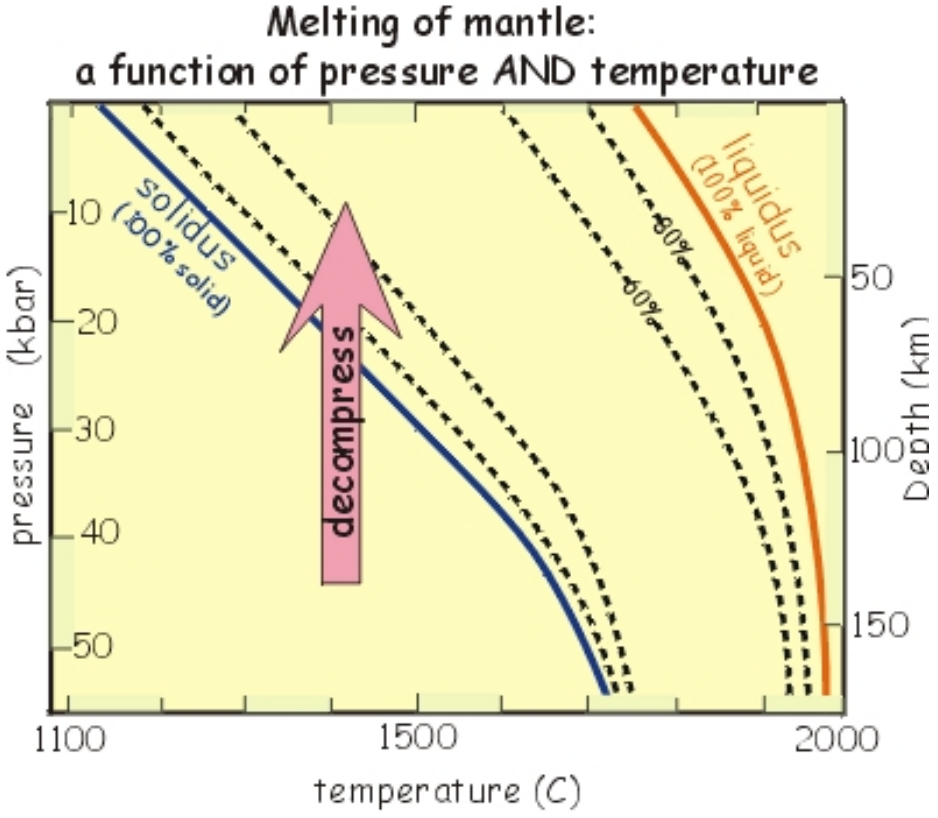
Where does magma come from? Convergent Margins



Francis & Oppenheimer

- slab dewaters at 50-150 km depth
- water rises into mantle wedge, promotes melting (bonds with minerals), creates basalt
- mature island arcs evolve in composition away from basalt (fractional crystallization)

Where does magma come from? 2. Decompression Melting



- mantle is not liquid!
- rock moves upward to MOR (heat upwelling, unloading)
- decompression brings peridotite into partial melting regime

Columbia University