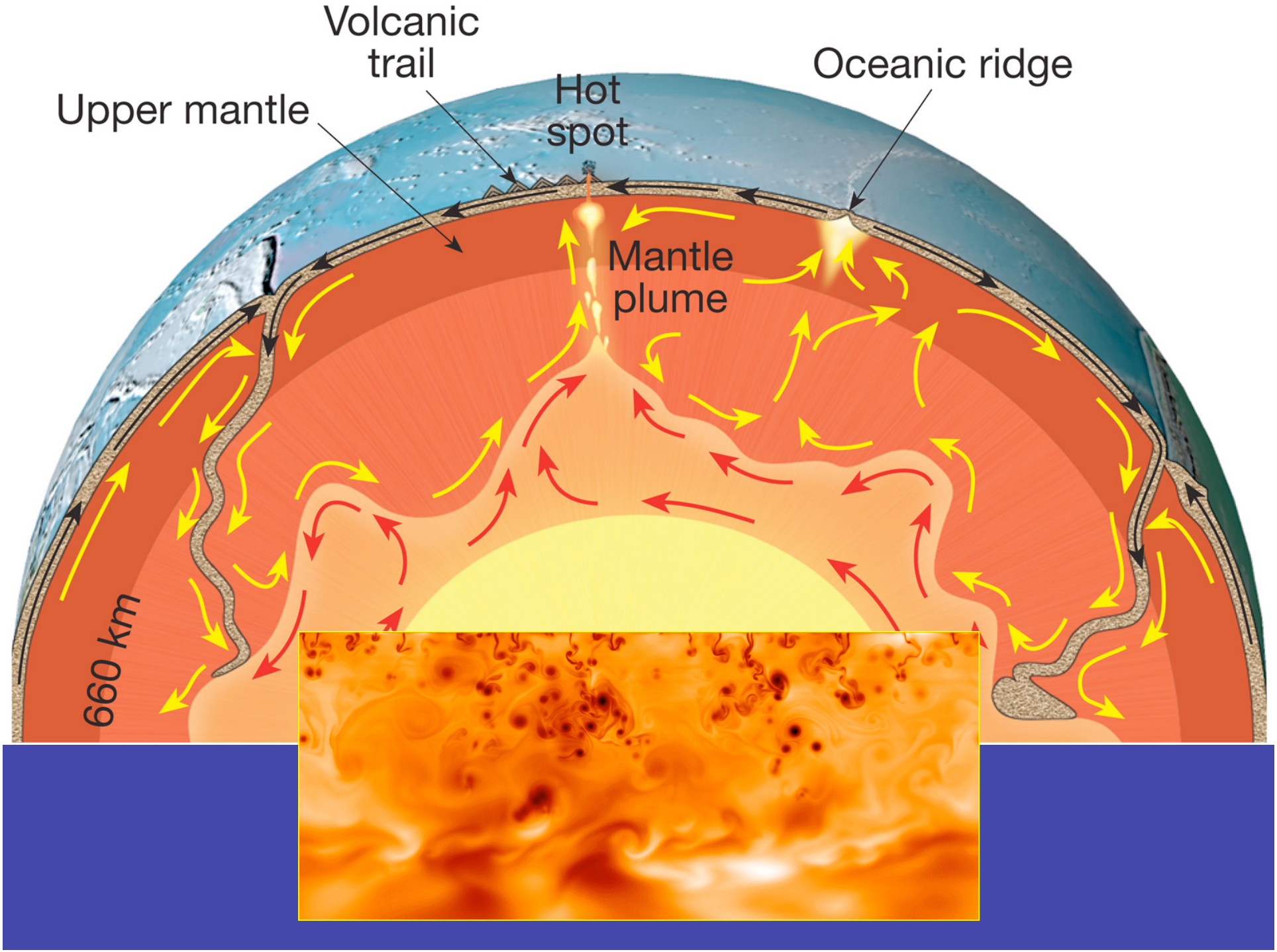
# Igneous rocks – *ignis* Latin for fire

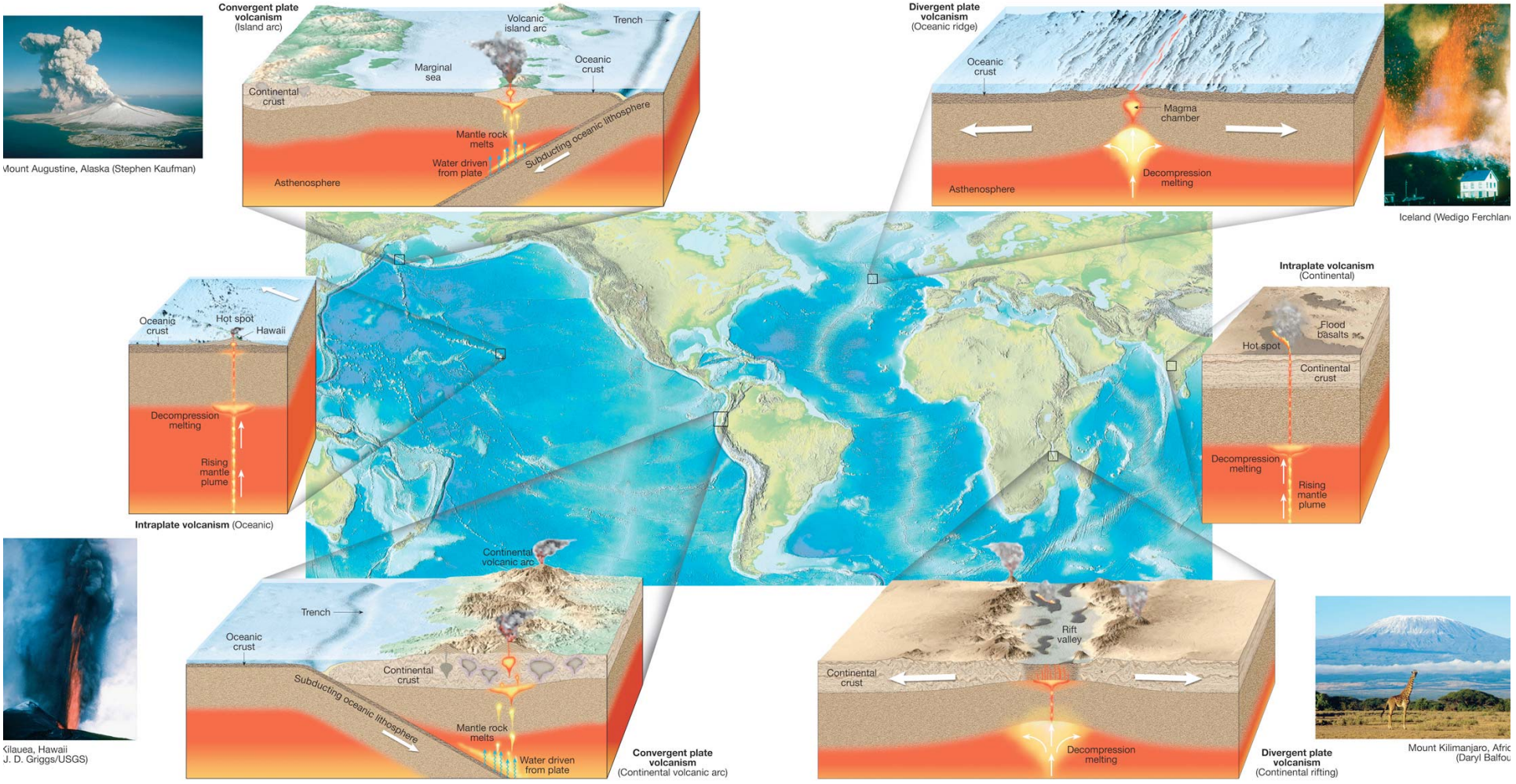





# Locations of world's volcanoes (on land)

# What is heat source?


Volcanic trail
Upper mantle
Hot spot
Oceanic ridge
Mantle plume
660 km



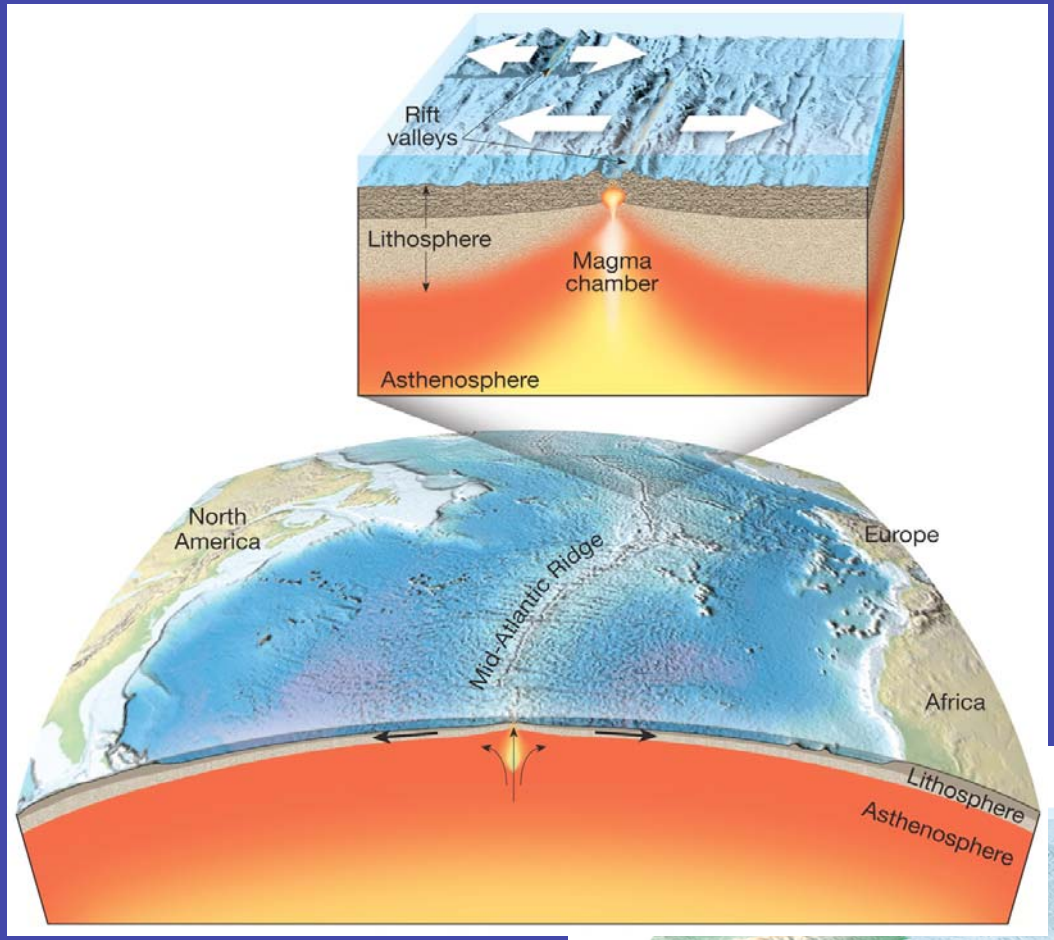

# Volcanism is governed by plate tectonics

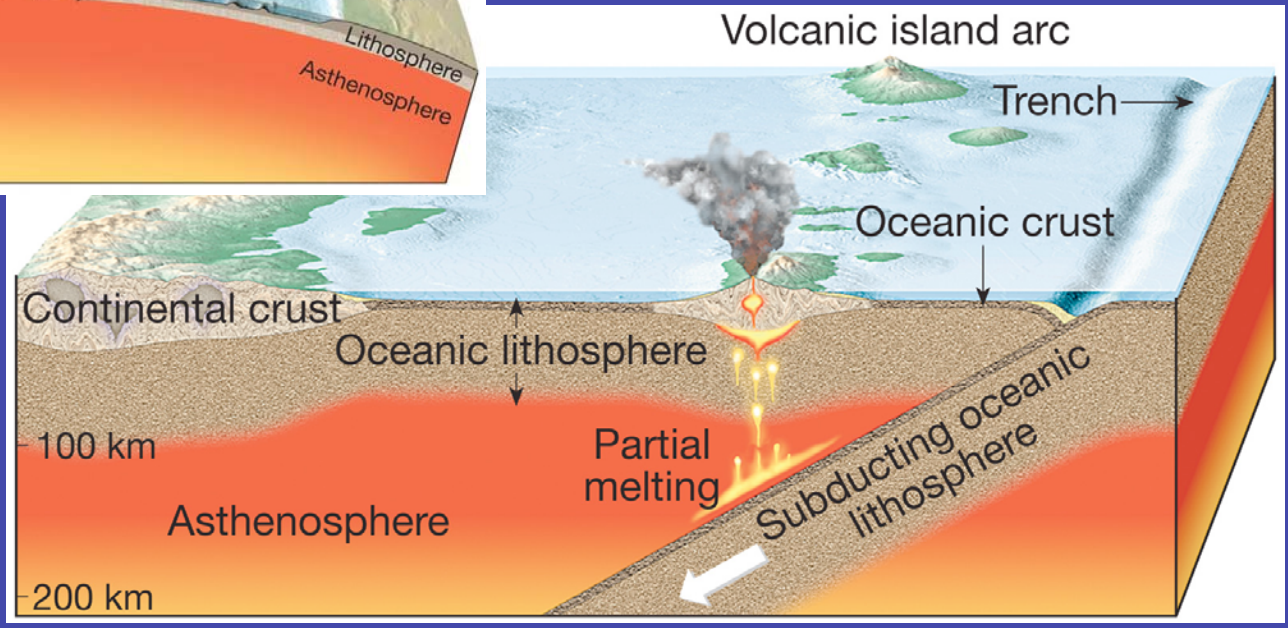
# What is the biggest source of new material?

# Igneous rocks on Earth

## #1 – Mid-ocean ridges (divergent)

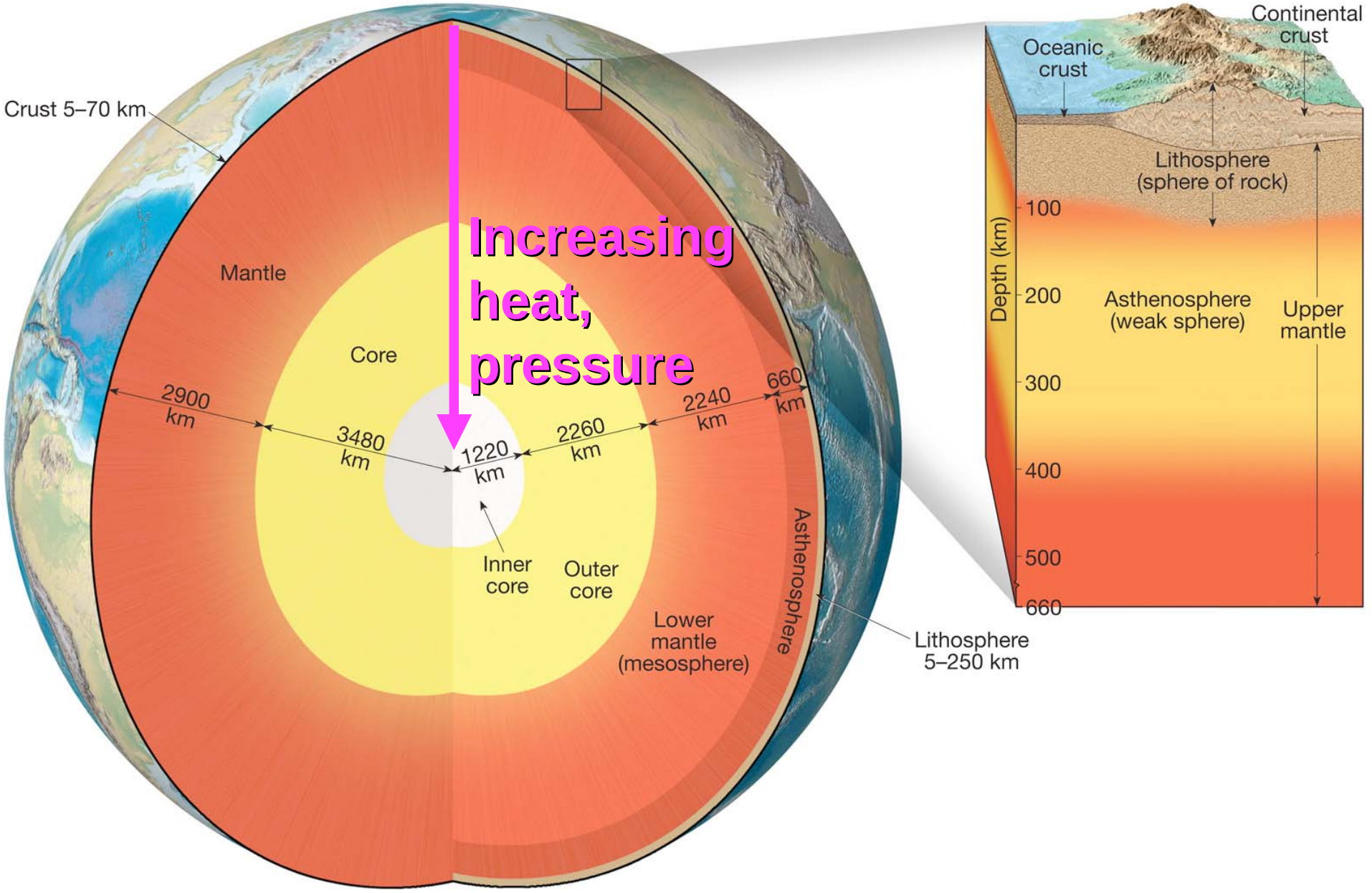
## #2 – Subduction zones (convergent)



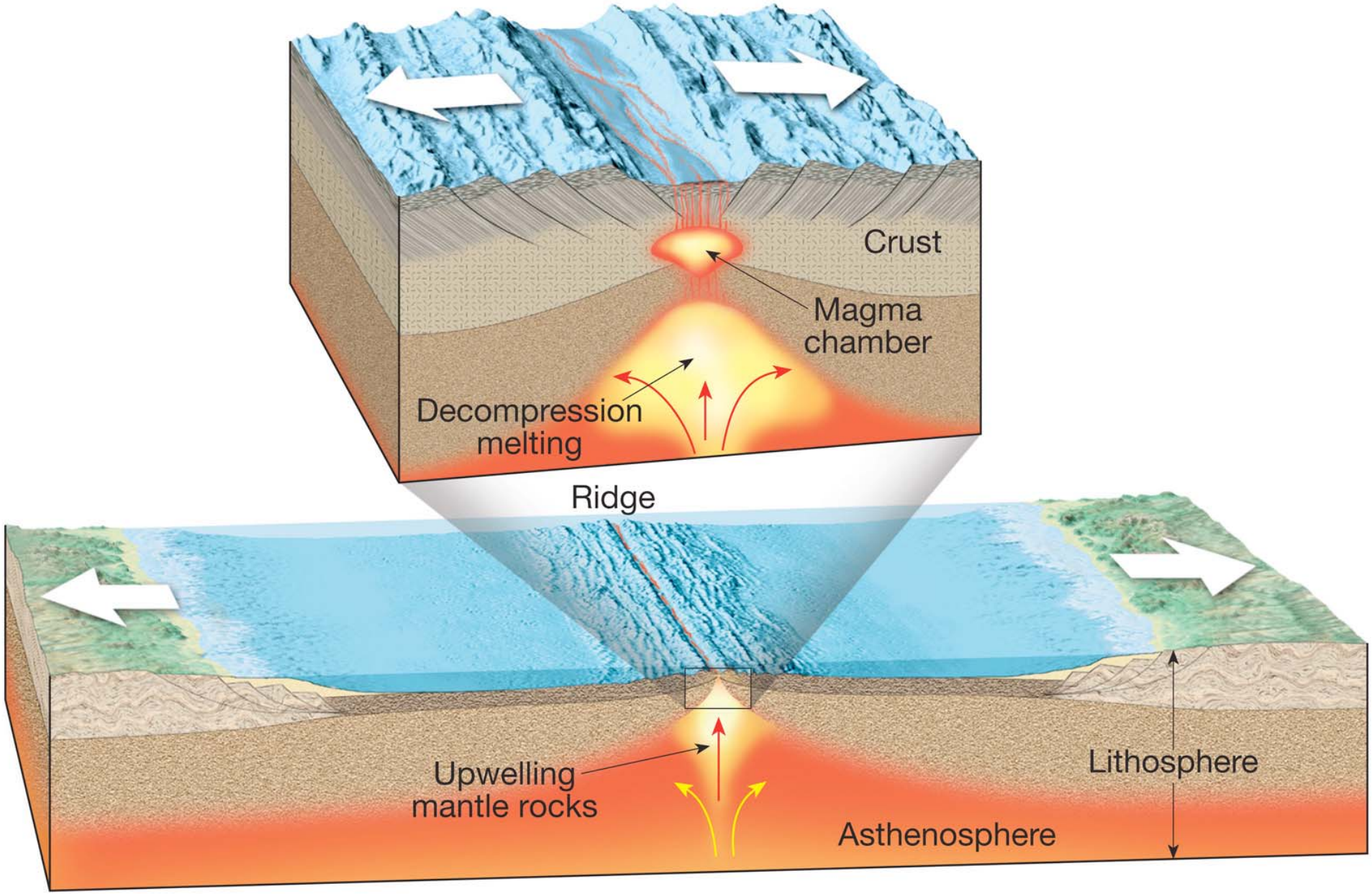



# What causes an eruption….anywhere?

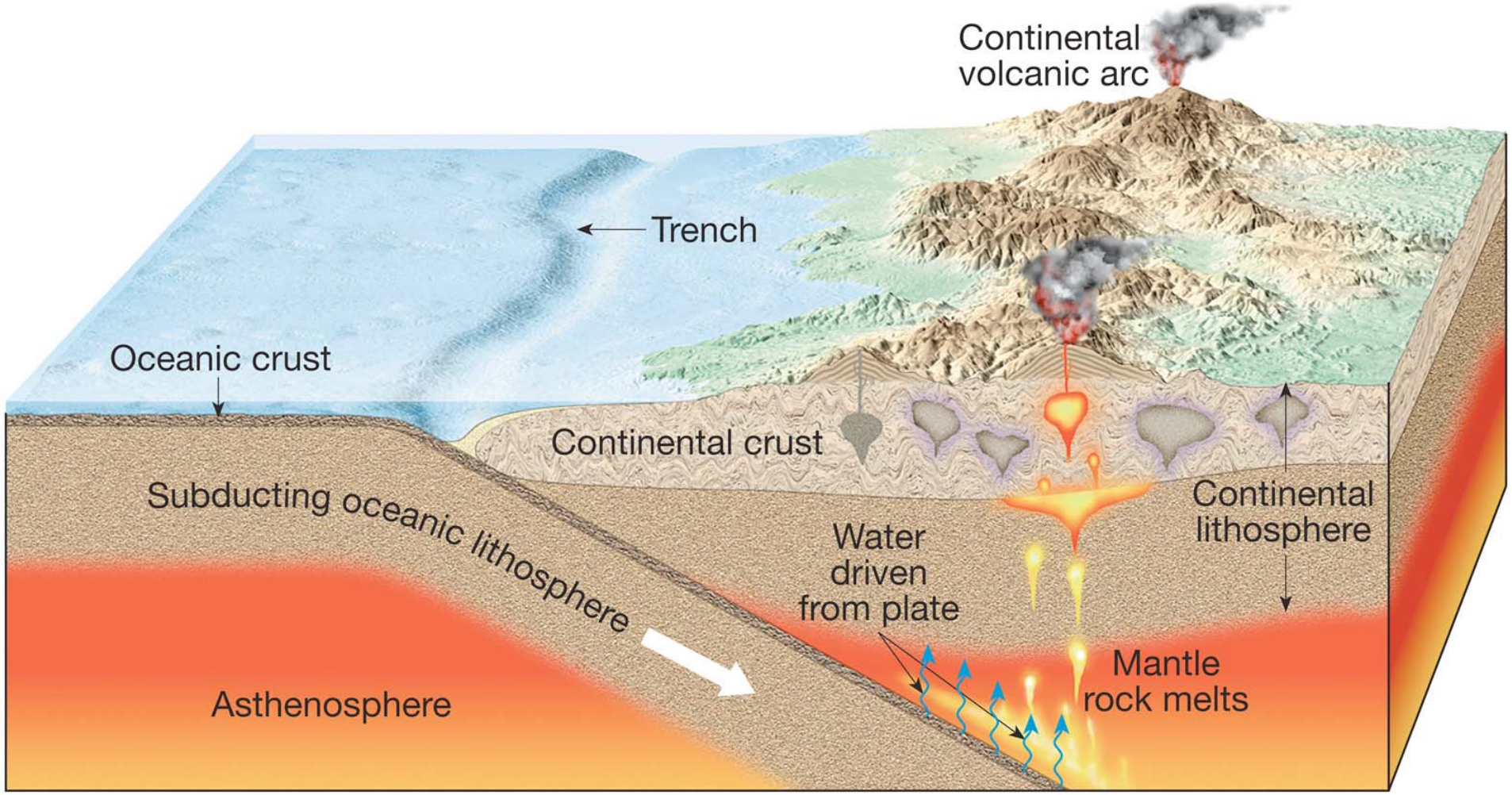
# What causes an eruption….anywhere?



# Decompression melting

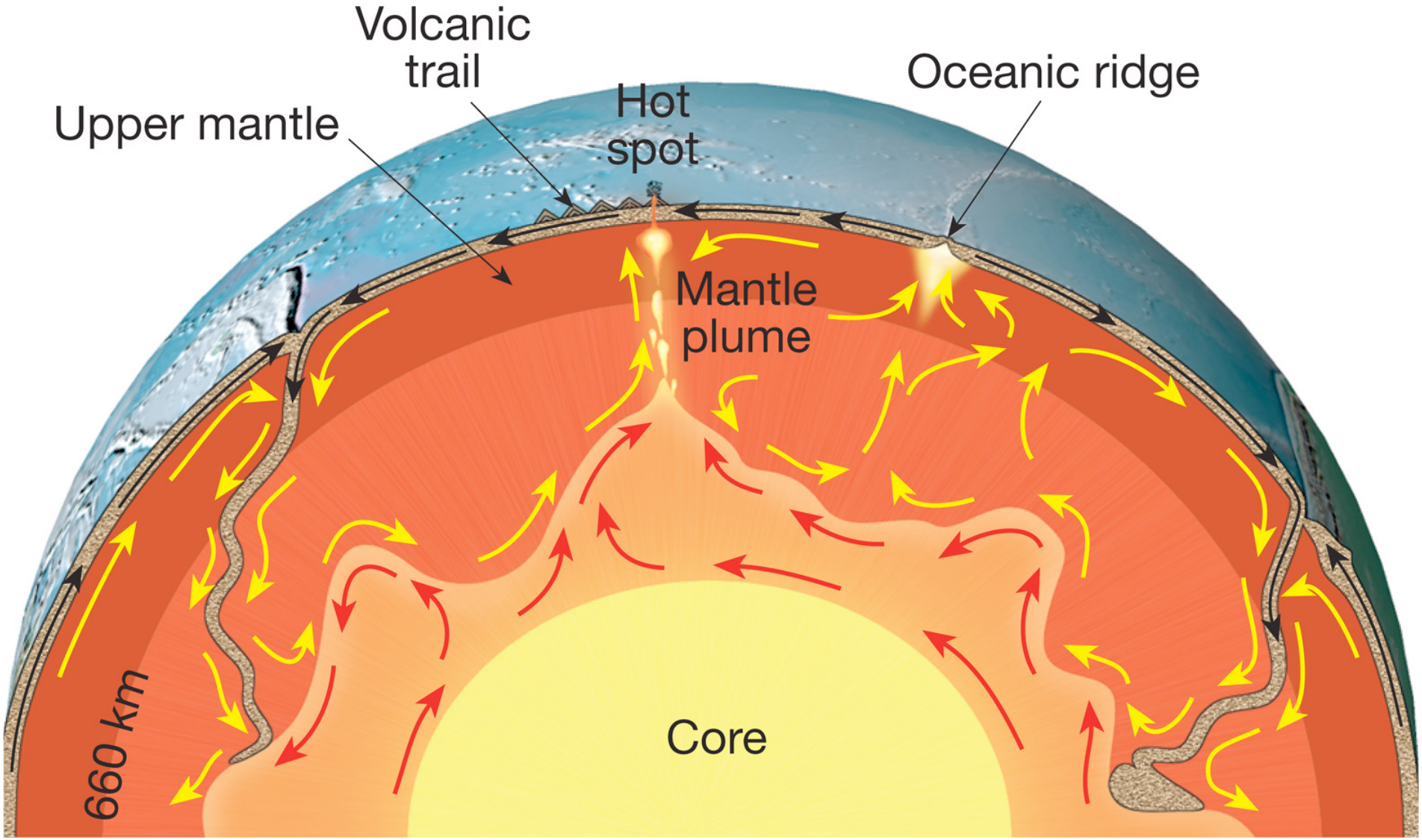


# Volatiles decrease melting temperature

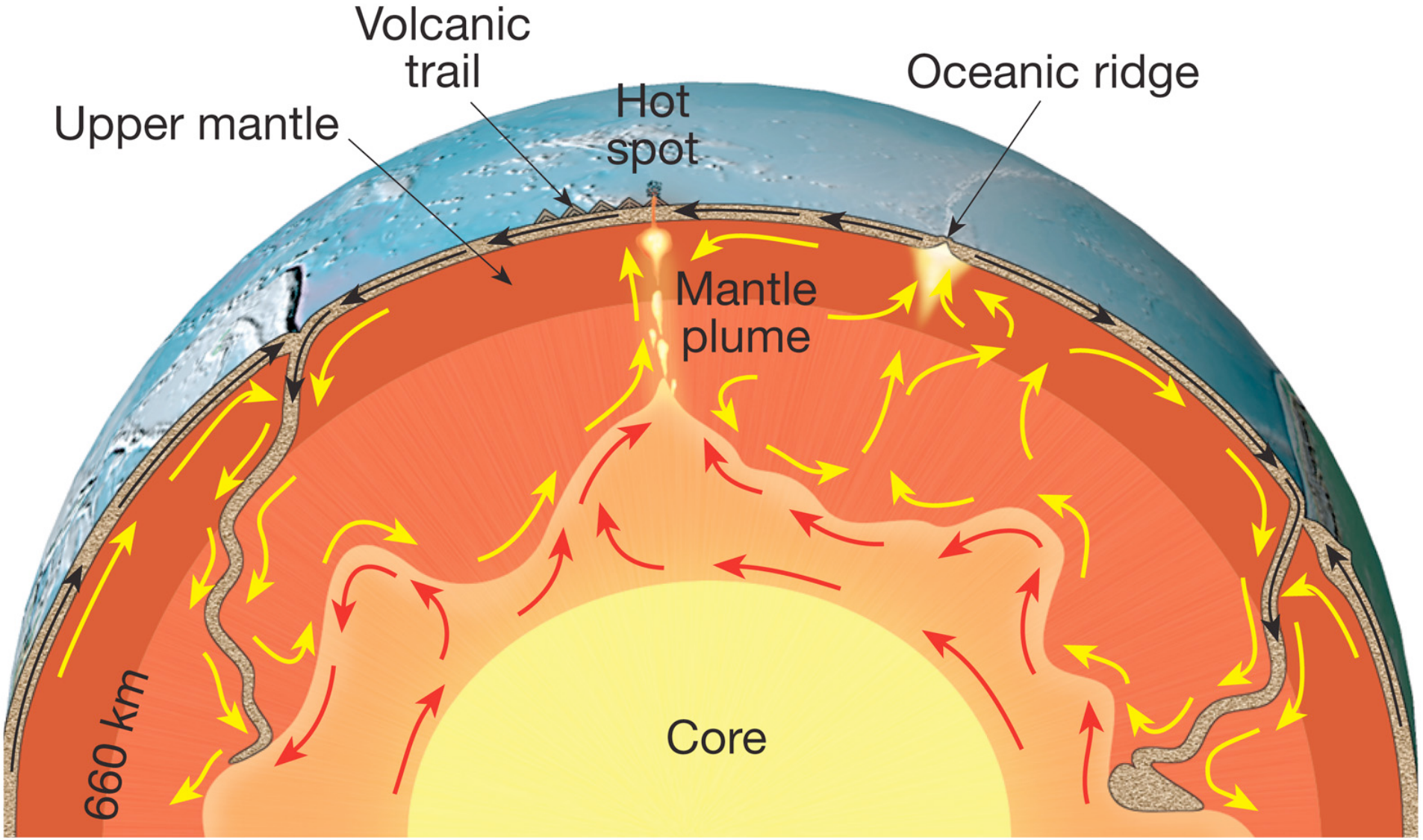


# What causes an eruption….anywhere?

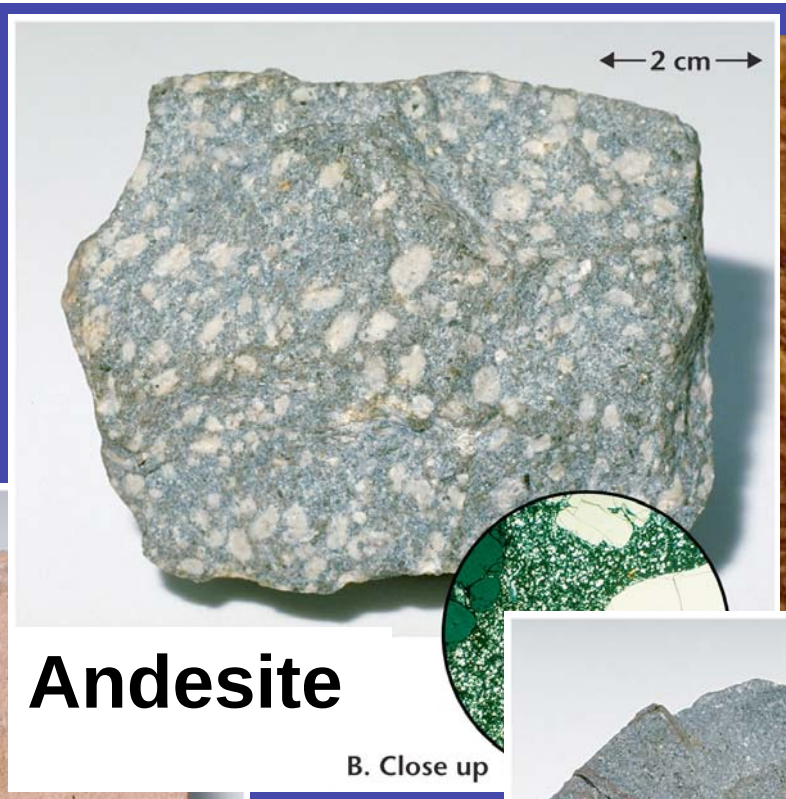
1. Decompression melting
2. Volatiles decrease melting temperature



# So why do we have different volcanic rock types?



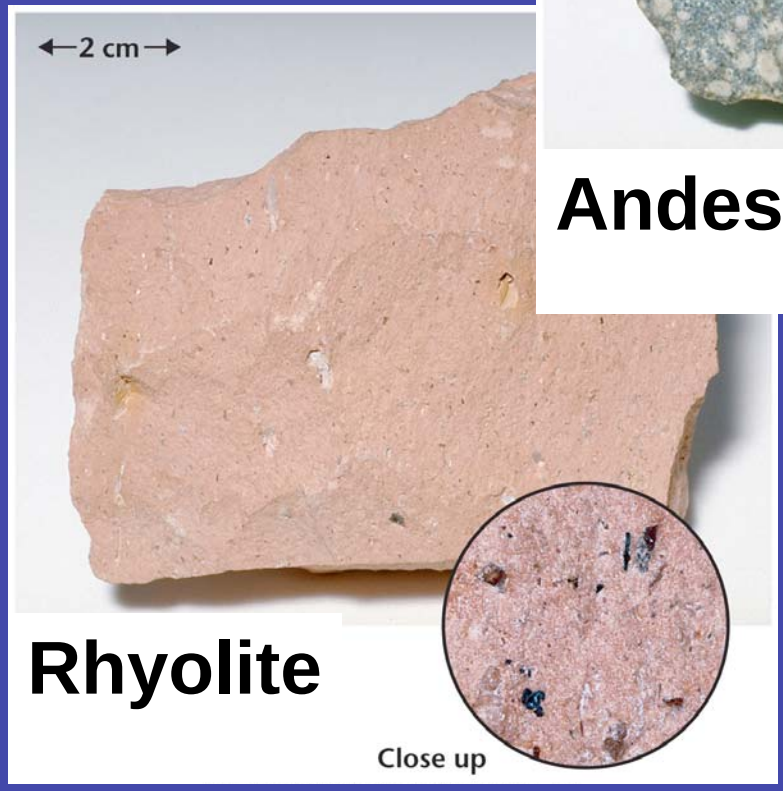
# 4 (common) extrusive igneous rocks



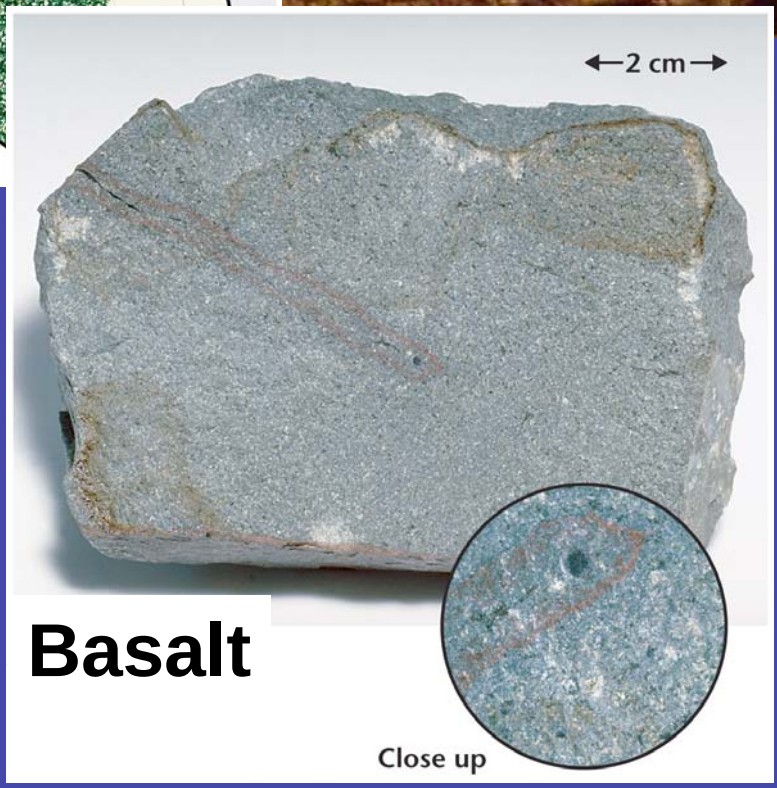

Andesite



Komatiite

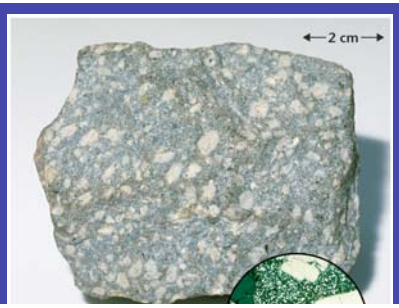



Rhyolite




Basalt

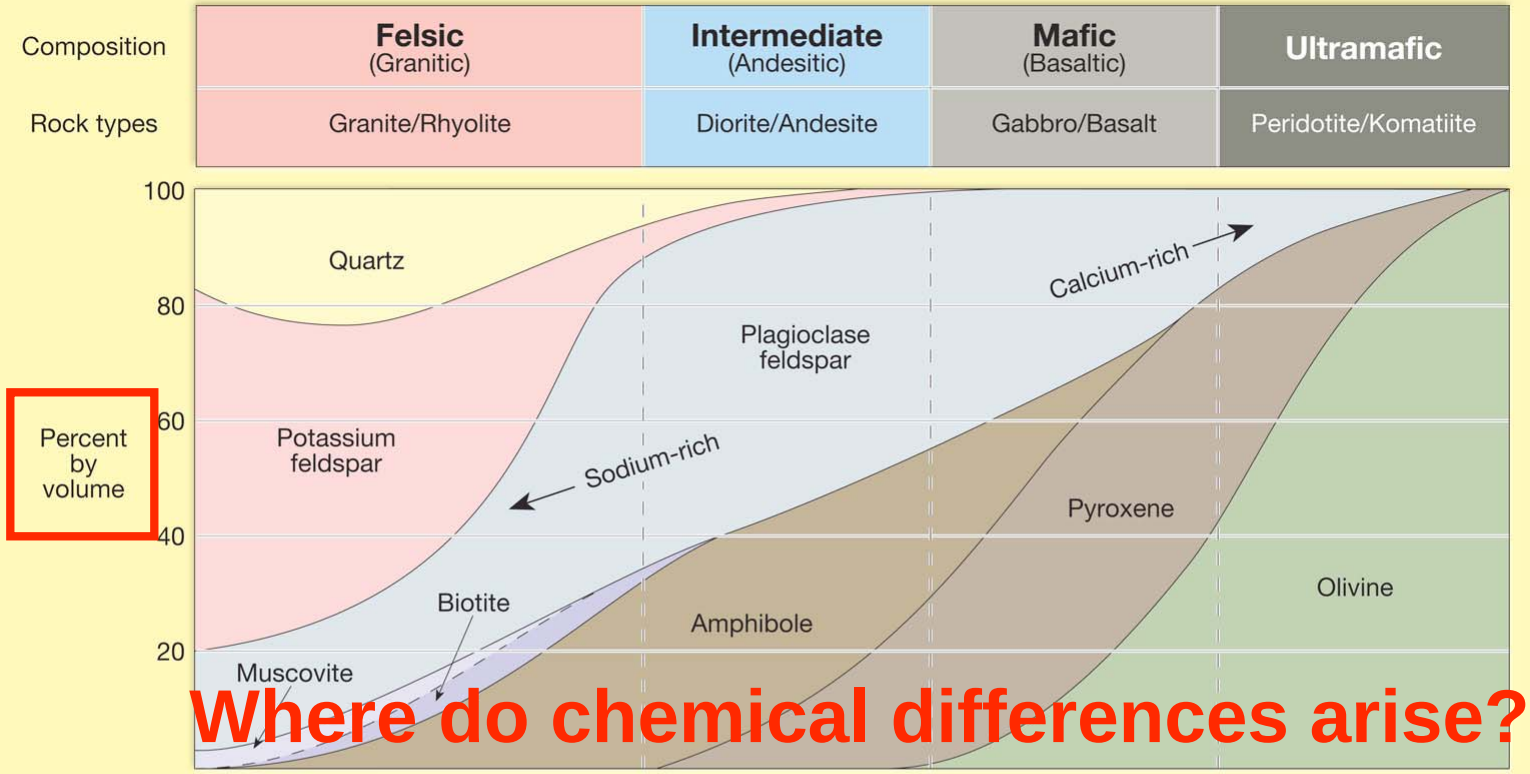




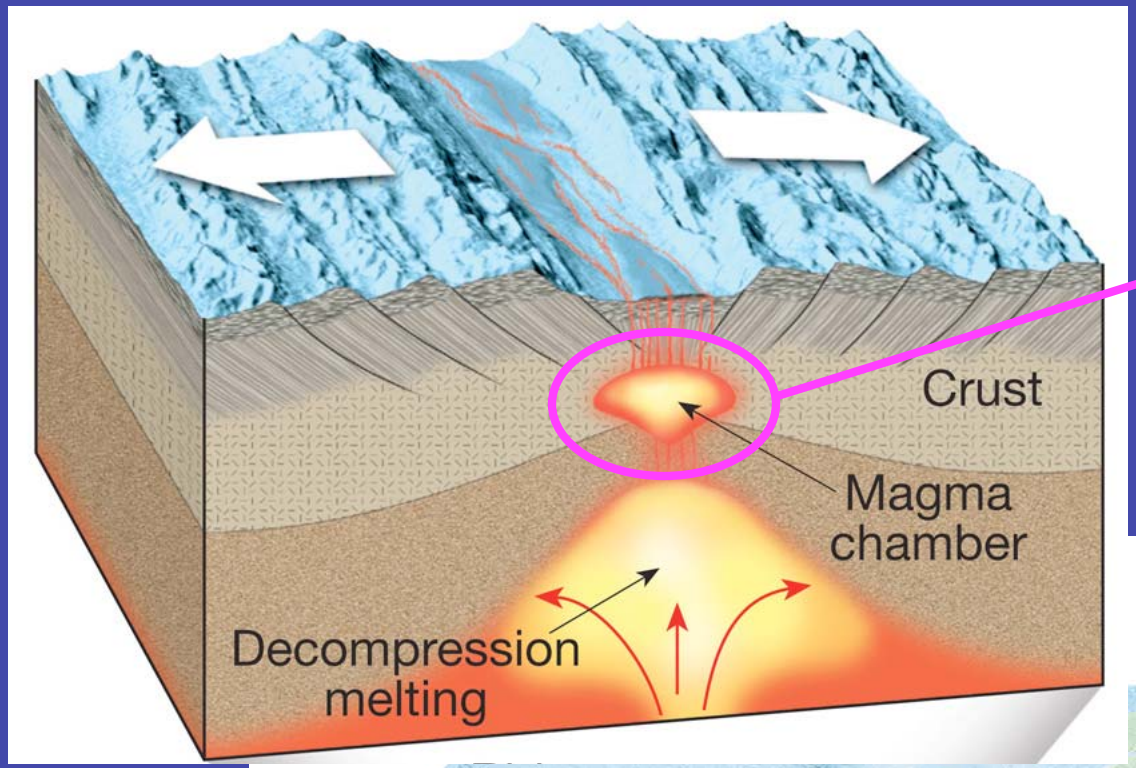


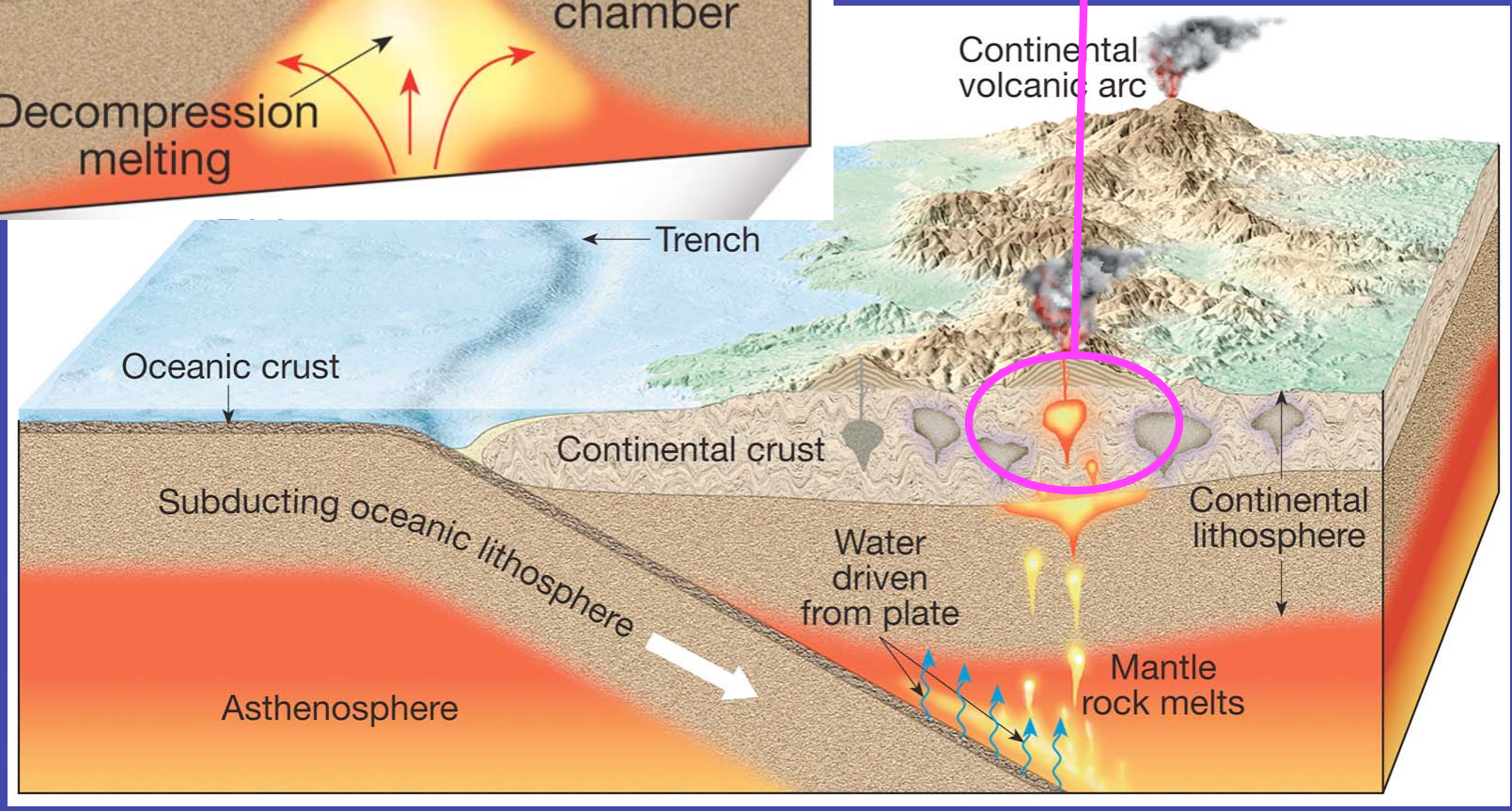





**Where do chemical differences arise?**

# Magma chamber processes



## So why do we have different volcanic rock types?

- Source material the same: mantle-derived
- Magma chamber processes:

  1. Magmatic differentiation (Bowen's Reaction Series)
  2. …
  3. …

# TRAIL MIX MODEL OF MAGMA FORMATION



**Initial composition:**

**25% M&Ms**

**25% Raisins**

**25% Peanuts**

**25% Almonds**

# TRAIL MIX MODEL OF MAGMA FORMATION



**2nd composition:**

~~**25% M&Ms**~~

**33% Raisins**

**33% Peanuts**

**33% Almonds**

# TRAIL MIX MODEL OF MAGMA FORMATION



**3rd composition:**

~~25% M&Ms~~

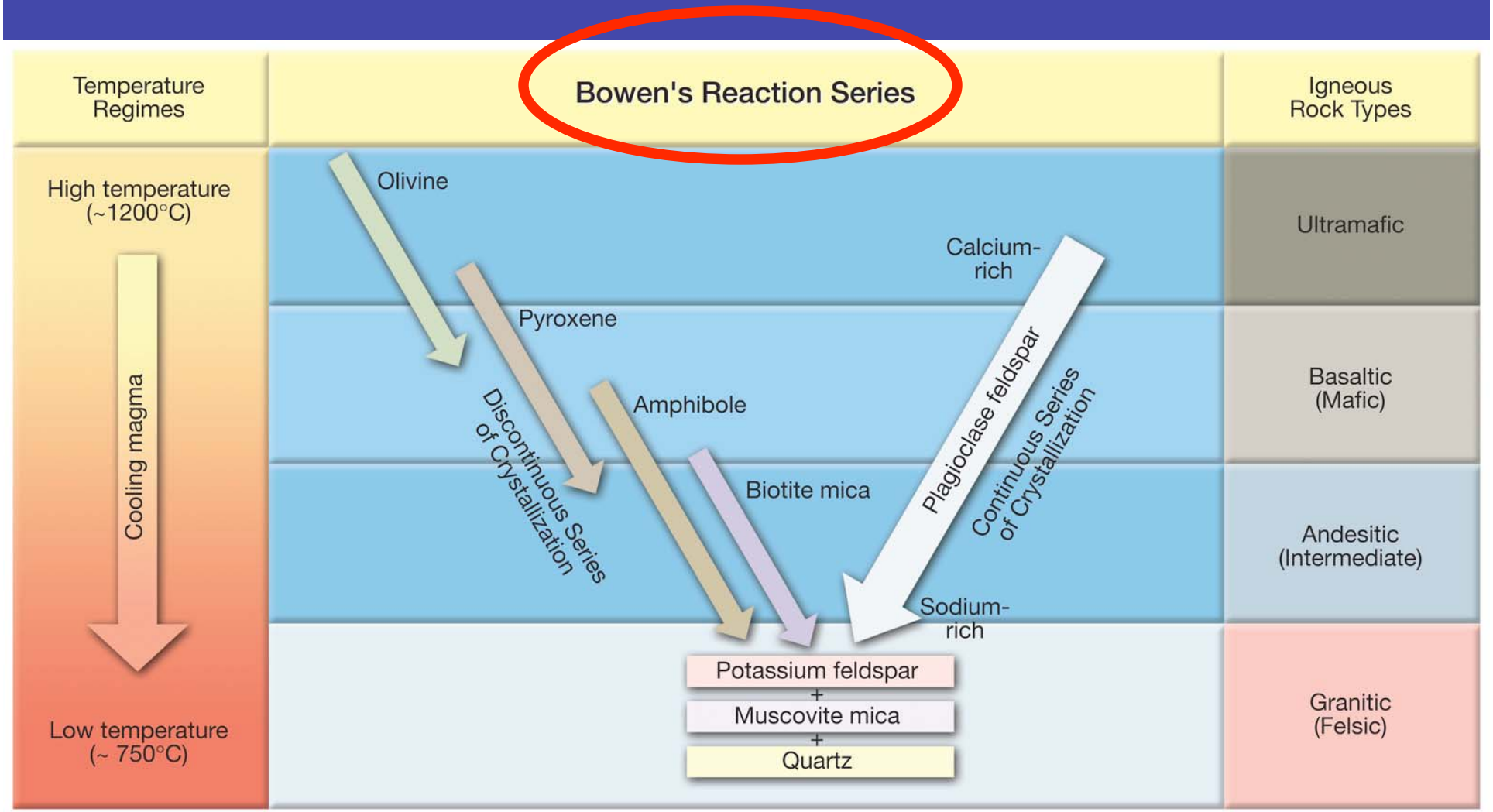
~~33% Raisins~~

50% Peanuts

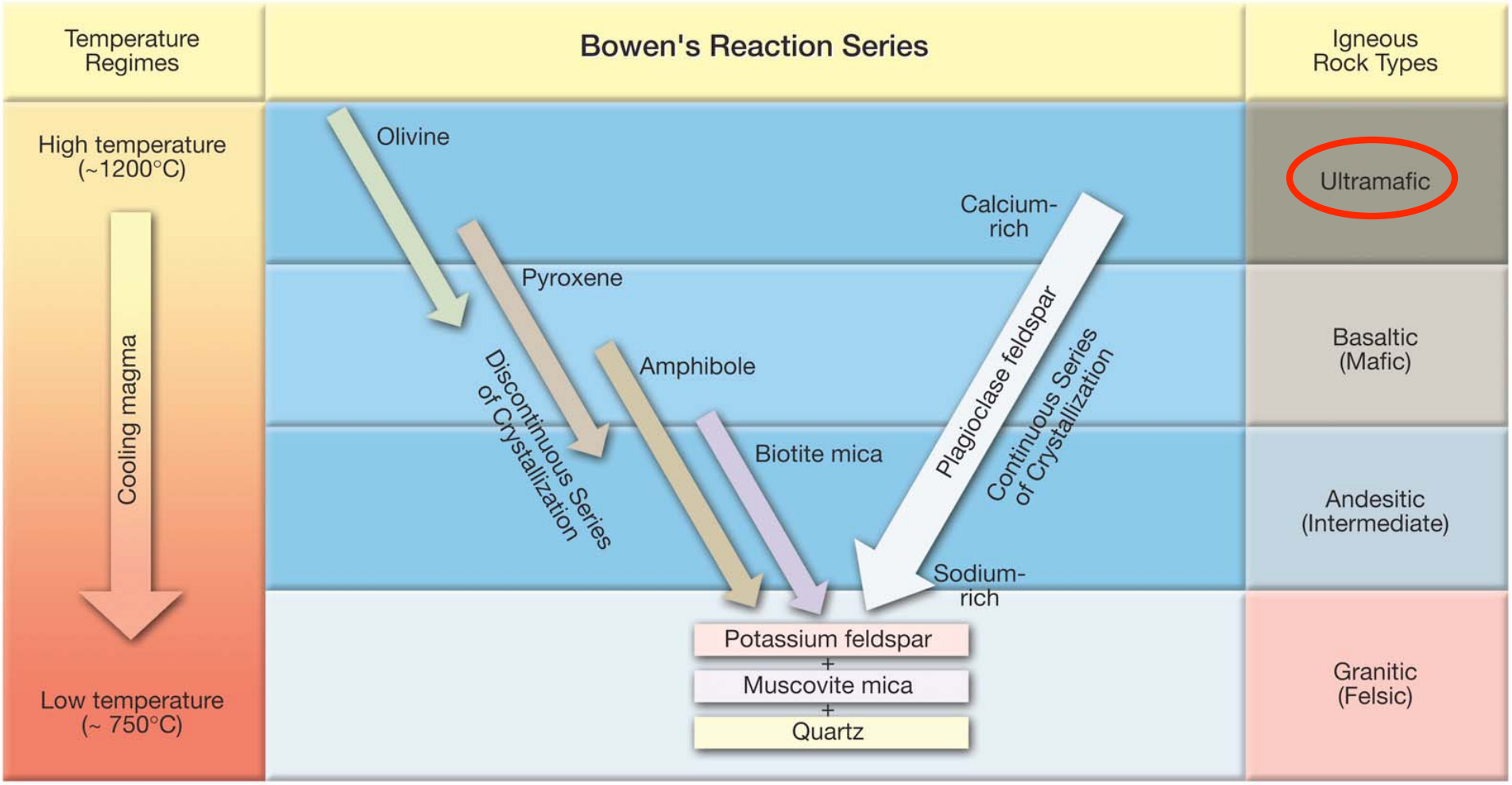
50% Almonds

# Magma crystallizes through 200°C+ of temperature

## Magmatic differentiation



# Scenario A: young, hot magma



# BOWEN'S MAGMATIC MIX



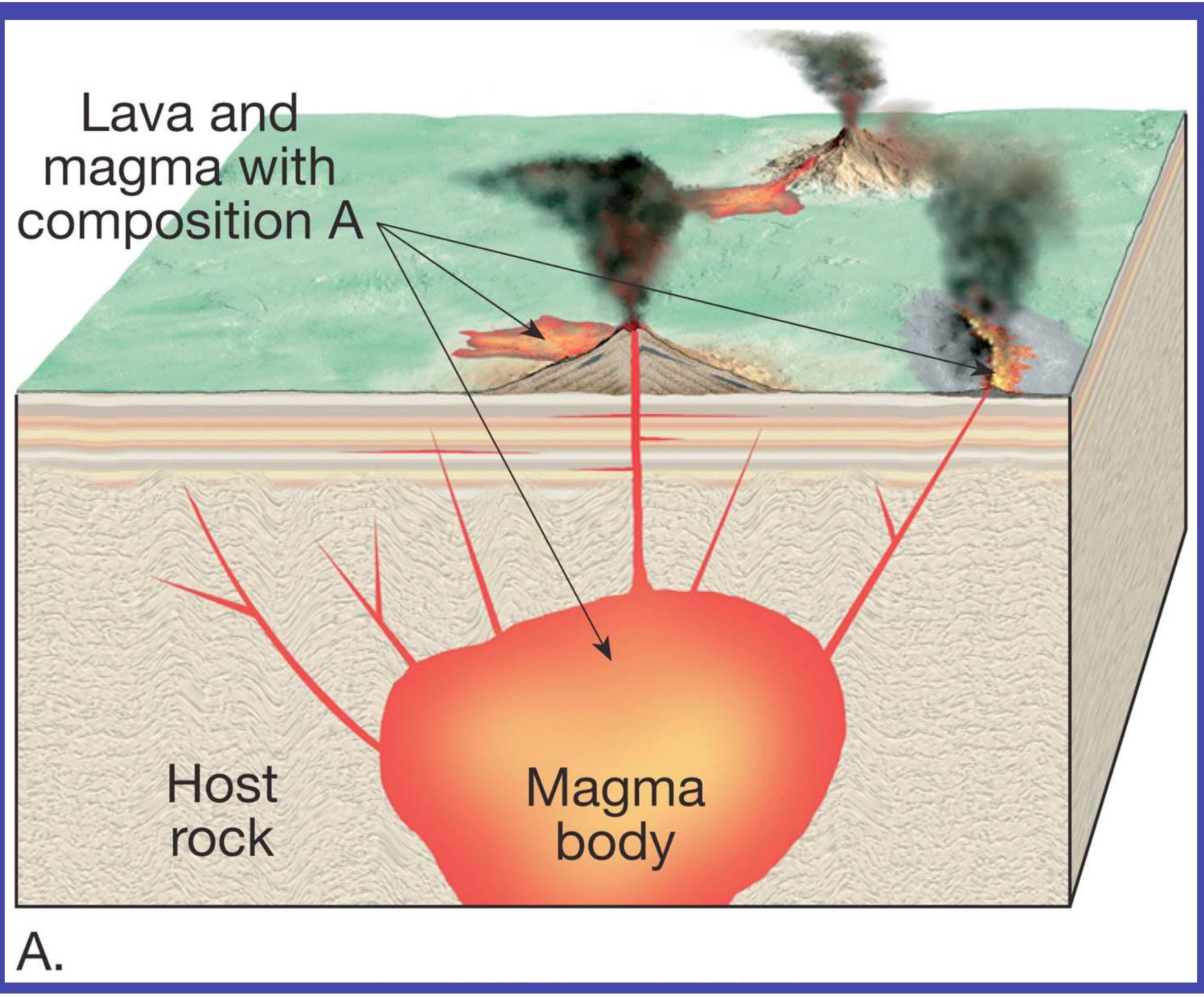
## Initial melt composition:

1. Olivine

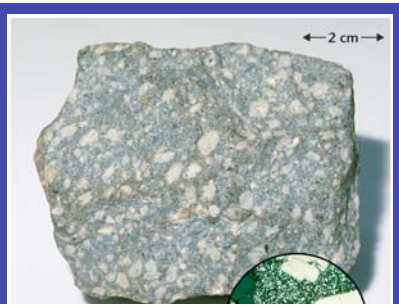
2. Pyroxene
   Ca-rich plagioclase feldspar

3. Amphibole
   Intermediate plagioclase feldspar

4. Biotite mica
   Na-rich plagioclase feldspar

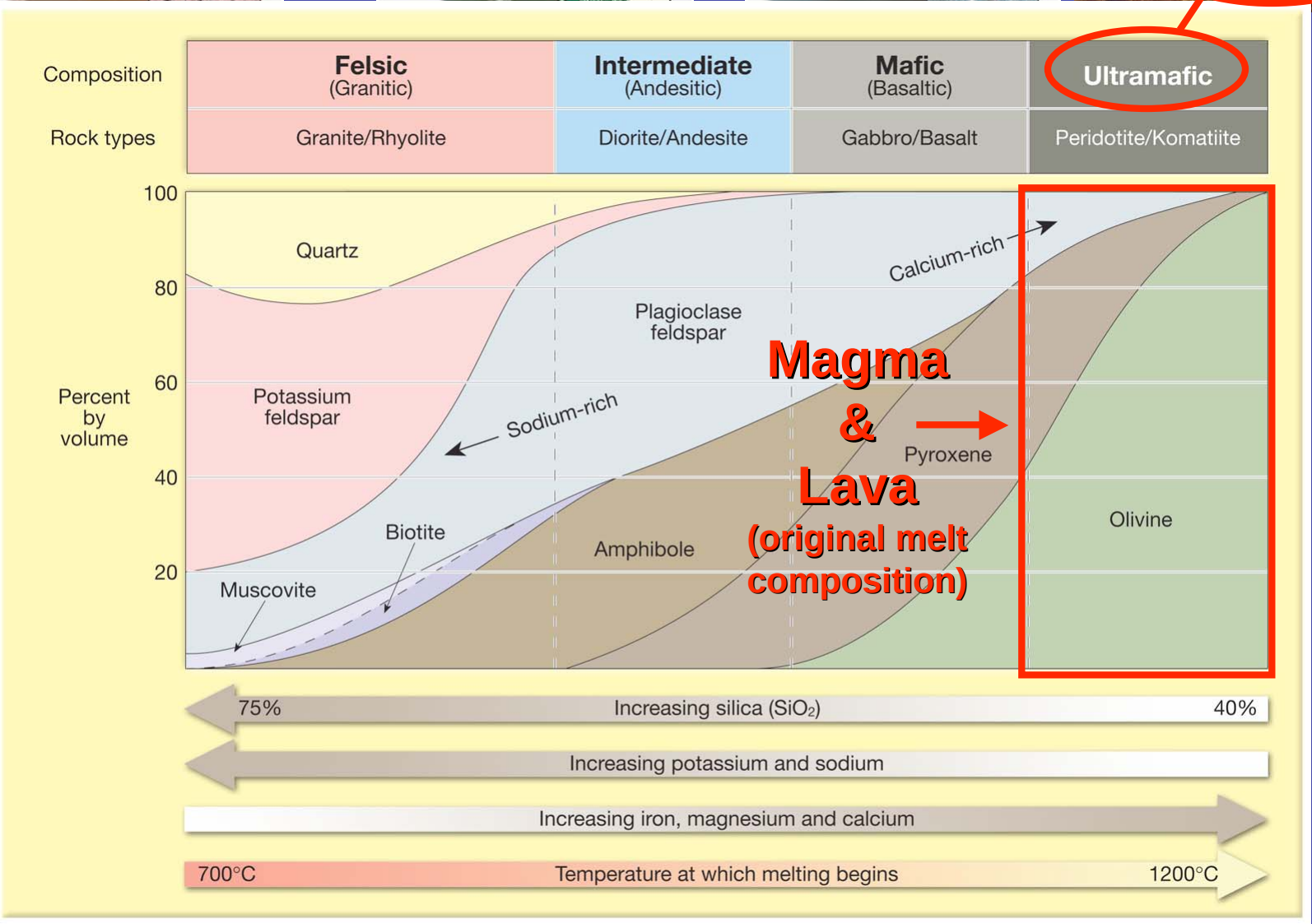

Lava and
magma with
composition A
Host
rock
Magma
body
A.


2 cm

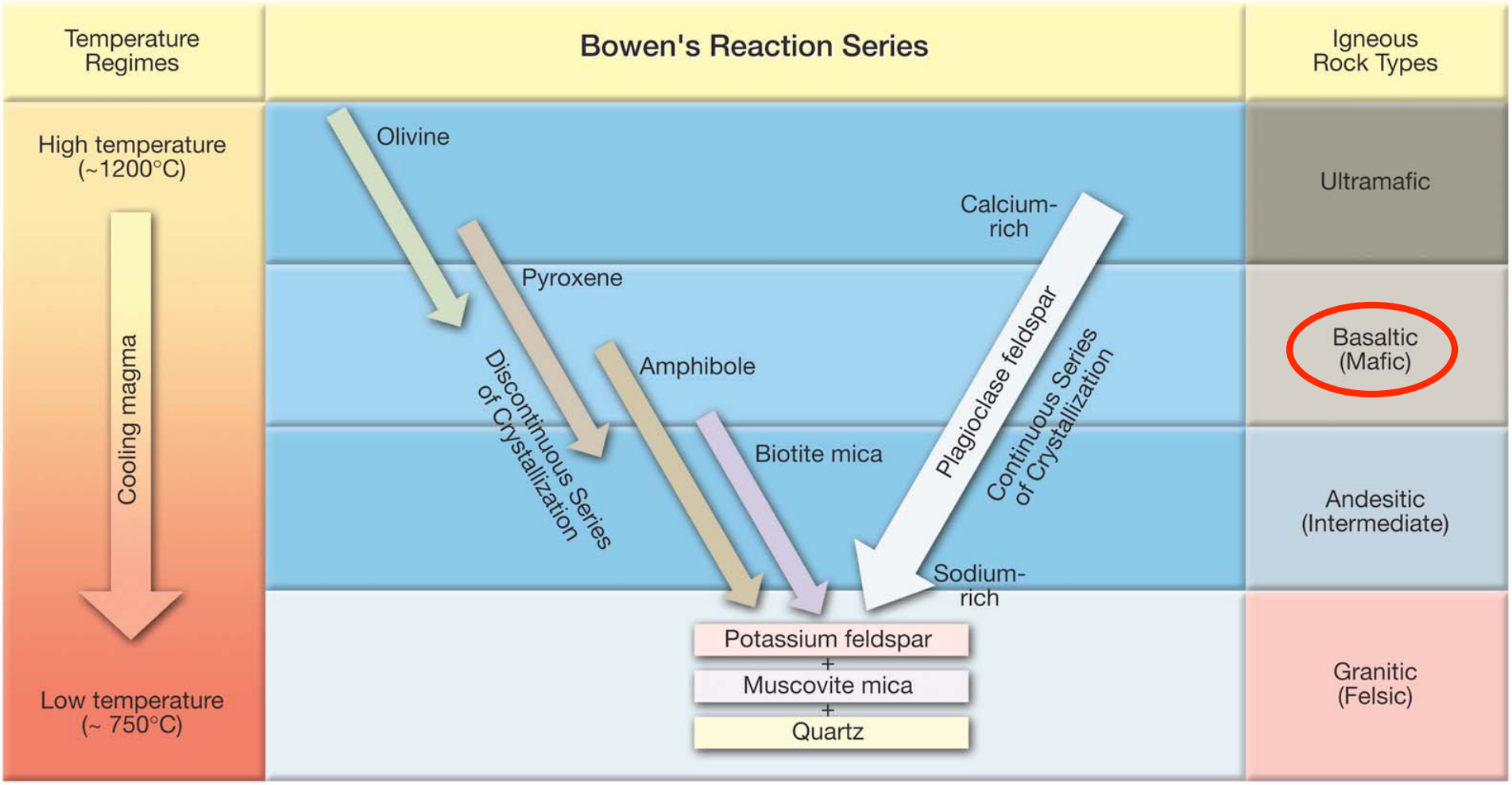

2 cm


2 cm




Composition
Felsic (Granitic)
Intermediate (Andesitic)
Mafic (Basaltic)
Ultramafic
Rock types
Granite/Rhyolite
Diorite/Andesite
Gabbro/Basalt
Peridotite/Komatiite
Percent by volume
100
80
60
40
20
Quartz
Potassium feldspar
Sodium-rich
Plagioclase feldspar
Calcium-rich
Biotite
Muscovite
Amphibole
Pyroxene
Olivine
Magma & Lava (original melt composition)
75%
Increasing silica (SiO2)
40%
Increasing potassium and sodium
Increasing iron, magnesium and calcium
700°C
Temperature at which melting begins
1200°C

# Scenario B: magma sits around, cools



# BOWEN'S MAGMATIC MIX



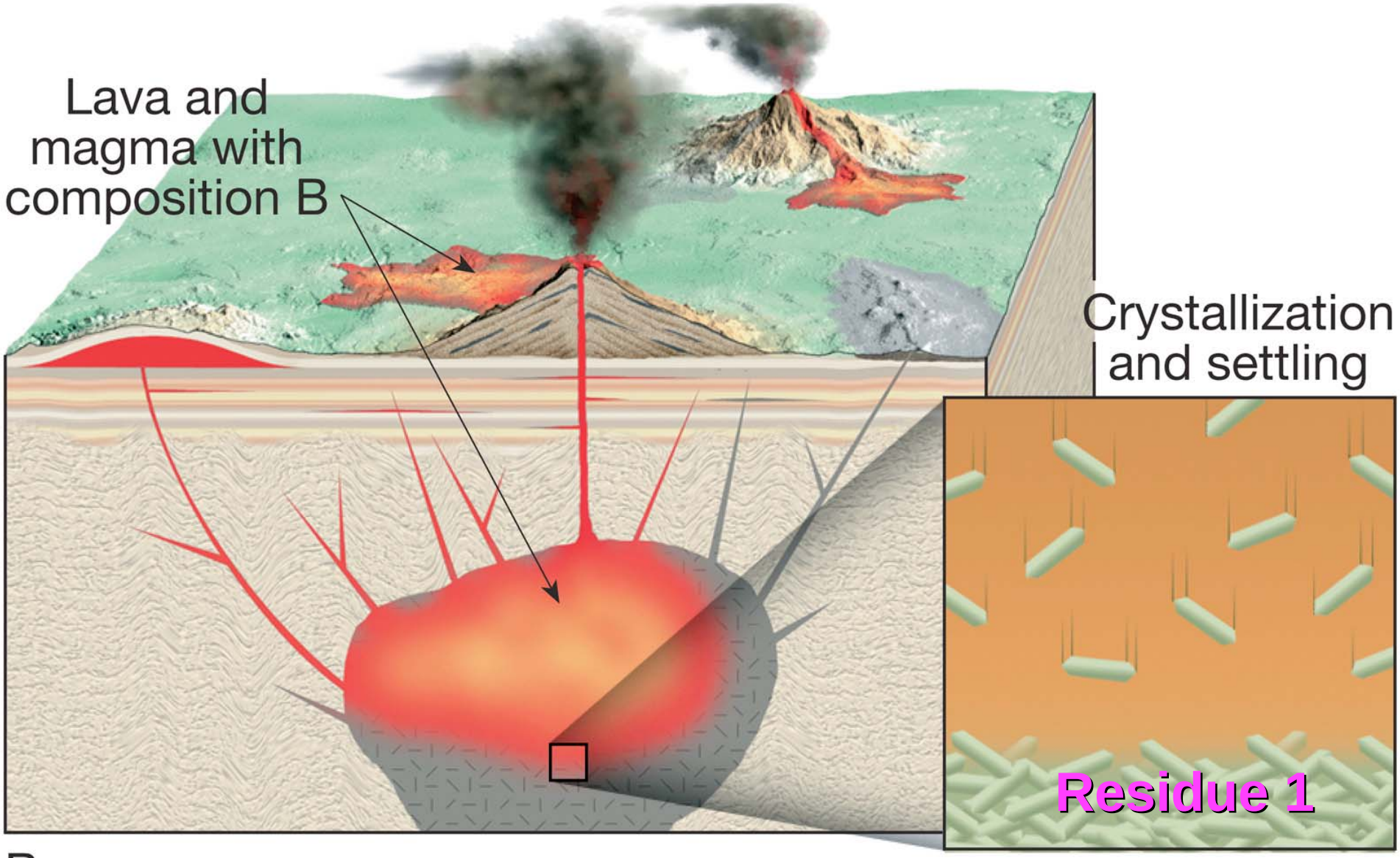
## 2nd melt composition:

~~1. Olivine~~

2. Pyroxene
   Ca-rich plagioclase feldspar

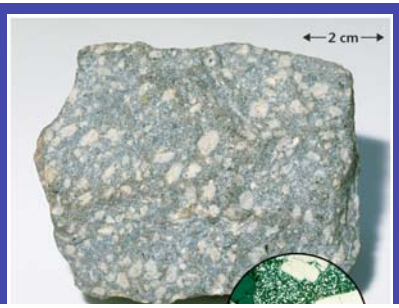
3. Amphibole
   Intermediate plagioclase feldspar

4. Biotite mica
   Na-rich plagioclase feldspar


Lava and
magma with
composition B
Crystallization
and settling
Residue 1

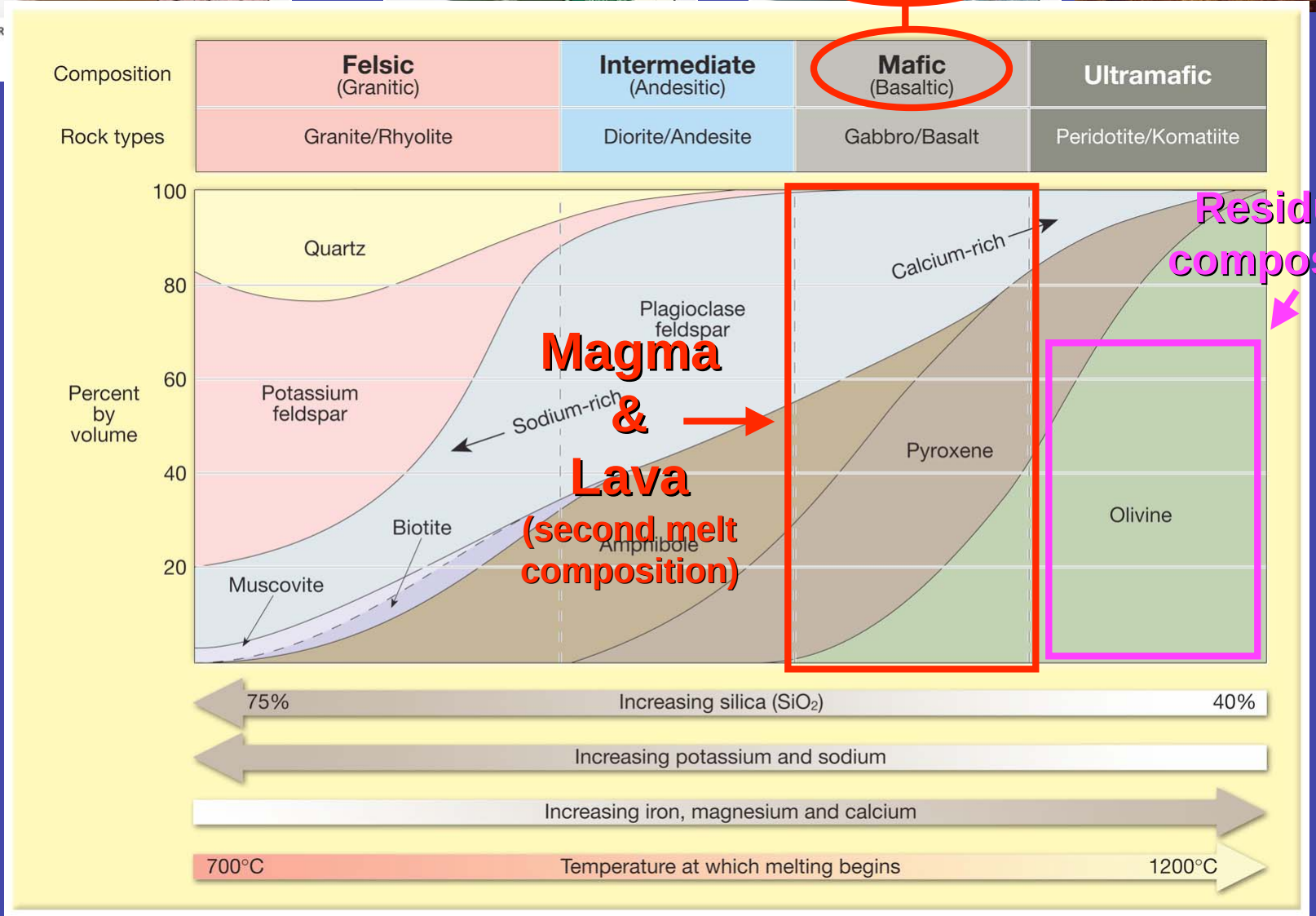
B.


2 cm

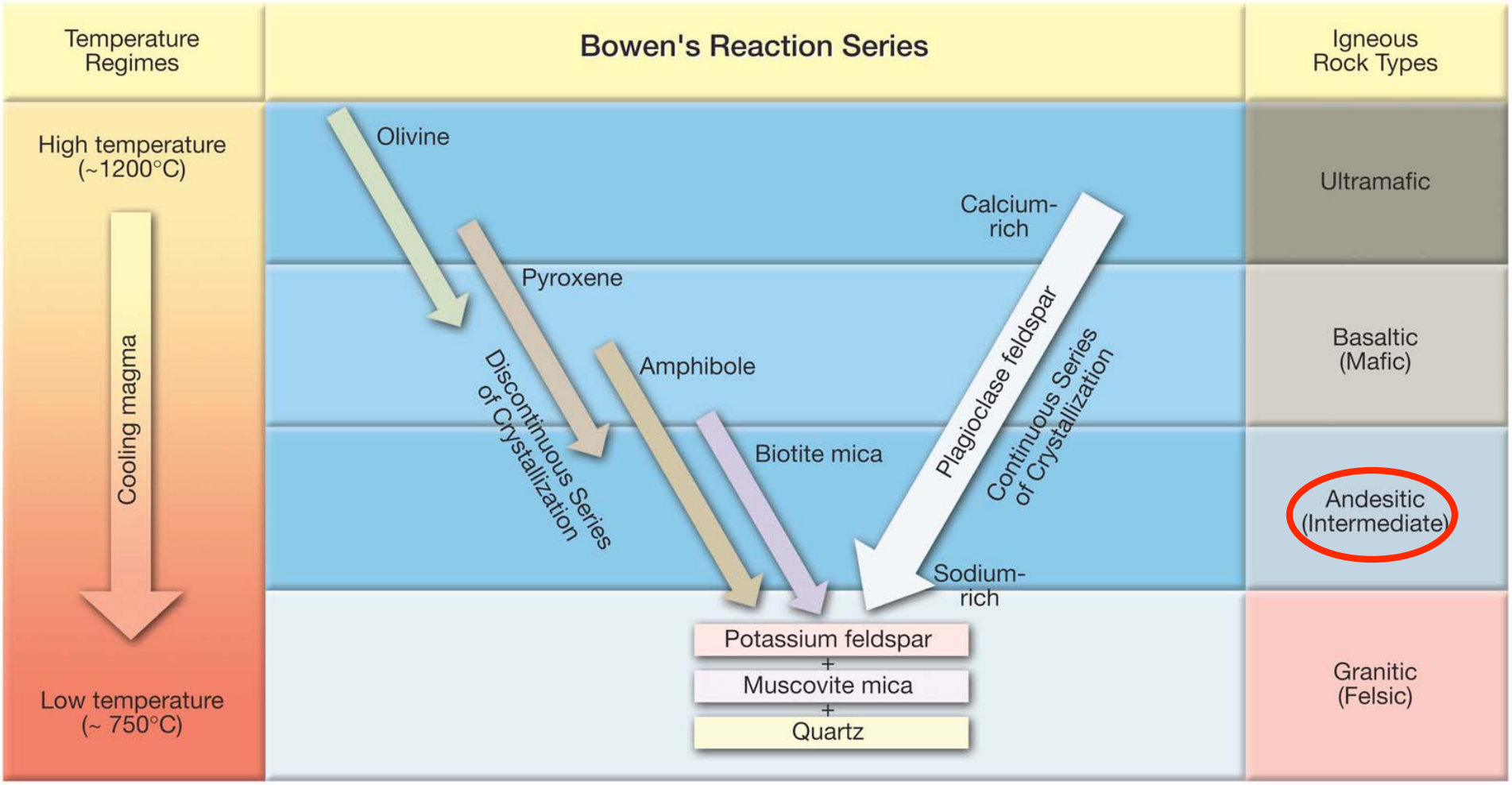

2 cm


2 cm




Composition
Felsic (Granitic)
Intermediate (Andesitic)
Mafic (Basaltic)
Ultramafic
Rock types
Granite/Rhyolite
Diorite/Andesite
Gabbro/Basalt
Peridotite/Komatiite
Percent by volume
100
80
60
40
20
Quartz
Potassium feldspar
Plagioclase feldspar
Sodium-rich
Calcium-rich
Biotite
Muscovite
Amphibole
Pyroxene
Olivine
Magma & Lava (second melt composition)
Residue 1 composition
75%
Increasing silica (SiO2)
40%
Increasing potassium and sodium
Increasing iron, magnesium and calcium
700°C
Temperature at which melting begins
1200°C

# Scenario C: (relatively) old, cold magma



# BOWEN'S MAGMATIC MIX



## 3rd composition:

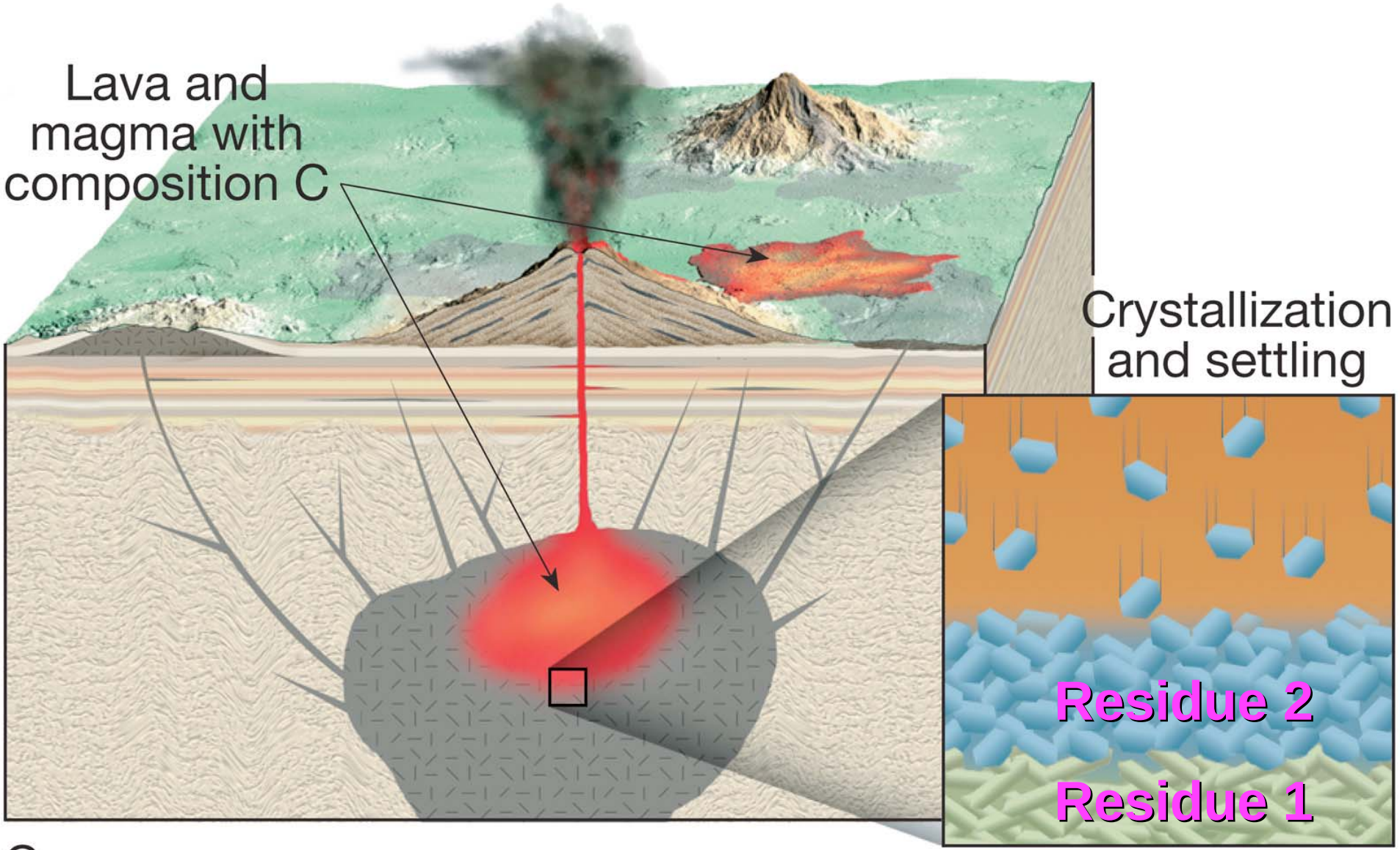
~~1. Olivine~~

~~2. Pyroxene~~

~~Ca-rich plagioclase feldspar~~

3. Amphibole
   Intermediate plagioclase feldspar

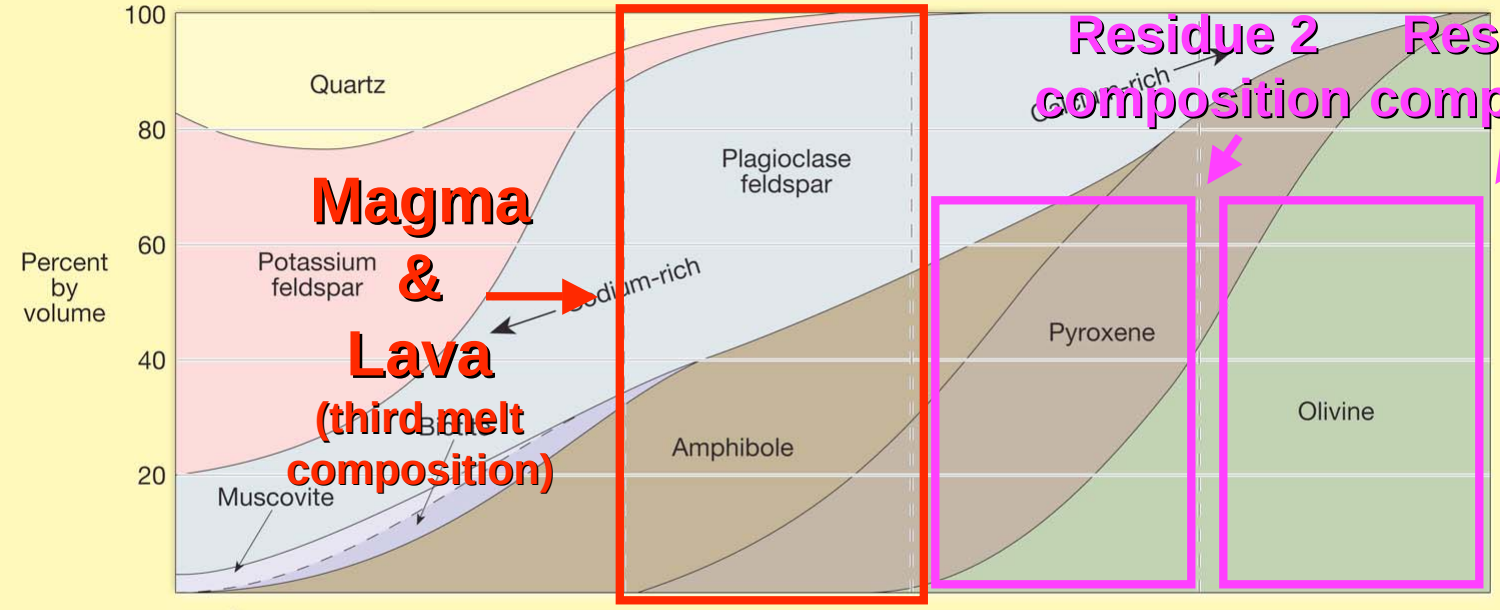
4. Biotite mica
   Na-rich plagioclase feldspar


Lava and magma with composition C
Crystallization and settling
Residue 2
Residue 1

C.



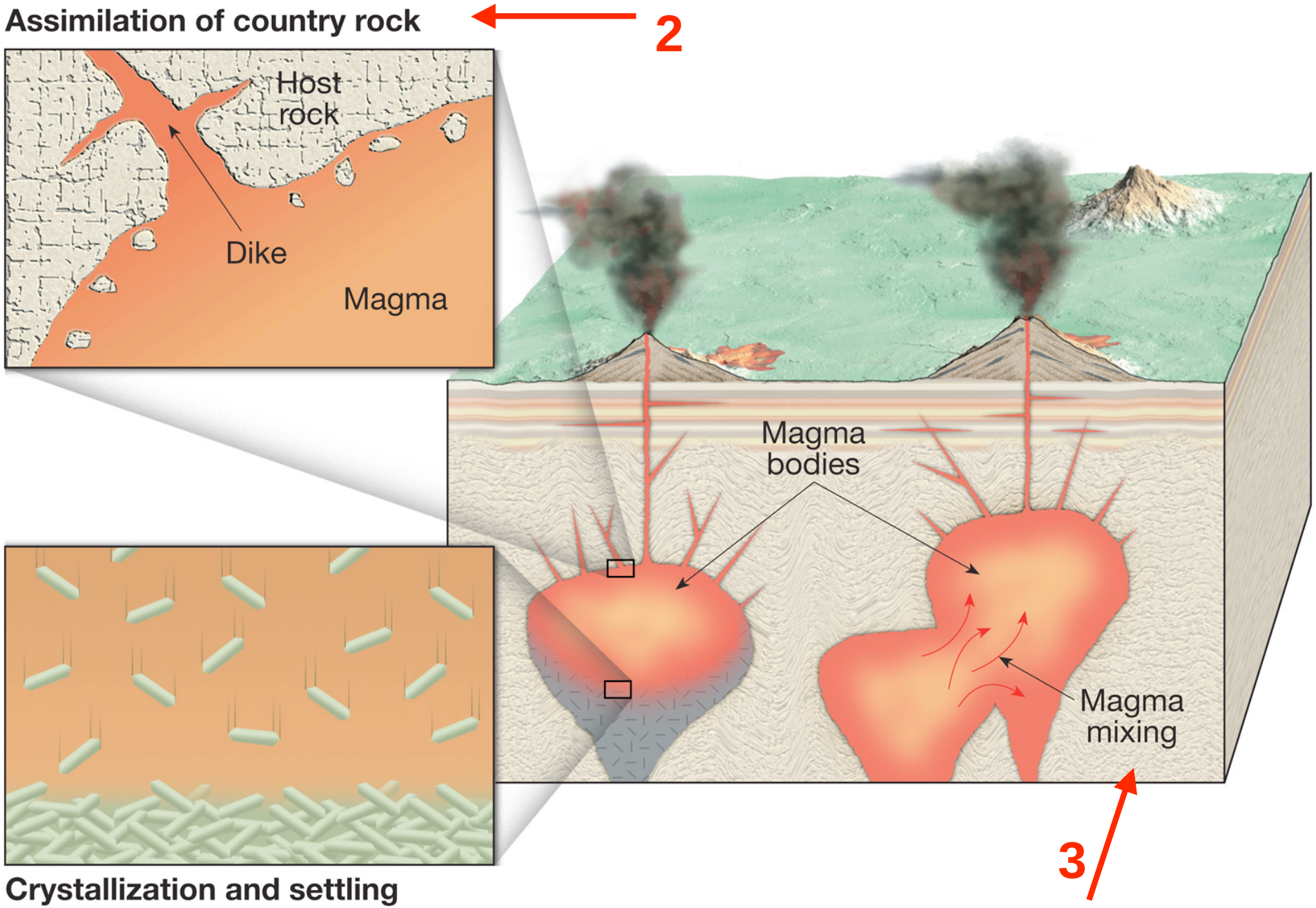

| Composition | Felsic (Granitic) | Intermediate (Andesitic) | Mafic (Basaltic) | Ultramafic |
|---|---|---|---|---|
| Rock types | Granite/Rhyolite | Diorite/Andesite | Gabbro/Basalt | Peridotite/Komatiite |



## So why do we have different volcanic rock types?

- Source material the same: mantle-derived
- Magma chamber processes:

  1. Magmatic differentiation (Bowen's Reaction Series)
  2. …
  3. …


Assimilation of country rock
2
Host rock
Dike
Magma
Magma bodies
Magma mixing
3
Crystallization and settling

## So why do we have different volcanic rock types?

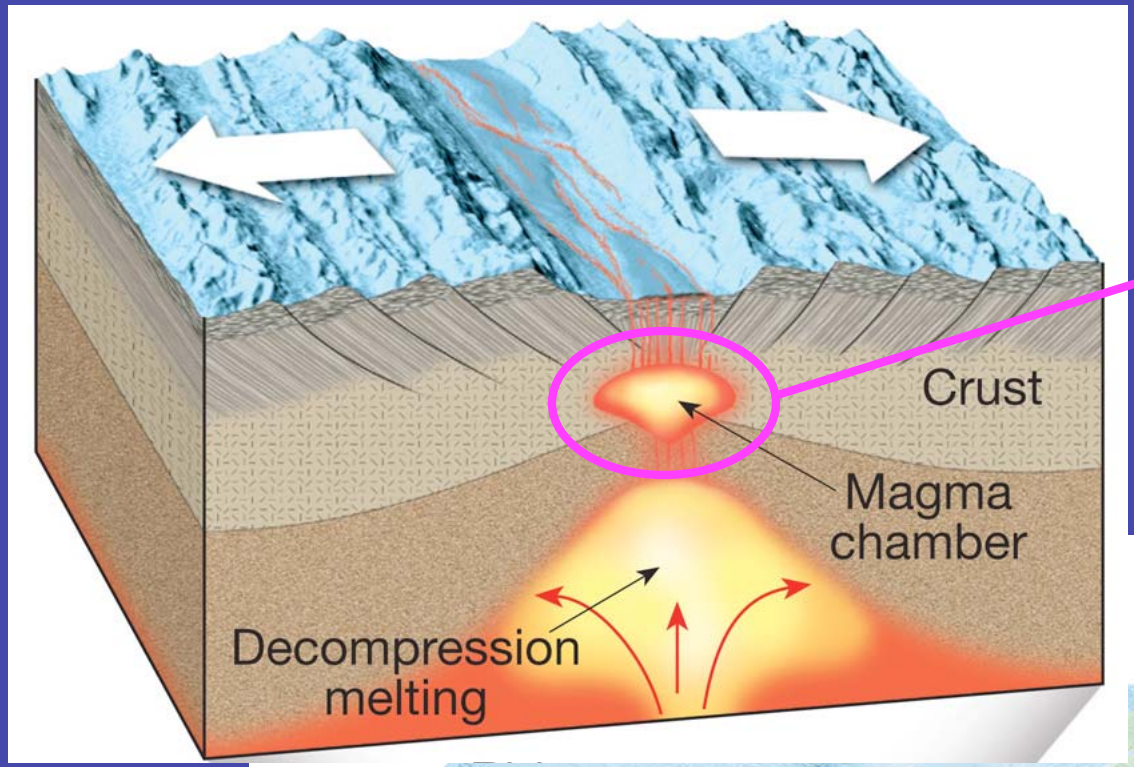
- Source material the same: mantle-derived
- Magma chamber processes:

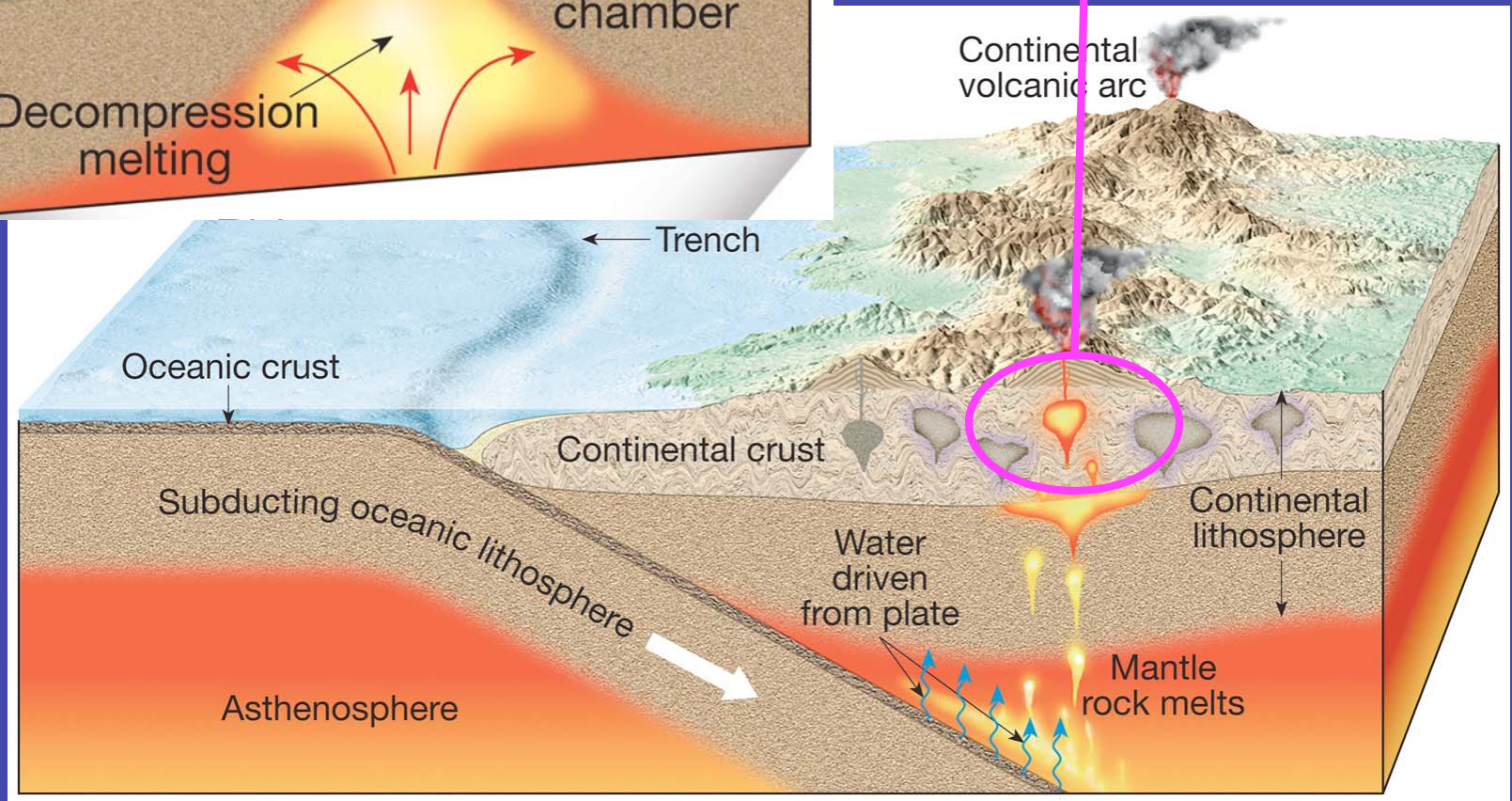
1. Magmatic differentiation (Bowen's Reaction Series)
2. Assimilation
3. Magma mixing

take a long time ~ imply distance from source

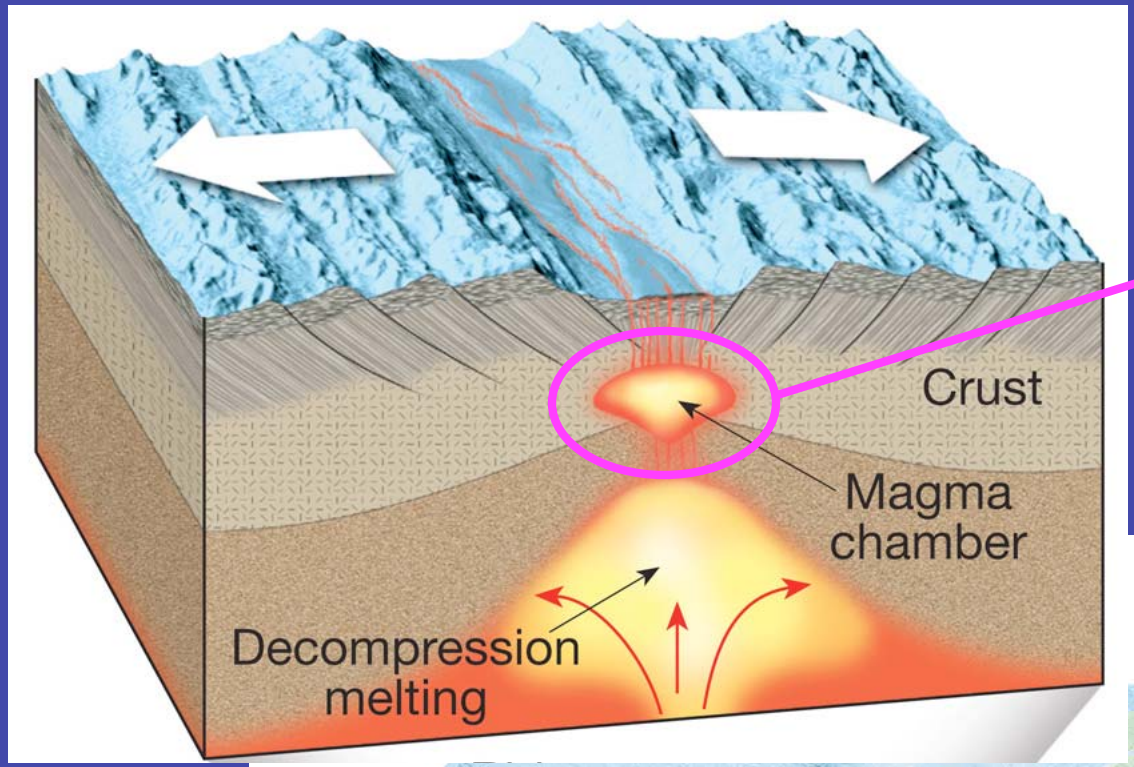
# How can you predict where you'll find different rock types?

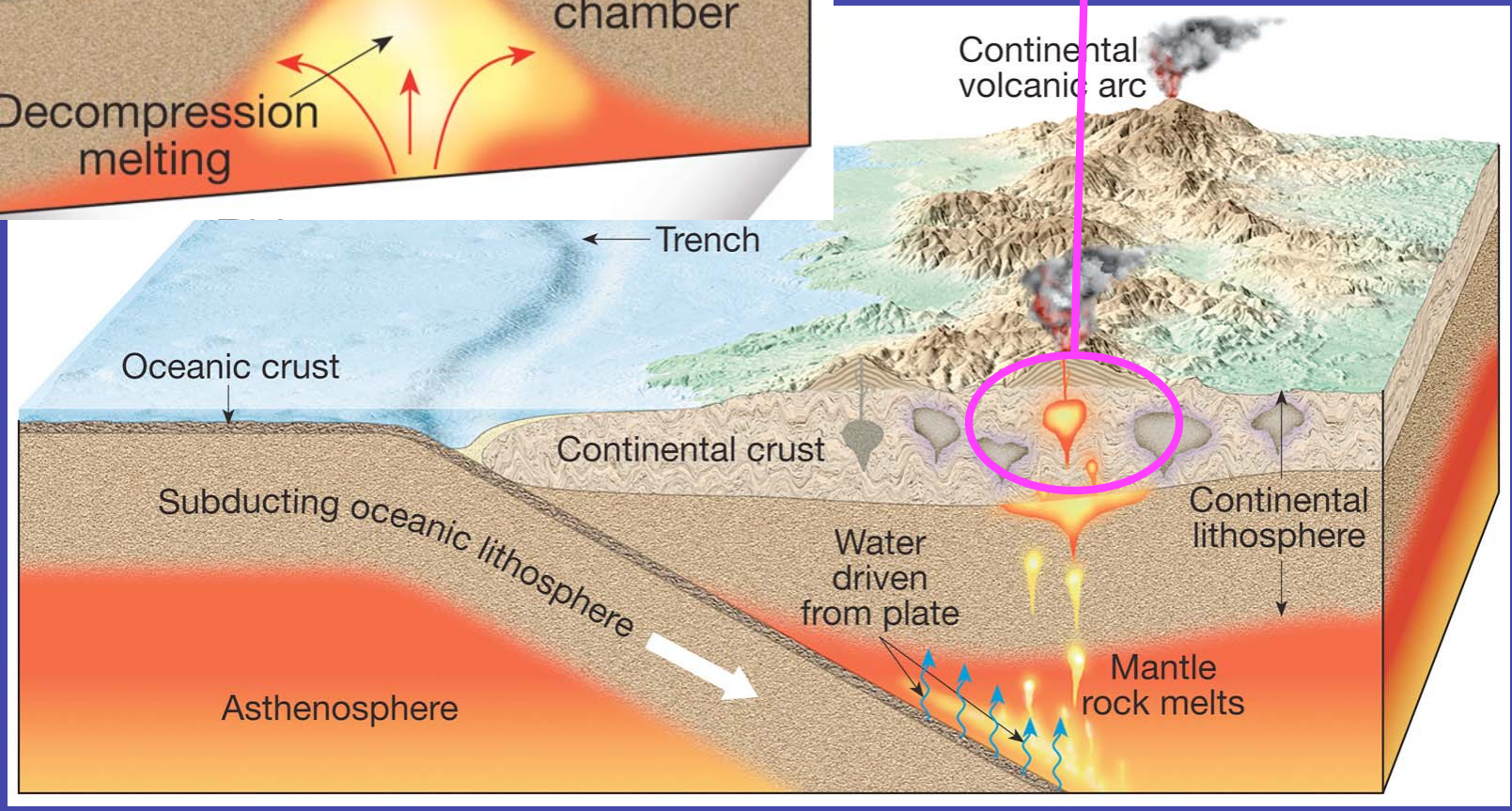
**Which magma has to travel farthest?**



**Which magma sits around longest?**



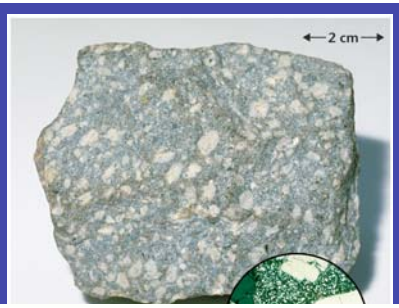
## So why do we have different volcanic rock types?

- Source material the same: mantle-derived
- Magma chamber processes:

1. Magmatic differentiation (Bowen's Reaction Series)
2. Assimilation
3. Magma mixing

take a long time ~ imply distance from source

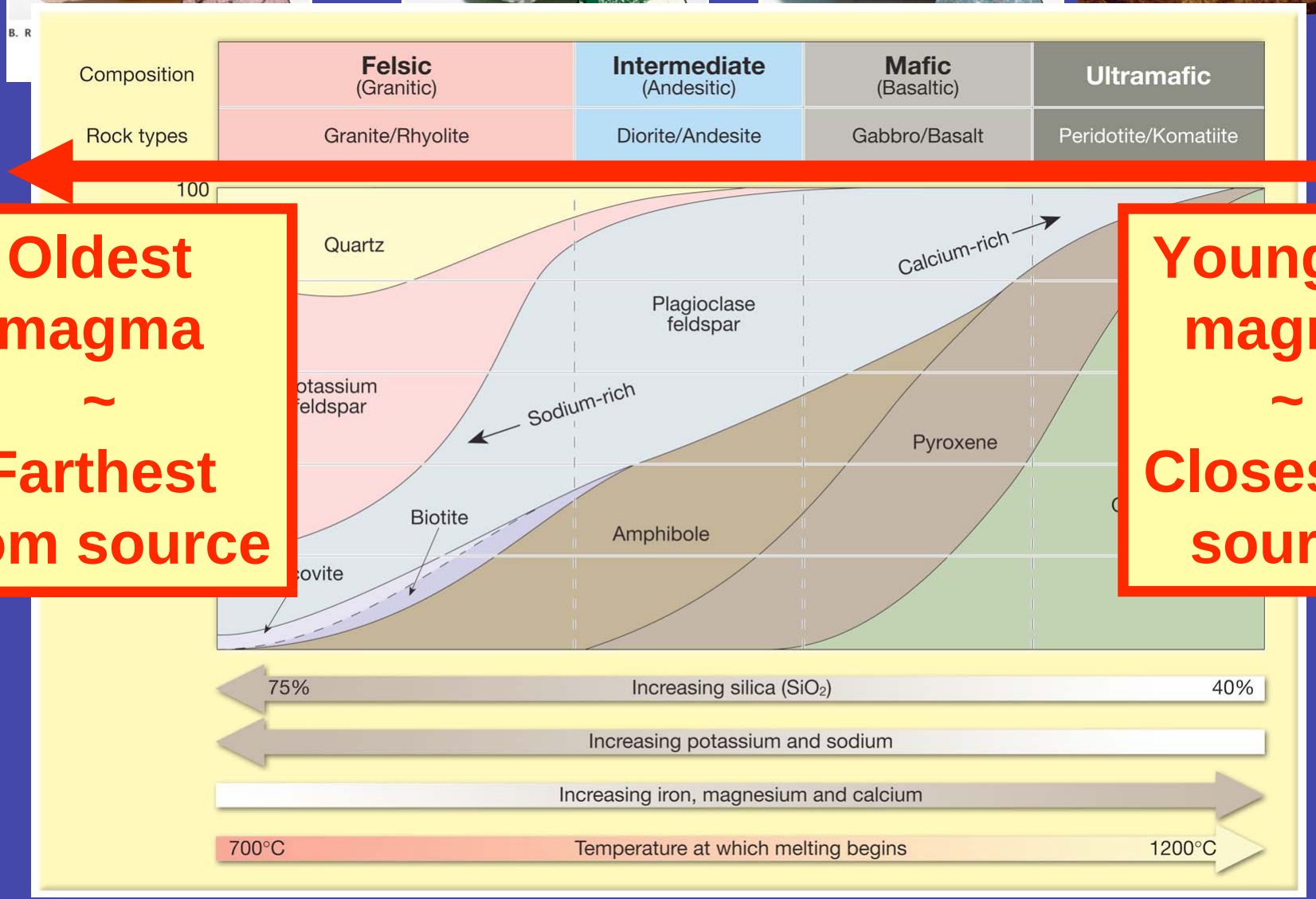




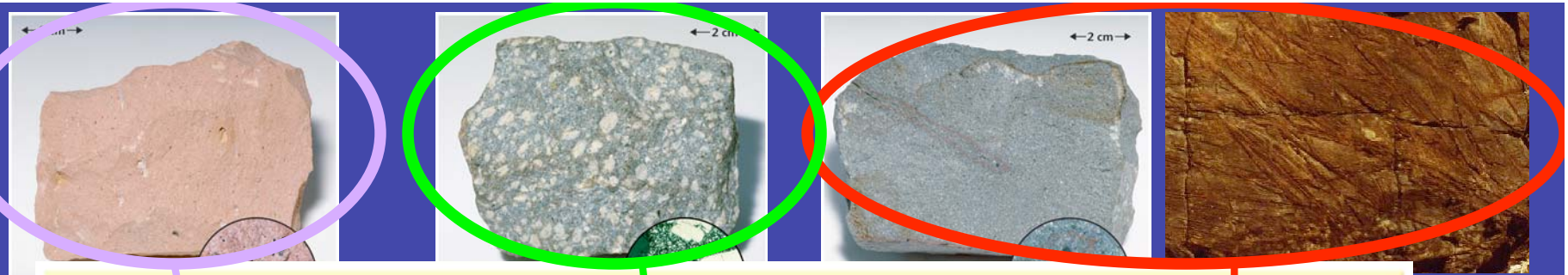




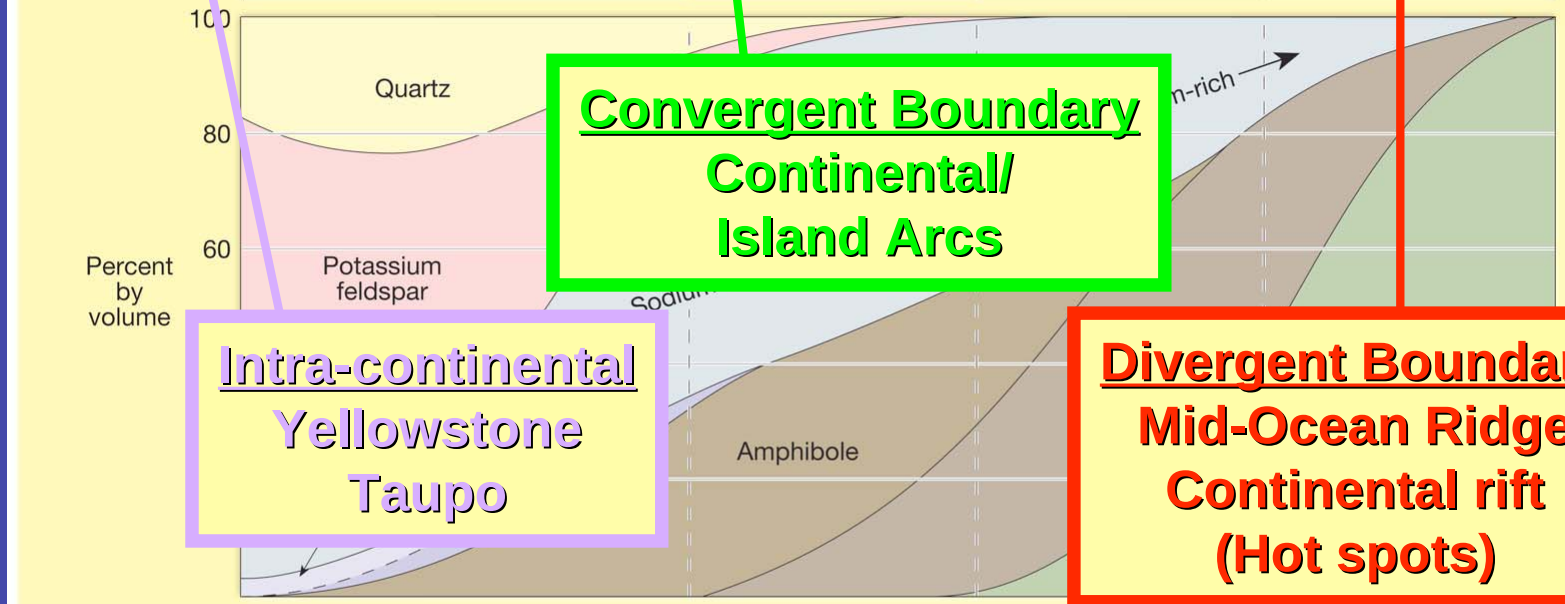



**Oldest magma ~ Farthest from source**

**Youngest magma ~ Closest to source**



| Composition | Felsic (Granitic) | Intermediate (Andesitic) | Mafic (Basaltic) | Ultramafic |
|---|---|---|---|---|
| Rock types | Granite/Rhyolite | Diorite/Andesite | Gabbro/Basalt | Peridotite/Komatiite |




75% — Increasing silica ($SiO_2$) — 40%

Increasing potassium and sodium

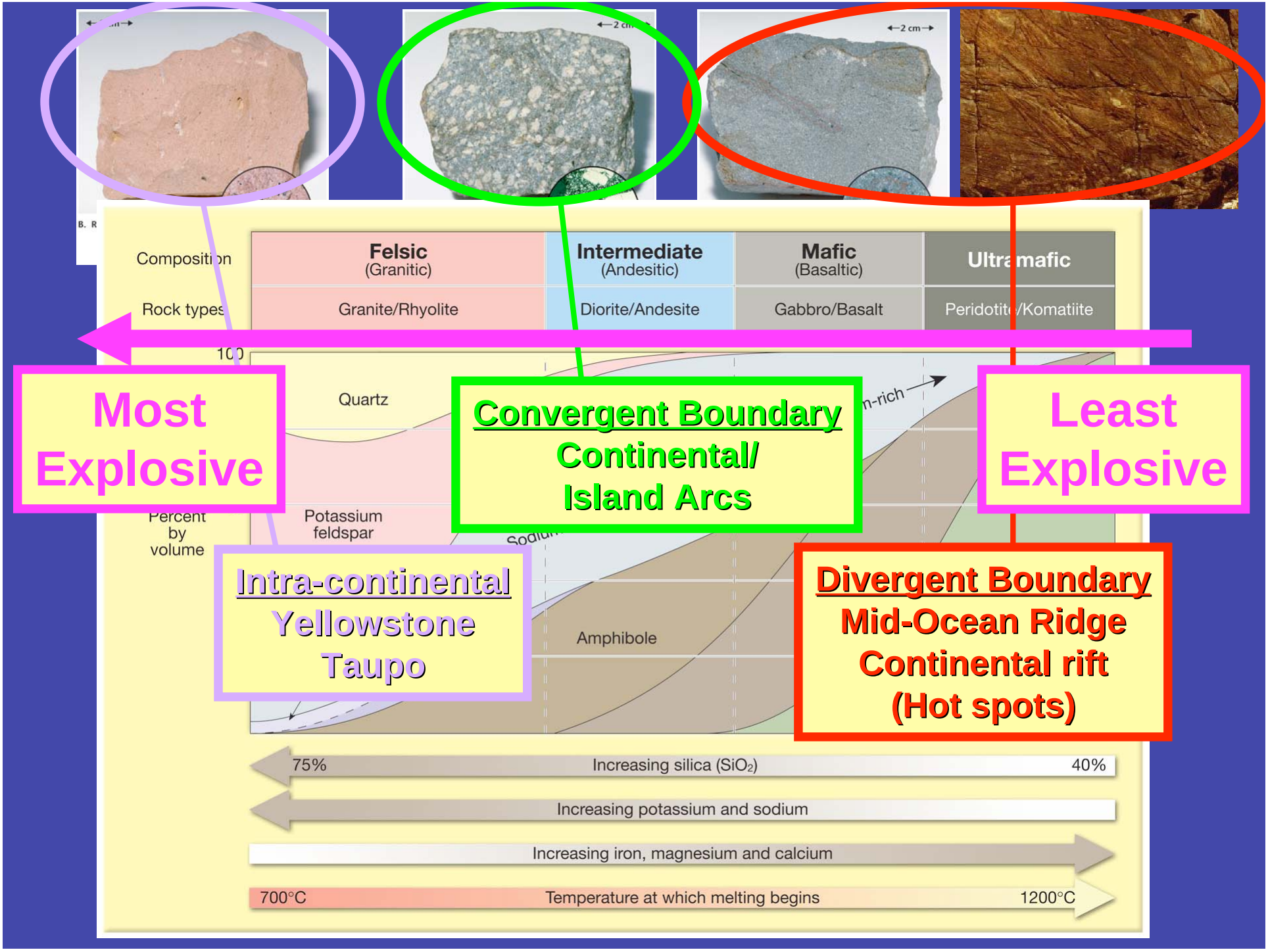
Increasing iron, magnesium and calcium

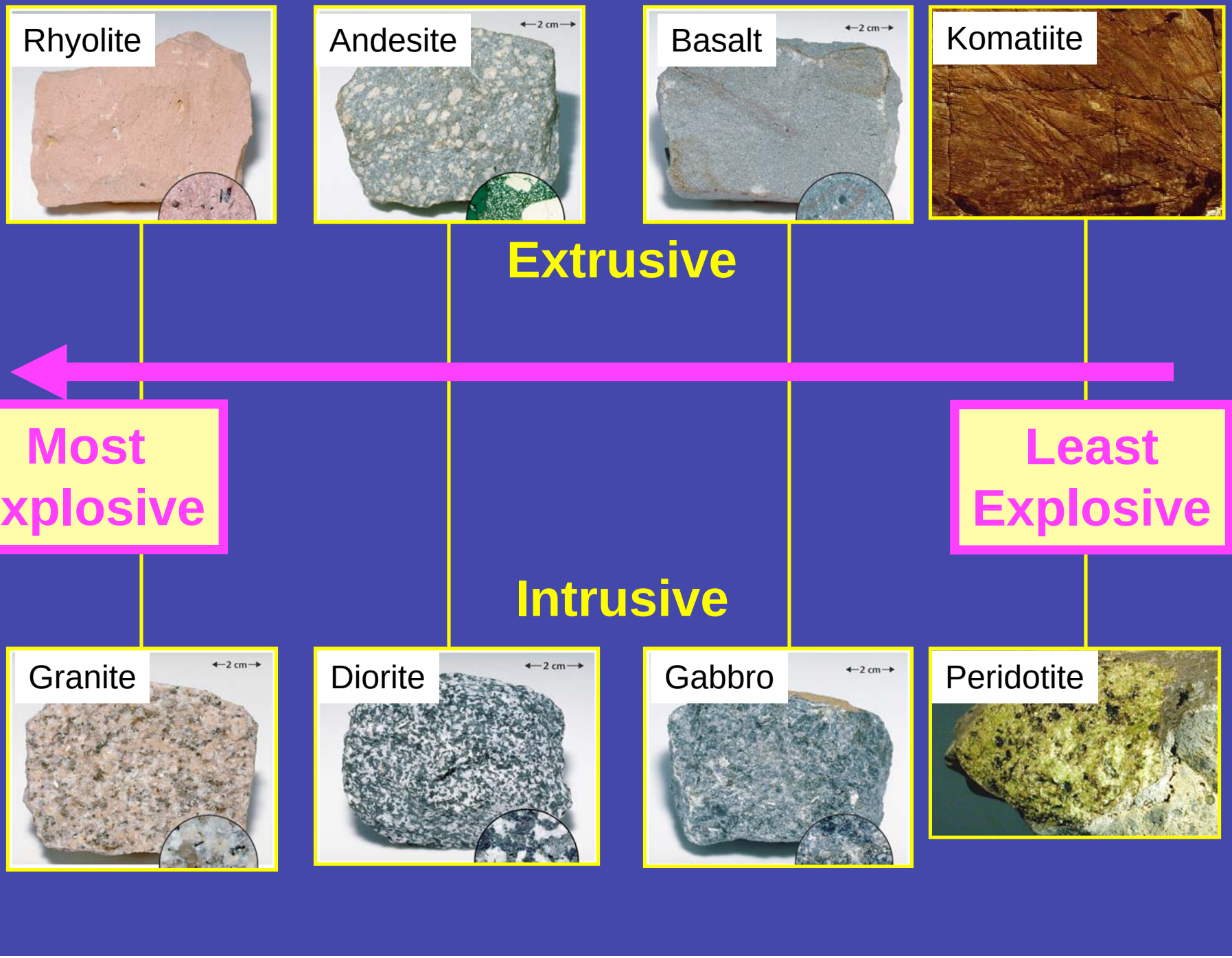
700°C — Temperature at which melting begins — 1200°C

**Convergent Boundary**
**Continental/**
**Island Arcs**

**Intra-continental**
**Yellowstone**
**Taupo**

**Divergent Boundary**
**Mid-Ocean Ridge**
**Continental rift**
**(Hot spots)**


Composition
Felsic (Granitic)
Intermediate (Andesitic)
Mafic (Basaltic)
Ultramafic
Rock types
Granite/Rhyolite
Diorite/Andesite
Gabbro/Basalt
Peridotite/Komatiite
100
Quartz
Potassium feldspar
Amphibole
Percent by volume
Most Explosive
Convergent Boundary
Continental/
Island Arcs
Least Explosive
Intra-continental
Yellowstone
Taupo
Divergent Boundary
Mid-Ocean Ridge
Continental rift
(Hot spots)
75%
Increasing silica ($SiO_2$)
40%
Increasing potassium and sodium
Increasing iron, magnesium and calcium
700°C
Temperature at which melting begins
1200°C


Rhyolite
Andesite
Basalt
Komatiite
Extrusive
Most Explosive
Least Explosive
Intrusive
Granite
Diorite
Gabbro
Peridotite