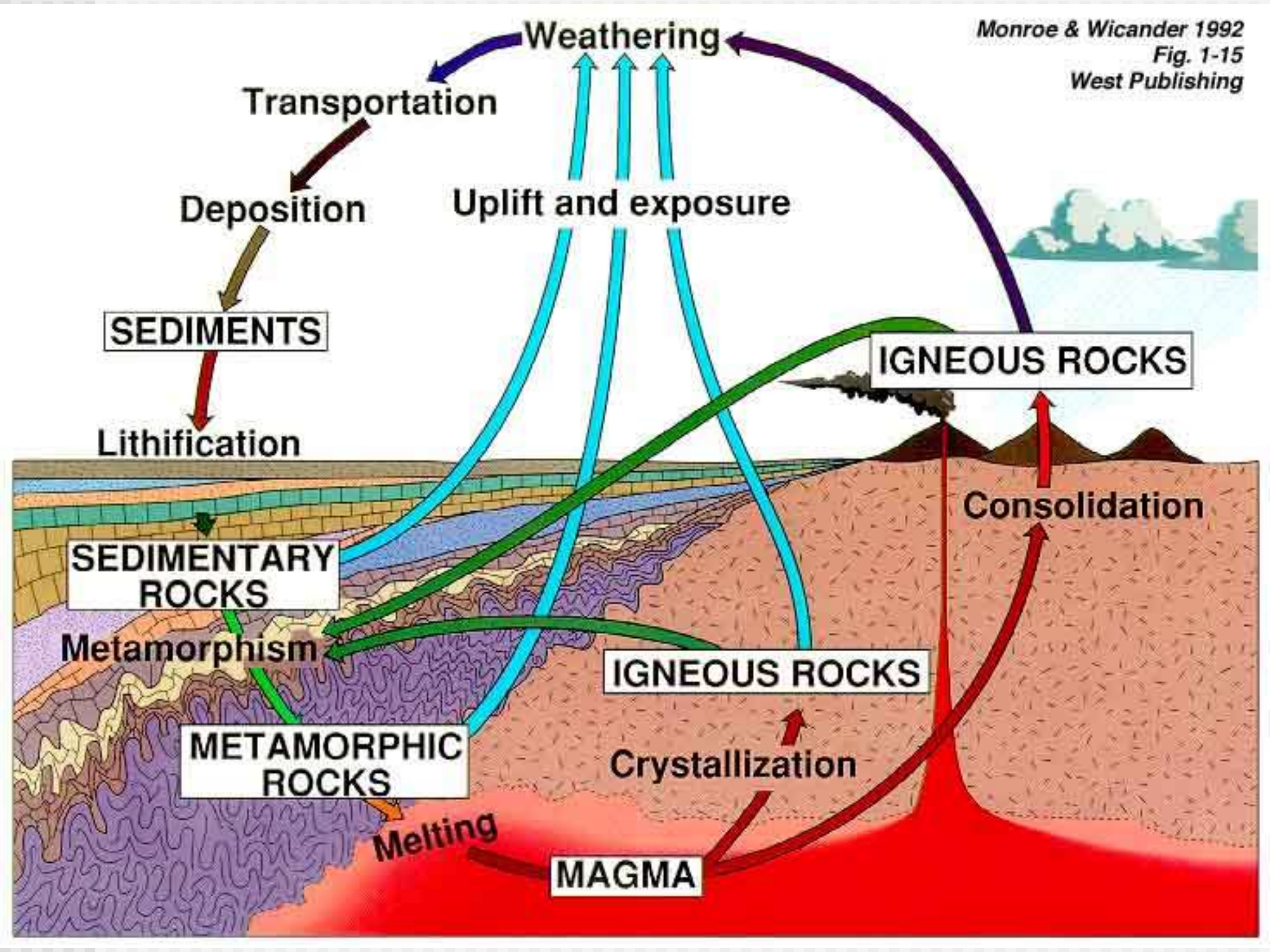
Geology 12

Igneous Rocks

Part 1


Monroe & Wicander 1992
Fig. 1-15
West Publishing
Weathering
Transportation
Deposition
Uplift and exposure
SEDIMENTS
Lithification
IGNEOUS ROCKS
Consolidation
SEDIMENTARY ROCKS
Metamorphism
IGNEOUS ROCKS
METAMORPHIC ROCKS
Crystallization
Melting
MAGMA

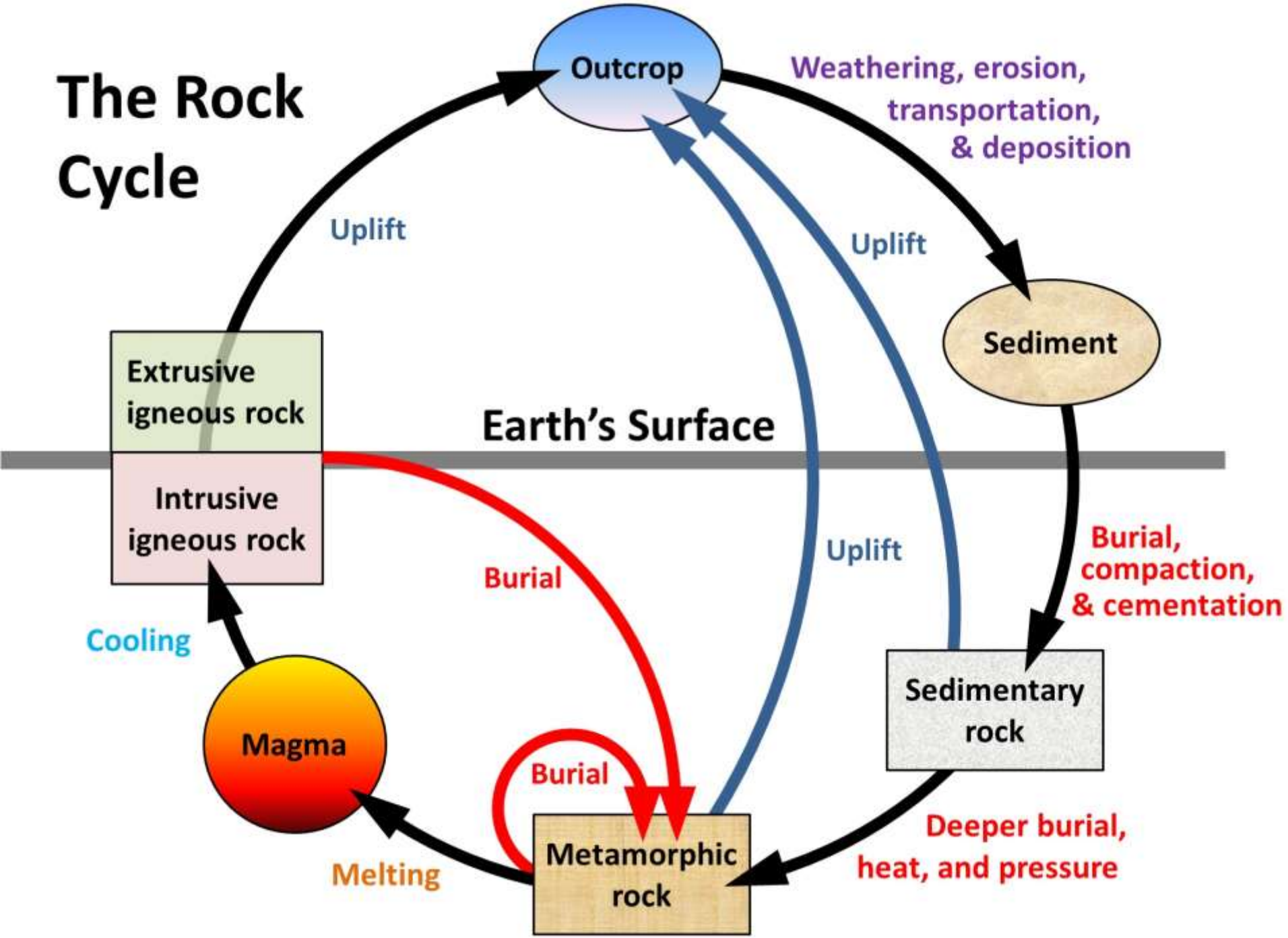
Understanding the Rock Cycle

Side 1: Draw the Rock Cycle (combine the images and notes from figure 4.2 and 4.1)

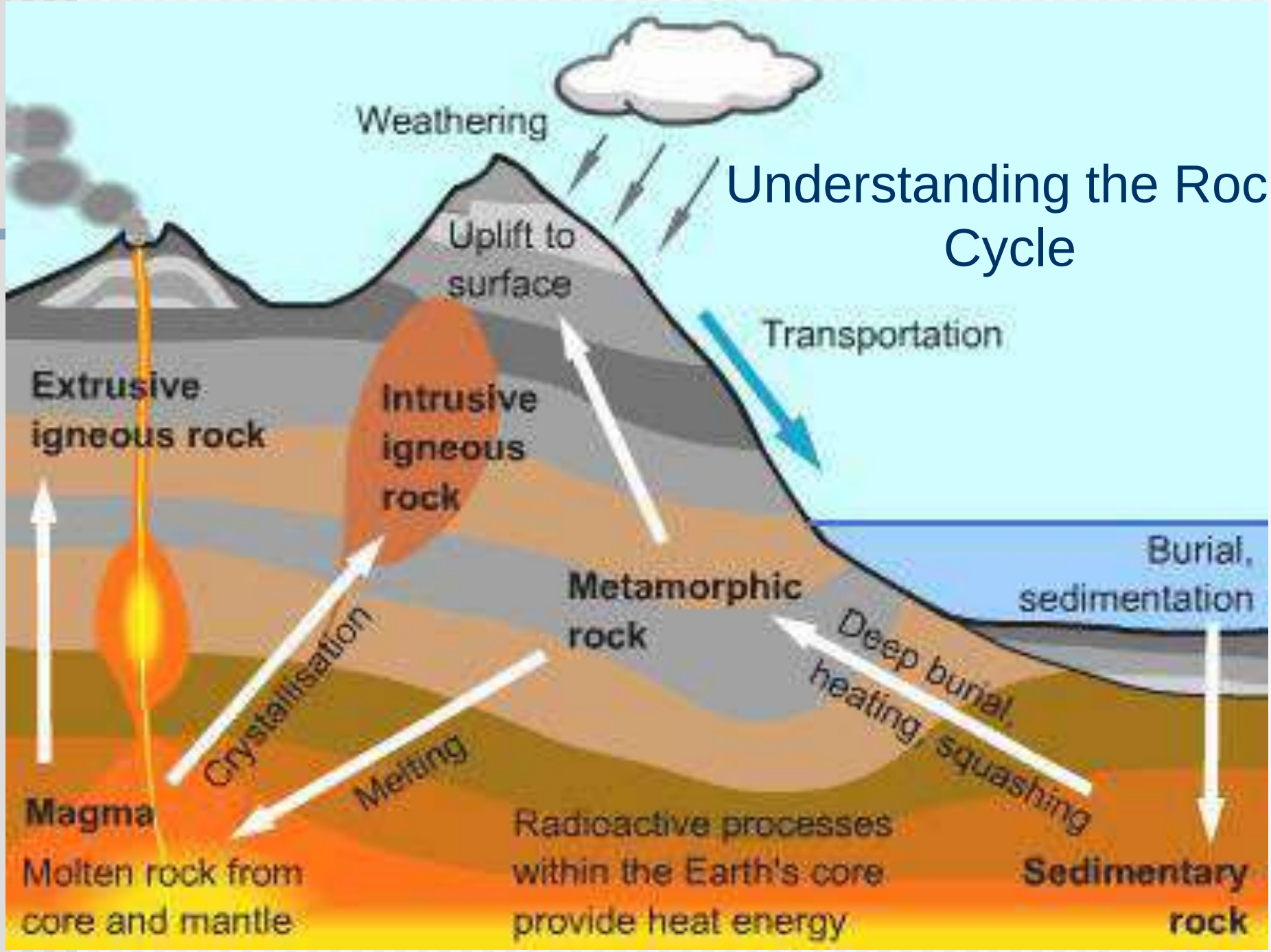
Side 2: Copy and complete Activity 4.5

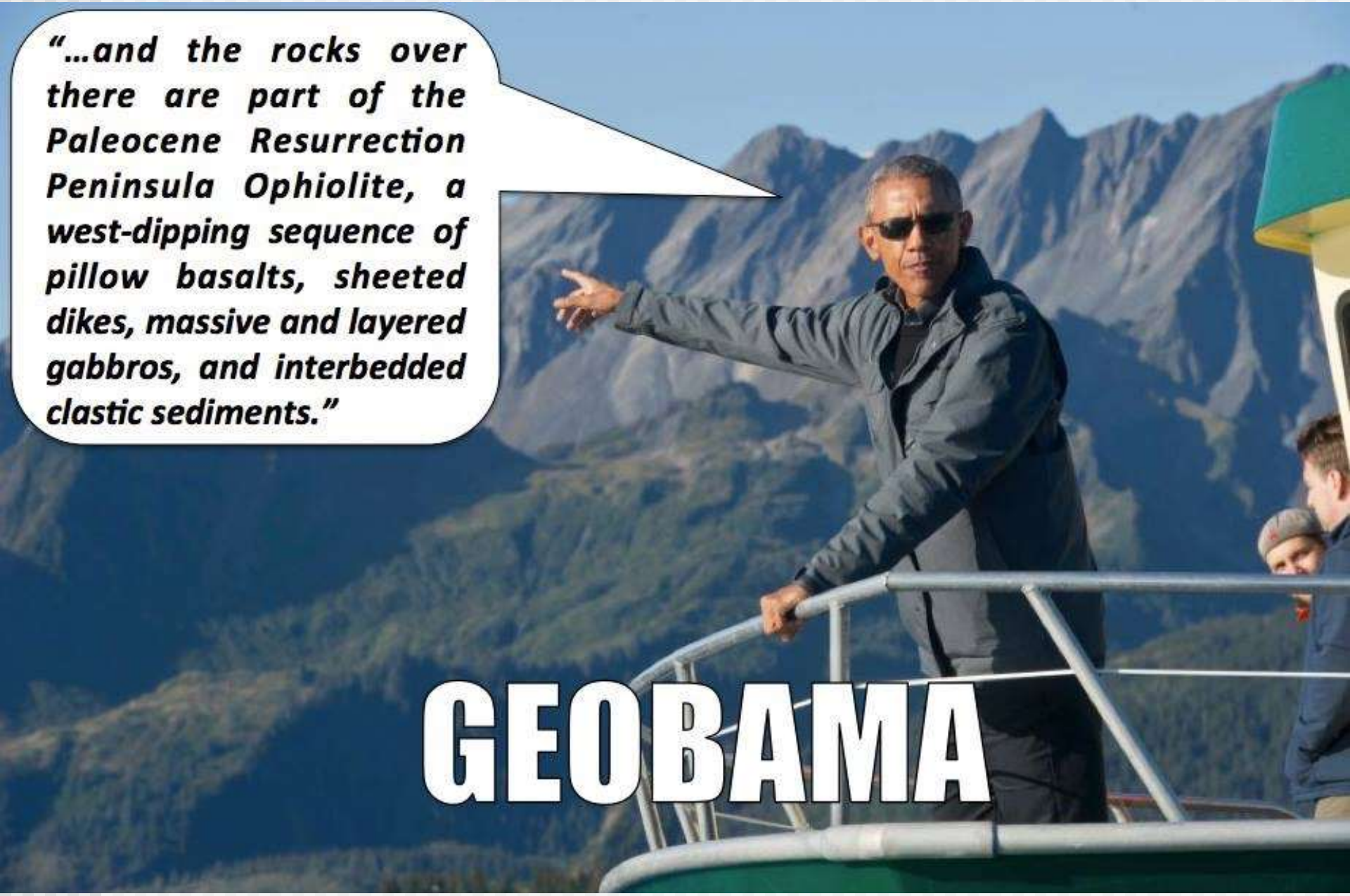
A - copy and complete the chart

C - starting from a sedimentary rocks, describe a path through the rock cycle.


The Rock Cycle
Outcrop
Weathering, erosion, transportation, & deposition
Uplift
Uplift
Uplift
Sediment
Extrusive igneous rock
Earth's Surface
Intrusive igneous rock
Burial
Burial, compaction, & cementation
Cooling
Magma
Sedimentary rock
Burial
Deeper burial, heat, and pressure
Melting
Metamorphic rock

Understanding the Rock Cycle




"...and the rocks over there are part of the Paleocene Resurrection Peninsula Ophiolite, a west-dipping sequence of pillow basalts, sheeted dikes, massive and layered gabbros, and interbedded clastic sediments."
GEOBAMA

Geology 12

Igneous Rocks

Part 1

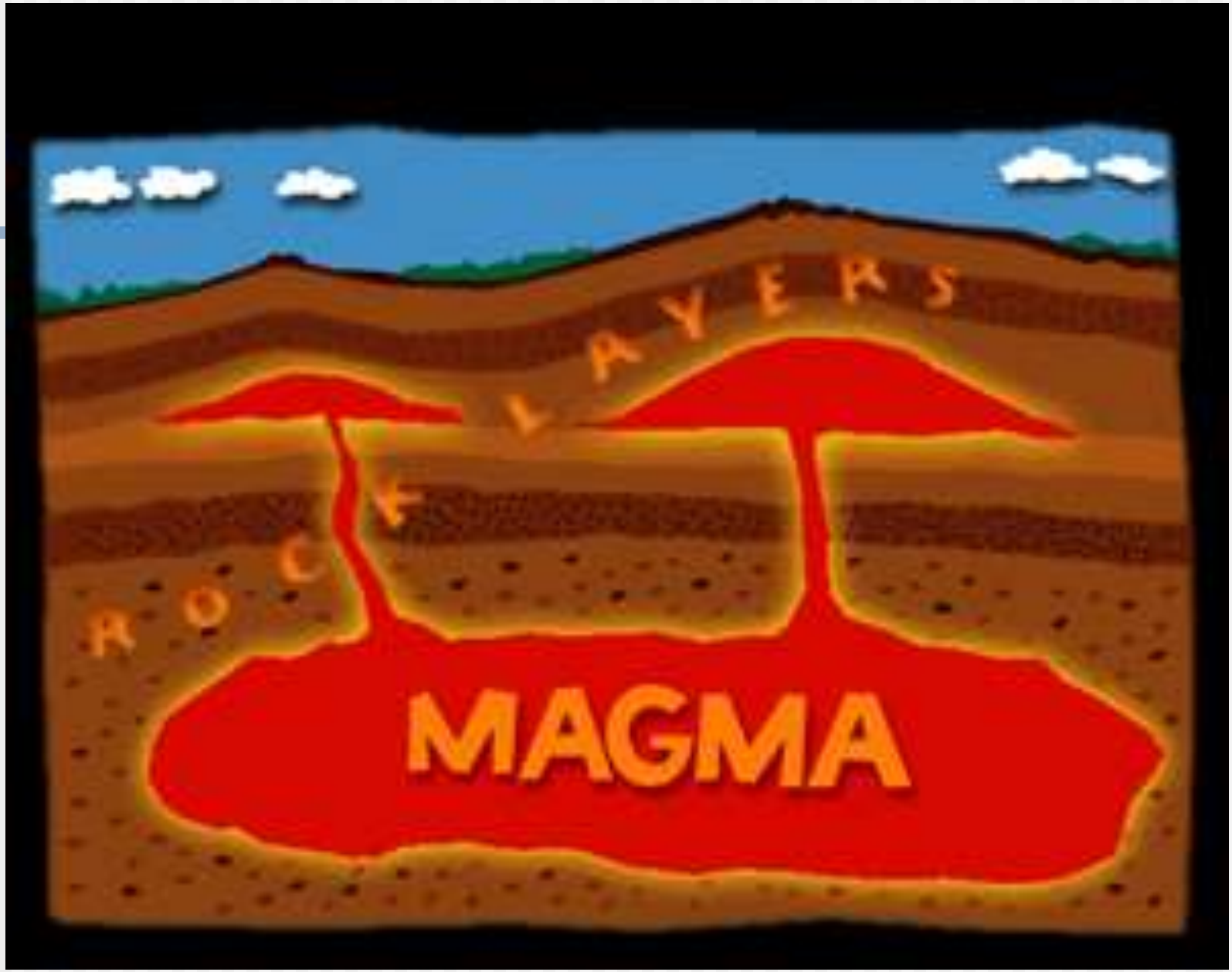
Geol. 12 - Igneous rocks - Part #1:

1) **Origin Of Magma:**

2) **Crystallization of Magma:**

3) **Classification of Igneous Rocks:**

Origin Of Magma


ROCK LAYERS
MAGMA


Magma


Lava

- **The word igneous comes from the Latin word for FIRE!!**
- **Igneous rocks are formed at high temperatures.**
- **High temperatures cause solid, silicate-mineral based materials to melt.**

The resulting liquid silicate material is called MAGMA!

Solid Rock $\Rightarrow\Rightarrow$ Heated $\Rightarrow\Rightarrow$ MAGMA

Made from

Silicate minerals

Once these Magmas cool, they form Igneous rocks!!

Factors Effecting Magma Origin:

- **Heat melts solid material to produce Magma!**
- ***Temperature increases with depth* –**
- **Called the geothermal gradient.**
- **Therefore, magmas occur deep (50-250km) within the crust/mantle, where heat is sufficient to cause melting!**

- **Exact depths of melting are influenced by interactions between several complex factors:**

1. **Pressure**
2. **Dissolved Volatiles**
3. **Mixtures of solids**
4. **Compositional Ranges**
5. **Other Heat Sources**

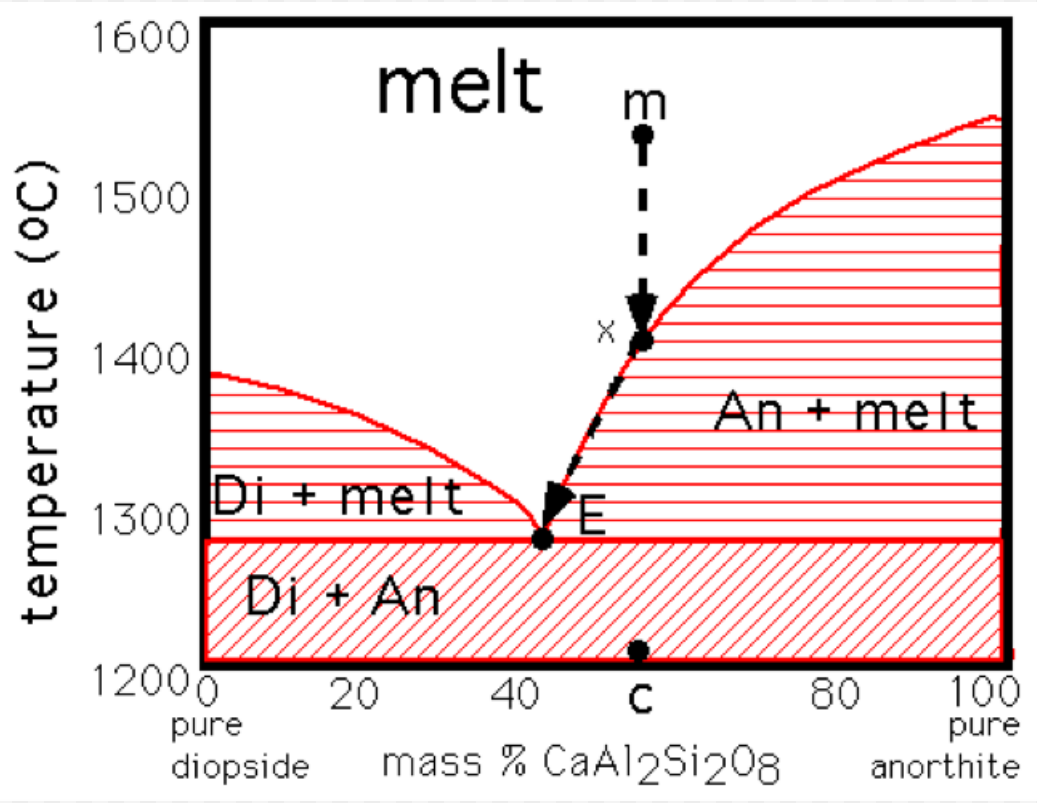
1. **Pressure –**

High pressure = High melting temperatures!

2. **Dissolved Volatiles –**

The more gasses dissolved in a magma, the lower the melting temperature!

3. Mixtures of Solids –



Two minerals together lower each other's melting points; therefore, **magmas from mixtures of minerals will melt at lower temperatures** than magmas from pure minerals (which are rare).

4. Solid Solution –

Most minerals have compositional ranges.

Melting temperatures vary through this range.

Melting temperatures are dependent on the exact composition present at any given time/location.

5. Heat Sources Besides Depth –

In various locations extra heat may play a role in melting rocks to form MAGMA.

Some sources of heat are:

i. **Naturally occurring radioactive decay.**

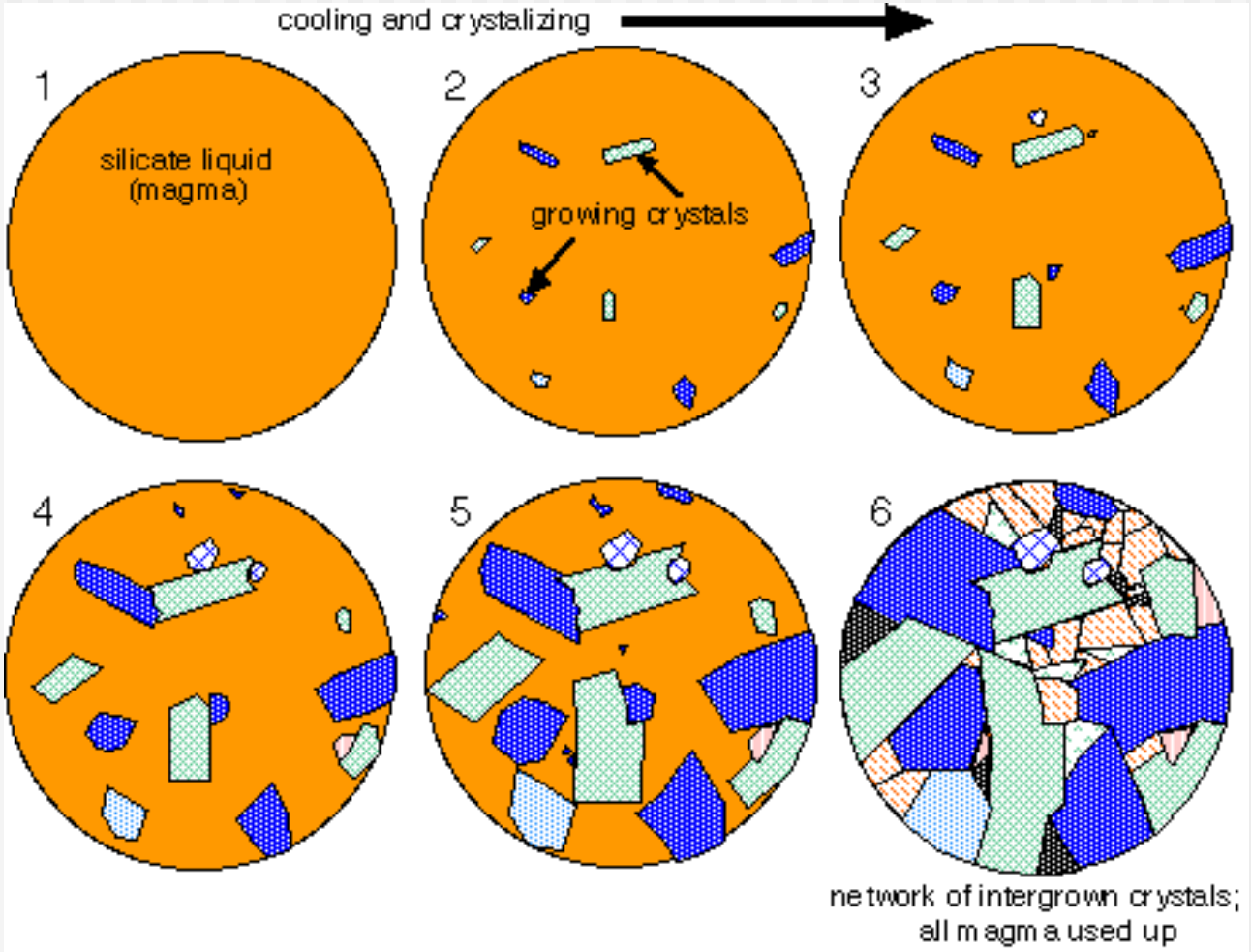
ii. **Friction caused by plate motion.**

iii. **Presence of a neighbouring magma.**

Crystallization Of Magma

- **Once all the factors come together to melt silicate rocks into a magma, it begins to move upward.**
- **This upward motion allows the melt to COOL!**

COOLING = CRYSTALLIZATION



The type of rock produced as the magma cools depend on:

1. **Mineral Composition of the Magma.**

   (i.e. What minerals are present and in what proportions?)

2. **Conditions Under which the Magma Crystallizes.**

   (Things like pressure, space, temperature, and rate come into play in a complex interaction!)

Sequence of Crystallization

- **Magmas cool through a range of temperatures from high to low, slowly over time.**

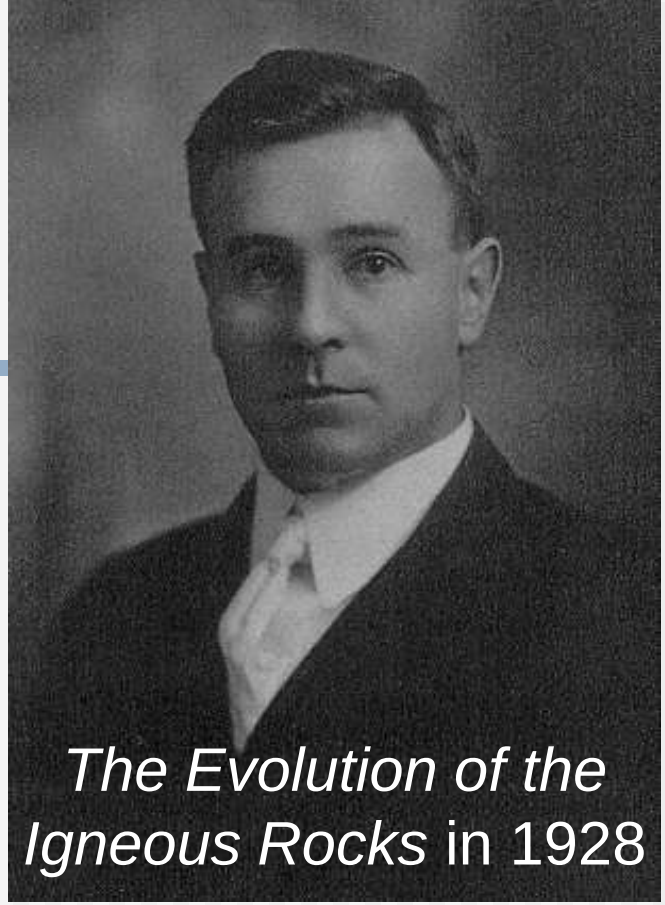
- **Different minerals begin to crystallize at various stages of this cooling process (and then react with the melt).**

- **The sequence in which minerals crystallize is predictable.**

- **This sequence was discovered by**

  Norman Levi Bowen

  (Canadian!)

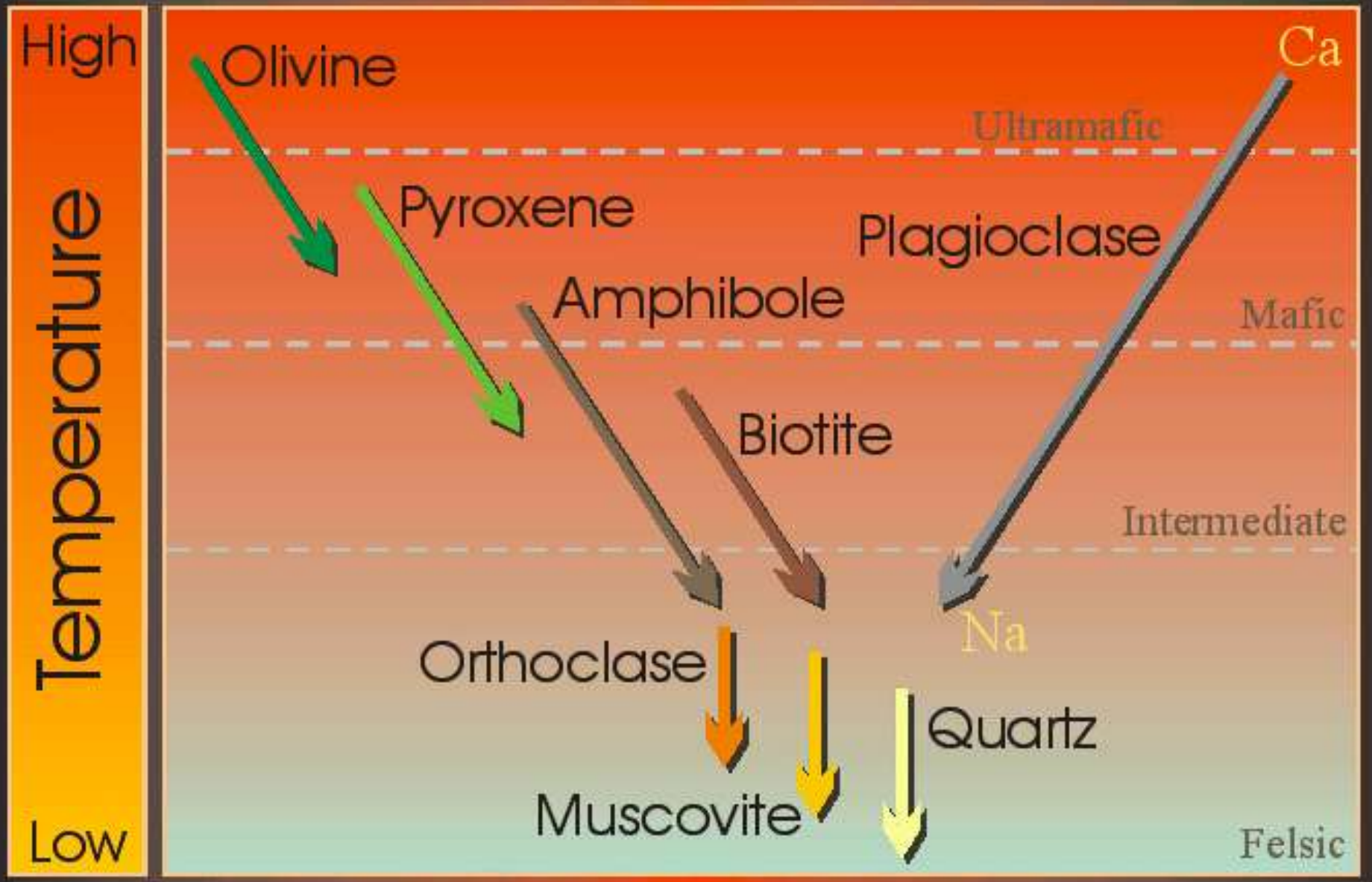


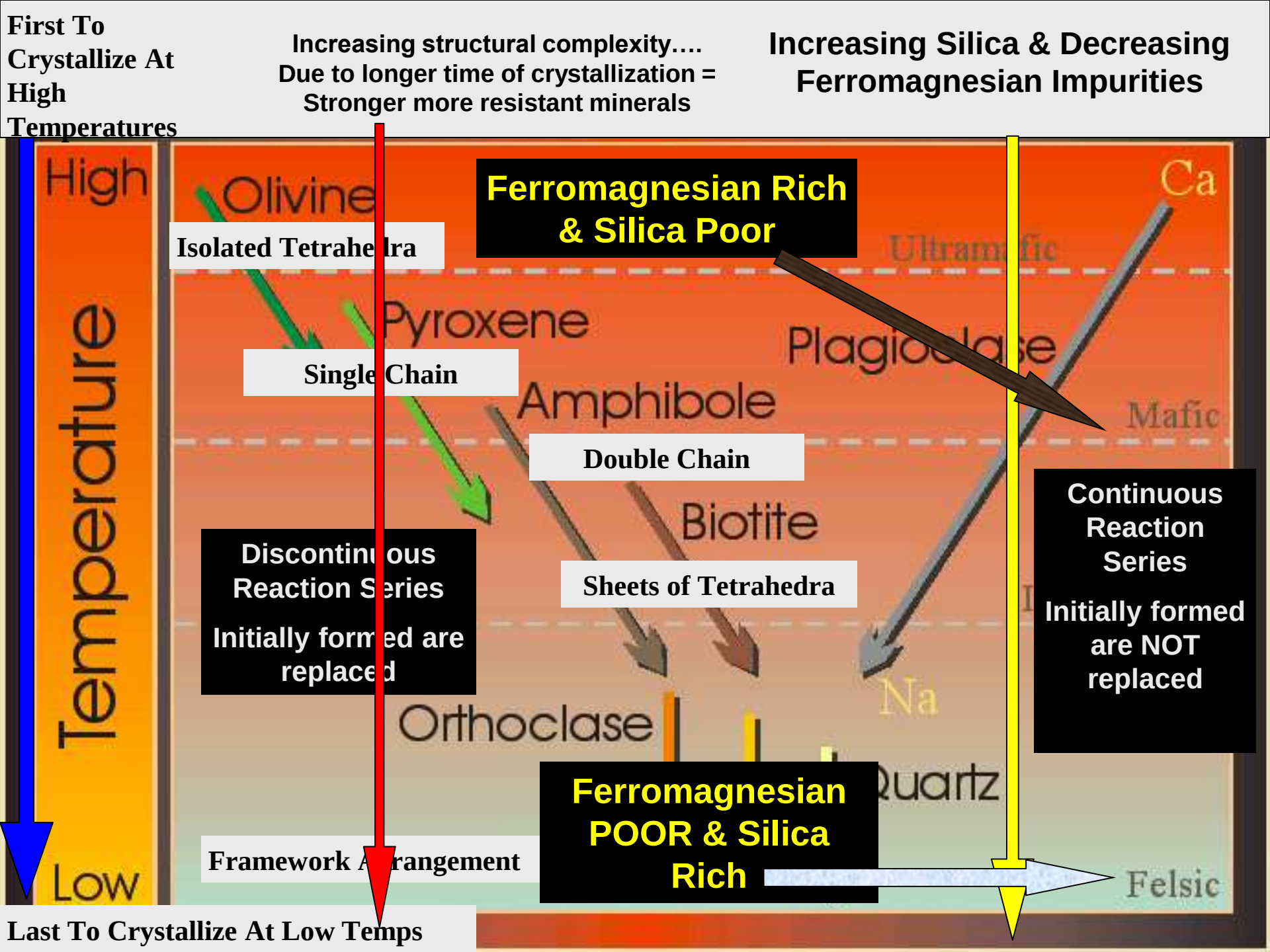
The Evolution of the Igneous Rocks in 1928

- **It is called - "Bowen's Reaction Series"**

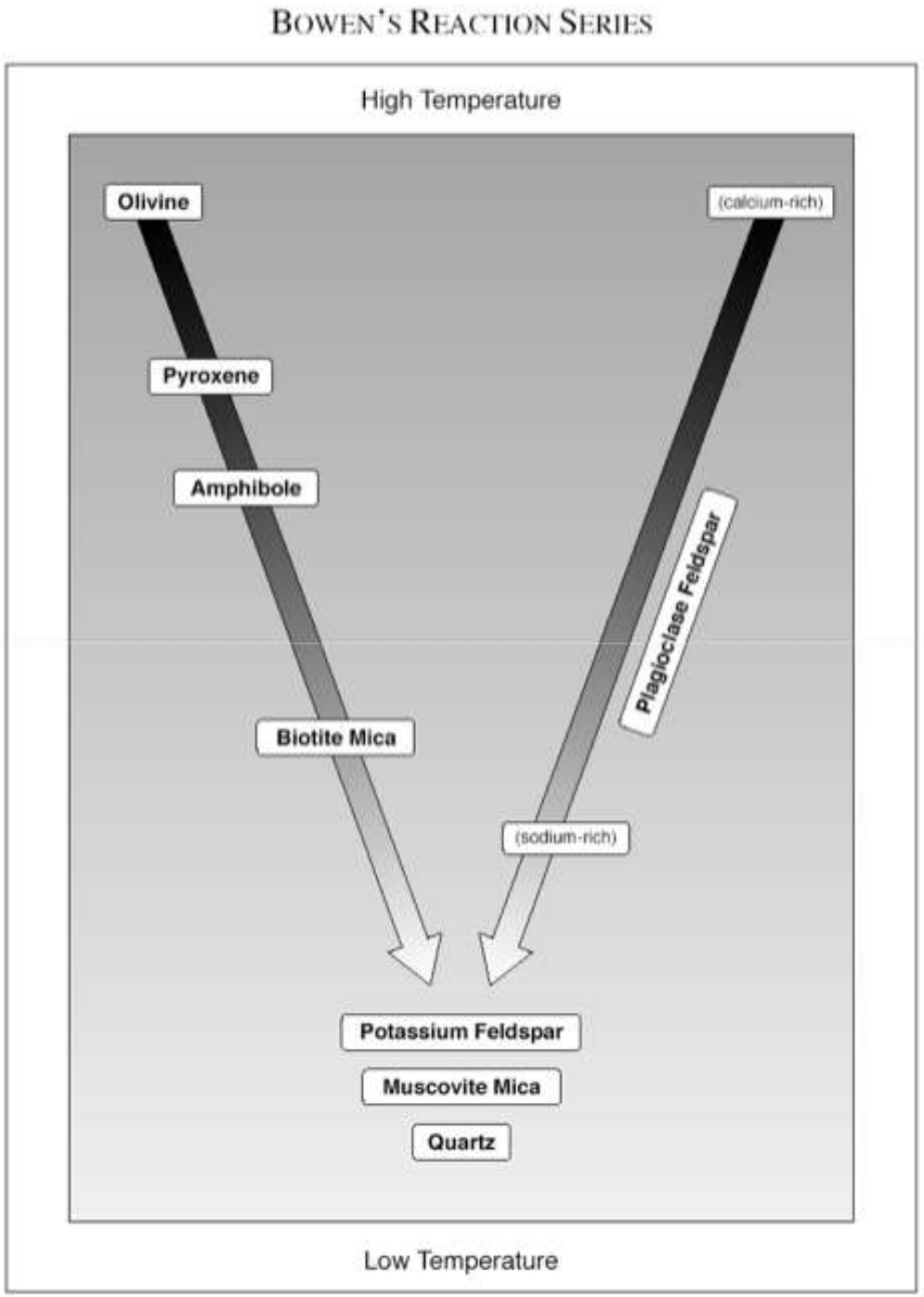
- **See page 138– Figure 5.6 (or the next page in these notes)**

Bowens Reaction Series




First To Crystallize At High Temperatures
Increasing structural complexity….
Due to longer time of crystallization =
Stronger more resistant minerals
Increasing Silica & Decreasing Ferromagnesian Impurities
High
Temperature
Low
Olivine
Isolated Tetrahedra
Ferromagnesian Rich & Silica Poor
Ca
Ultramafic
Pyroxene
Single Chain
Plagioclase
Amphibole
Double Chain
Mafic
Biotite
Sheets of Tetrahedra
Discontinuous Reaction Series
Initially formed are replaced
Continuous Reaction Series
Initially formed are NOT replaced
Na
Orthoclase
Quartz
Ferromagnesian POOR & Silica Rich
Framework Arrangement
Felsic
Last To Crystallize At Low Temps

This is the one you'll probably see on any test!!



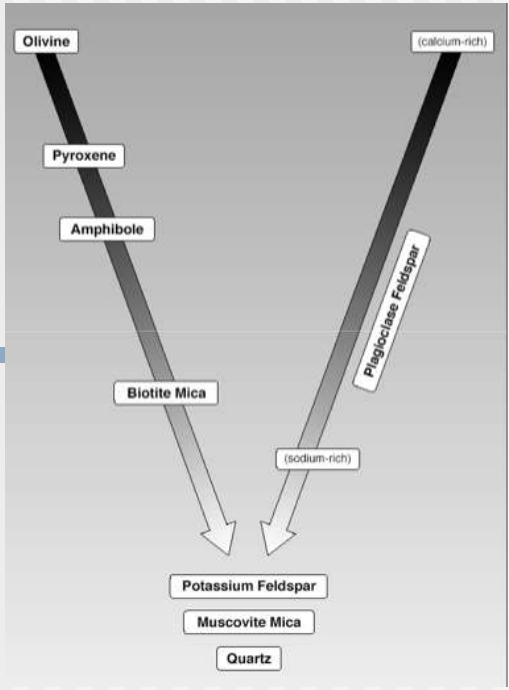
Not all magmas progress through the whole sequence!!

- Depends on the starting composition of the melt…if you start with little silica…you can't end up with all silicate based minerals.
- The more silica you start with the further down the series you can go
- The less silica you start with the shorter down the series you will go!!

Result is Two Main Magma Types:

1. Magma Type A - MAFIC
2. Intermediate
3. Magma Type B - FELSIC
4. Ultramafic

Magma Type A - MAFIC



- Poor in Silicate based minerals (Quartz & Feldspar)
- **Rich** in **Magnesium** & **Iron** based minerals (**ferromagnesians**)
- Don't progress far down Bowen's Reaction Series…Not enough Silica to make it very far!

- **Produces Rocks dominated by the higher minerals on Bowen's Reaction Series….** (i.e. Ferromagnesian Rich - Silicate Poor!)

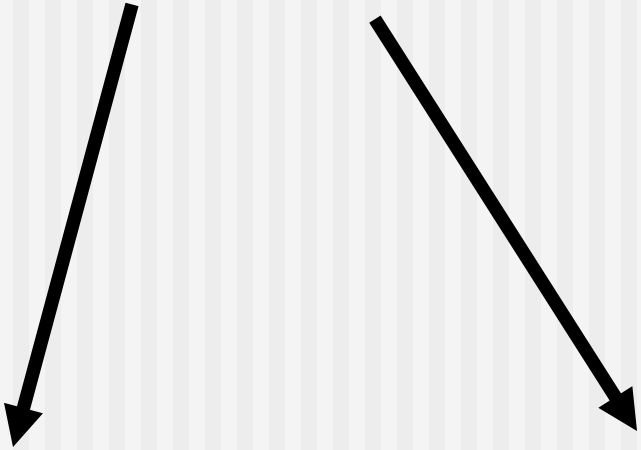
- Result is Lots of DARK Ferromagnesian Minerals

- Iron (Fe) & Magnesium (Mg)…**Ferromagnesians**!

- Therefore called **MAFIC ROCKS!!**

- Very **DARK** in color

MaFic



Magnesium (Mg) **Iron (Fe)**

Contain Iron (Ferrous - Fe) & Magnesium (Mg)
Therefore also called "Ferromagnesians"

Magma & Viscosity:

- **Viscosity** refers to the thickness or resistance of a liquid to flow.
- Molasses has **HIGHER viscosity**… resistant to flow and is thick
- Water has **LOWER viscosity**… flows well and is thin

- **LOWER viscosity**
- **HIGHER viscosity**

- In magmas…viscosity is mainly controlled by the **amount of SILICA present**.

- In other words the more Silica/Oxygen Tetrahedra present, the thicker the magma!!

- **LOWER viscosity**
  - **Runny!!!**

- **HIGHER viscosity**
  - **Thick & Chunky!!!**

Mafic Magma & Viscosity:

- **Mafic magmas contain mostly ferromagnesians (with little silica)…these have simple structures that flow past each other easily!**
- **Magmas composed of ferromagnesians contain little silica and are therefore "runny".**
- **Therefore, they flow easily & allow GAS to escape!**
- **They have the Lowest Viscosity among magmas.**

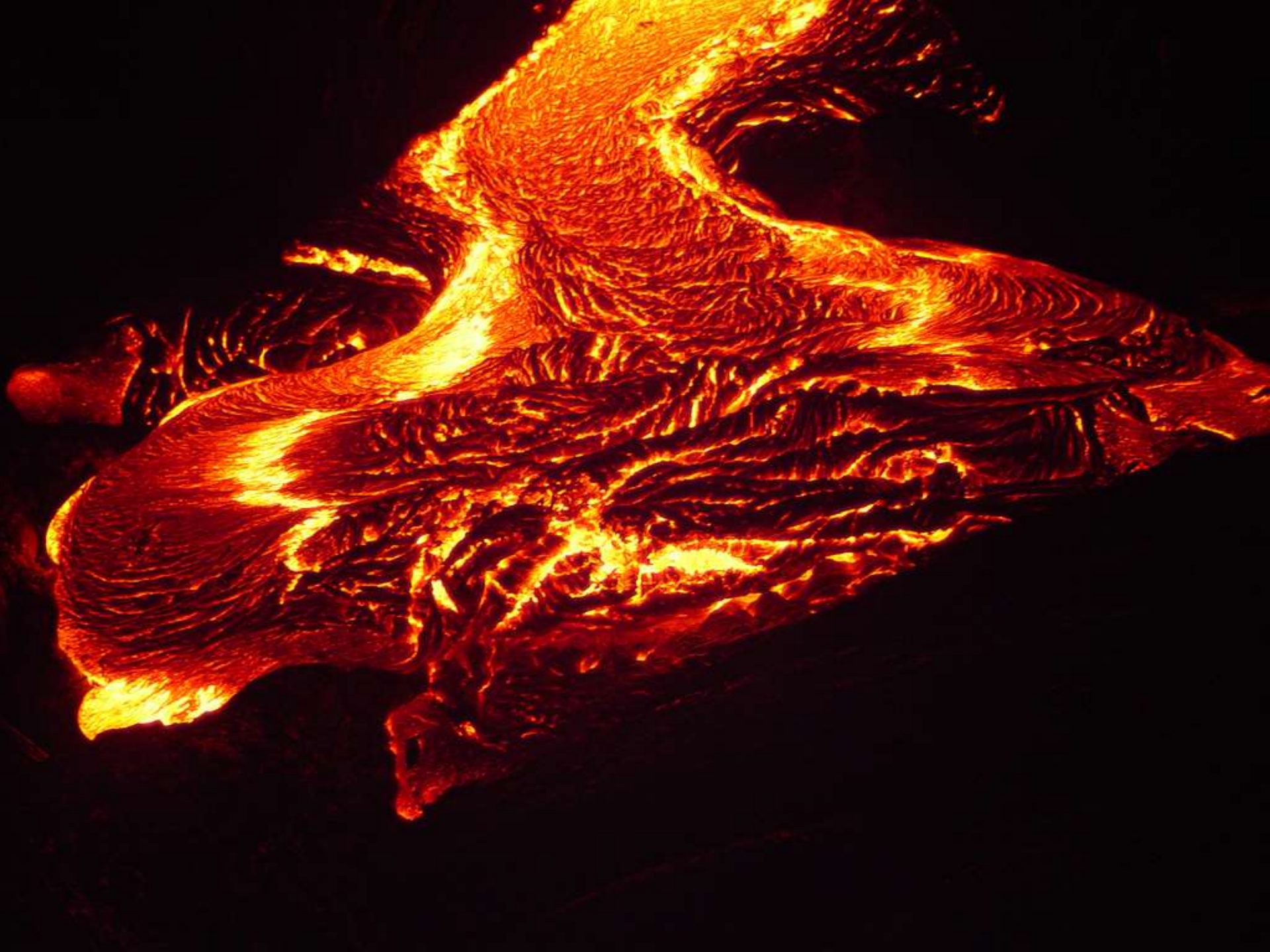
- **Volcanoes that erupt Mafic Magmas are quiet and gentle eruptions with out large explosions!**

- **Therefore they are far less destructive than Felsic eruptions!**

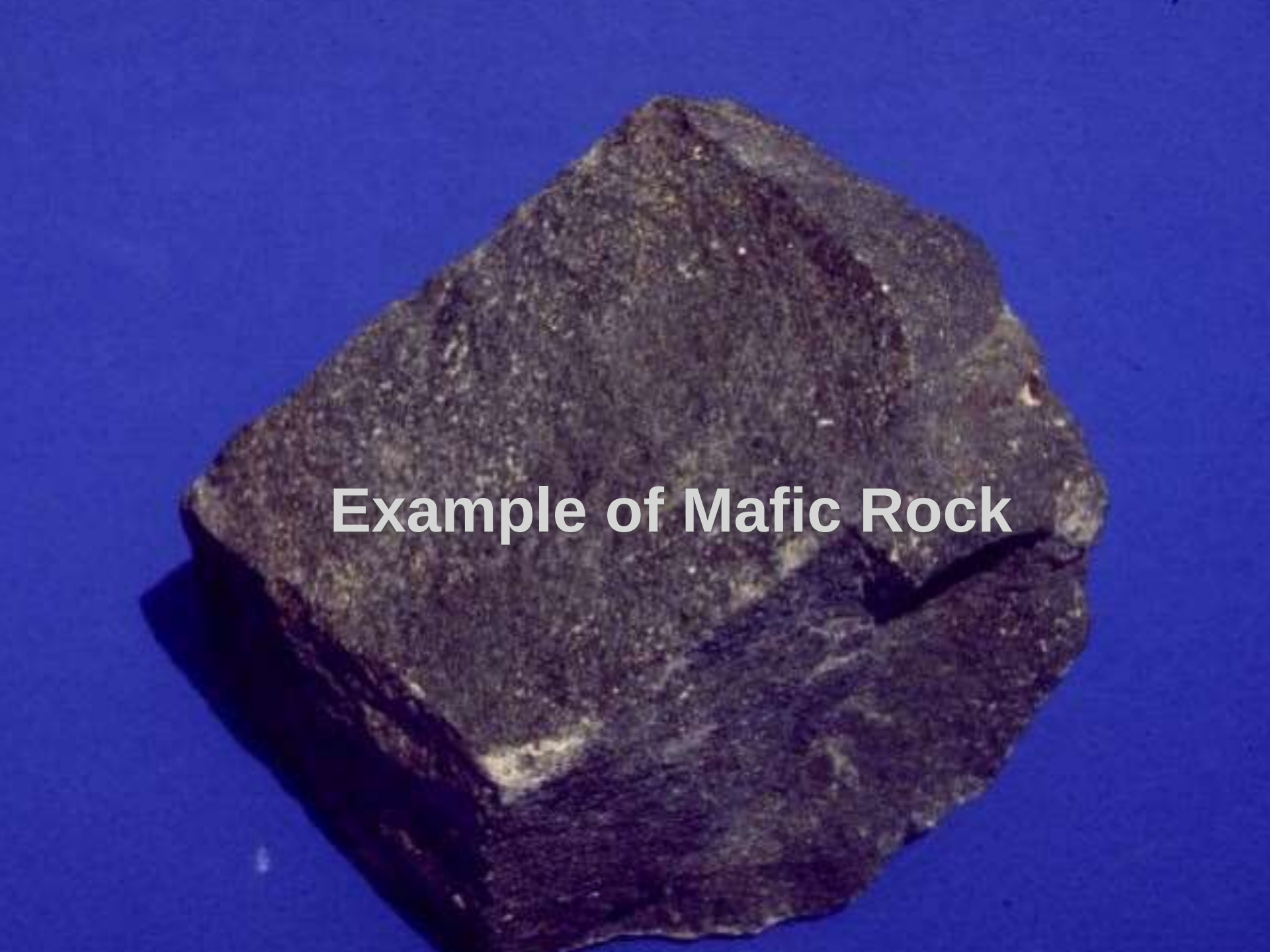
- **Because Mafic magmas (lavas) flow readily, you can stand around and watch them.**

- **They may flow readily and even rapidly, but you can see them coming and get out of the way.**

- **You can't watch them too closely, however, because the high heat is unbearable.**

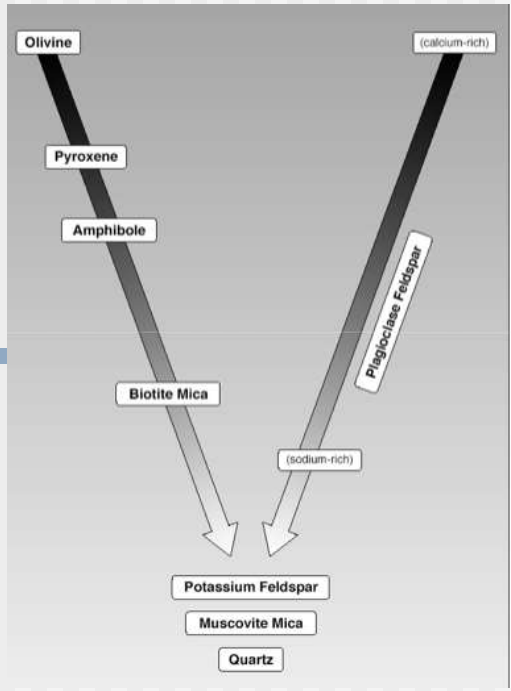



I WAS AN IGNEOUS ROCK
BEFORE IT WAS COOL
Condoria


Example of Mafic Rock


Another Mafic Rock

Magma Type B – FELSIC



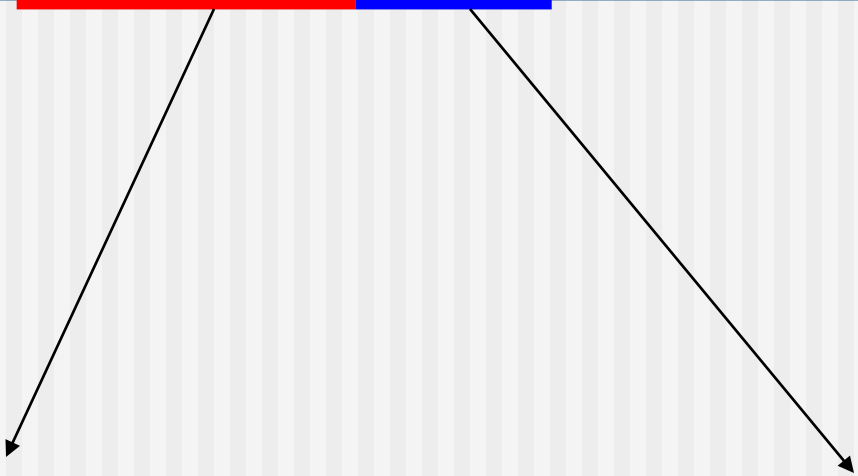
- **Rich** in **Silicate** based minerals (**Quartz & Feldspar**) & **Aluminum**
- **Poor** in **Magnesium** and **Iron** based minerals (ferromagnesians)
- Makes it to the end of Bowen's Reaction Series!

- **Produces rocks dominated by the lower minerals (i.e. Ferromagnesian poor - Silicate rich!)**

- **Result is lots of Quartz (silica) & Feldspar so…a.k.a. FELSIC ROCKS!!**

- **Tend to be LIGHT COLORED**

Felsic



Feldspar

Silica i.e. Quartz

Both Silicates therefore also called "Silicic"

Be Careful!

"Felsic" Fe is part of Fel for Feldspar…

Feldspar Rich IRON POOR

Don't confuse it with "Fe" which represents the symbol for Iron (Fe) in the IRON RICH "MAFIC" rocks

Felsic Magma & Viscosity:

- **Felsic Magmas Contain lots of Quartz & Feldspar – (Framework Silicates) i.e. LOTS of SILICA!**
- **Magmas composed of framework silicates are "sticky".**
- **Therefore they do not flow easily and readily trap GASES.**
- **They have the Highest Viscosity/Gas Content among magmas**
- **As they rise towards the Earth's surface, they get "stuck in the pipes", and GAS pressure builds!**

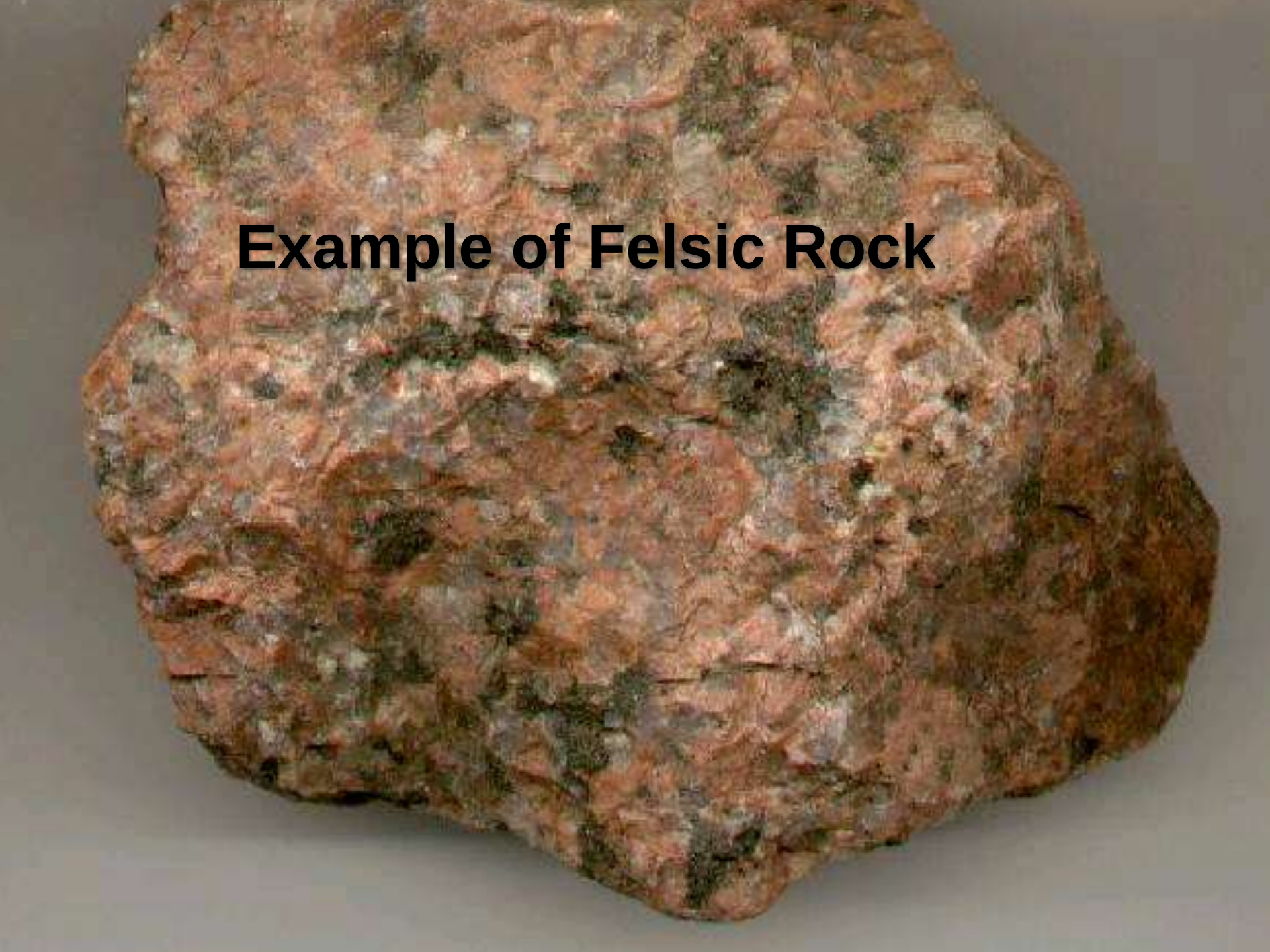
- More magma keeps rising from below, and pressures build to a critical point....

- At that point, the magma and gas still trying to rise **explode**, shattering all of the overlying, hardened lava (and/or magma).

- Volcanoes that erupt Felsic Magmas are **extremely dangerous & EXPLOSIVE!!**

- It may not be safe even 10s of km's from them.


AHHH!!! PYROCLASTIC CLOUD!!!
ALBERT GARCIA


Example of Felsic Rock


Another Felsic Rock


Another Felsic Rock

Modifying Melt Composition –

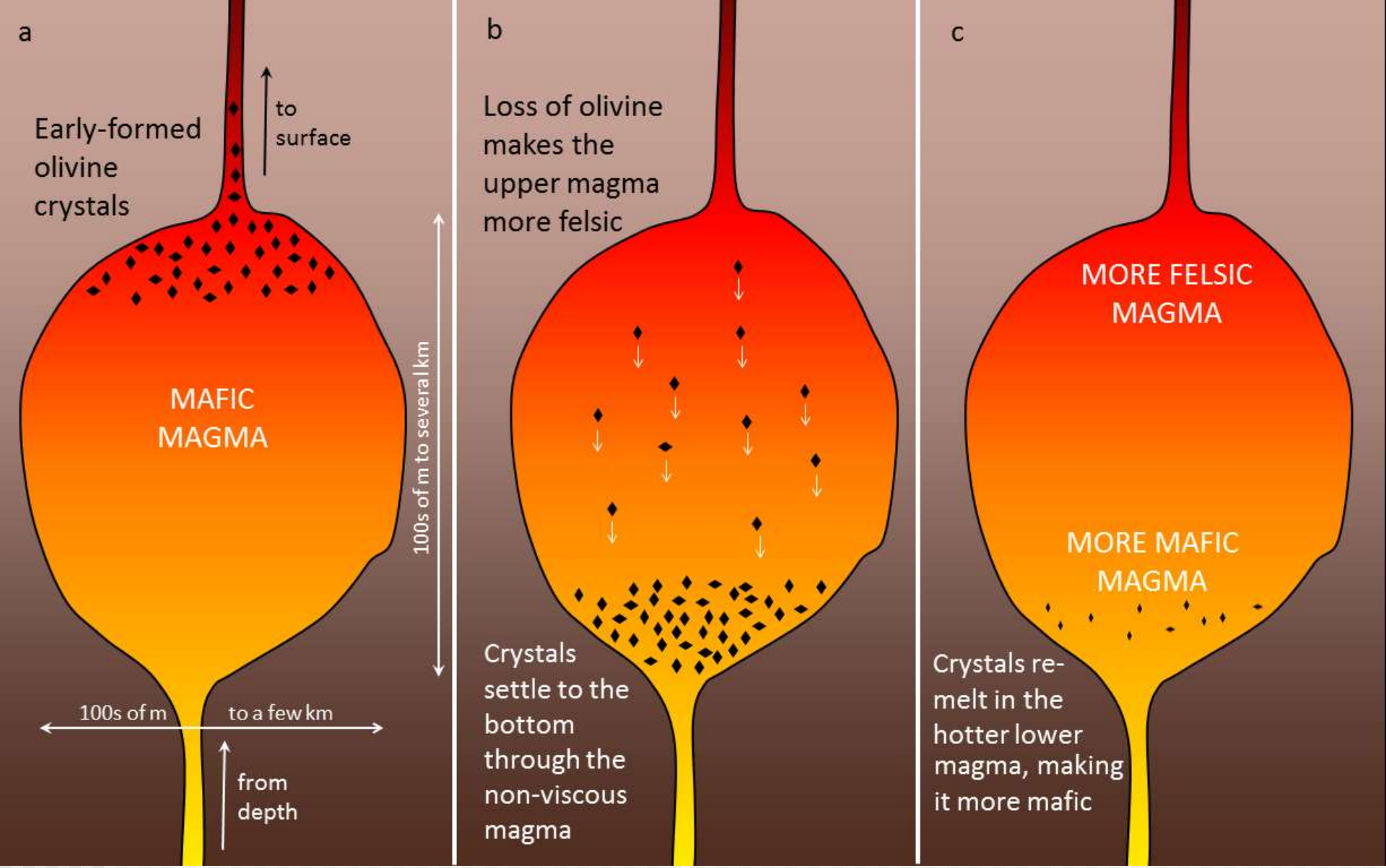
- **Sometimes a magma's mineral composition is changed after the melt is formed.**
- **This can happen if various minerals are added or subtracted.**
- **Results in rocks that are different than would be expected from the original magma's composition.**

***Three Main Ways:

1. **FRACTIONAL CRYSTALLIZATION**
2. **WALL ROCK ASSIMILATION**
3. **MAGMA MIXING**

FRACTIONAL CRYSTALLIZATION

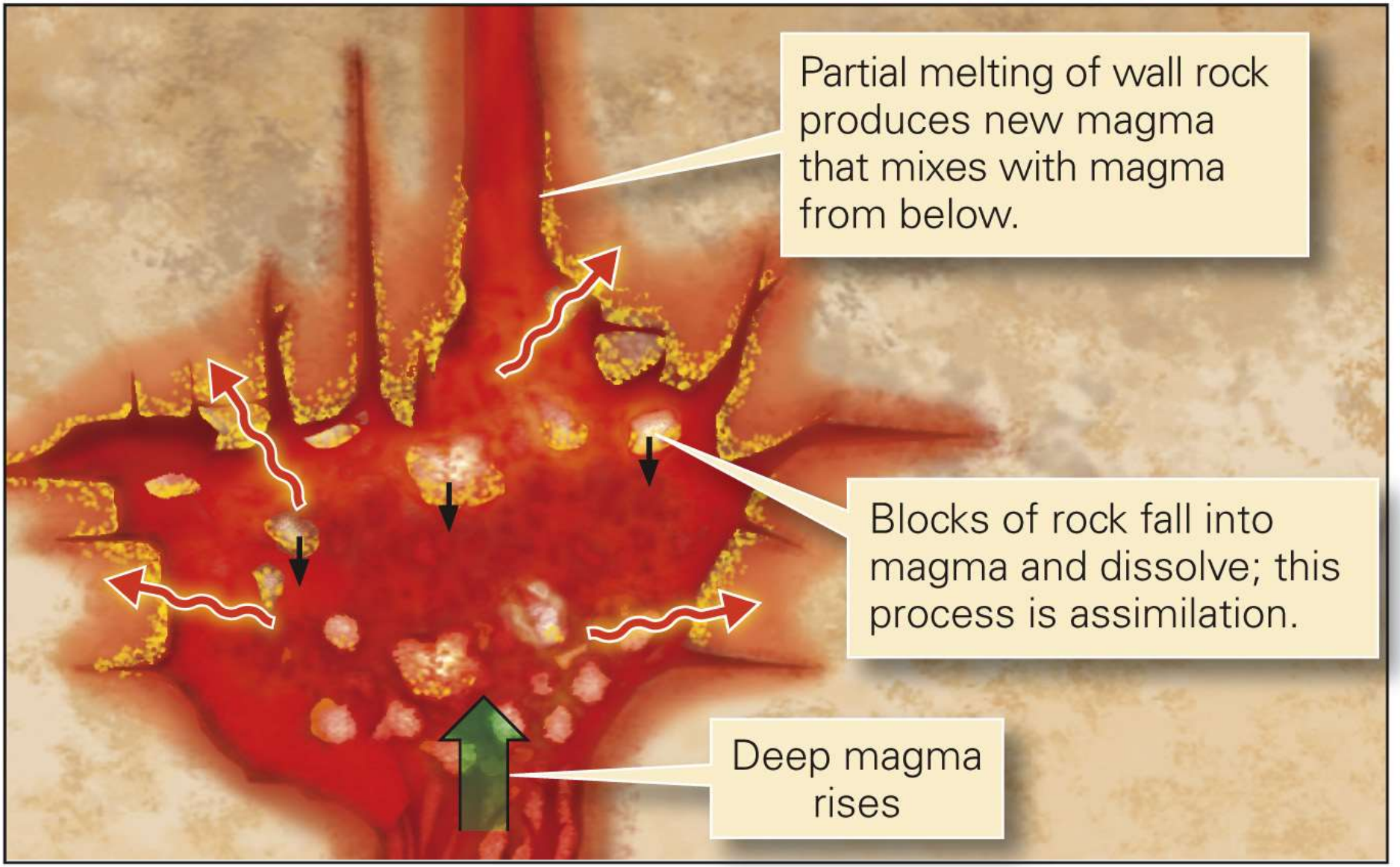
- **Most common way Magmas are modified.**
- **Early formed crystals are physically removed from the melt – See Page#50 Figure 3.6.**
- **Since they are removed…the early crystals can't continue to react with the melt.**
- **Melt is shifted to a more Silicic composition (WHY??) and progresses further down Bowen's Reaction Series.**



FRACTIONAL CRYSTALLIZATION

Wall Rock ASSIMILATION

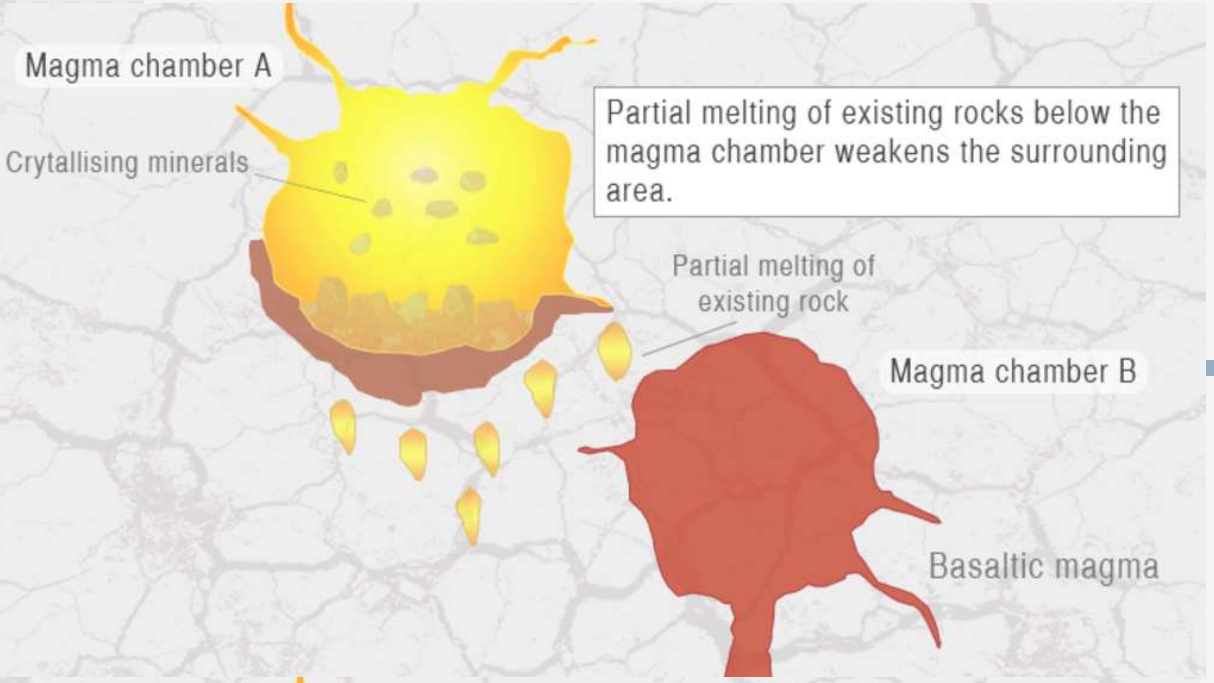
- **Surrounding rock (Called COUNRTY ROCK) becomes assimilated into magma.**
- **New rock is melted and mixed with magma.**
- **Results in a shift in the magma's composition.**

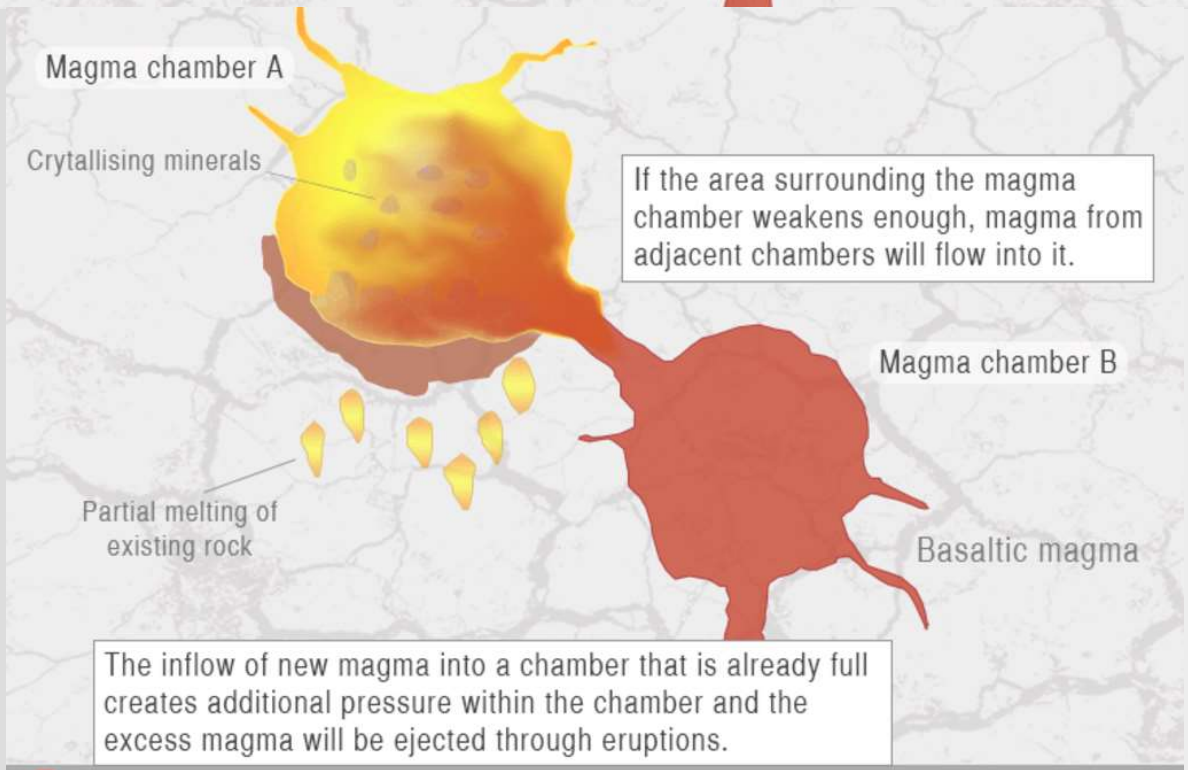


Wall Rock ASSIMILATION

MAGMA MIXING

- **Occurs when two magmas (melts) combine.**
- **Result is a new magma with a hybrid composition.**
- **Tends to be rare!**





MAGMA MIXING


LAVA? EVER HEARD OF MAGMA?
ITS SO UNDERGROUND
quickmeme.com

Classification Of Igneous Rocks

Igneous Rocks can be Broken into two main groups:

Plutonic or INTRUSIVE –

Rocks that cool SLOWLY and DEEP within the interior of the earth.

Slow Deep cooling = LARGE CRYSTALS

Volcanic or EXTRUSIVE –

Rocks that cool RAPIDLY and ABOVE the crust of the earth.

Rapid Above Ground cooling = SMALL CRYSTALS

Intrusive / Plutonic:

Depth of crystallization affects rate of crystallization and is therefore reflected in texture…

PLUTONIC (Intrusive) Rocks –

Crystallize at great depths within the Earth; therefore, Intrusive!

Well Insulated = Slow Cooling,

Slow Cooling = Coarse Grained,

Coarse Grained = LARGE CRYSTALS!

Extrusive / Volcanic:

Depth of crystallization affects rate of crystallization and is therefore reflected in texture…

VOLCANIC (Extrusive) Rocks –

Crystallize very near or above the Earth's surface (exit onto the surface); therefore extrusive!

Poorly Insulated = Fast Cooling,

Fast Cooling = Fine Grained,

Fine Grained = SMALL CRYSTALS!

Igneous Rocks are classified by TWO criteria:

1. **TEXTURE**

(basically how big are the crystals in the rock)

and

2. **MINERAL COMPOSITION**

(what minerals are present and in what proportions)

TEXTURE:

The most important textural feature is:

Crystal or Grain SIZE.

Fast-Cooling = Fine Grained = Extrusive = Volcanic

No time for proper crystal growth!!

Slow-Cooling = Coarse Grained = Intrusive = Plutonic

Lots of time for proper crystal growth!!

Plutonic (Intrusive) rocks tend to have crystals that are large and visible to the naked eye.

Most often PHANERITIC!

Volcanic (extrusive) rocks tend to have crystals that are small and not visible to the naked eye.

Most often APHANITIC!

There are Seven Main Textures you need to know:

1. **Pegmatitic**
2. **Phaneritic**
3. **Porphyritic**
4. **Aphanitic**
5. **Glassy**
6. **Vesicular**
7. **Pyroclastic or Fragmental**

***These are all diagramed and explained in The Lab Manual.

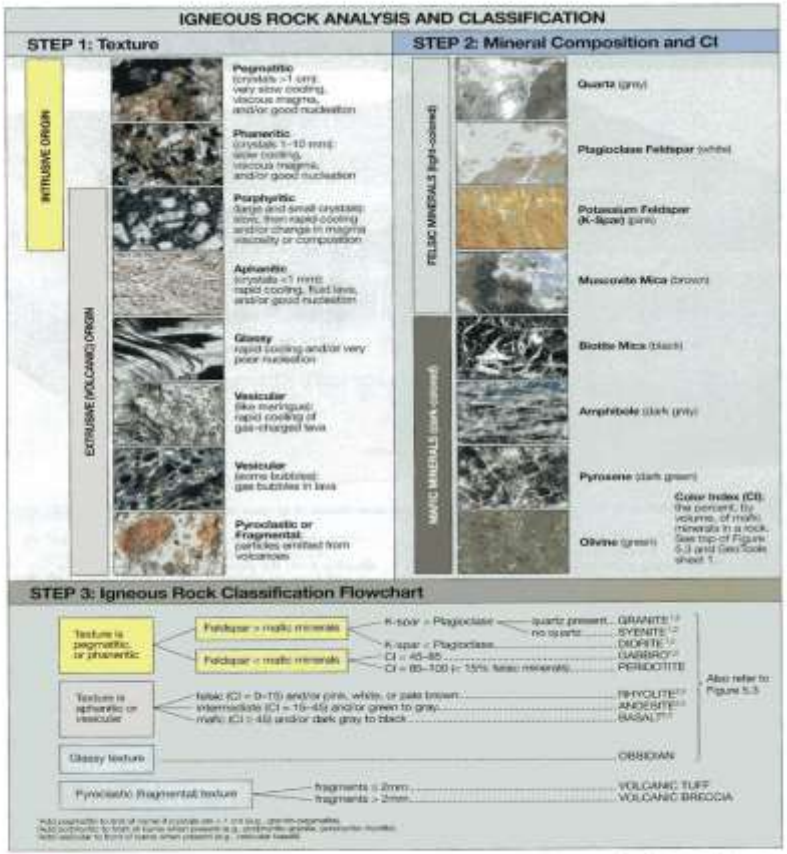


FIGURE 5.2 Igneous rock analysis and classification. **Step 1**—Identify the texture(s) of the rock. **Step 2**—Identify the mineral composition of the rock by identifying the main rock-forming minerals that comprise it, estimating the relative abundances of each mineral (using a Visual Estimation of Percent chart from GeoTools Template 1), and estimating the rock's color index. **Step 3**—Use the Igneous Rock Classification Flowchart to name the rock. Start on the left side of the flowchart, and work toward the right side to the rock name.

STEP 1: Texture

INTRUSIVE ORIGIN

EXTRUSIVE (VOLCANIC) ORIGIN

Pegmatitic
(crystals >1 cm):
very slow cooling,
viscous magma,
and/or good nucleation

Phaneritic
(crystals 1–10 mm):
slow cooling,
viscous magma,
and/or good nucleation

Porphyritic
(large and small crystals):
slow, then rapid cooling
and/or change in magma
viscosity or composition

Aphanitic
(crystals <1 mm):
rapid cooling, fluid lava,
and/or good nucleation

Glassy
rapid cooling and/or very
poor nucleation

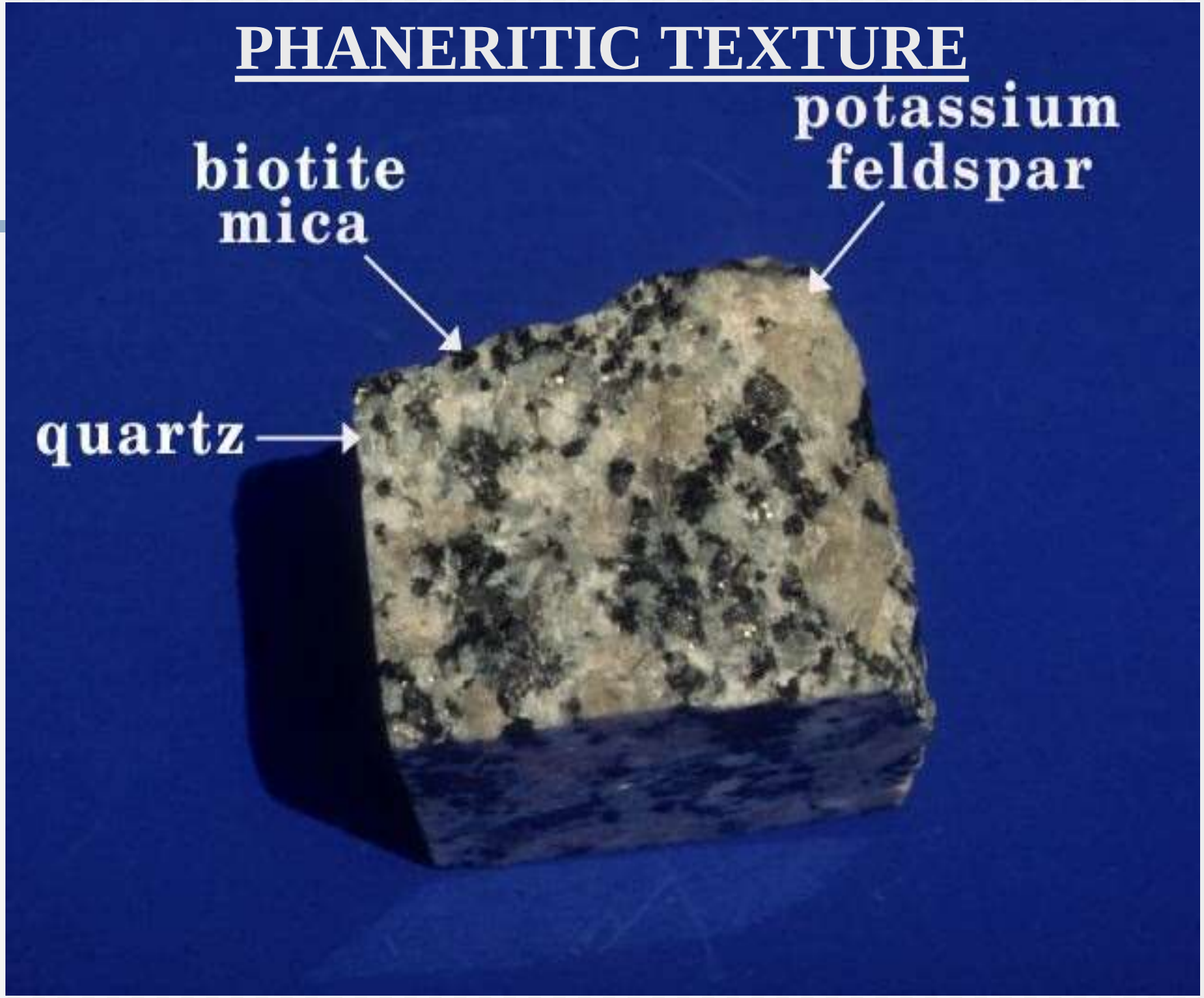
Vesicular
(like meringue):
rapid cooling of
gas-charged lava

Vesicular
(some bubbles):
gas bubbles in lava

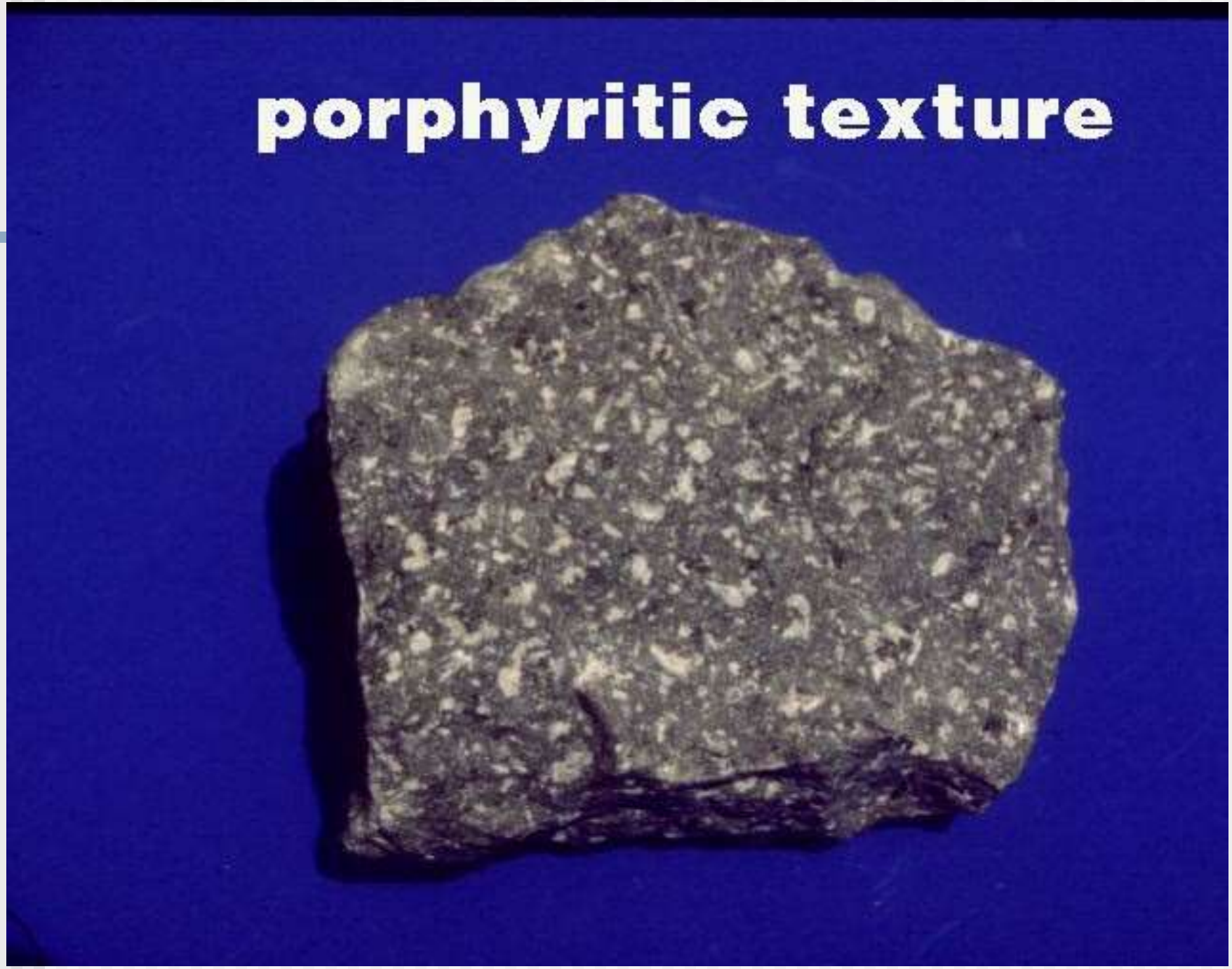
Pyroclastic or Fragmental:
particles emitted from
volcanoes

PEGMATITIC TEXTURE

PHANERITIC TEXTURE



Phaneritic


porphyritic texture

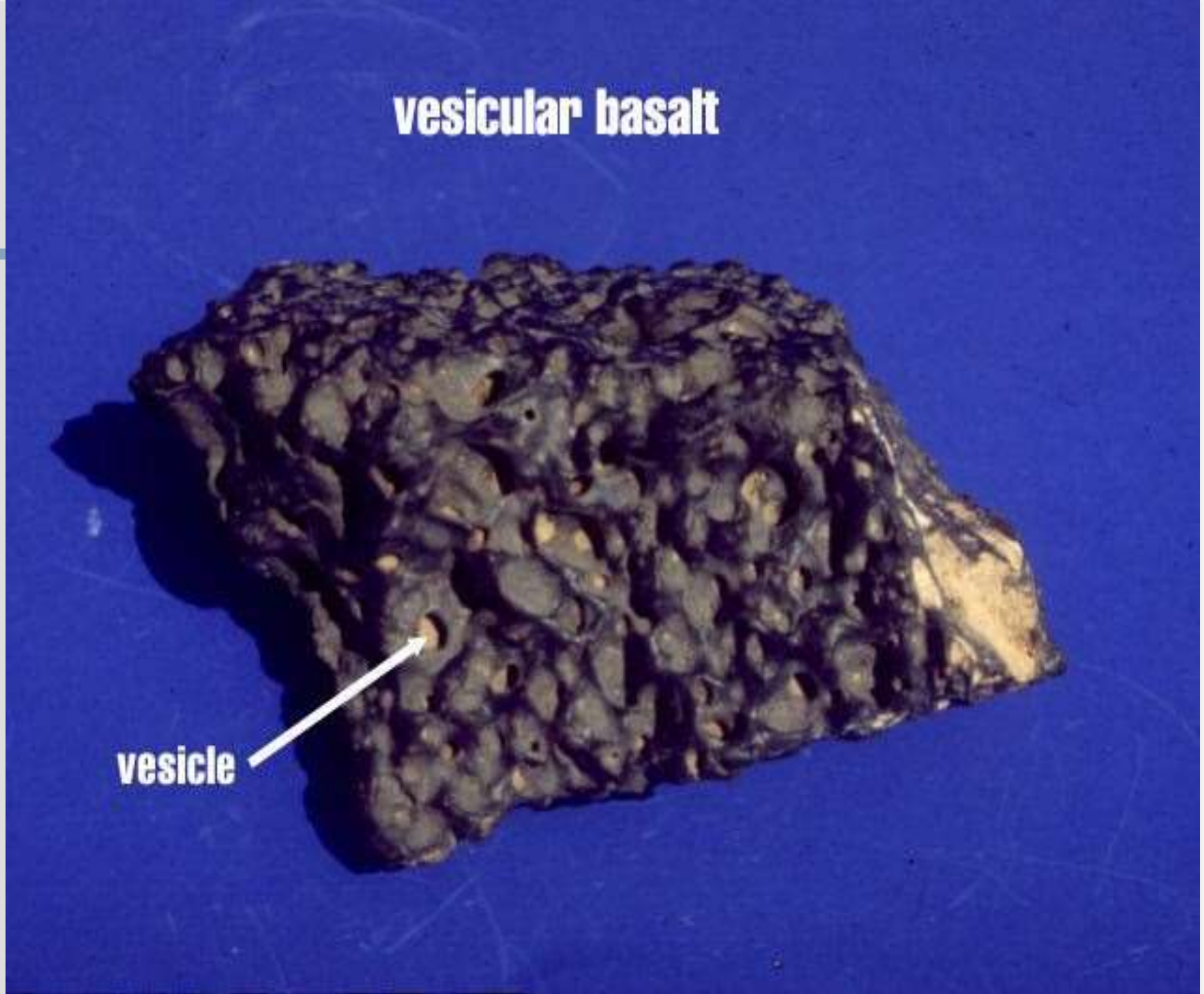
Porphyritic texture

APHANITIC texture


obsidian
glassy
texture

photograph 2

Notice The Conchoidal Fracture!


vesicular basalt
vesicle

Scoria=Vesicular Basalt

Pumice

Pyroclastic texture

Sub Group of Volcanic Rocks

Are rocks that result from the fragmentation and breaking up of volcanic materials as they are ejected from the earth during violent volcanic eruptions.

PYRO = FIRE

CLAST = CHUNK


pyroclastic texture

A **Volcanic Bomb** = Pyroclastic/Fragmental

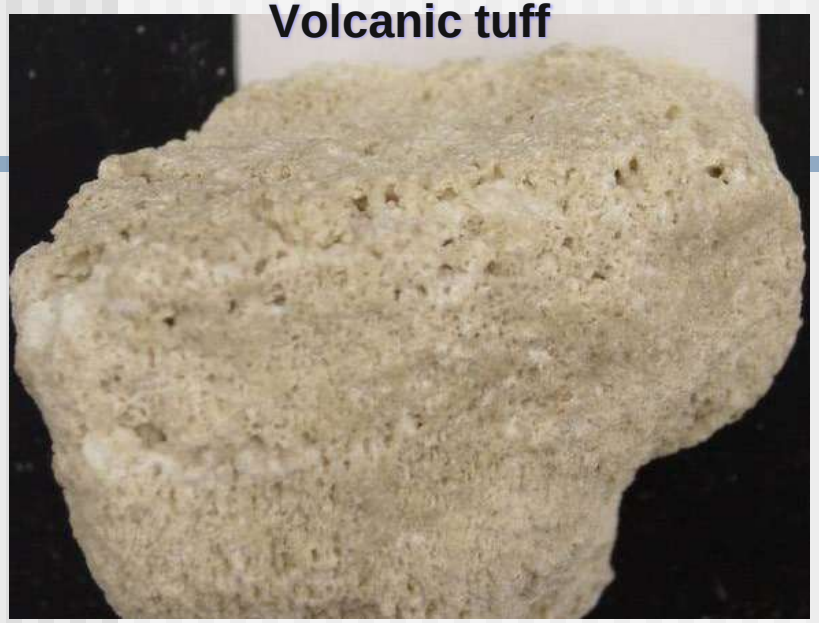
Cools Rapidly on the outside as it flies through the air…

Rapid cooling results in cracked outer surface!

Cools more slowly on the inside...

More Examples Of Pyroclastic

Volcanic tuff



Volcanic breccia

Volcanic bombs

Mineral Composition:

- This one is easy!

- Basically a Rock is **Mafic**, **Felsic**
- or between the two = called **Intermediate**
- or more mafic = **Ultramafic**

- The Composition is based on what minerals made up the magma that formed the rock…
  - **More silica = More FELSIC**
  - **More Ferromagnesians = More MAFIC**

- The composition can span anywhere from one extreme to the other.

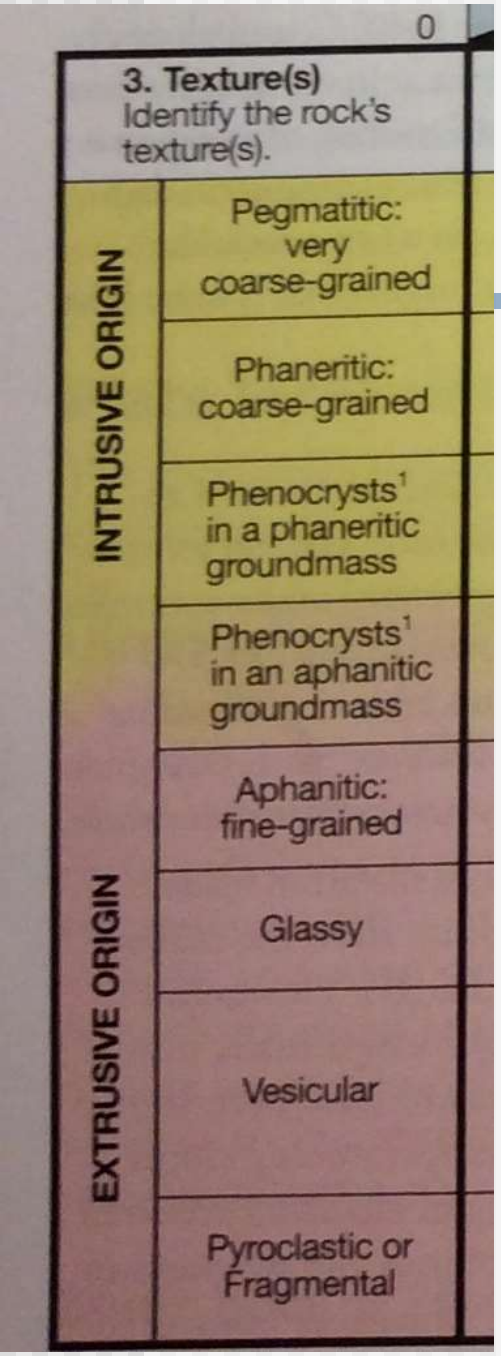
Naming Igneous Rocks!

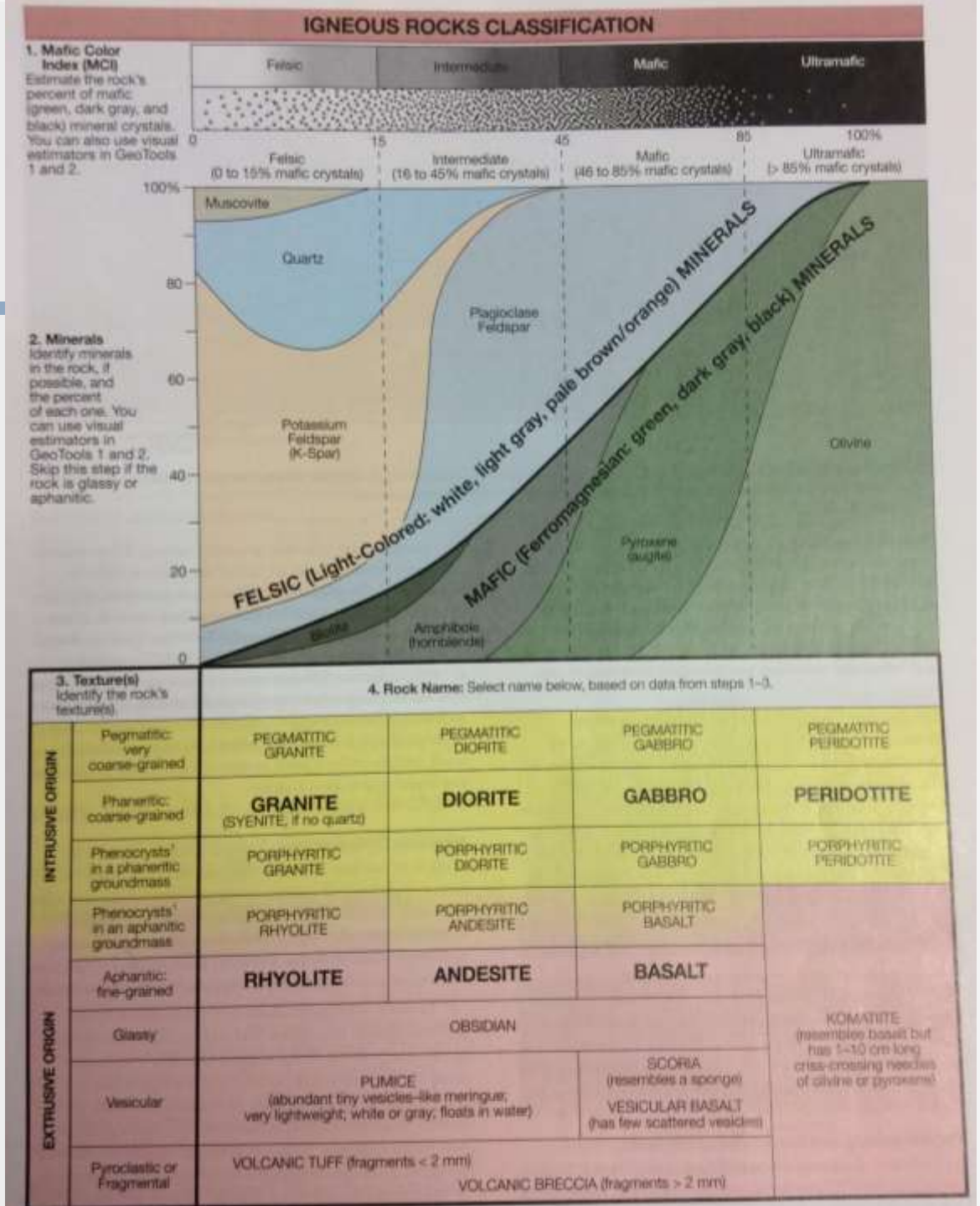
- We use one table, found in our data package, text book, note package, or lab book.

- This table combines:

TEXTURE & COMPOSITION

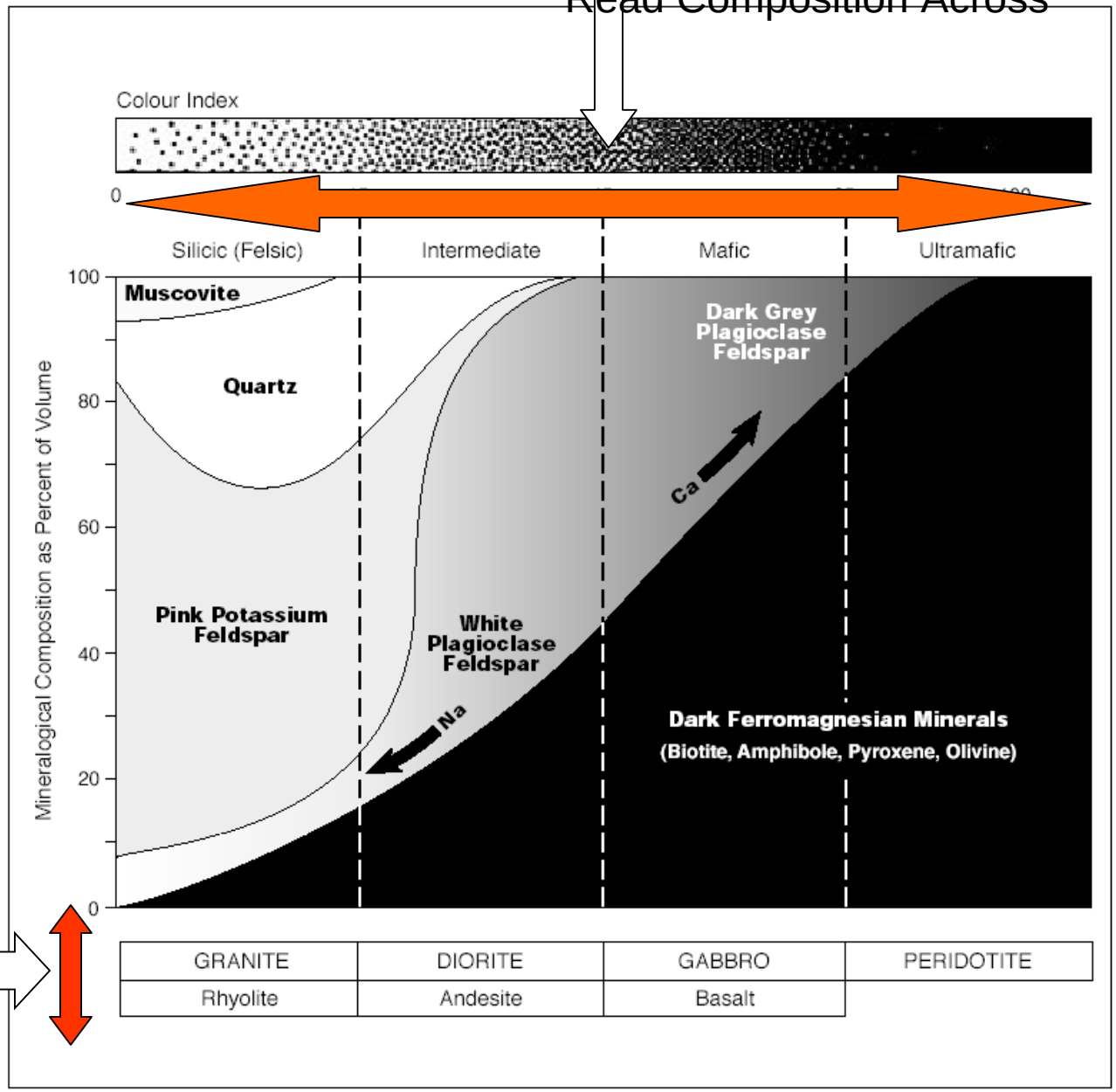
It looks like this…..


0
3. Texture(s)
Identify the rock's texture(s).
INTRUSIVE ORIGIN
Pegmatitic: very coarse-grained
Phaneritic: coarse-grained
Phenocrysts[1] in a phaneritic groundmass
Phenocrysts[1] in an aphanitic groundmass
Aphanitic: fine-grained
EXTRUSIVE ORIGIN
Glassy
Vesicular
Pyroclastic or Fragmental


IGNEOUS ROCKS CLASSIFICATION
1. Mafic Color Index (MCI)
Estimate the rock's percent of mafic (green, dark gray, and black) mineral crystals. You can also use visual estimators in GeoTools 1 and 2.
Felsic
Intermediate
Mafic
Ultramafic
0
15
45
85
100%
Felsic (0 to 15% mafic crystals)
Intermediate (16 to 45% mafic crystals)
Mafic (46 to 85% mafic crystals)
Ultramafic (> 85% mafic crystals)
2. Minerals
Identify minerals in the rock, if possible, and the percent of each one. You can use visual estimators in GeoTools 1 and 2. Skip this step if the rock is glassy or aphanitic.
100%
80
60
40
20
0
Muscovite
Quartz
Plagioclase Feldspar
Potassium Feldspar (K-Spar)
Biotite
Amphibole (hornblende)
Pyroxene (augite)
Olivine
FELSIC (Light-Colored: white, light gray, pale brown/orange) MINERALS
MAFIC (Ferromagnesian: green, dark gray, black) MINERALS
3. Texture(s)
Identify the rock's texture(s).
4. Rock Name: Select name below, based on data from steps 1–3.
INTRUSIVE ORIGIN
EXTRUSIVE ORIGIN
Pegmatitic: very coarse-grained
PEGMATITIC GRANITE
PEGMATITIC DIORITE
PEGMATITIC GABBRO
PEGMATITIC PERIDOTITE
Phaneritic: coarse-grained
GRANITE (SYENITE, if no quartz)
DIORITE
GABBRO
PERIDOTITE
Phenocrysts[1] in a phaneritic groundmass
PORPHYRITIC GRANITE
PORPHYRITIC DIORITE
PORPHYRITIC GABBRO
PORPHYRITIC PERIDOTITE
Phenocrysts[1] in an aphanitic groundmass
PORPHYRITIC RHYOLITE
PORPHYRITIC ANDESITE
PORPHYRITIC BASALT
Aphanitic: fine-grained
RHYOLITE
ANDESITE
BASALT
Glassy
OBSIDIAN
Vesicular
PUMICE (abundant tiny vesicles–like meringue; very lightweight; white or gray; floats in water)
SCORIA (resembles a sponge)
VESICULAR BASALT (has few scattered vesicles)
Pyroclastic or Fragmental
VOLCANIC TUFF (fragments < 2 mm)
VOLCANIC BRECCIA (fragments > 2 mm)
KOMATIITE (resembles basalt but has 1–10 cm long criss-crossing needles of olivine or pyroxene)

Percentage of Minerals in Igneous Rocks

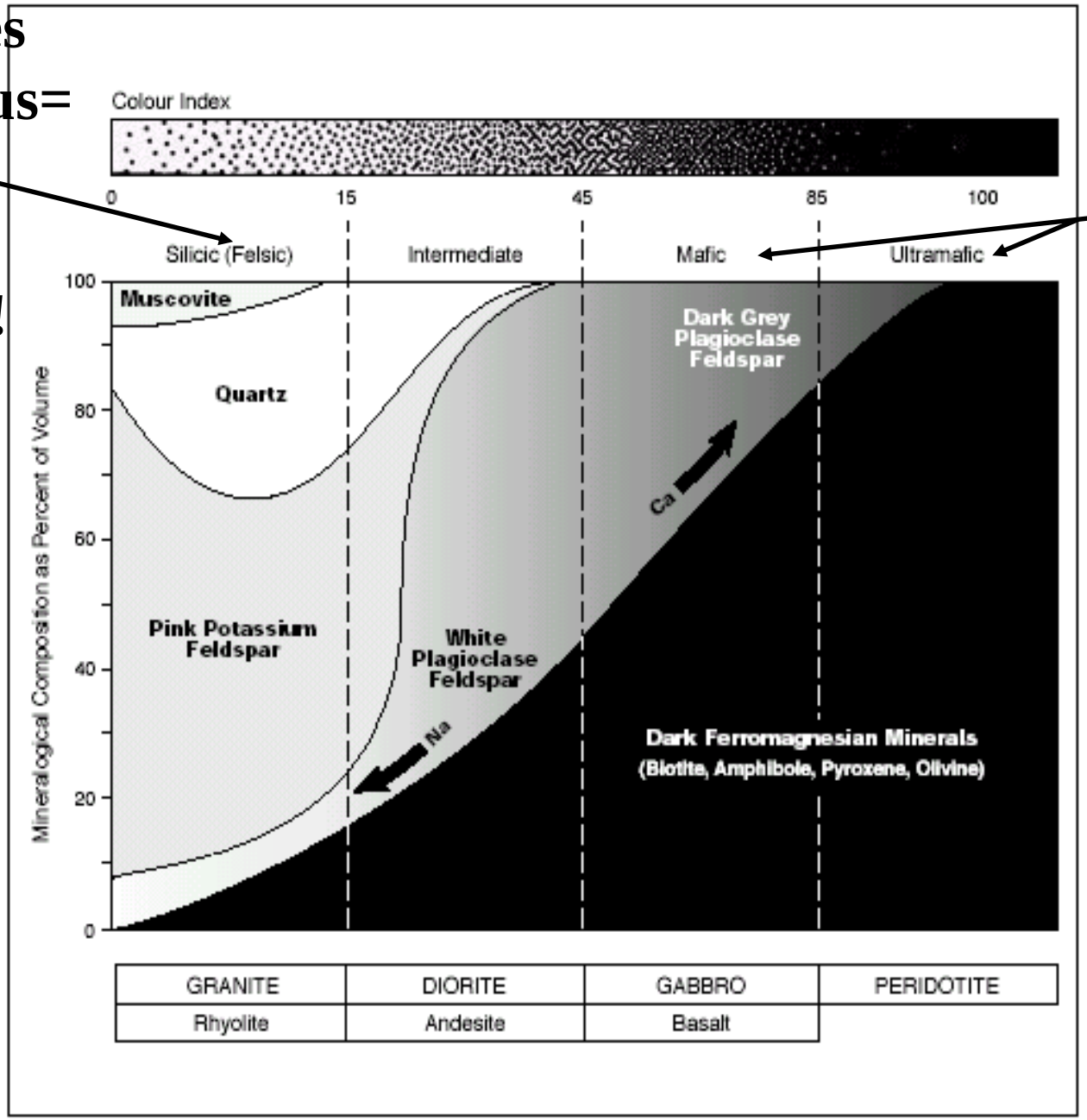
Read Composition Across



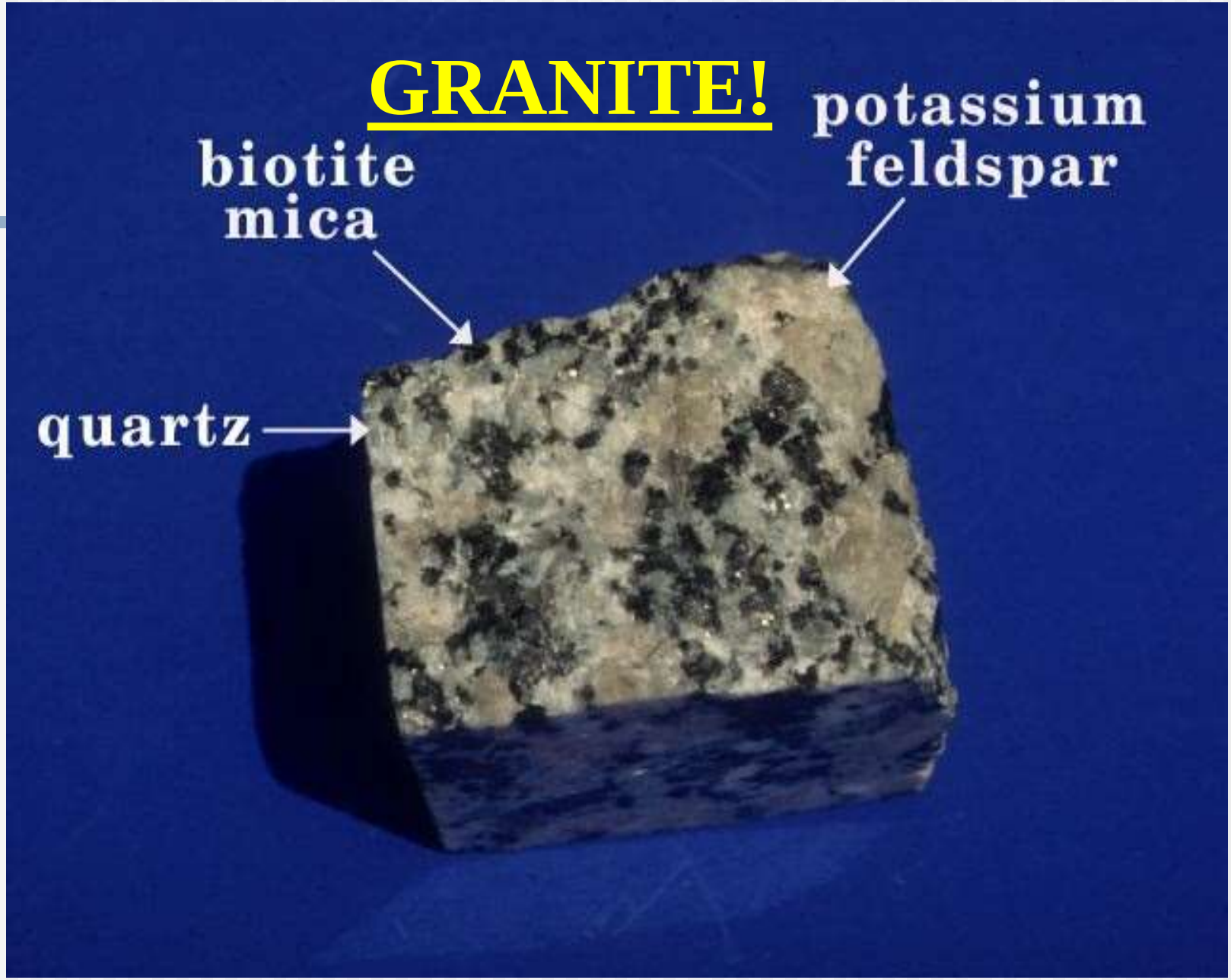
Read Texture up and down

Percentage of Minerals in Igneous Rocks

These Ones Are Viscous= Thick = Violent Eruptions!

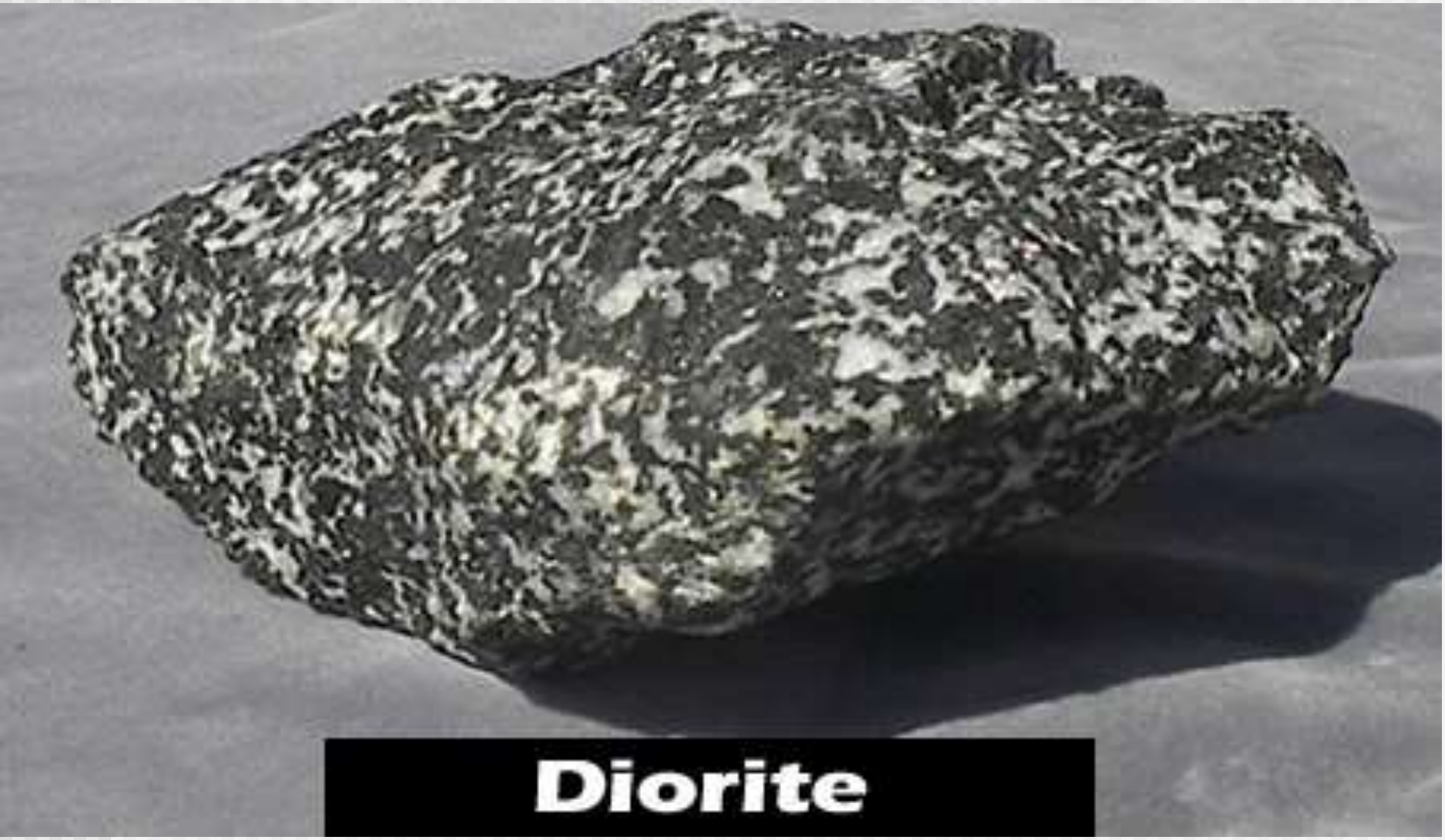


These Ones Are Not Very Viscous = Runny = Quiet Eruptions!


GRANITE!
biotite mica
potassium feldspar
quartz


Pink=Light!
Granite
Light in colo
White, gray
Pink

DIORITE!


Diorite

GABBRO!


Rhyolite
Light in color


Pink=Light!


0
2


Basalt
Andesite


Basalt
Dark in color


basalt

Use the Percentage of Minerals in Igneous Rocks table and the following table to answer the question below:

Percentage of minerals in four samples of igneous rocks

Mineral composition	Rock W	Rock X	Rock Y	Rock Z
Quartz	**40**	**16**	**0**	**2**
Pink potassium feldspar	**53**	**20**	**0**	**2**
Plagioclase feldspar	**6**	**42**	**5**	**64**
Dark ferromagnesians	**7**	**22**	**95**	**32**
All other minerals	**4**	**0**	**0**	**0**

1. Which of the igneous rocks above would be considered ultramafic?

A. W
B. X
C. Y
D. Z

2. Classify all three other rocks as Felsic, Intermediate, Mafic, or Ultramafic…