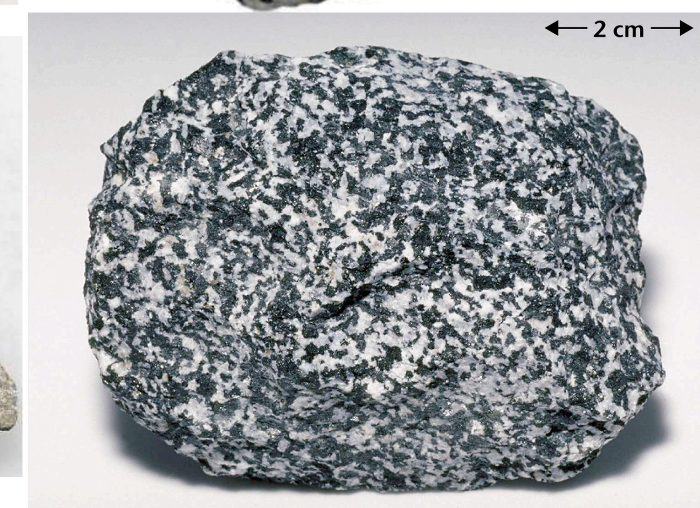
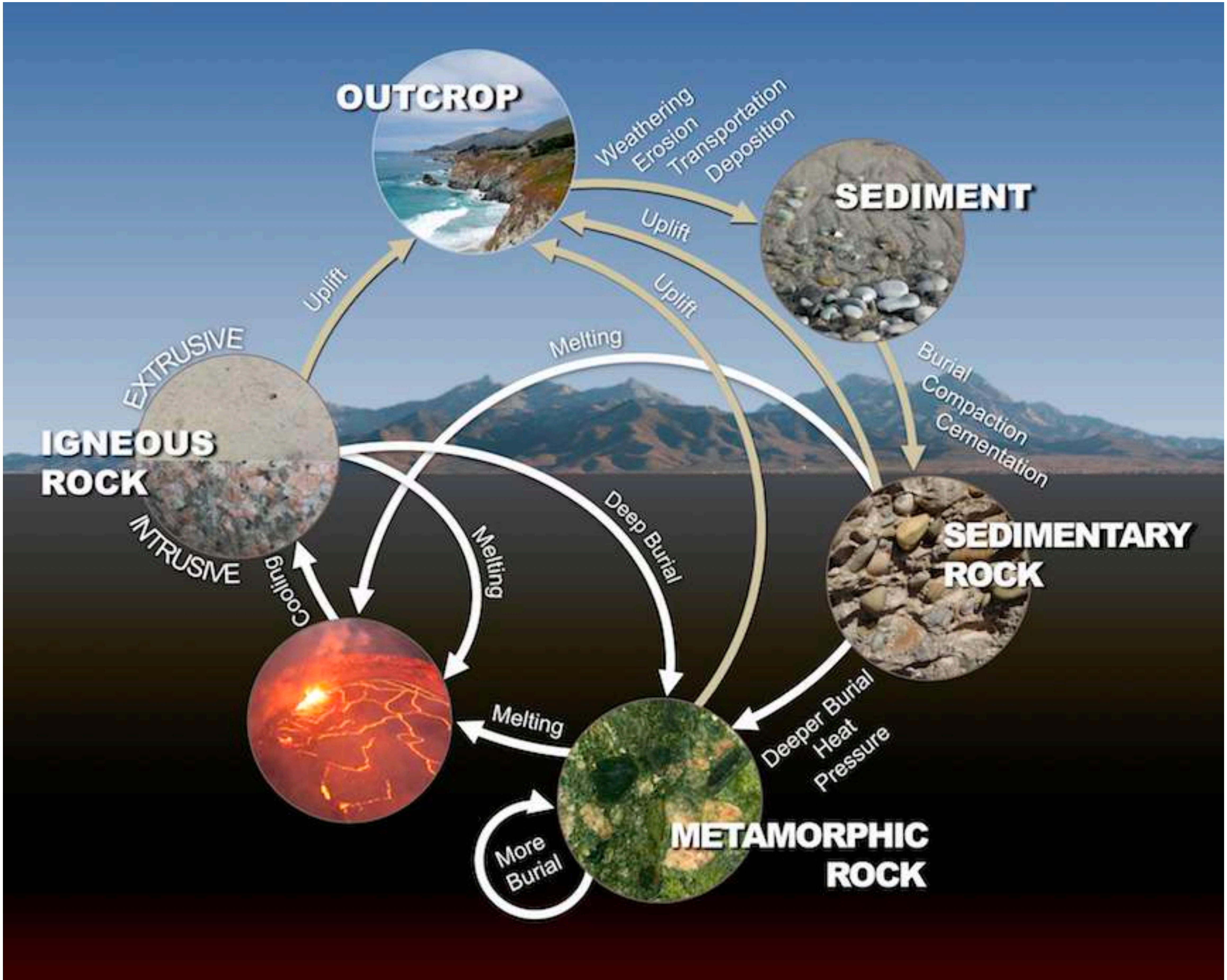
Lecture 6
Igneous Rocks

- Igneous Rocks
- Igneous Rock Textures
- Igneous Compositions
- Magma
- Intrusive Activity



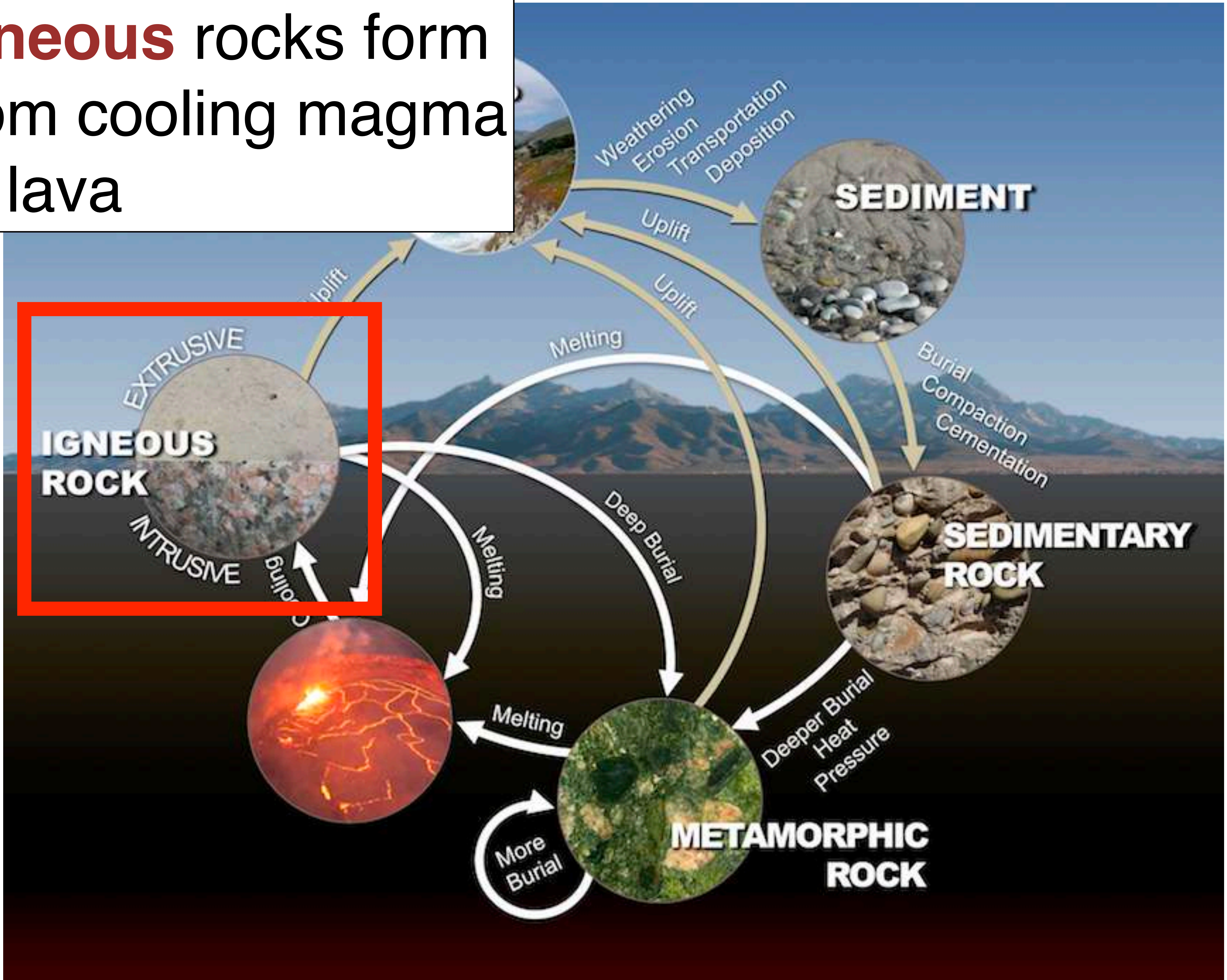
THE ROCK CYCLE



Igneous Rocks

THE ROCK CYCLE

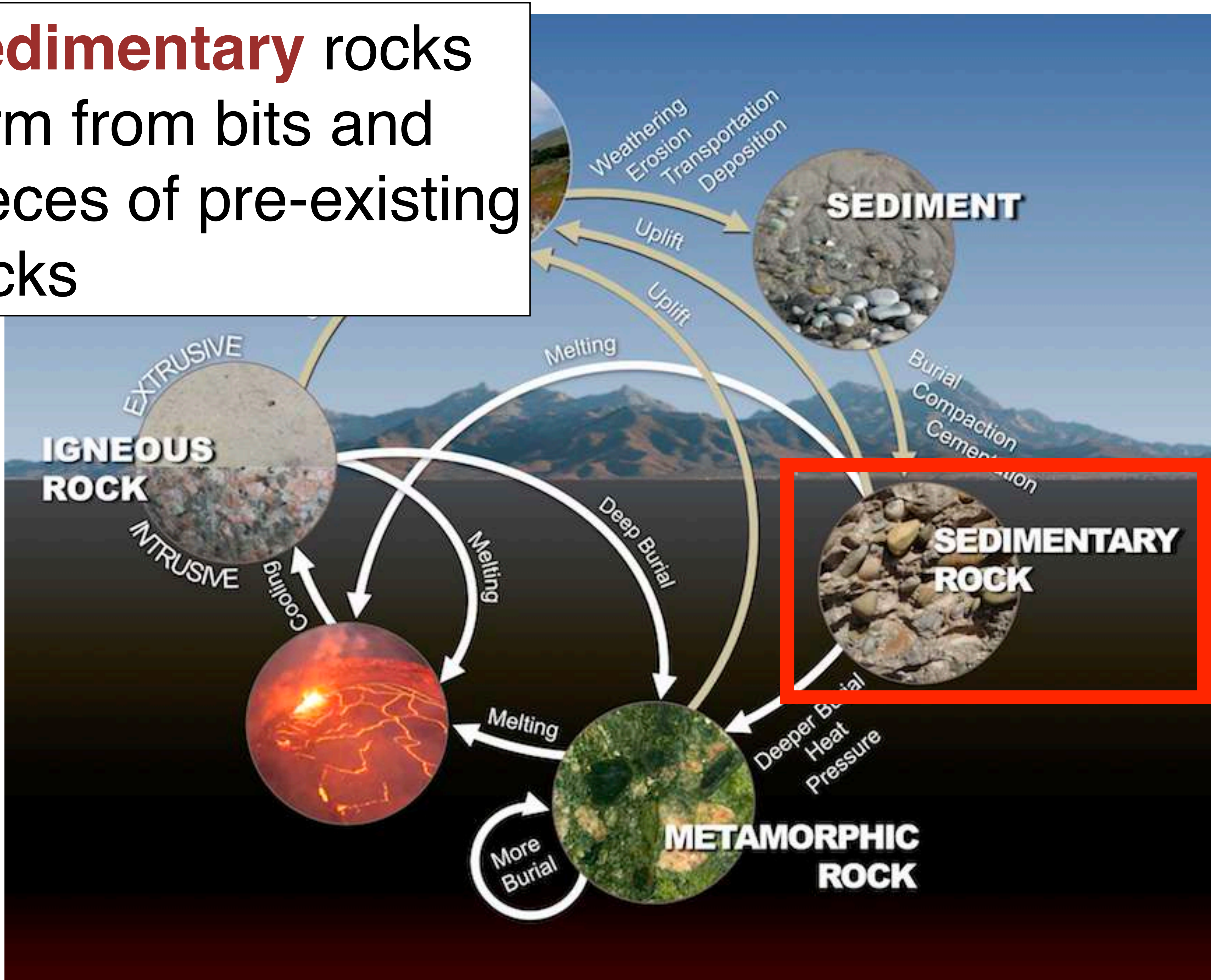
Igneous rocks form from cooling magma or lava



Igneous Rocks

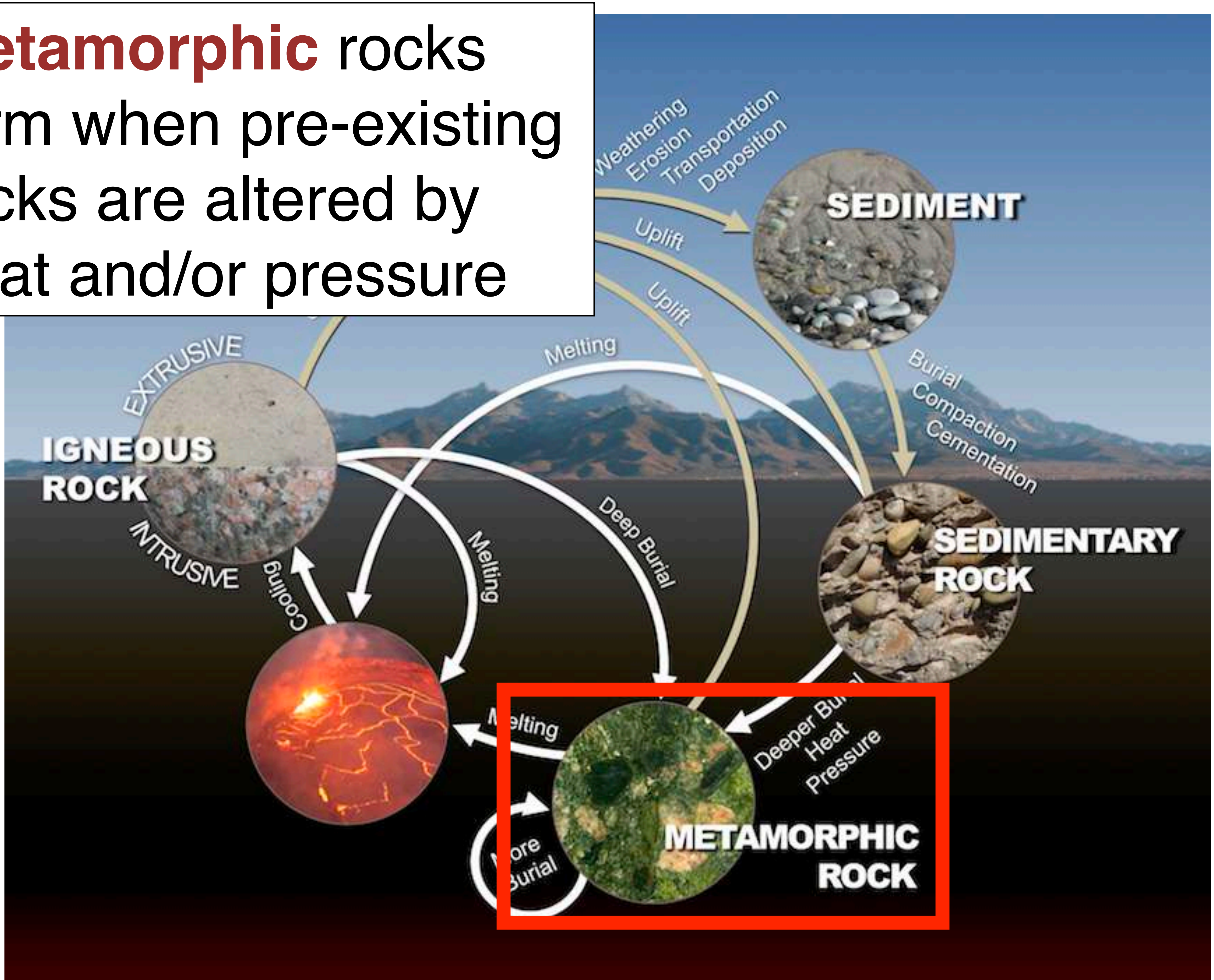
THE ROCK CYCLE

Sedimentary rocks form from bits and pieces of pre-existing rocks



THE ROCK CYCLE

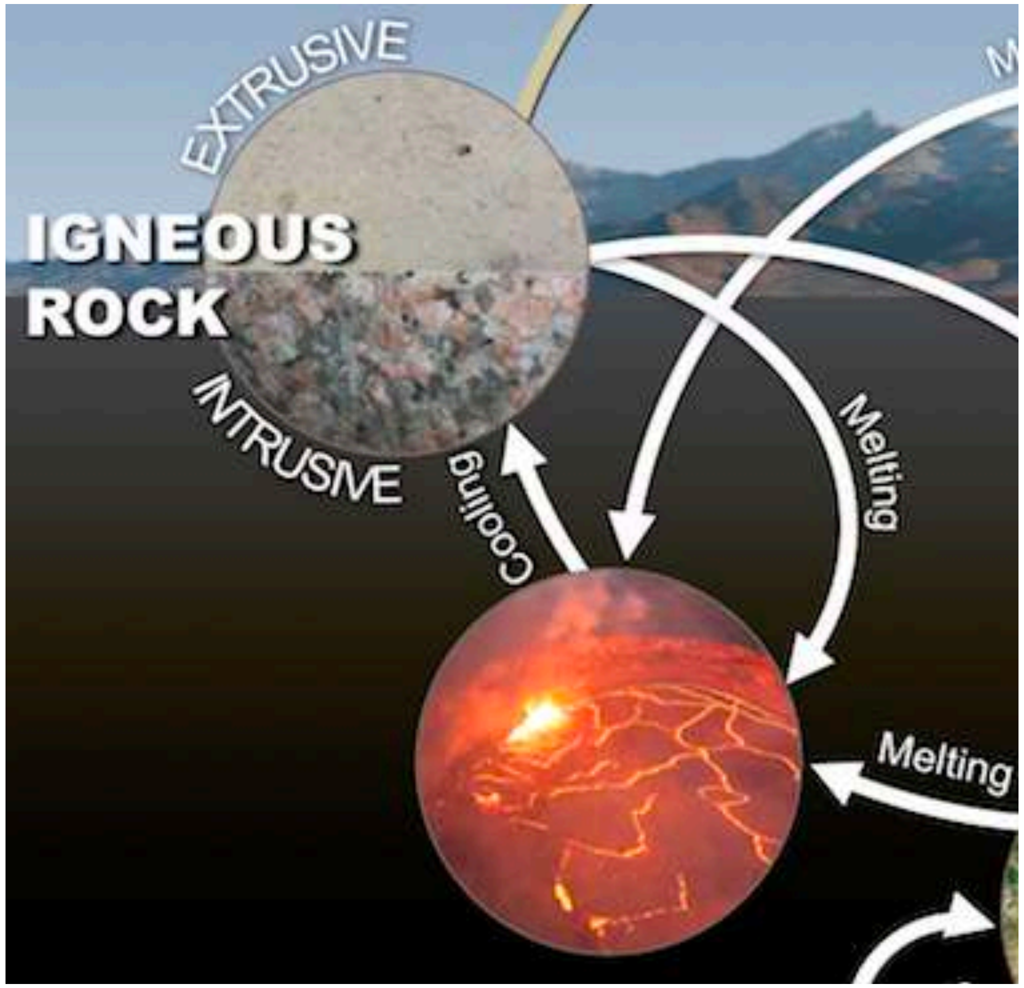
Metamorphic rocks form when pre-existing rocks are altered by heat and/or pressure



Igneous Rocks

Igneous rocks form from cooling magma or lava

- **Intrusive**
- **Extrusive**

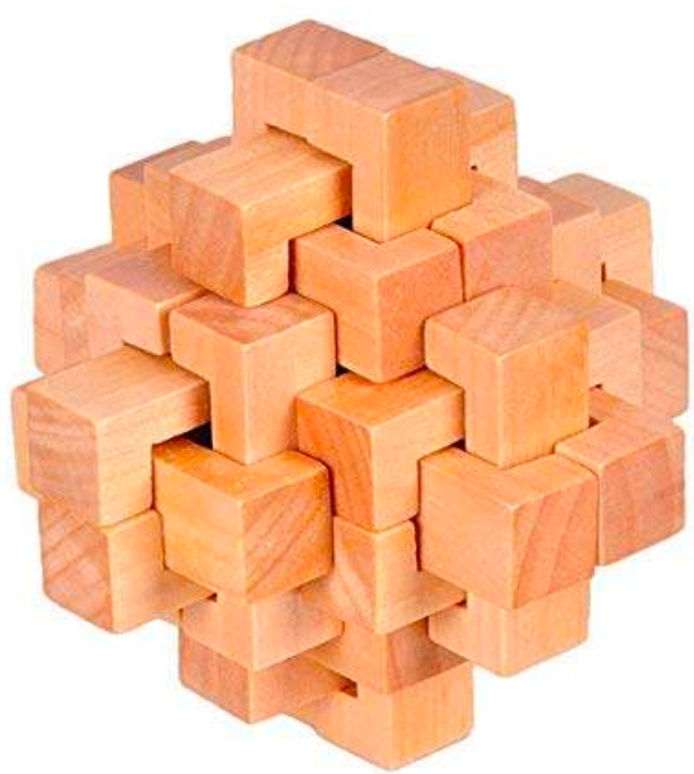


Igneous Rocks

- **Magma/lava** is completely or partially melted material:
  - **Melt** – Liquid portion
  - **Solids** – Minerals present in magma
  - **Volatiles** – Dissolved gasses in magma
    - Substances that easily evaporate

Igneous Rocks

- **Crystallization -** Formation of mineral grains as magma/lava cools
- As magma cools, **ions** slow down and arrange themselves into orderly **crystalline structures**
  - Minerals
- Grains are interlocking



Igneous Rock Textures

- **Texture** refers to how a rock looks
- In igneous rocks, texture refers to the mineral grain size
- Igneous textures are controlled by:
  - **Rate at which magma cools**
  - The amount of silica present
  - The amount of dissolved gases present
- Cooling rates can be slow or fast

Igneous Rock Textures

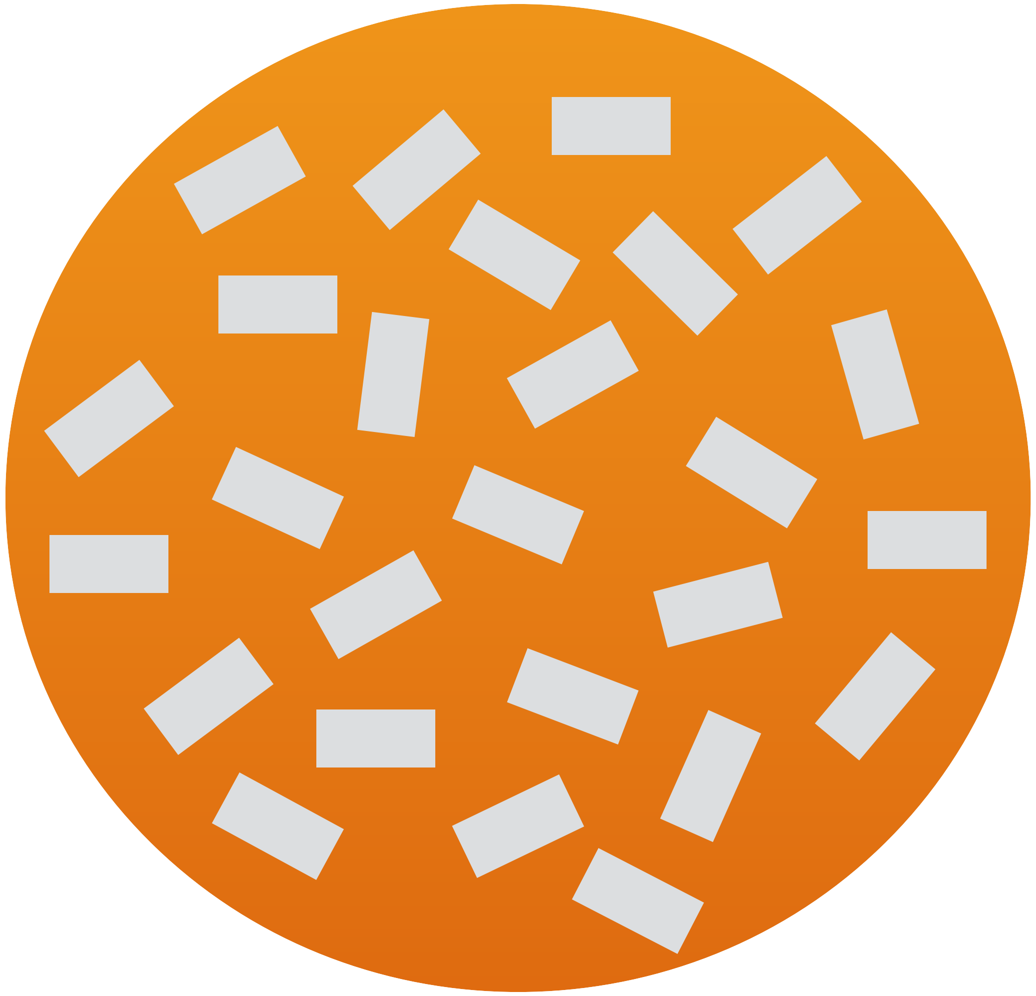
- These two rocks have the same minerals, but the size of the mineral grains are very different (different textures)
- Which one do you think cooled slowly?

Igneous Rock Textures

- **Slow cooling** (thousands to millions of years)
  - Few areas of mineral generation
  - Large minerals that can be seen
  - The slower the cooling, the larger the minerals
  - **Intrusive** (plutonic) igneous rocks

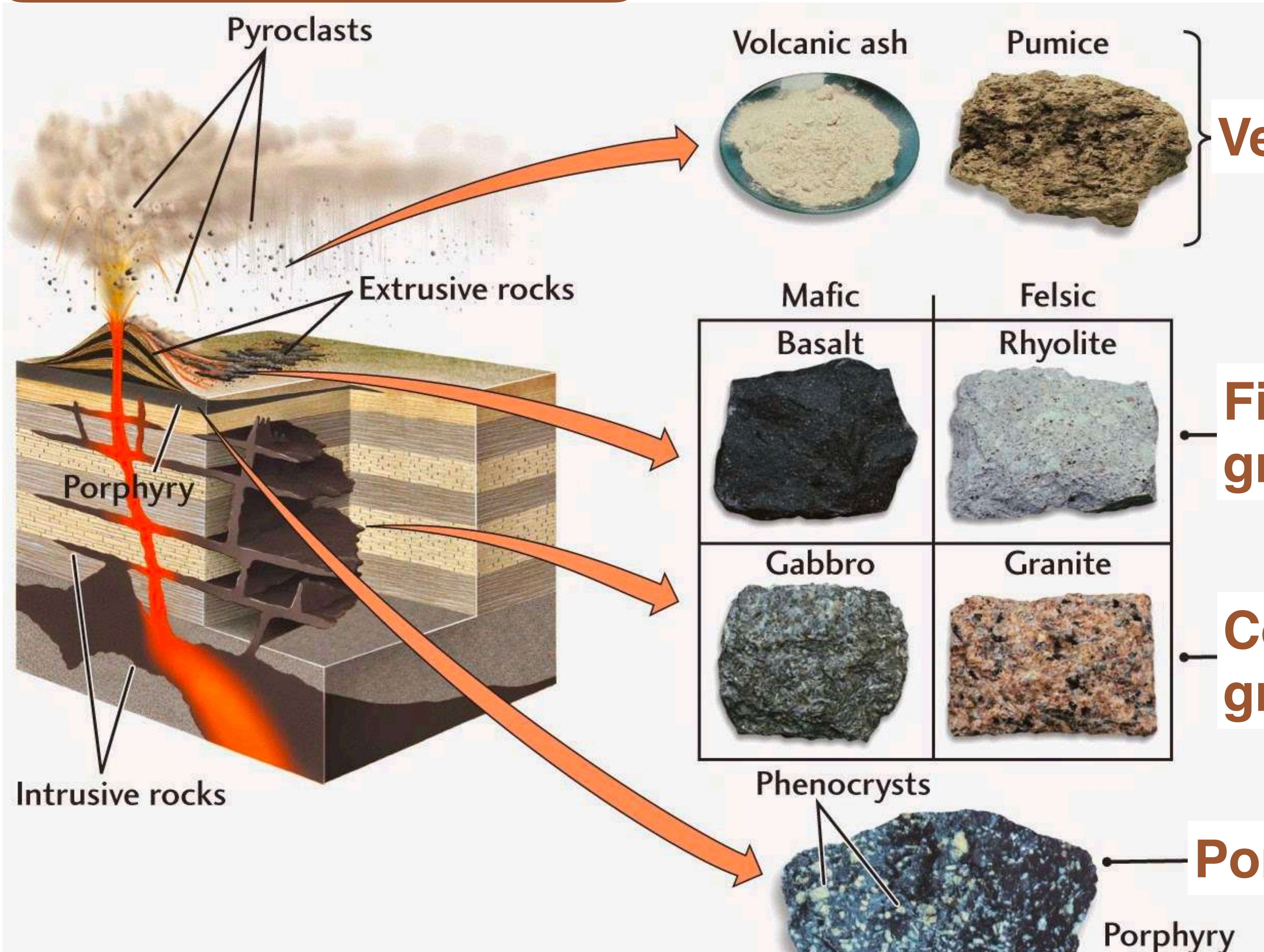
Igneous Rock Textures

- **Fast cooling** (days to years)
  - Many areas of mineral generation
  - Many small minerals that can only be seen with magnification
  - The faster the cooling, the smaller the minerals
  - **Extrusive** (volcanic) igneous rocks



Igneous Rock Textures

Textures



Vesicular

Fine-grained

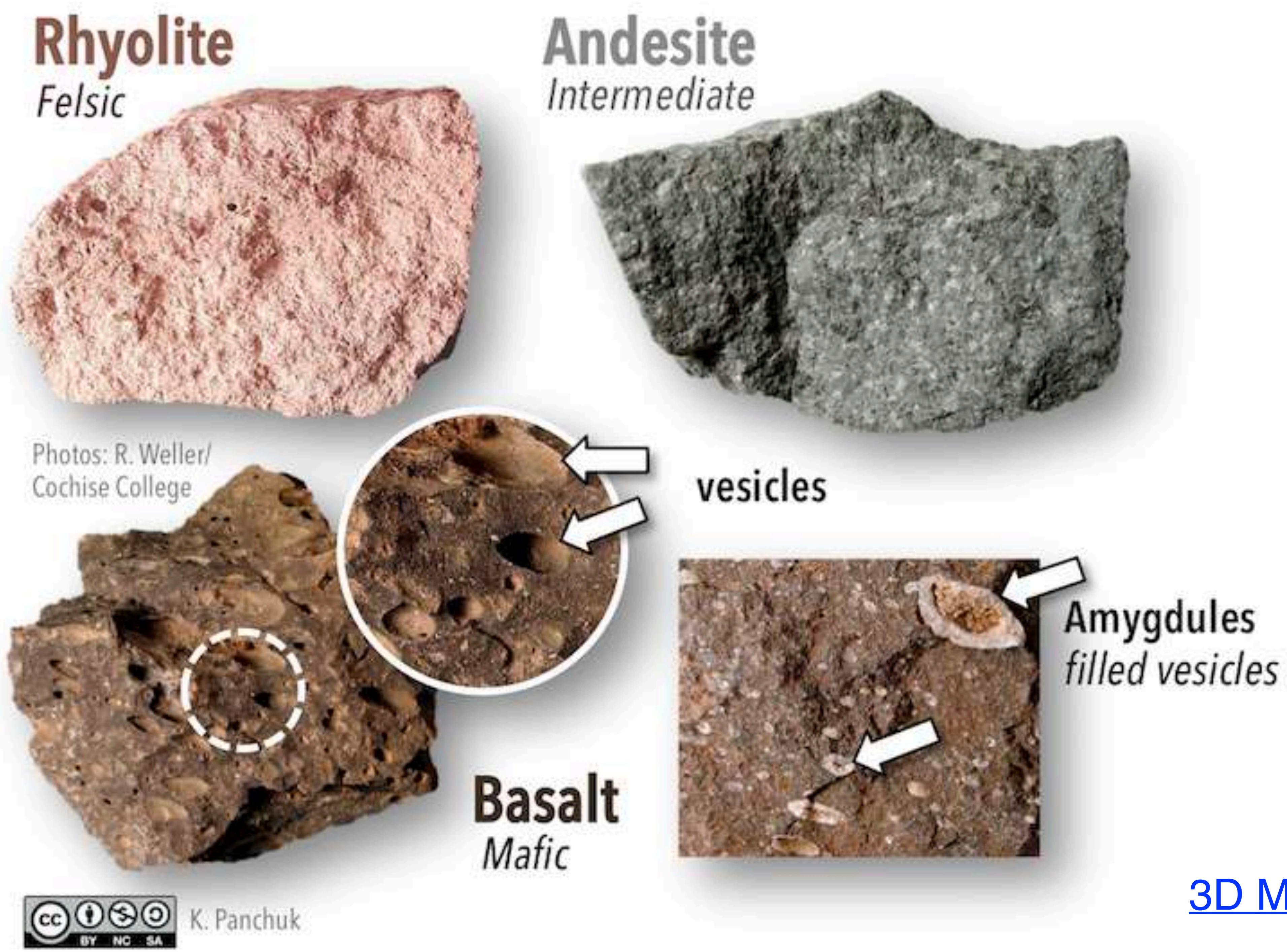
Coarse-grained

Porphyritic

Glassy Texture (not pictured)

Igneous Rock Textures

Fine-grained



3D Model

Coarse-grained

Diorite

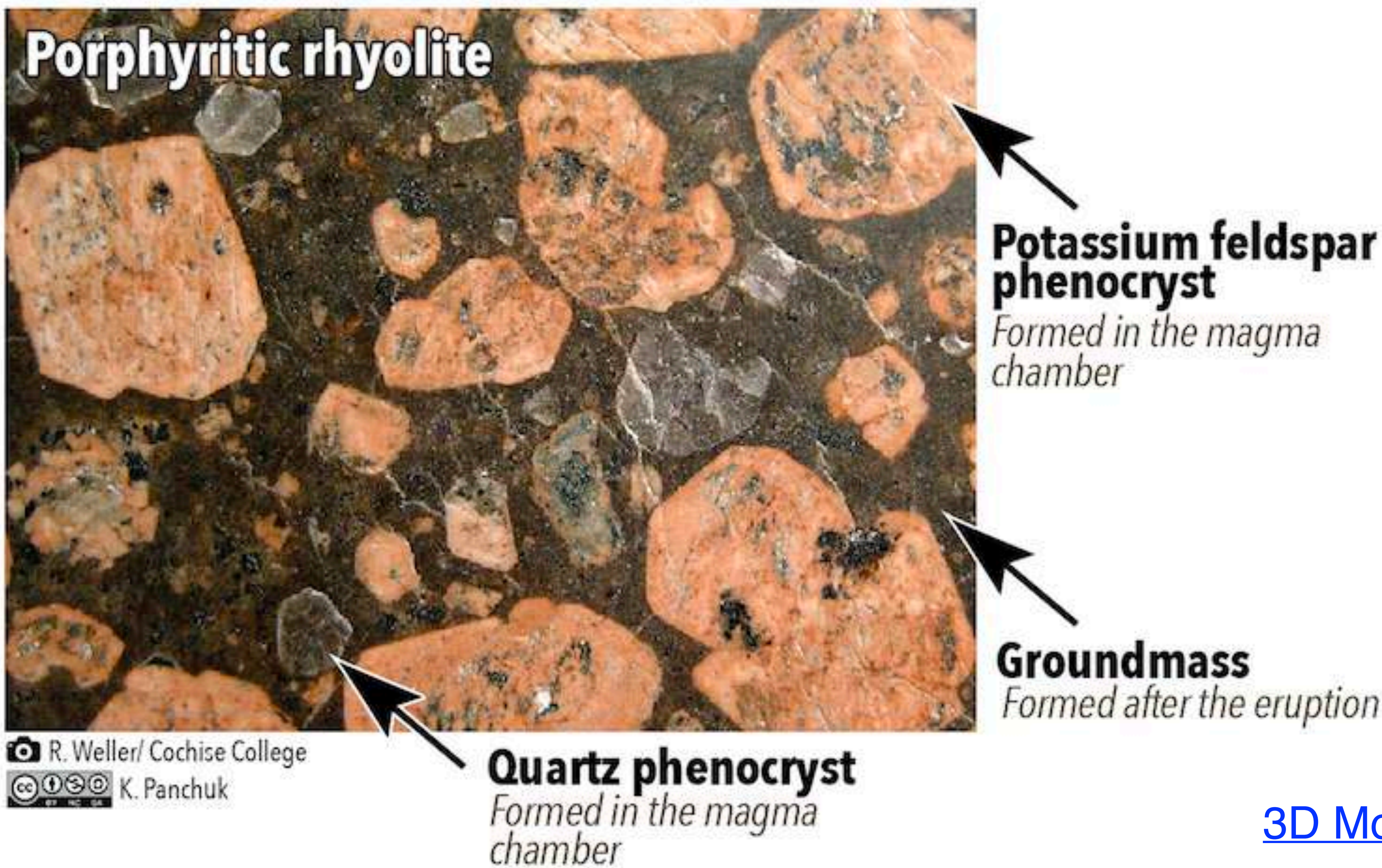
Granite

Pegmatite

Gabbro

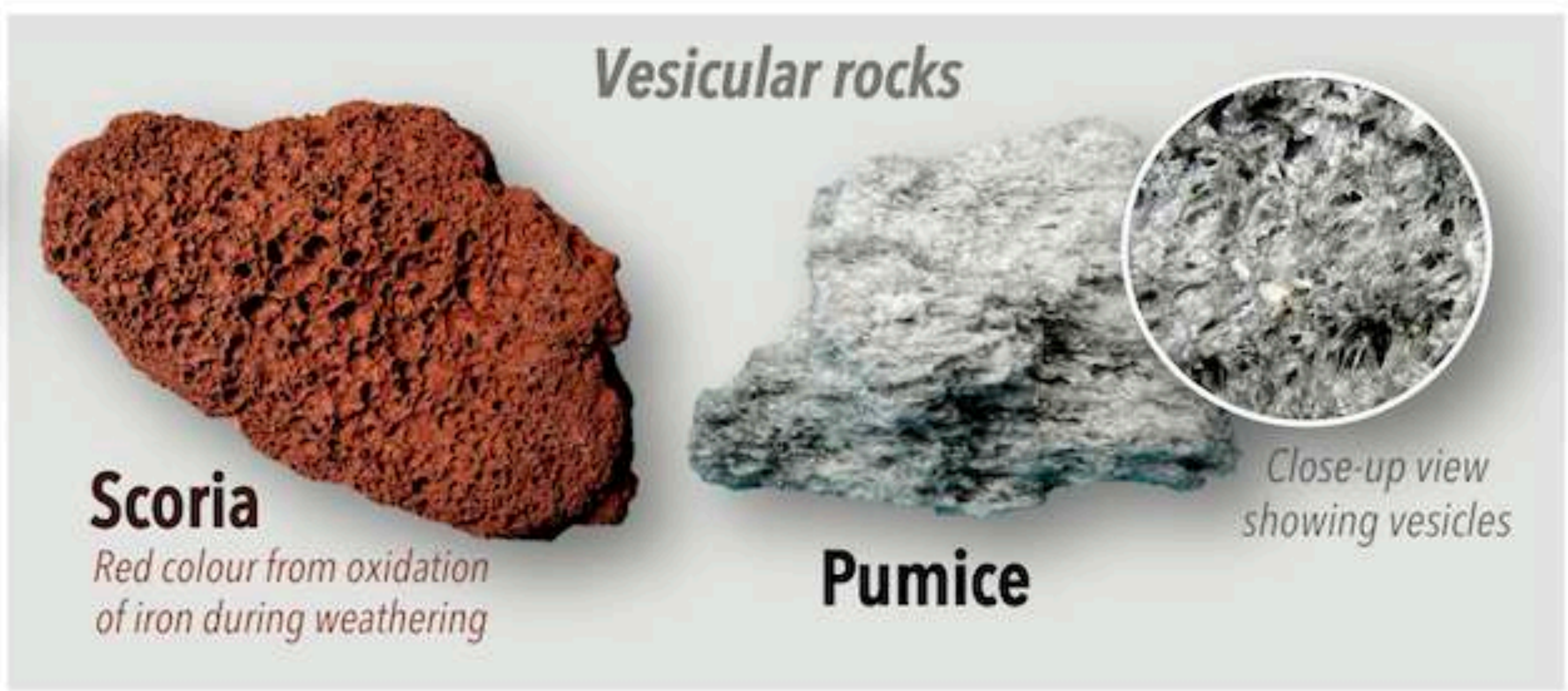
3D Model

Porphyritic



[3D Model]

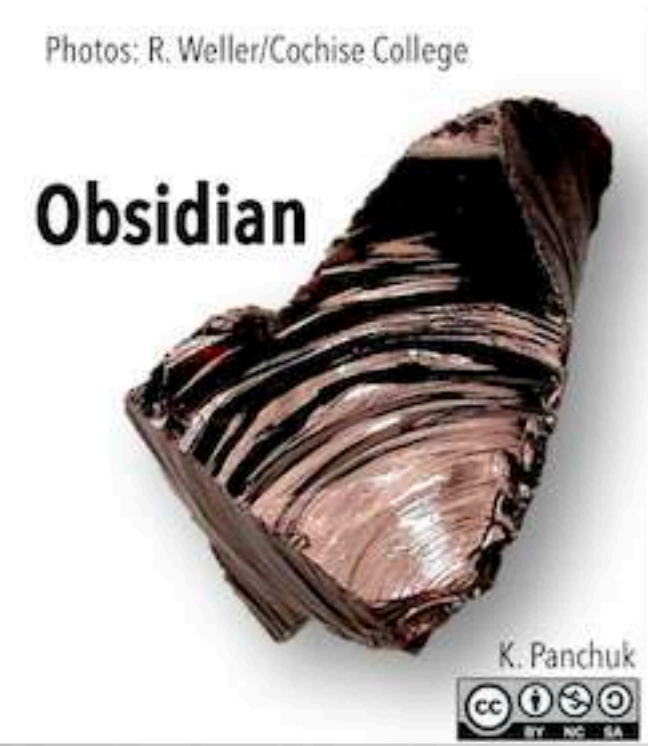
Vesicular



[3D Model]

Igneous Rock Textures

Glassy



3D Model

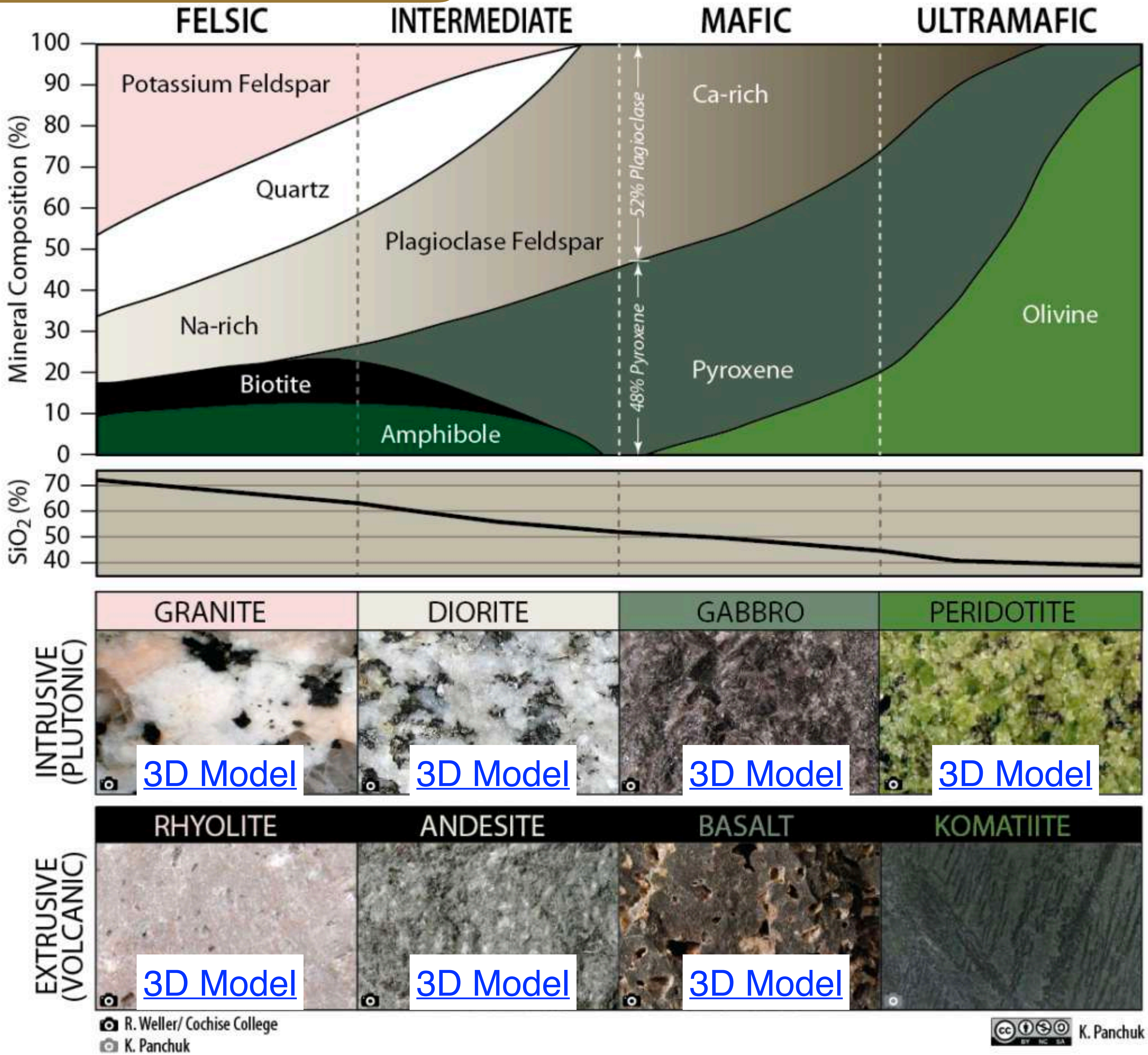
Igneous Compositions

- Chemical compositions of igneous rocks are controlled by the chemistry of the magma
- Broadly defined by relative abundances of light **(felsic)** and dark **(mafic)** minerals

Compositions:

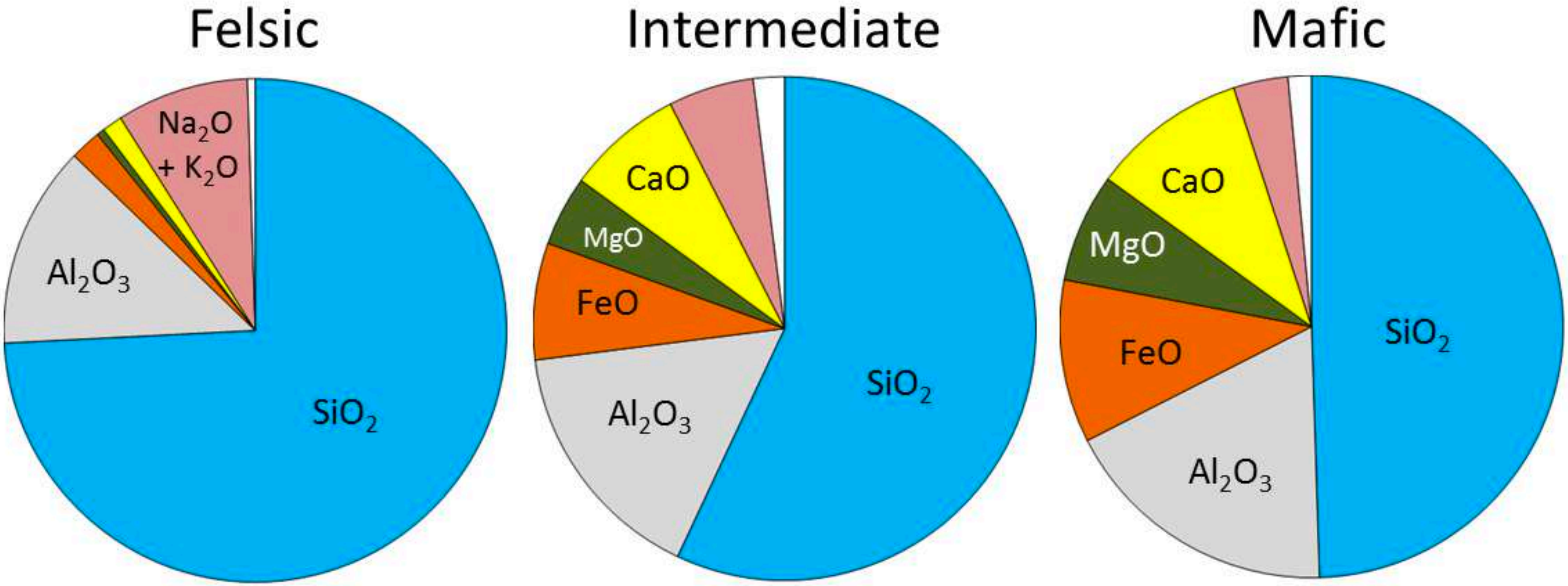
- Ultramafic
- Mafic
- Intermediate
- Felsic

Igneous Compositions



Igneous Compositions

Ultramafic not pictured

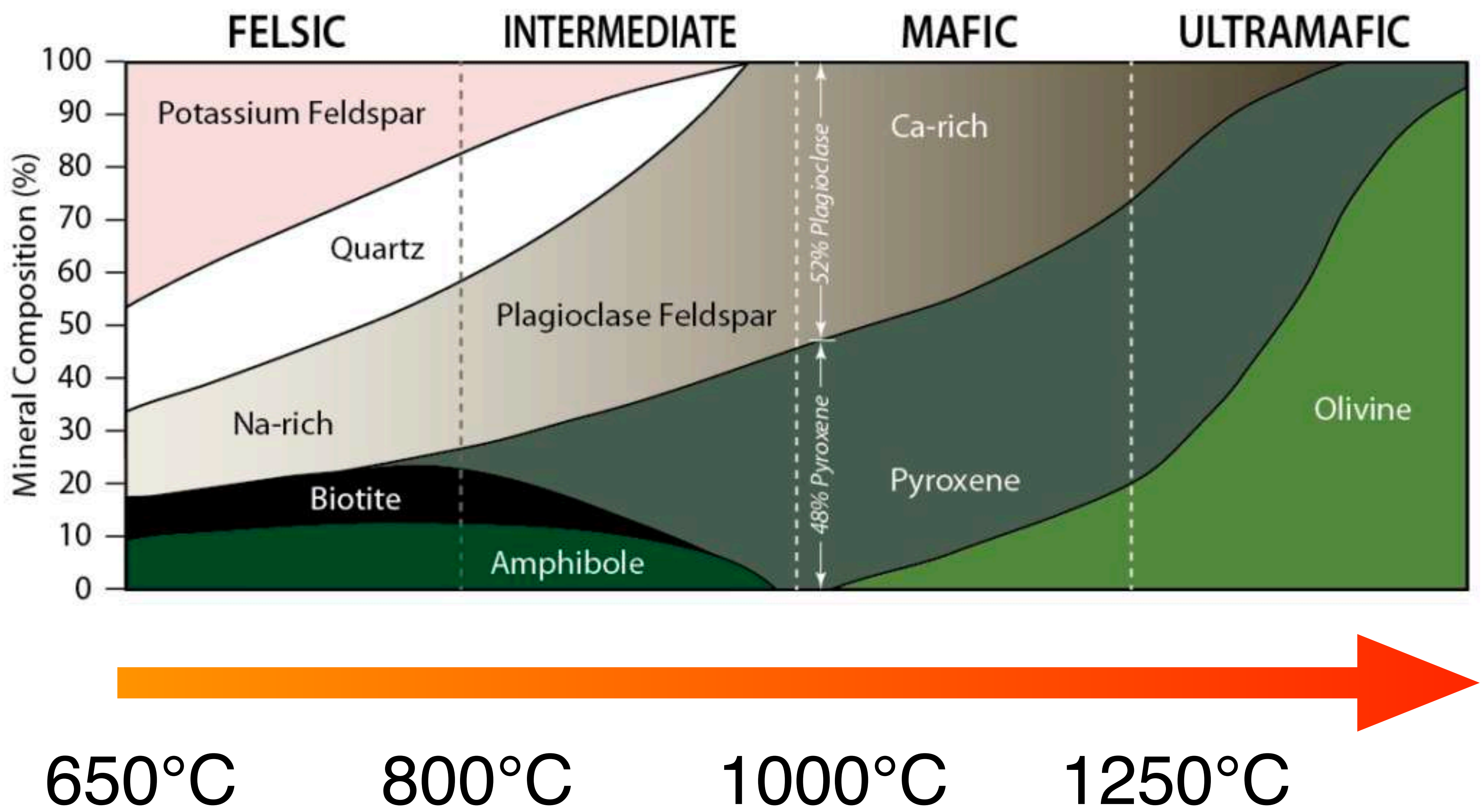


Important Trends:

Silica content *increases* from mafic to felsic

Fe, Mg, Ca content *decreases* from mafic to felsic

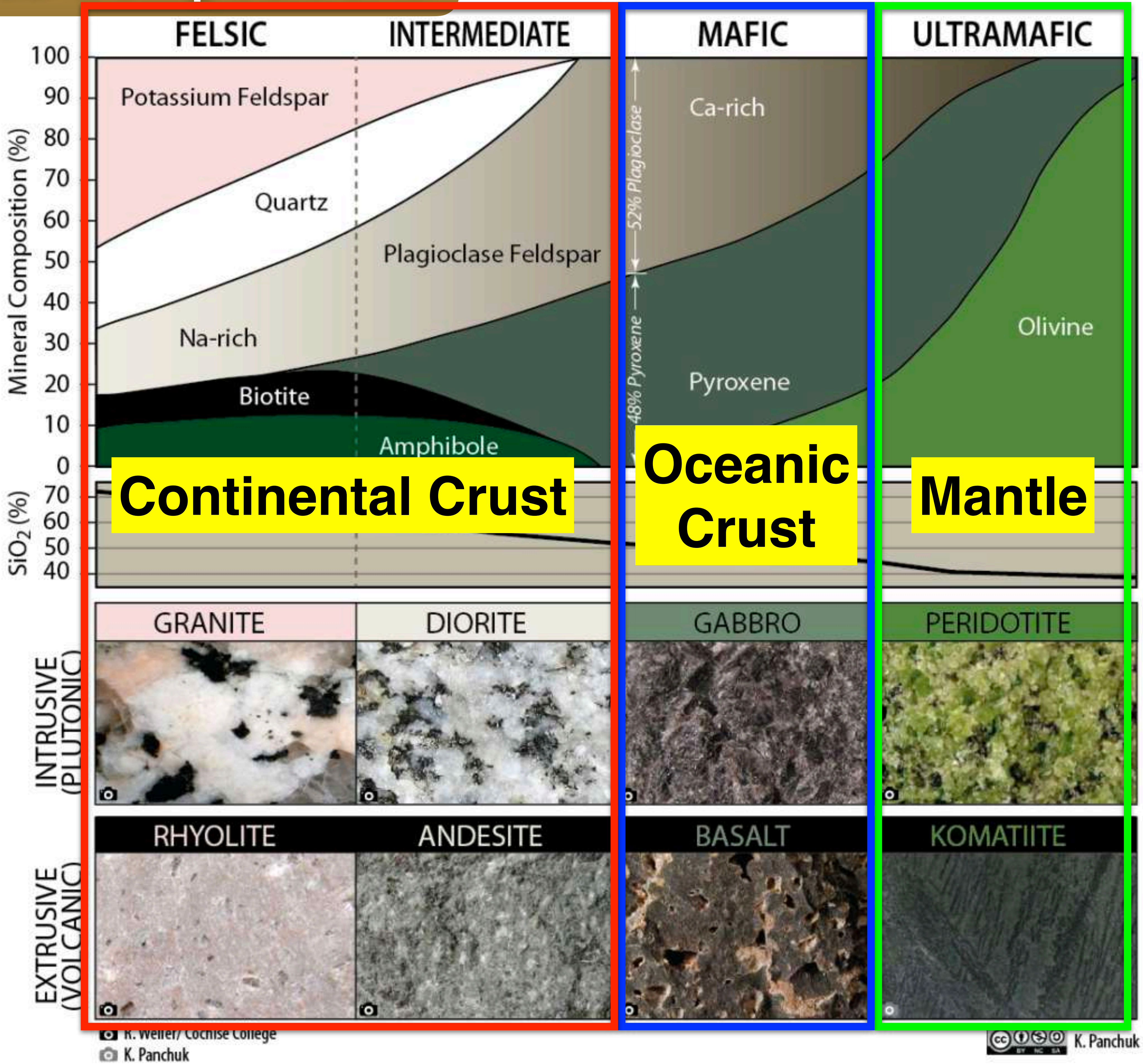
Igneous Compositions



Temperature rock forms *decreases* from ultramafic to felsic

- Mafic rocks form at a higher temperature than felsic rocks

Igneous Compositions



Igneous Compositions

Felsic - Intermediate - Mafic

Coarse-grained - Fine-grained

Igneous Compositions

Felsic - Intermediate - Mafic

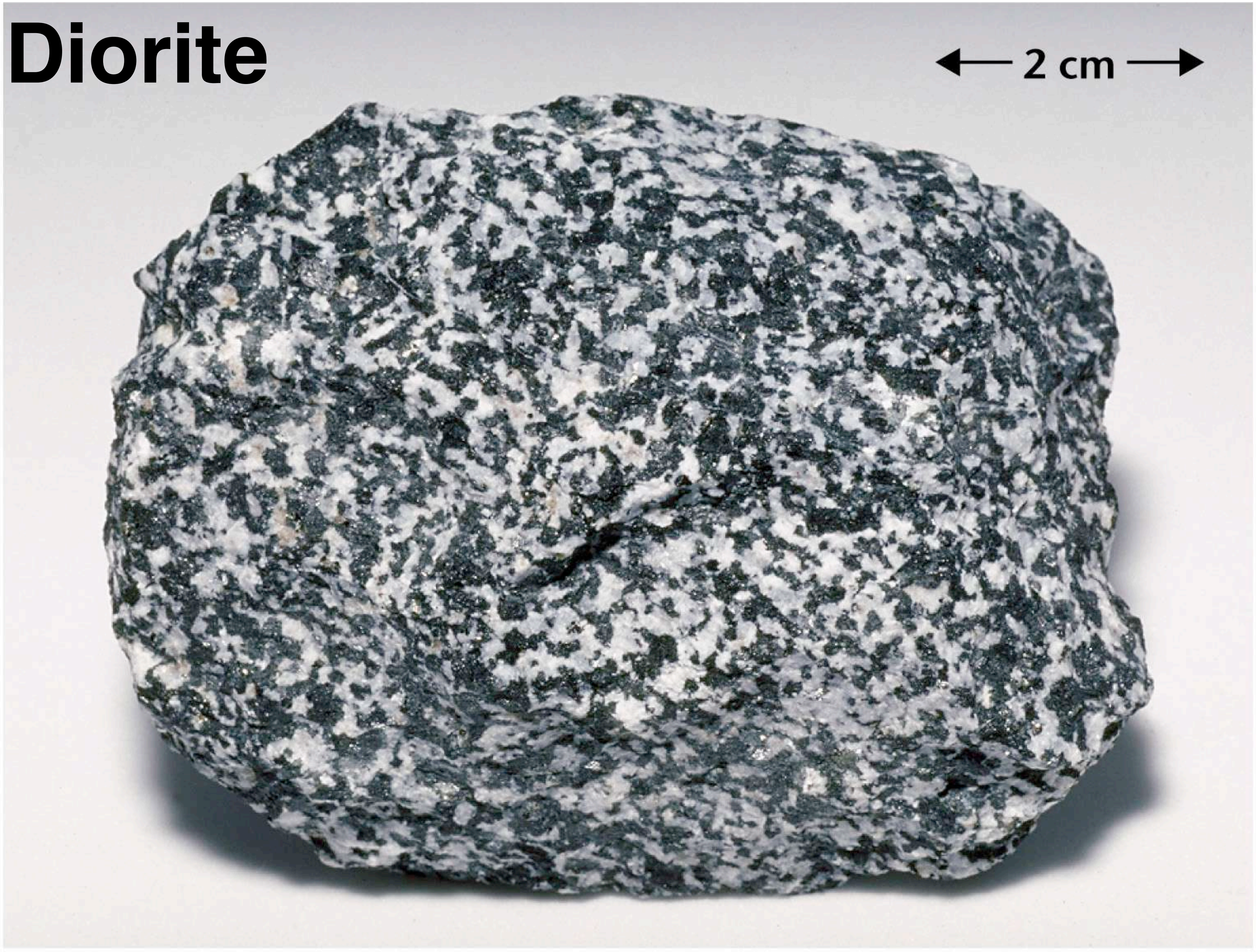
Coarse-grained - Fine-grained

Basalt

Igneous Compositions

Felsic - Intermediate - Mafic

Coarse-grained - Fine-grained



Igneous Compositions

Felsic - Intermediate - Mafic

Coarse-grained - Fine-grained

Rhyolite

Igneous Compositions

Felsic - Intermediate - Mafic

Coarse-grained - Fine-grained

Granite

Igneous Compositions

Felsic - $\boxed{\text{Intermediate}}$ - Mafic

Coarse-grained - $\boxed{\text{Fine-grained}}$

Andesite

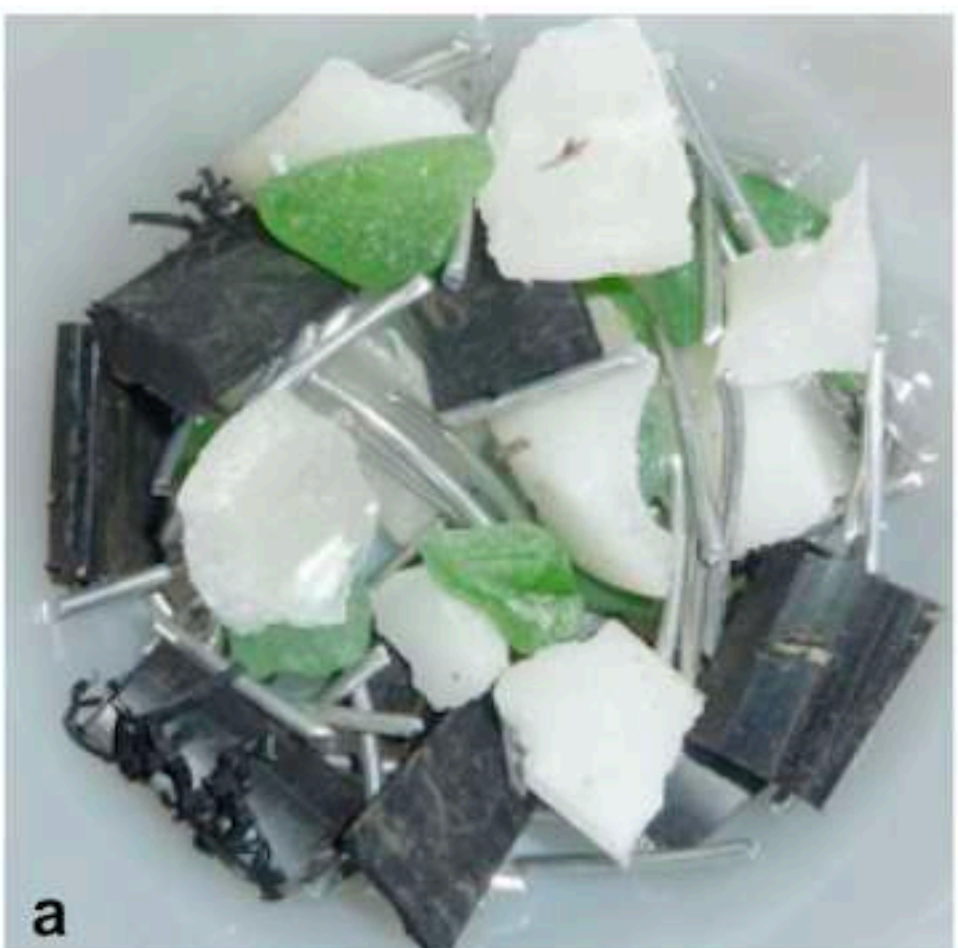
Magma

- Magmas are created when rocks in the mantle or crust melt
- Different rocks melt at different temperatures
- **Partial melting** - minerals with lower melting points will be the first to start melting
  - Silica-rich minerals, like quartz and feldspars, begin melting at lower temperatures than Fe- and Mg-rich minerals

Magma

Original composition

- white candle wax
- black plastic
- green glass
- aluminum wire



Heated to 50°C

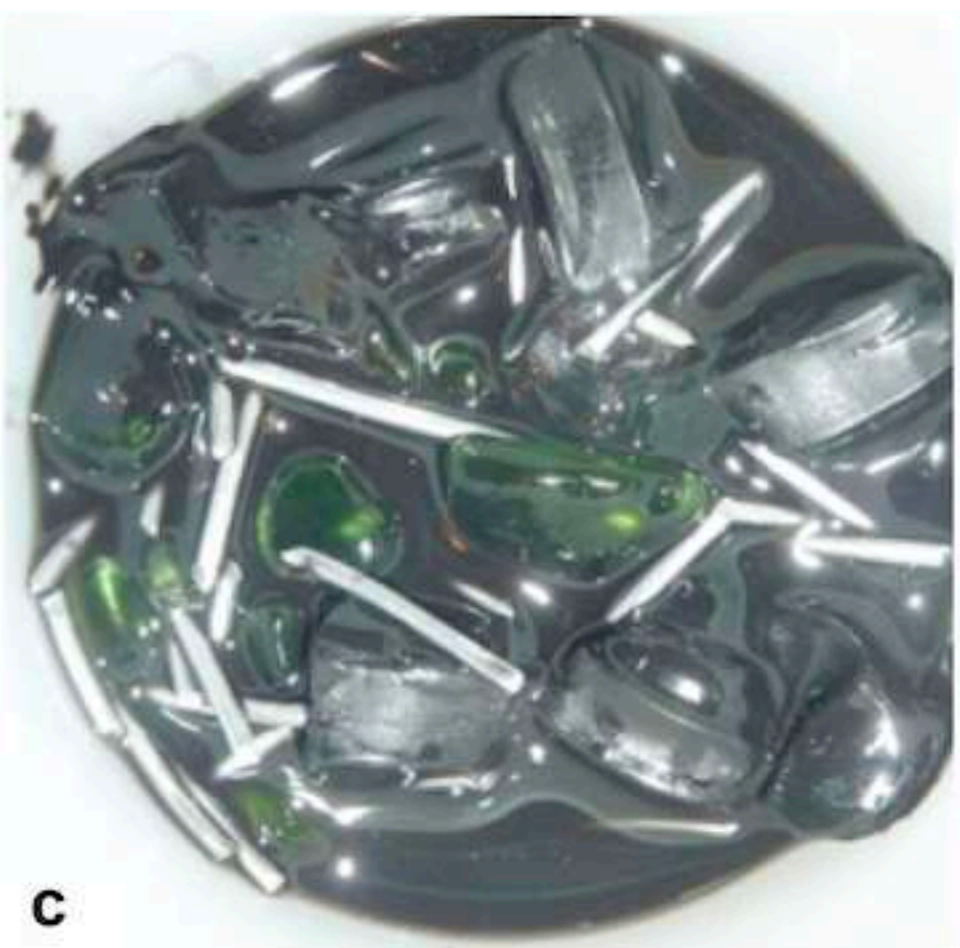
- ~~white candle wax~~
- black plastic
- green glass
- aluminum wire

Magma

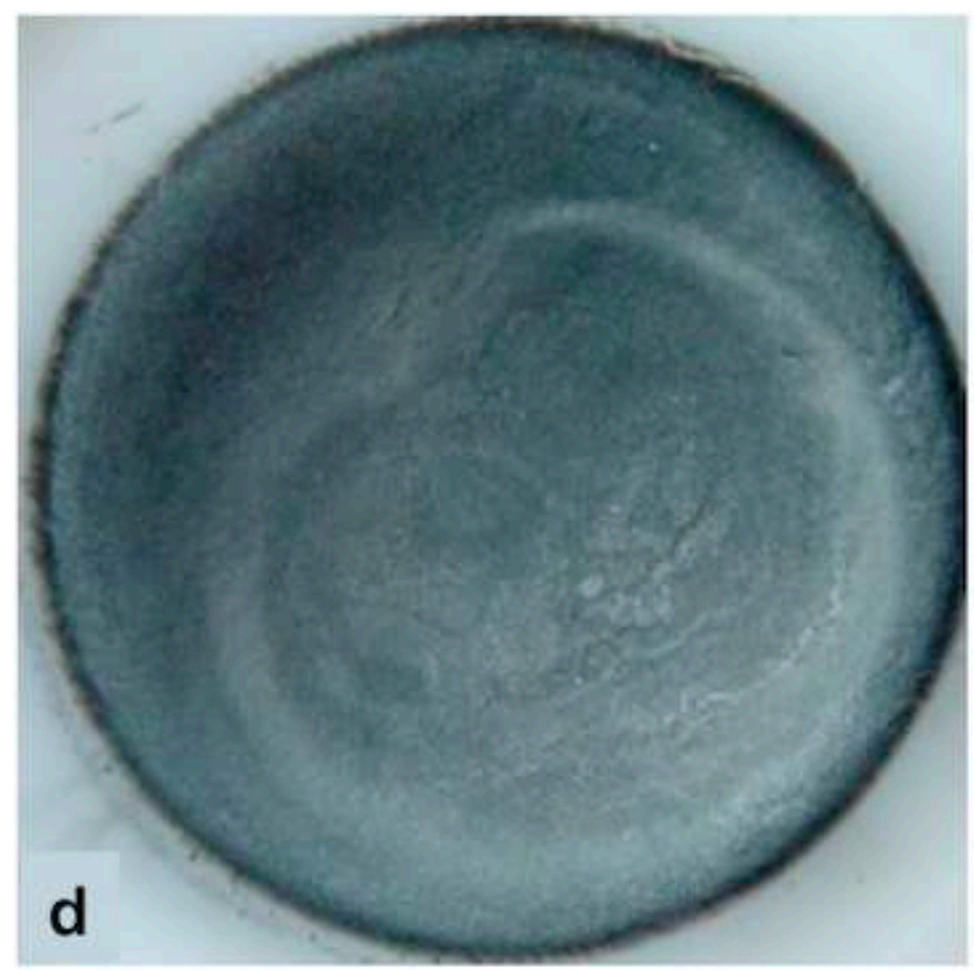
Heated to 120°C

- ~~white candle wax~~
- ~~black plastic~~
- green glass
- aluminum wire

- Wax and plastic liquid

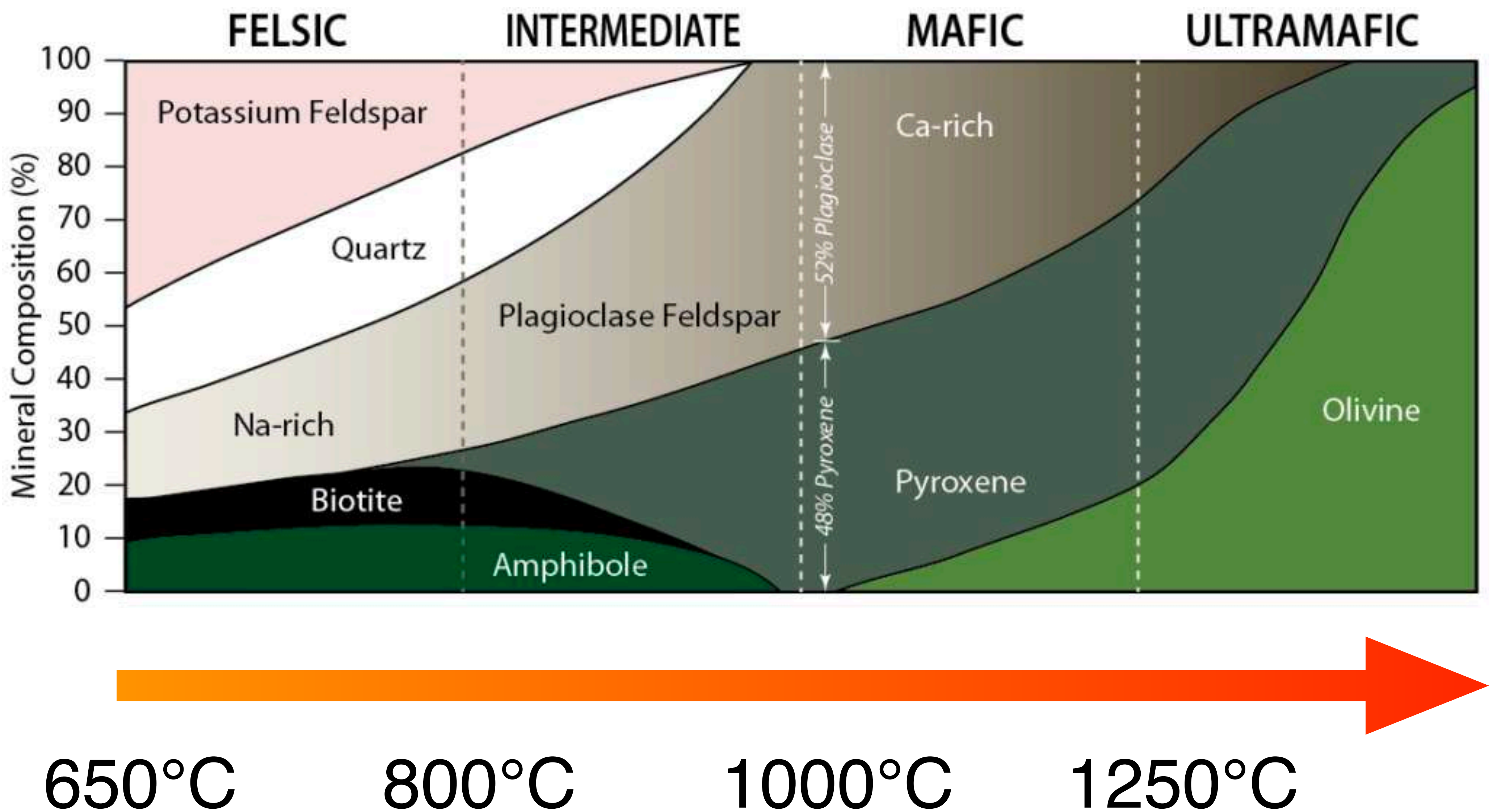


- Wax and plastic liquid poured off and cooled
- A solid with a different composition than the original mixture



Magma

Partial Melting - Minerals with the lowest melting points (more felsic) will be first to melt as you apply heat to a rock



Magma

Partial Melting - Minerals with the lowest melting points (more felsic) will be first to melt as you apply heat to a rock

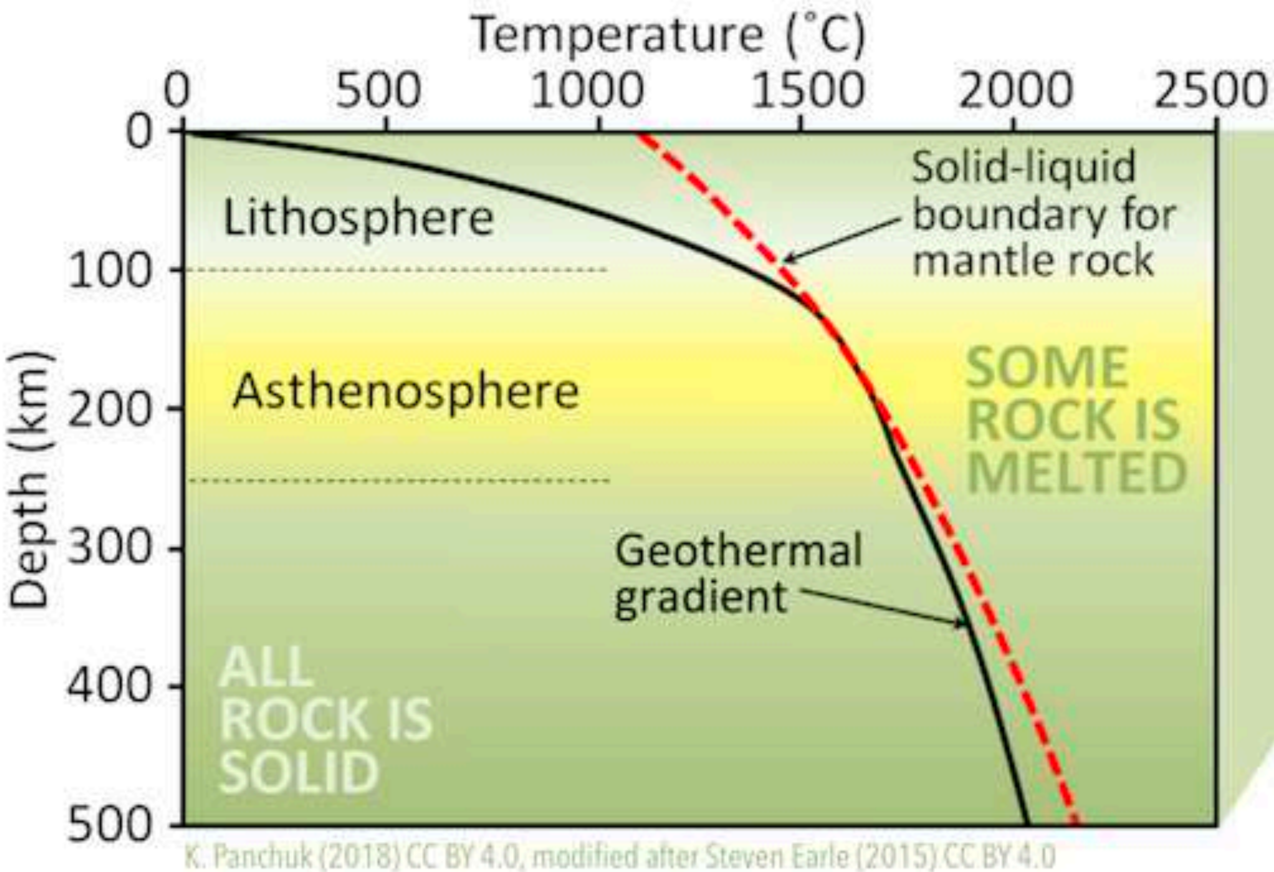
Partial Melting of:

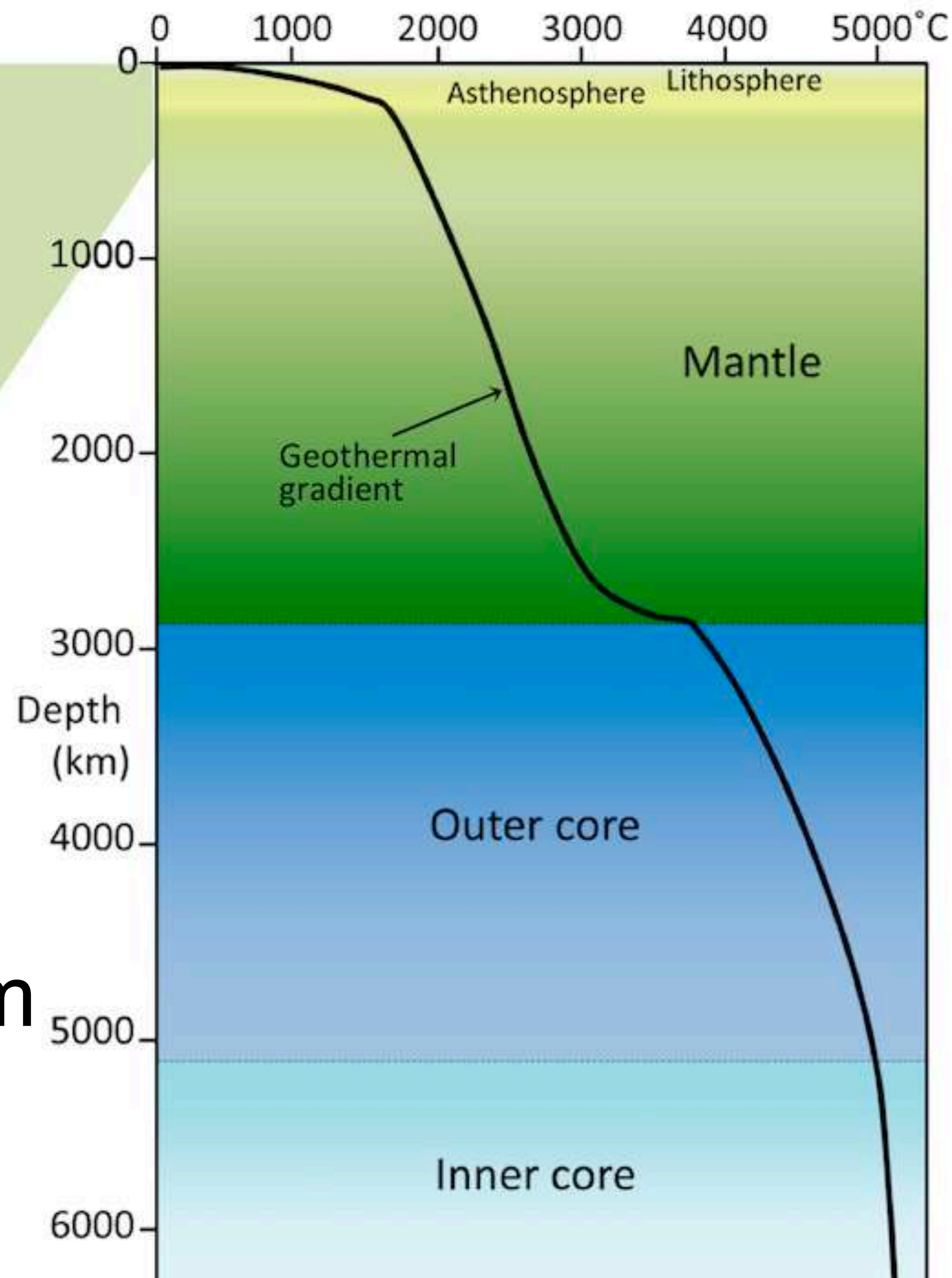
Ultramafic (mantle) → Mafic (oceanic crust)

Mafic → Intermediate (continental crust)

Intermediate → Felsic (continental crust)

Magma

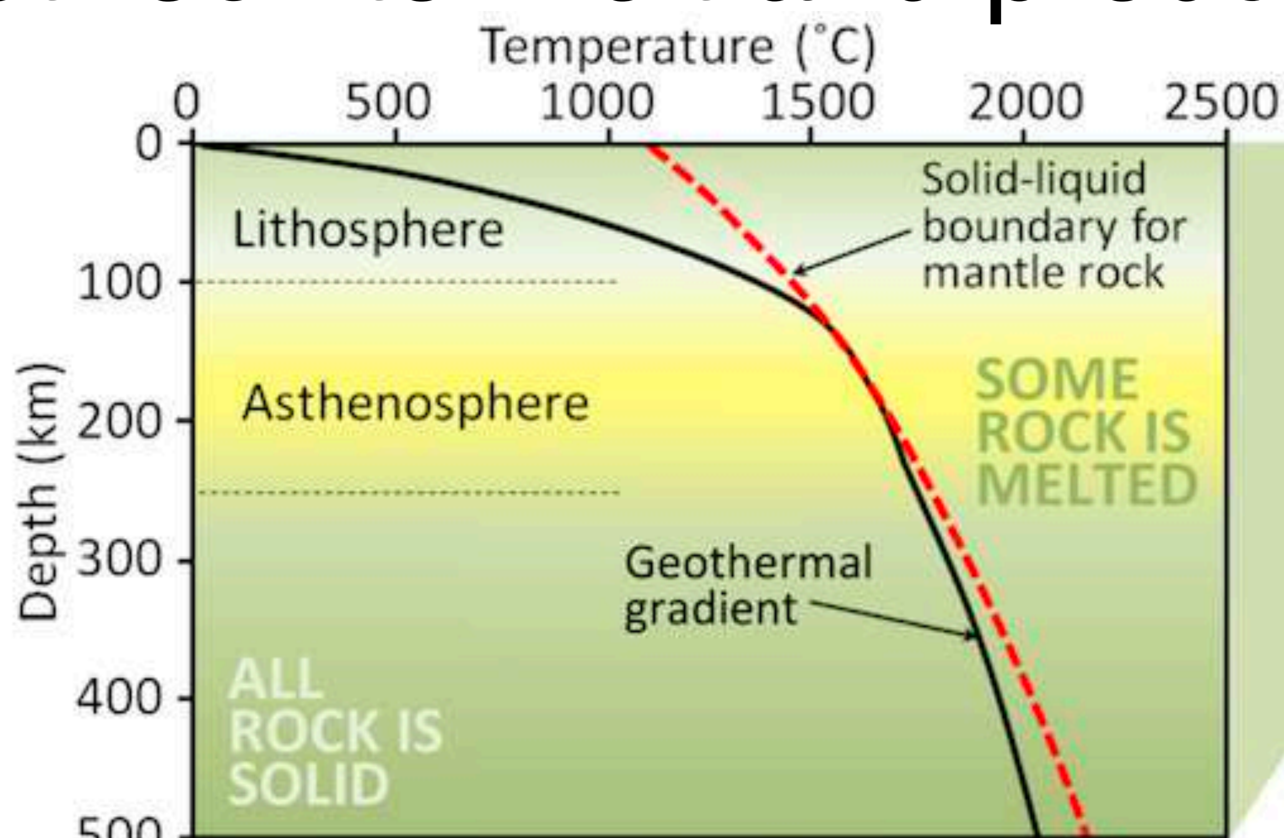




- Temperature increases with depth, called the **geothermal gradient**
- Lithosphere: 20-30°C/km
- By 100 km, T is 1200°C-1400°C

Magma

- Under normal conditions the crust and mantle are solid and do not melt
  - It doesn't get hot enough to melt
  - It gets close to melting in the asthenosphere, that's why it's "soft"
  - The only liquid layer is Earth's outer core
- How can you get rock to melt and produce magma?



Magma

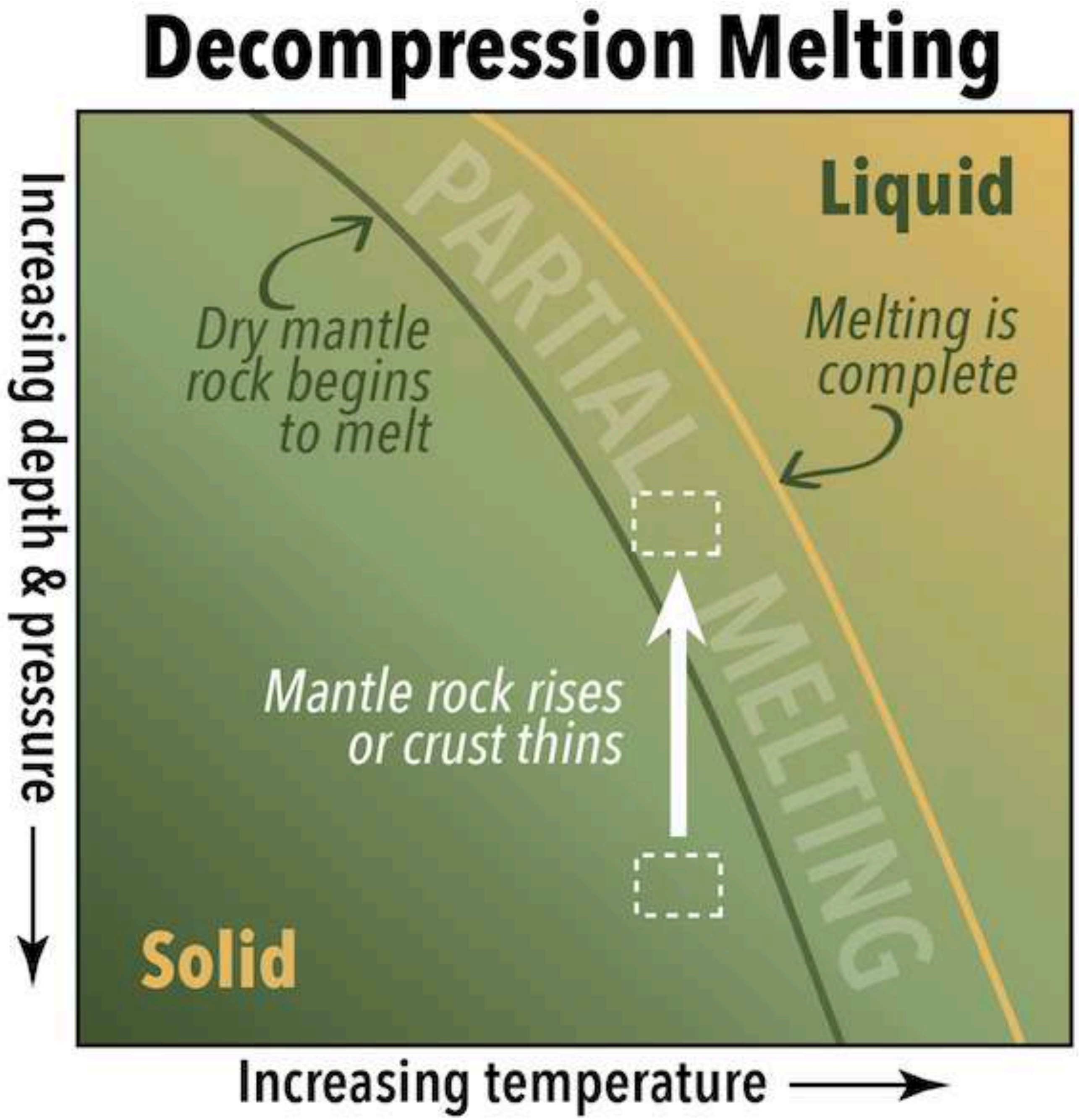
- How you get a rock to melt:
  - Increase **temperature**
  - Decrease **pressure**
  - Increase **volatiles**
    - Compounds/elements with low boiling points (water)

Magma

- Raise the temperature?
  - **Nope** - geothermal gradient is set
- Lower Pressure?
  - **Yes** - decreasing pressure will lower the melting point of hot rocks
  - Called decompression melting
- Add volatiles?
  - **Yes** - Water added to rocks in the earth will lower the rocks' melting point
  - Called flux melting
  - Volatiles are substances with low boiling points, like water and carbon dioxide

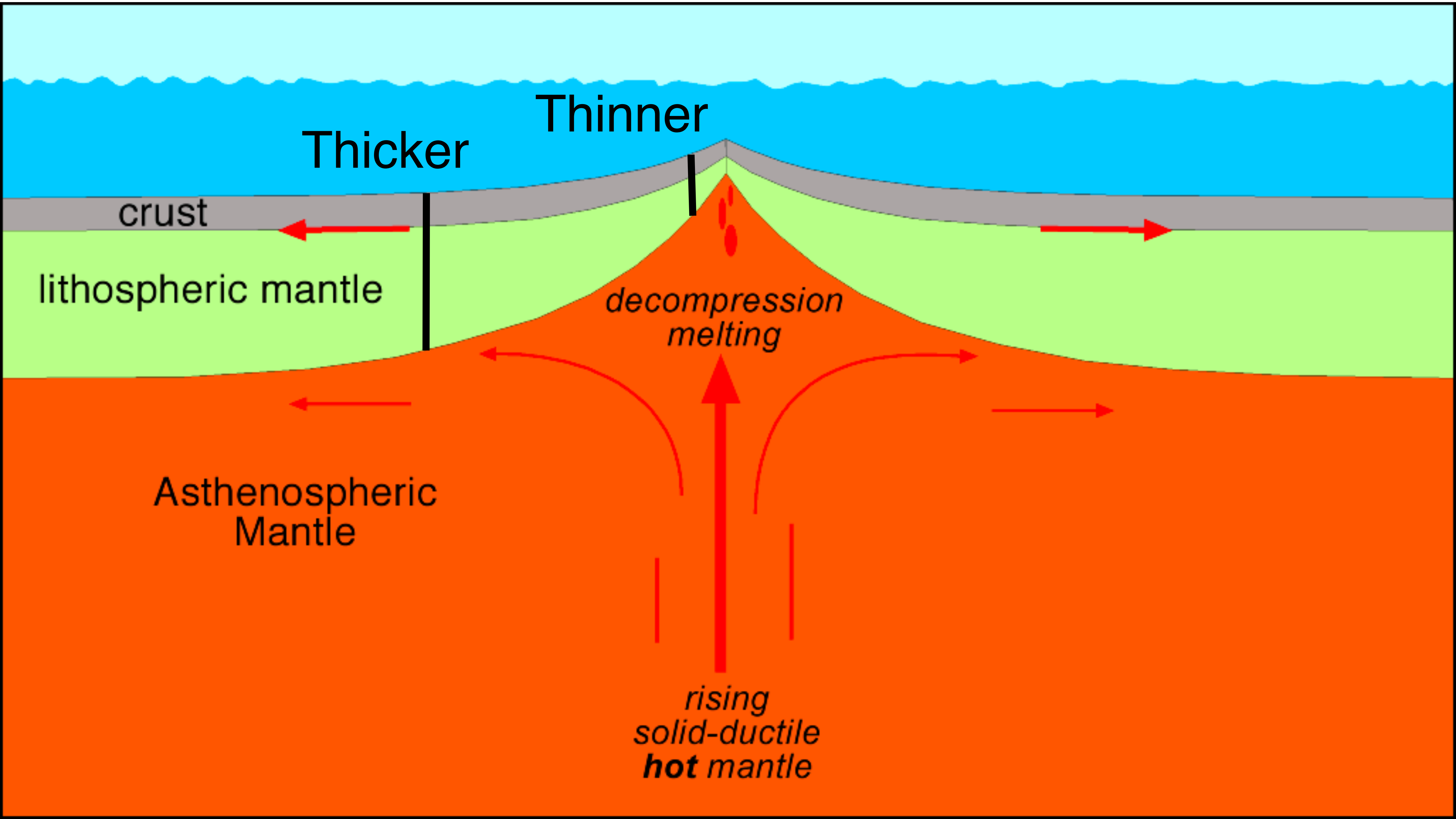
Magma

- **Decompression melting** - lowering the pressure on rock while maintaining a high temperature
  - Happens at divergent plate boundaries



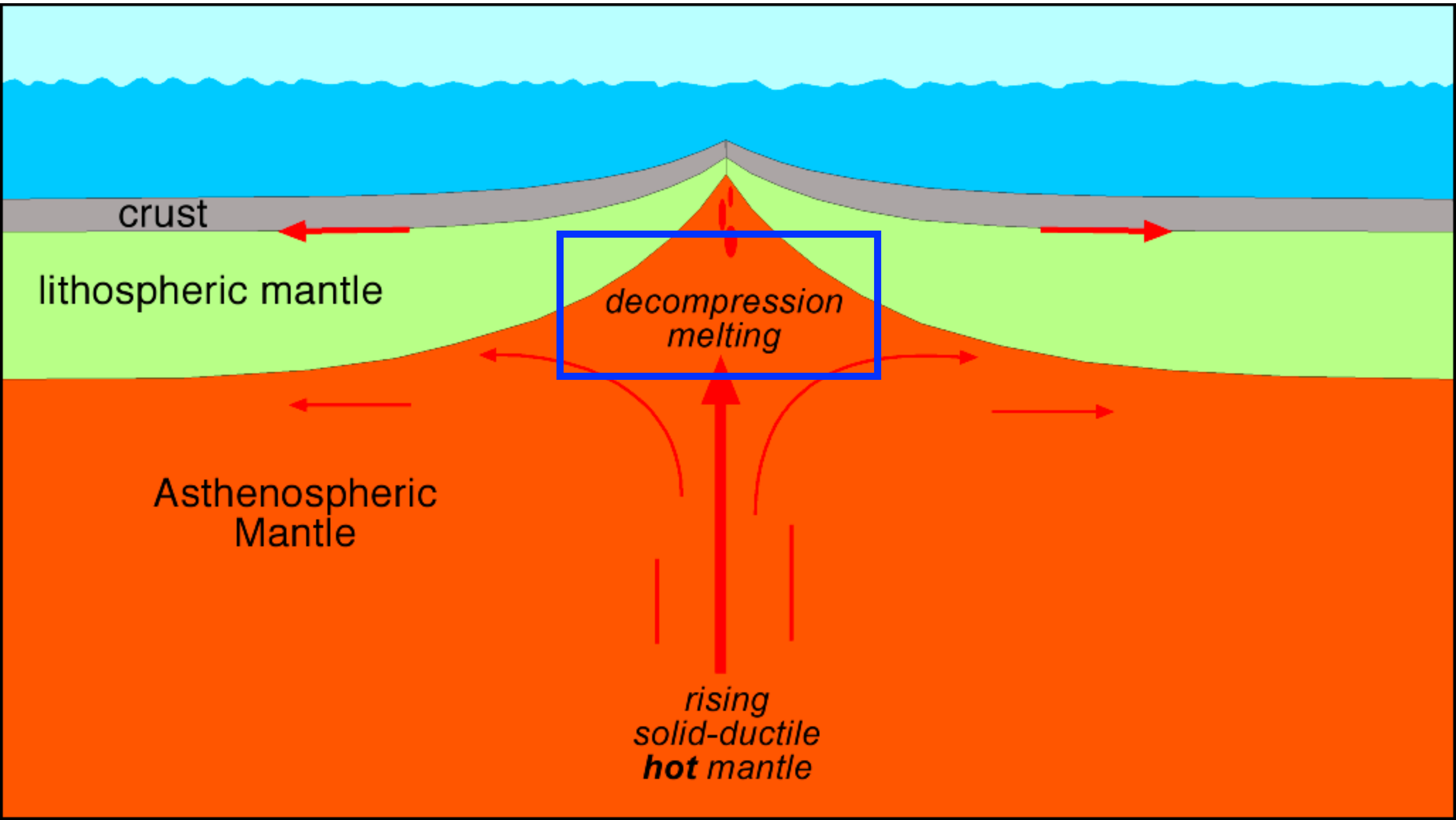
Magma

Thinner lithosphere at a mid-ocean ridge reduces pressure on the hot asthenosphere below



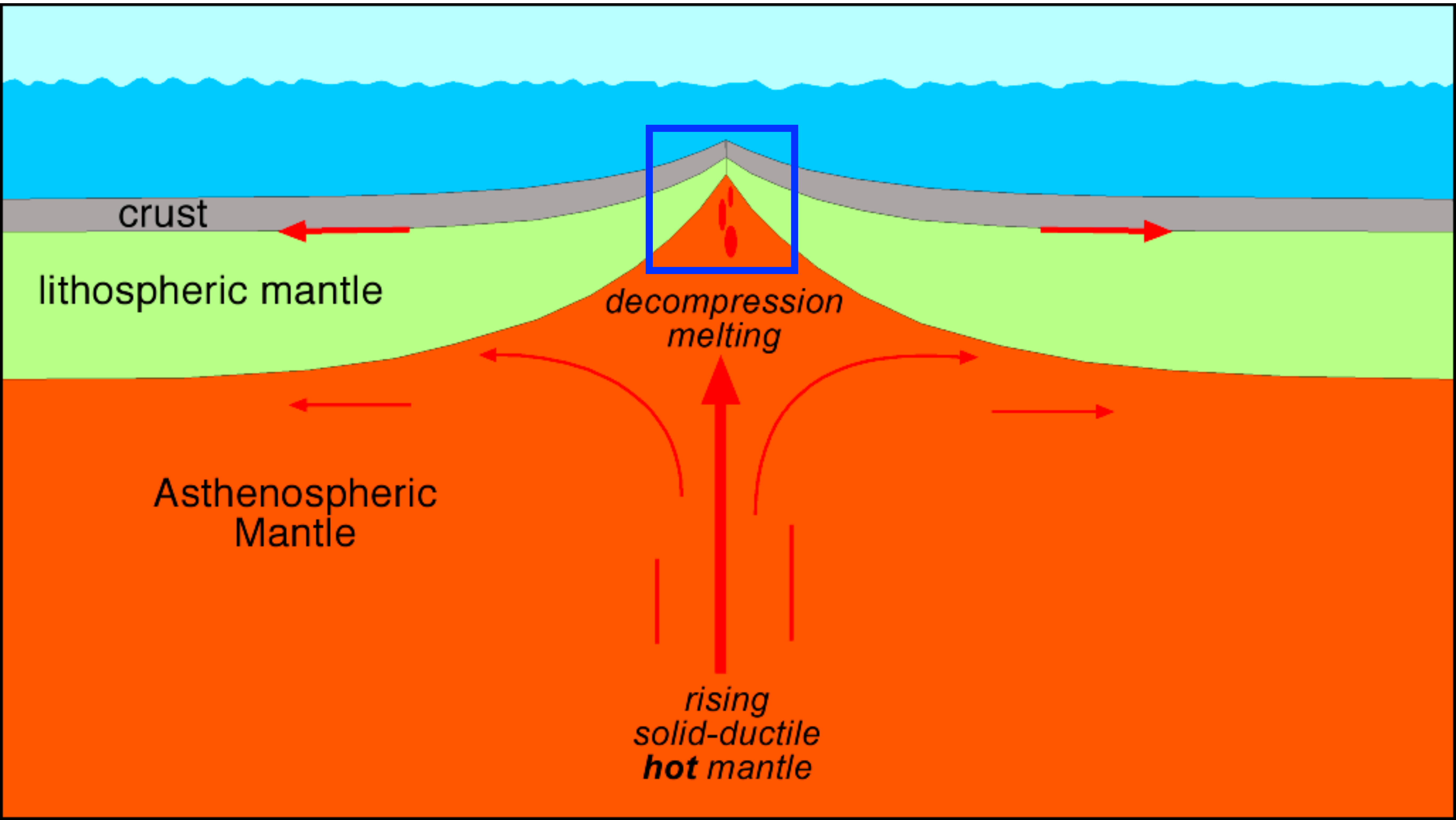
Magma

Reduced pressure lowers the melting point of the asthenosphere (ultramafic), so it partially melts



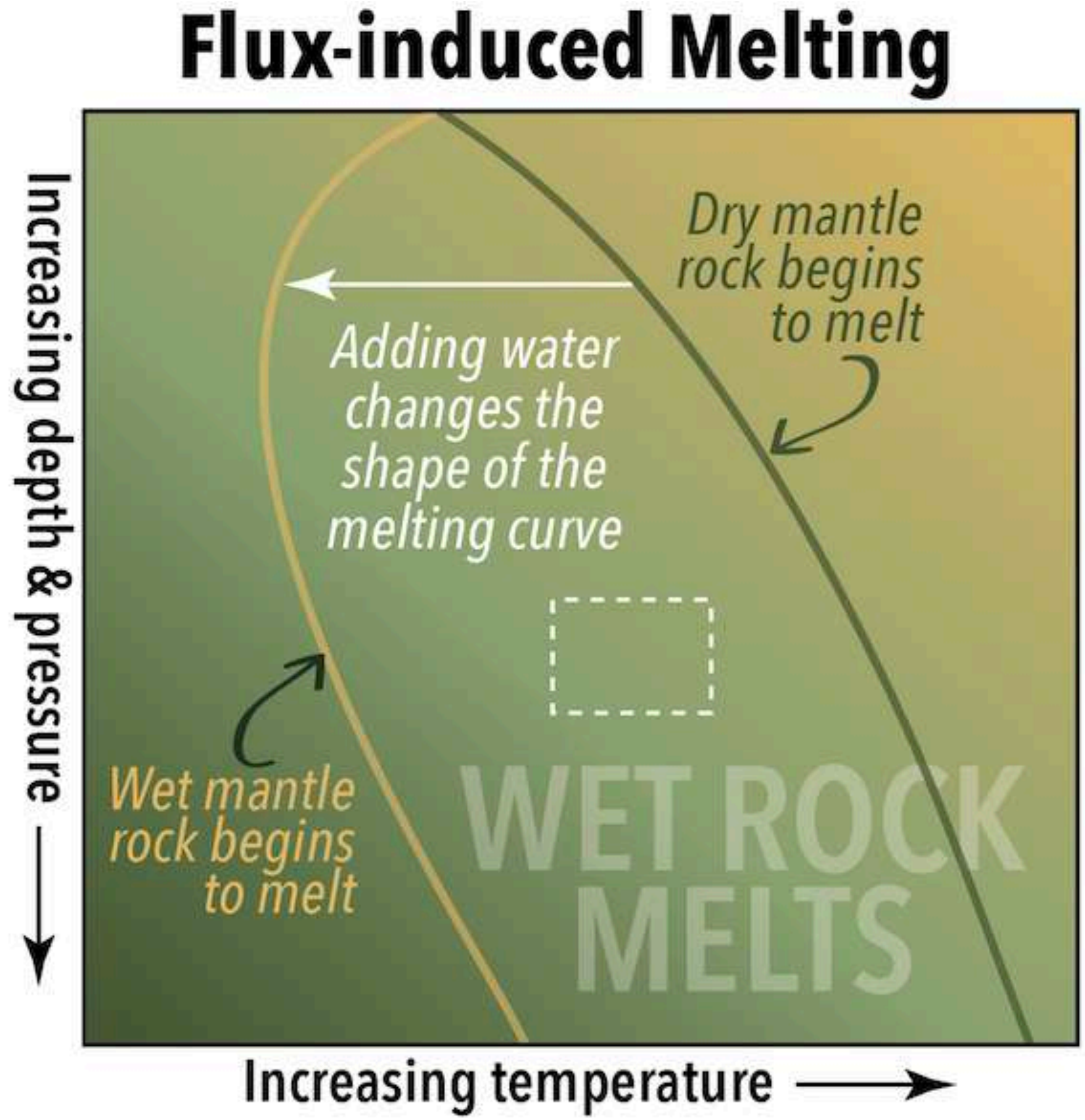
Magma

That magma rises to the surface, cools, and solidifies forming new oceanic crust (mafic)



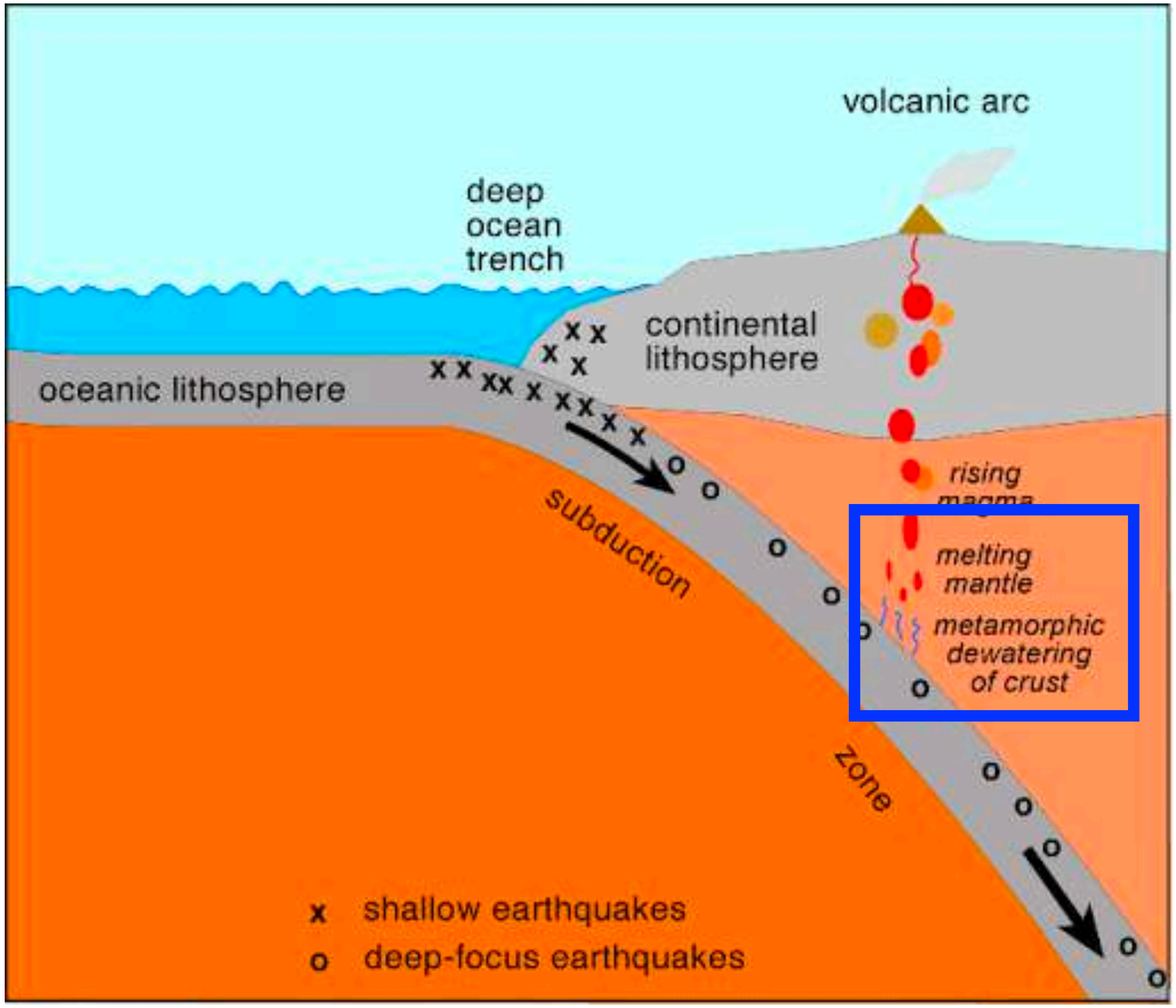
Magma

- **Flux melting** - adding water to the rock lowers the melting point
  - Happens in subduction zones



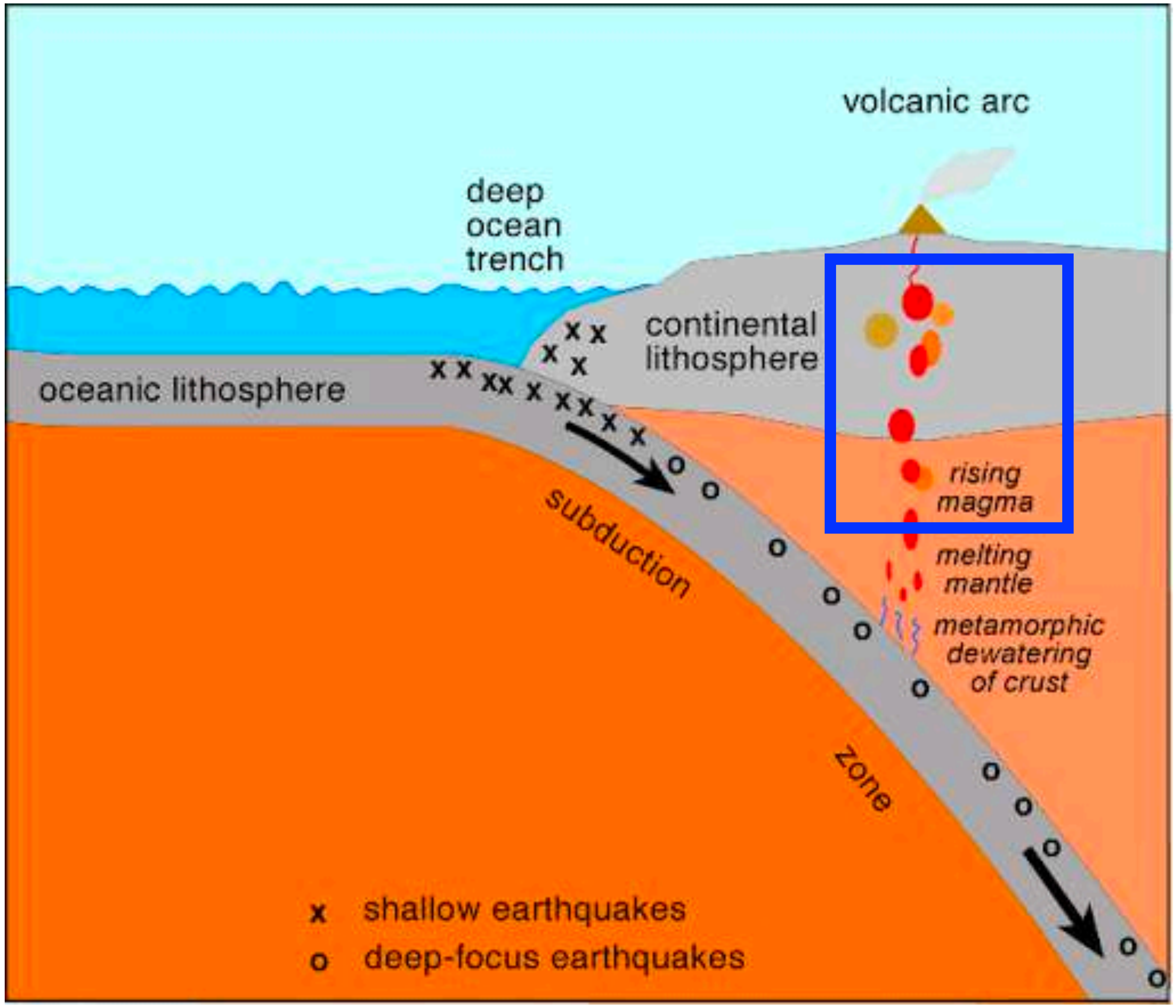
Magma

- Water from a subducting slab is released into the asthenosphere above it
- Lowers the melting point of the asthenosphere and causes partial melting (mafic magma)



Magma

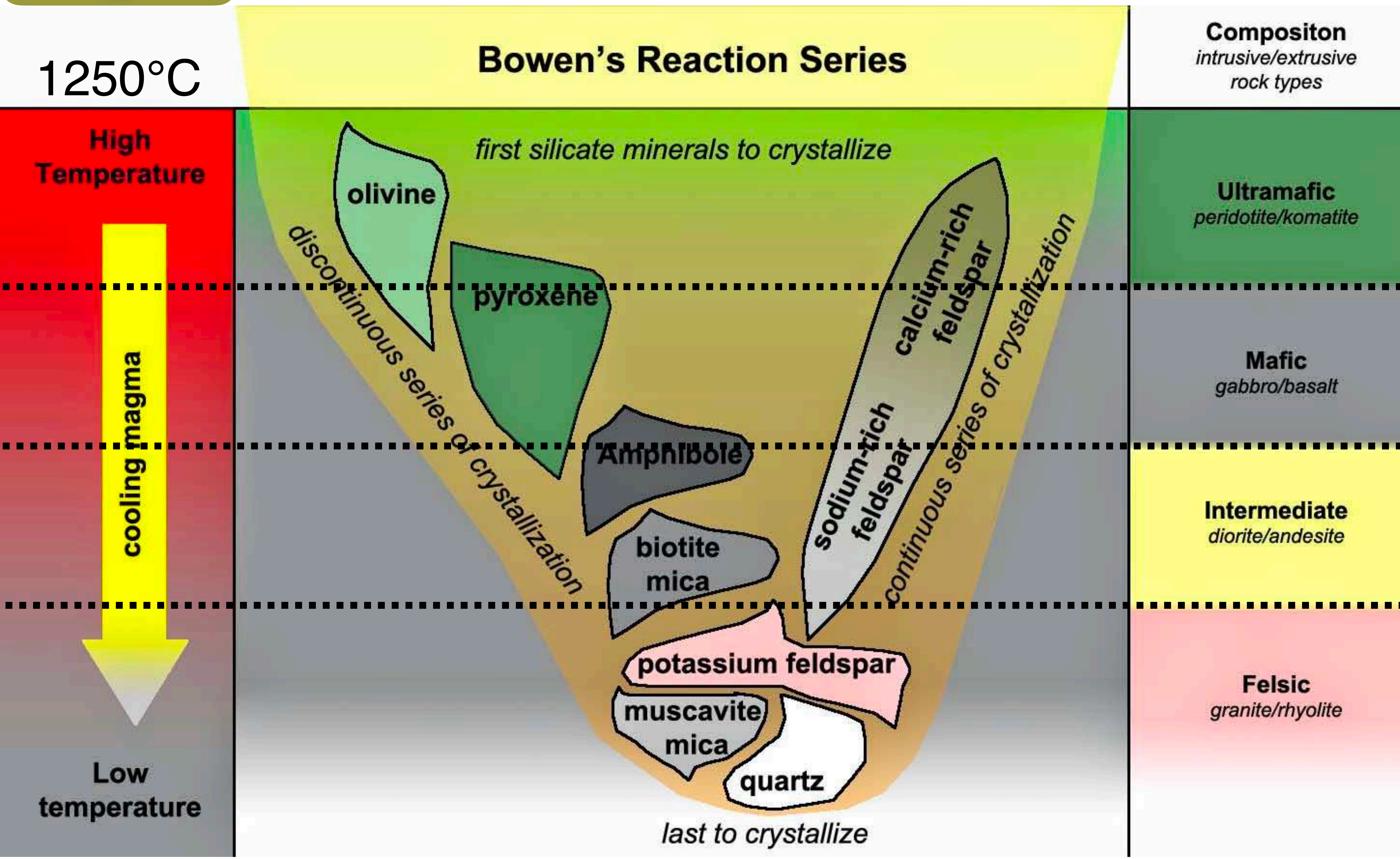
- Mafic magma rises and partially melts the lithosphere, changing to an intermediate or felsic magma (continental crust composition)
- If the magma reaches the surface, it creates a volcano



Magma

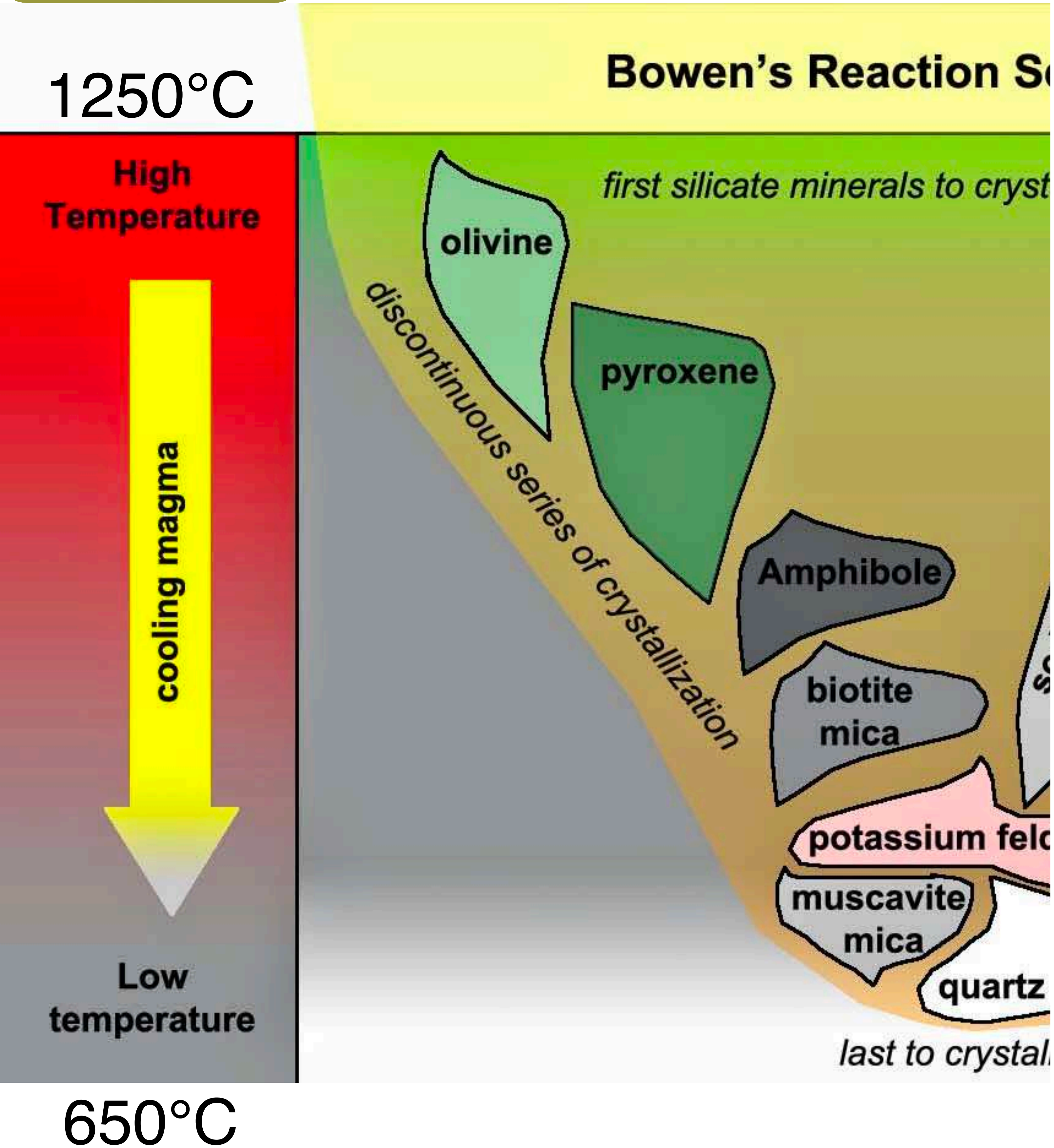
- What happens as magma begins to cool and solidify?
  - Minerals crystallize in a predictable way based on the chemistry and temperature of the magma
  - **Bowen's Reaction Series**

Magma



650°C Minerals that form at similar temperatures are found together in rocks

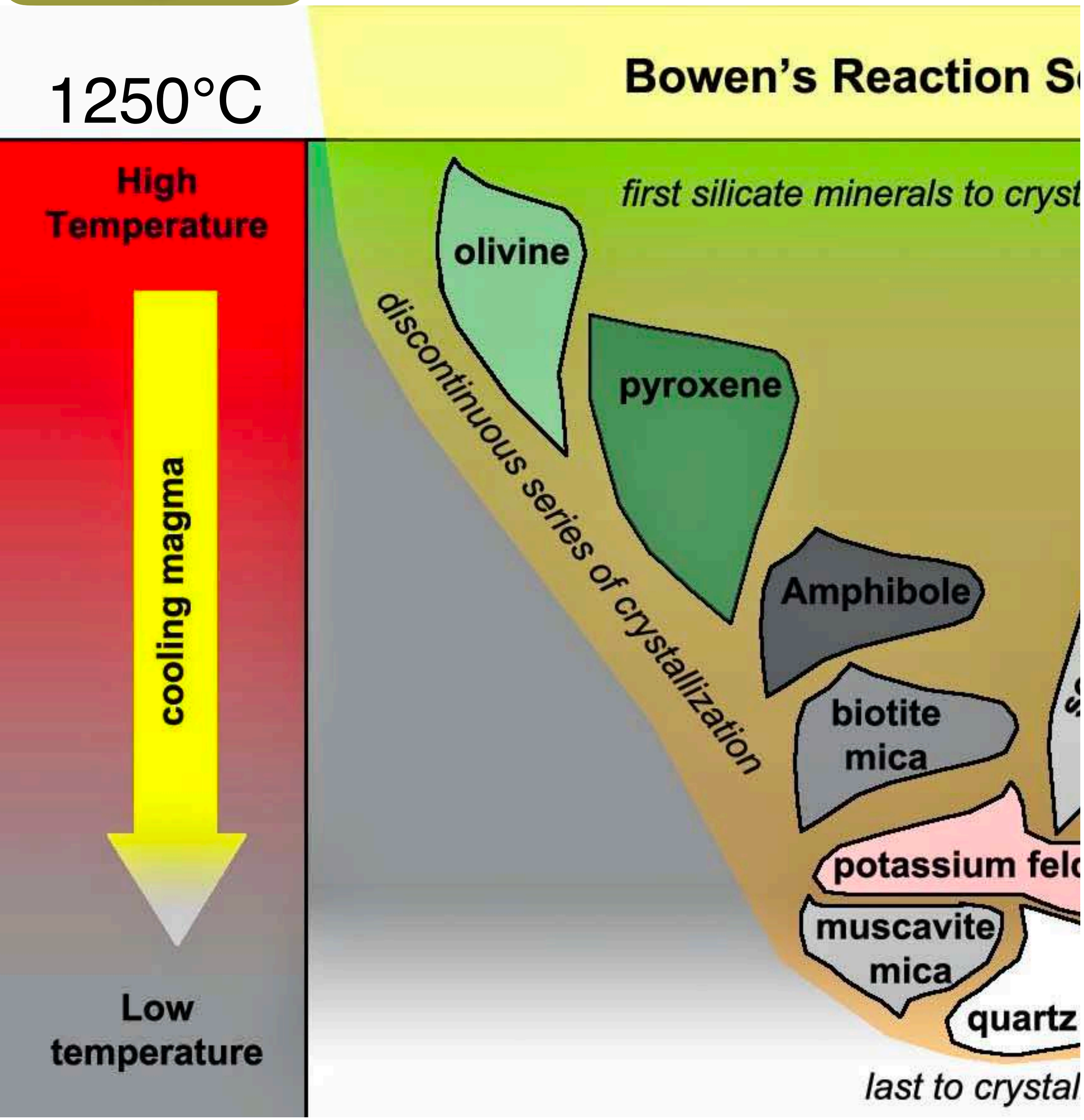
Magma



- **Discontinuous series** - minerals only form under a strict range of temperature
- Once outside that range, that mineral cannot form
- The grains that already exist begin converting into the next mineral in the series
- i.e. olivine turns into pyroxene

Magma

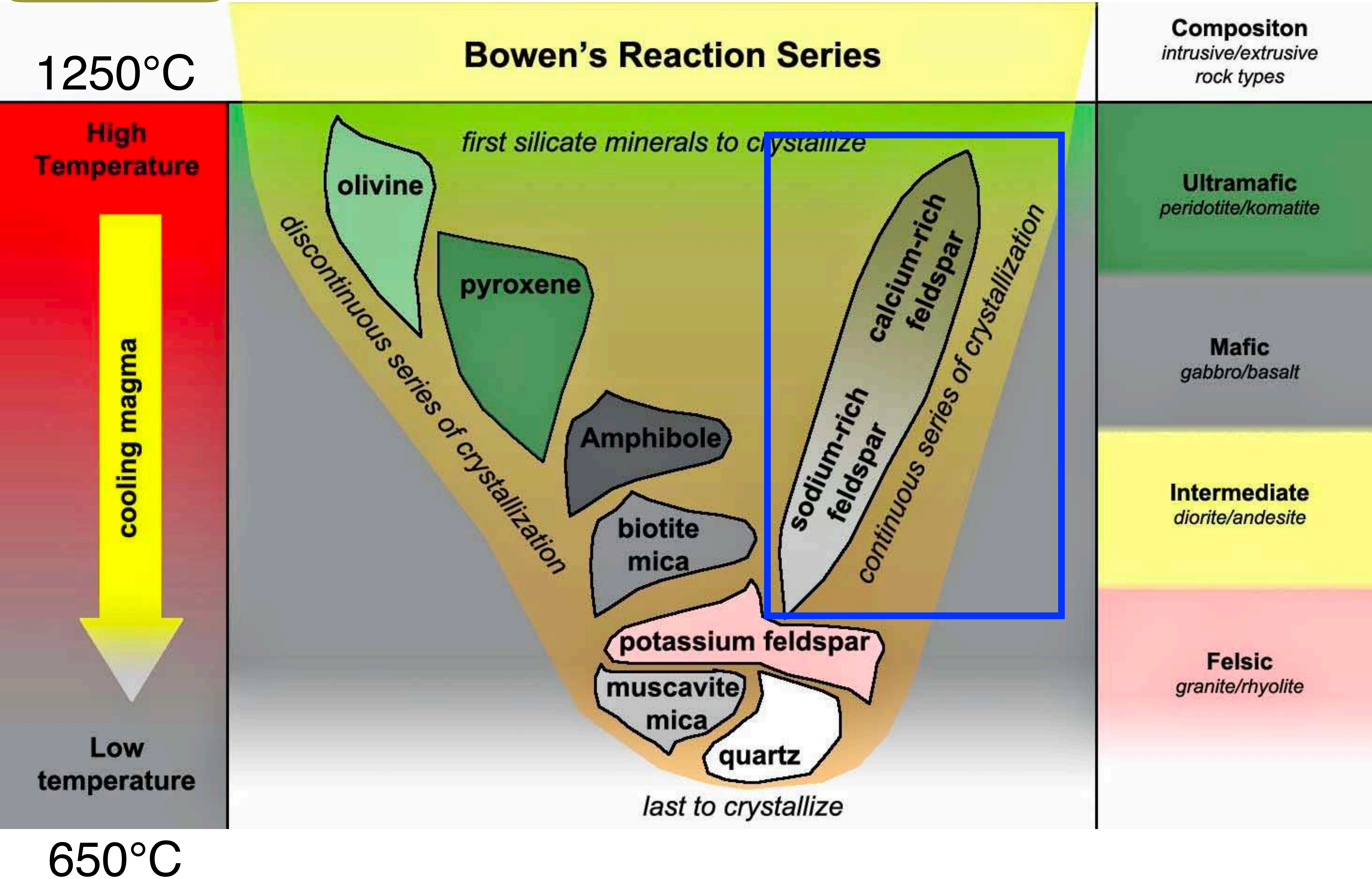
1250°C



650°C

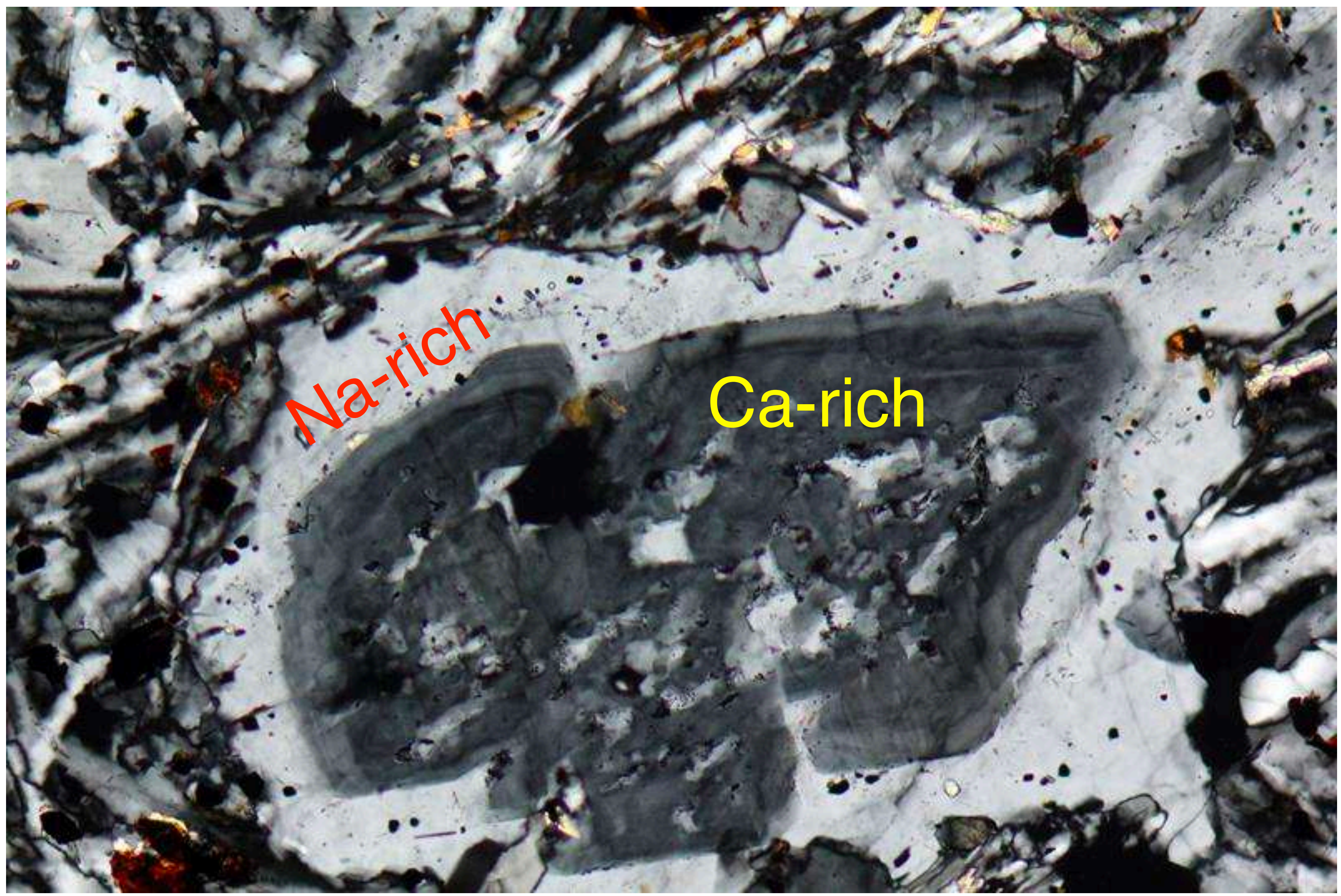
- Examples: olivine only forms under high temperatures, quartz only forms under low temperatures
- You will not find olivine and quartz in the same rock

Magma

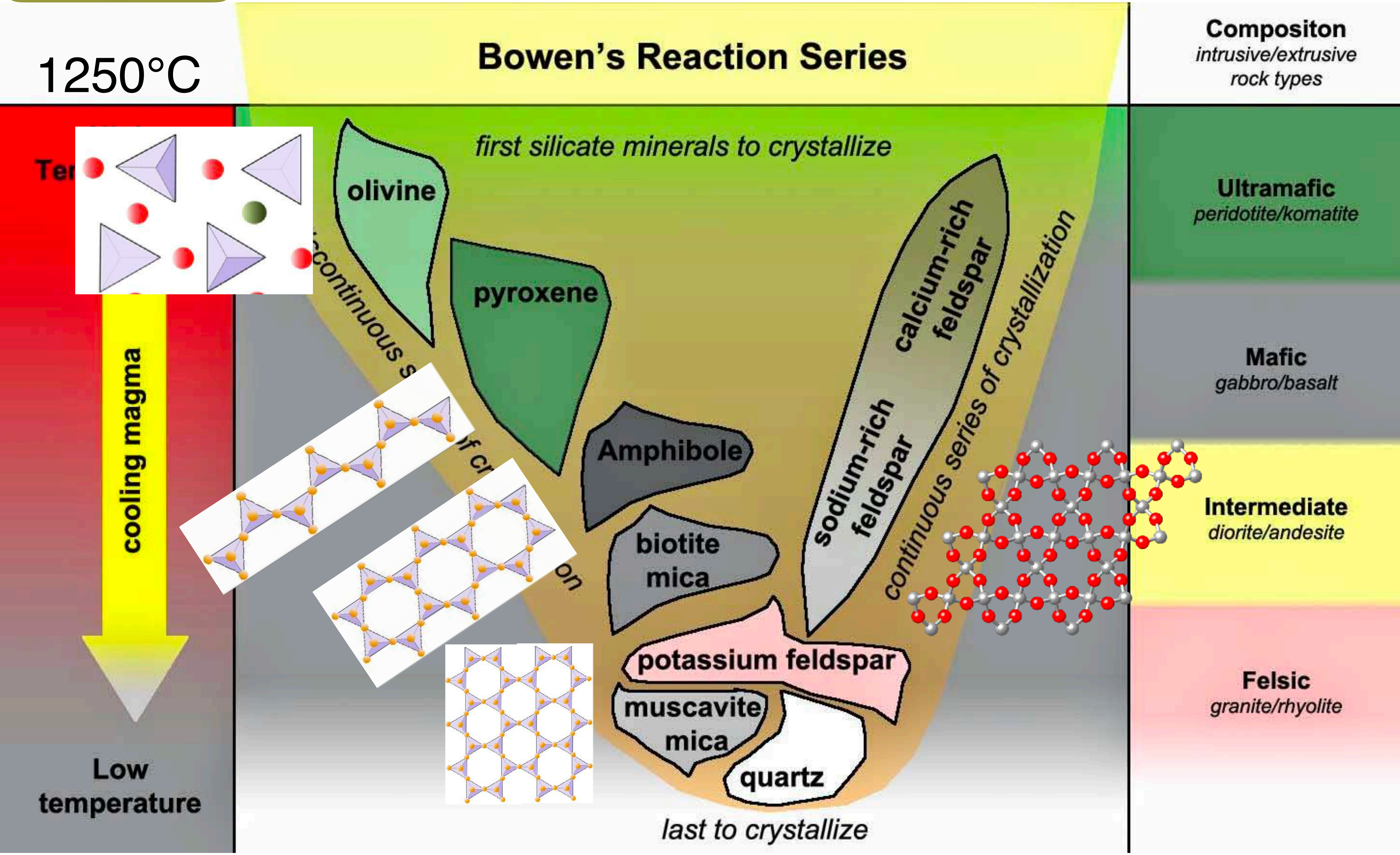

1250°C
Bowen's Reaction Series
Compositon
intrusive/extrusive
rock types
High
Temperature
cooling magma
Low
temperature
first silicate minerals to crystallize
olivine
pyroxene
Amphibole
biotite
mica
potassium feldspar
muscavite
mica
quartz
discontinuous series of crystallization
calcium-rich
feldspar
sodium-rich
feldspar
continuous series of crystallization
last to crystallize
Ultramafic
peridotite/komatite
Mafic
gabbro/basalt
Intermediate
diorite/andesite
Felsic
granite/rhyolite
650°C

Magma

- **Continuous series** - minerals keep forming and their chemistry changes, creating rims of enriched elements
- This plagioclase has a Ca-rich center with a Na-rich ring



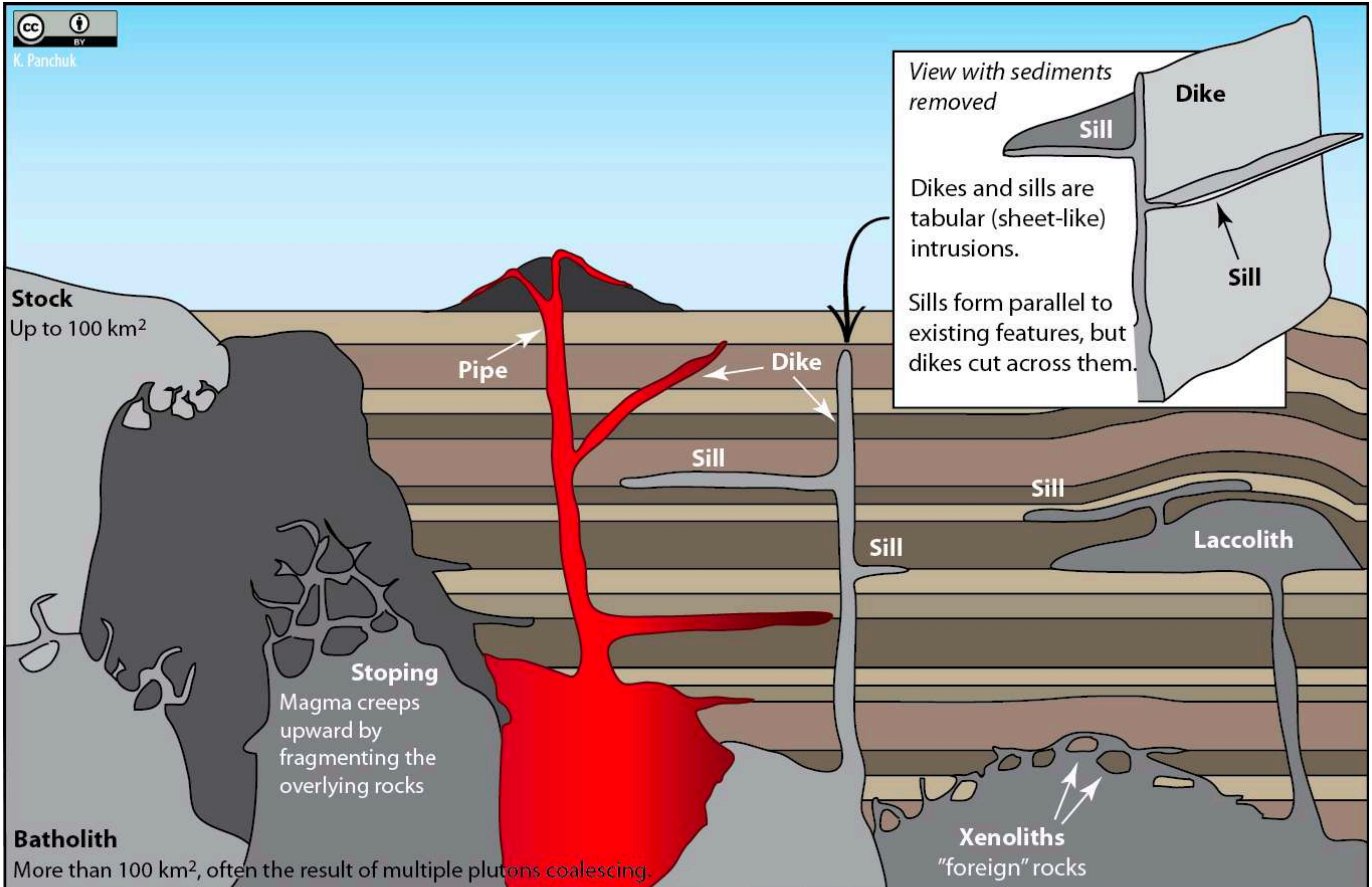
Magma



650°C Minerals that form at similar temperatures are found together in rocks

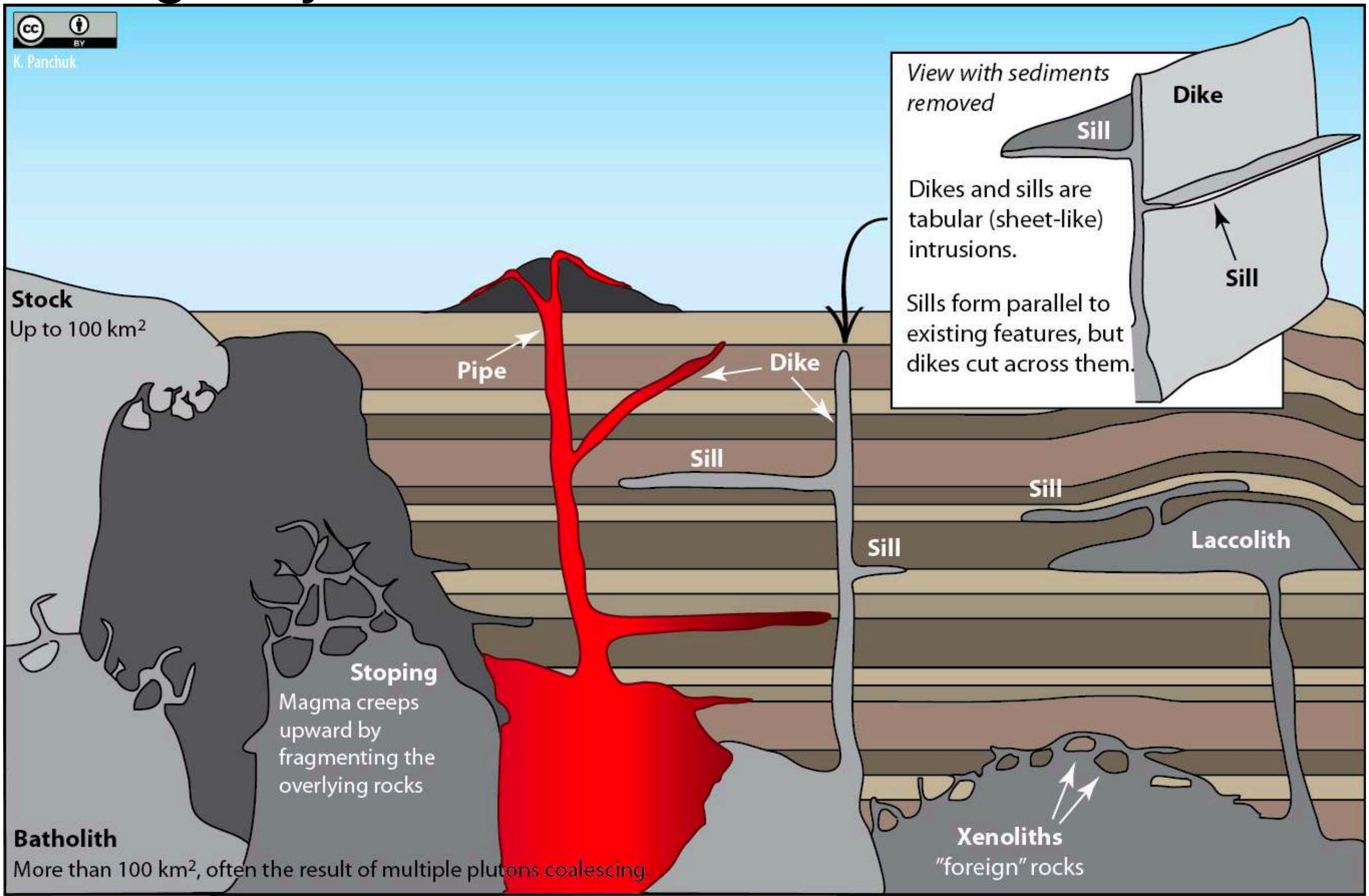
Intrusive Igneous Activity

- When magma is forced to cut through or in between rocks, it's called an **intrusion**



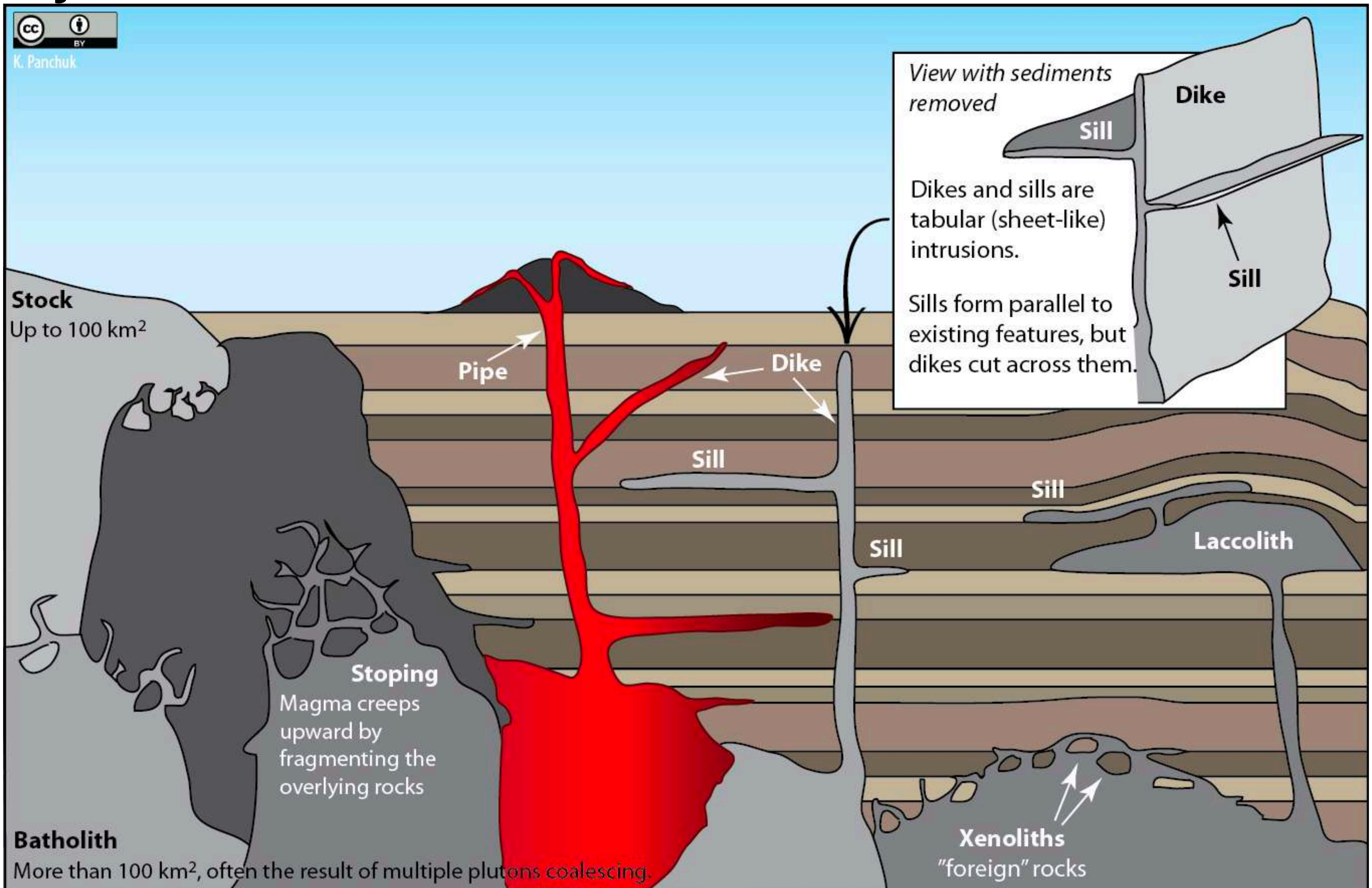
Intrusive Igneous Activity

- **Dikes** are vertical sheet intrusions that cut through layers of rock



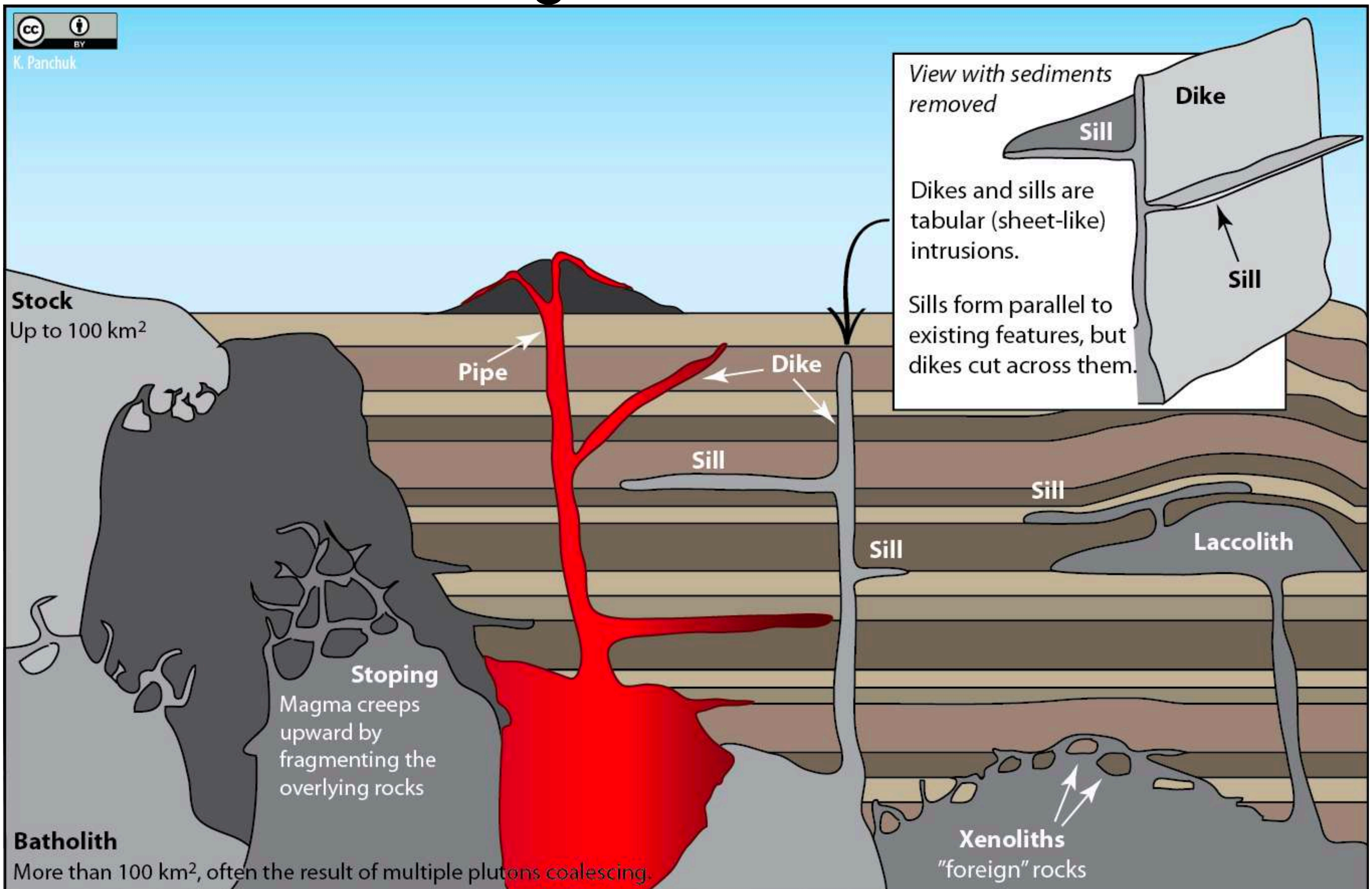
Intrusive Igneous Activity

- **Sills** are horizontal sheet intrusions in-between layers



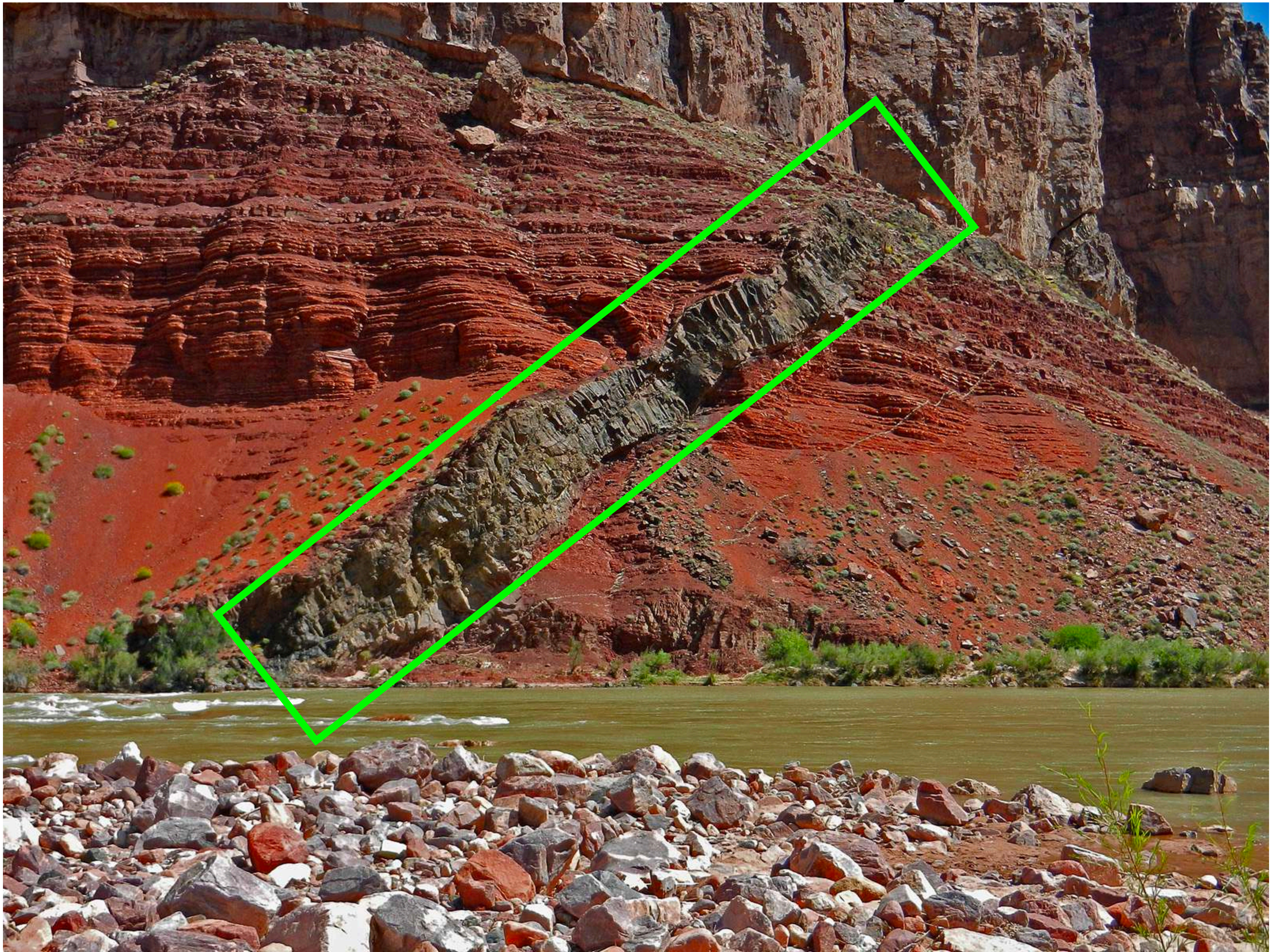
Intrusive Igneous Activity

- Batholiths, stocks, and plutons are terms for different sized magma chambers



Intrusive Igneous Activity

Dike in the Grand Canyon



Intrusive Igneous Activity

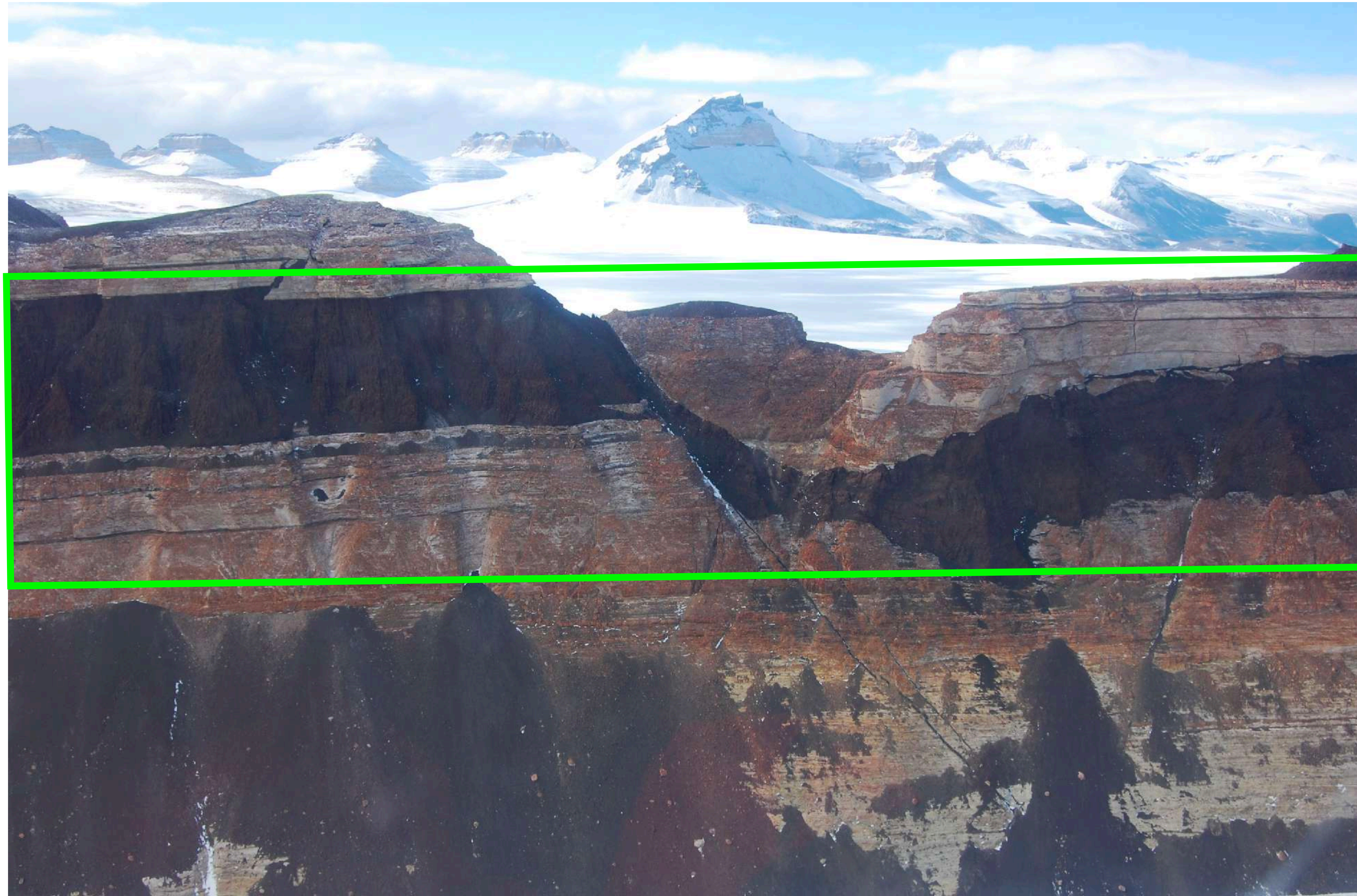
Dike near Golden Gate Canyon, CO

Intrusive Igneous Activity

Sill from Yellowstone National Park

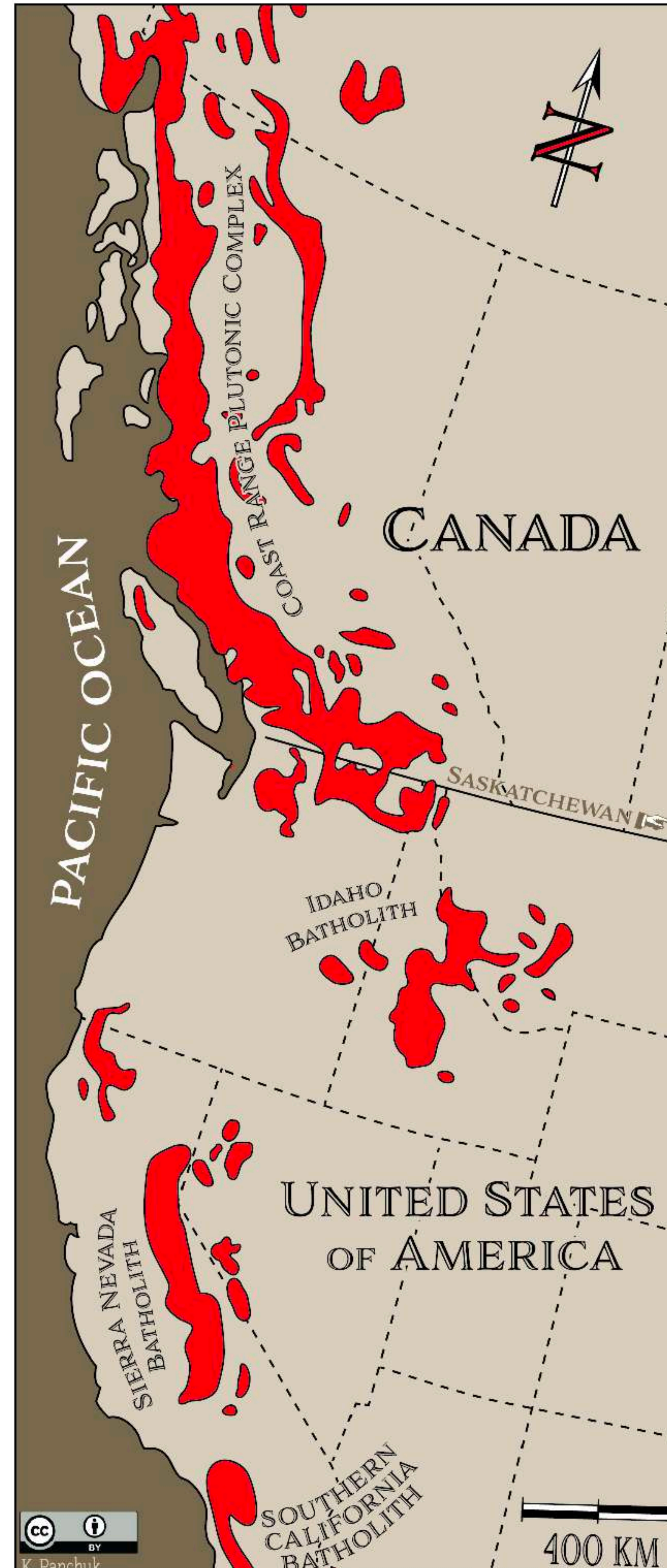
Intrusive Igneous Activity

Sill from Antarctica



Intrusive Igneous Activity

- Intrusions that don't make it to the surface can be exposed at a later time due to erosion
  - Erosion will be discussed in a couple weeks
- Places in North America where deep batholiths (intrusive igneous rocks) are now exposed at the surface



Intrusive Igneous Activity

- Enchanted Rock in central TX is one of these exposed batholiths