

# Rock Identification Lab



Intro to Earth Systems  
ENVI 110 Lab

Ray Rector - Instructor

# Types of Rocks

**Igneous Rocks**

**Sedimentary Rocks**

**Metamorphic Rocks**

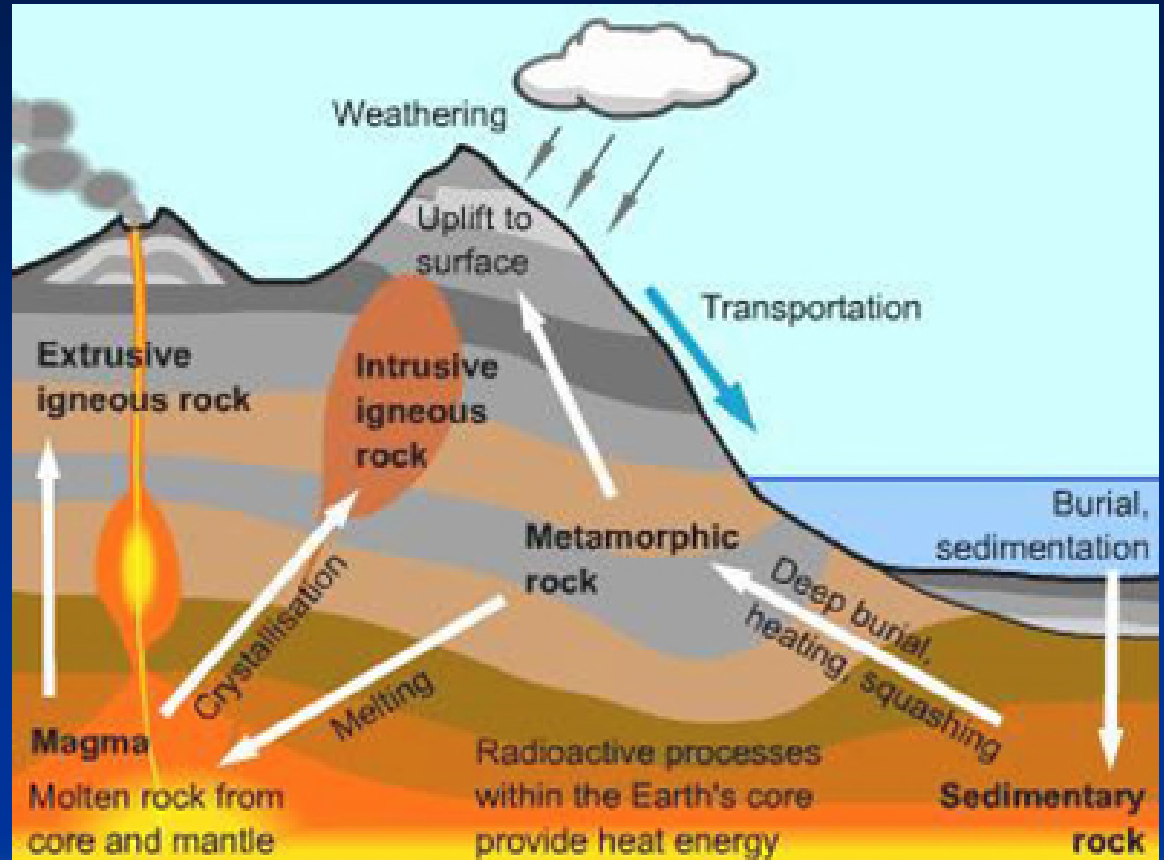
Texture	Composition		
	Felsic (Granitic)	Intermediate (Andesitic)	Mafic (Basaltic)
Phaneritic (coarse-grained)			
	Granite	Diorite	Gabbro
Aphanitic (fine-grained)			
	Rhyolite	Andesite	Basalt
Porphyritic			
	Granite porphyry	Andesite porphyry	Basalt porphyry



# The Rock Cycle

## Three Primary Rock Types

- 1) **Igneous**
- 2) **Metamorphic**
- 3) **Sedimentary**

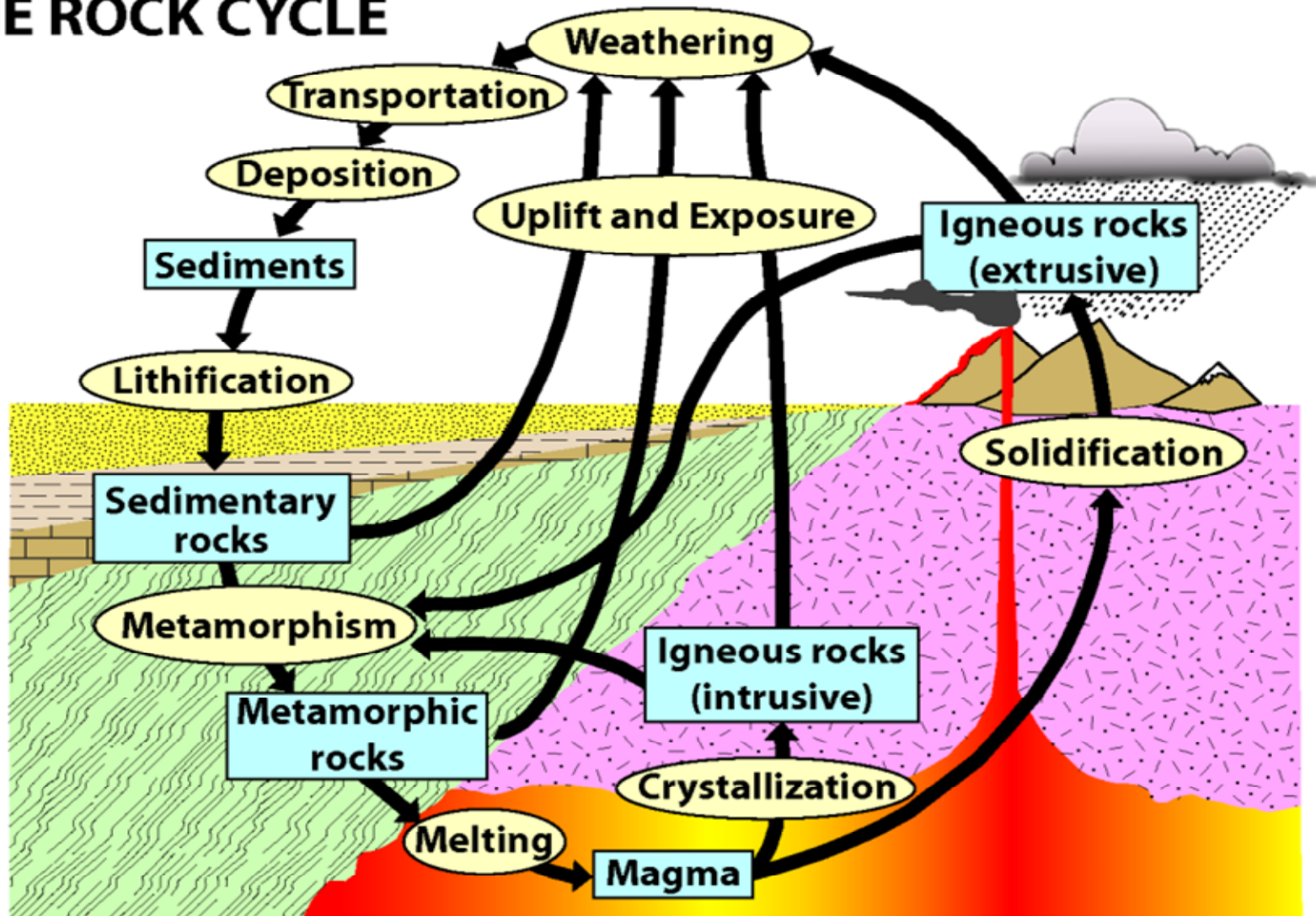


## Key Concept:

## The Rock Cycle is Perpetuated by Several Major Processes

- 1) Magmatic Activity
- 2) Uplift and Mountain Building
- 3) Weathering, Erosion, Deposition, and Burial of Sediment

# THE ROCK CYCLE



## Igneous Rocks -

Rocks that form from the cooling of molten rock (magma), Example: granite and basalt

## Sedimentary Rocks -

Rocks that are formed from pieces of other rocks, Example: sandstone, or that are deposited from the ocean by chemical processes, Example: limestone

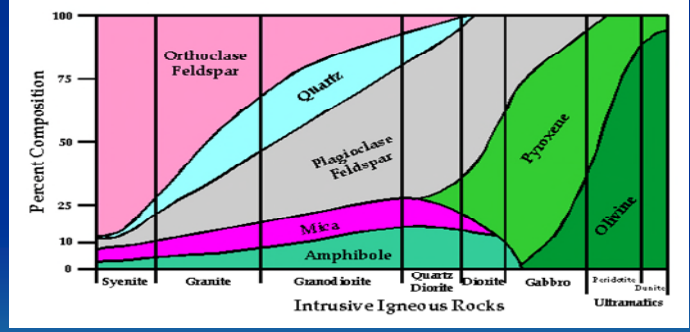
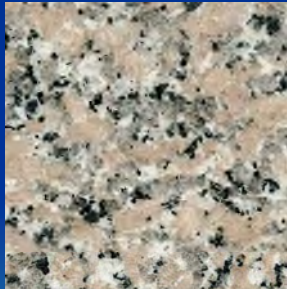
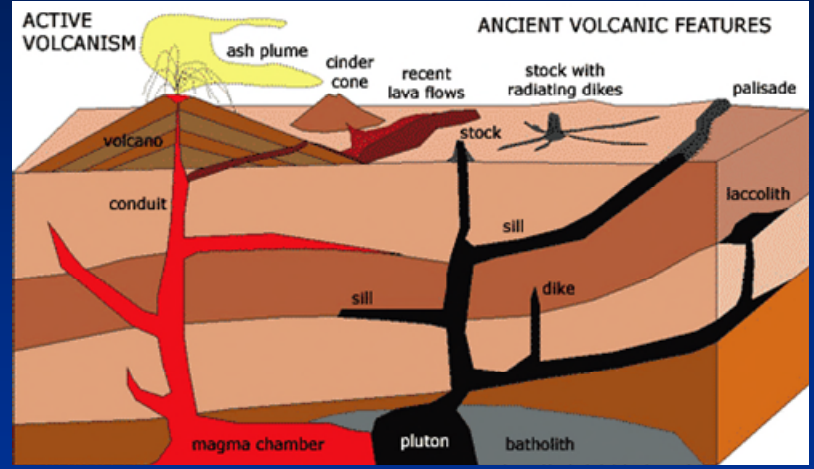
## Metamorphic Rocks -

Rocks that are changed by heat and pressure without melting, Example: gneiss



# Igneous Rocks

## Origin, Properties and Identification

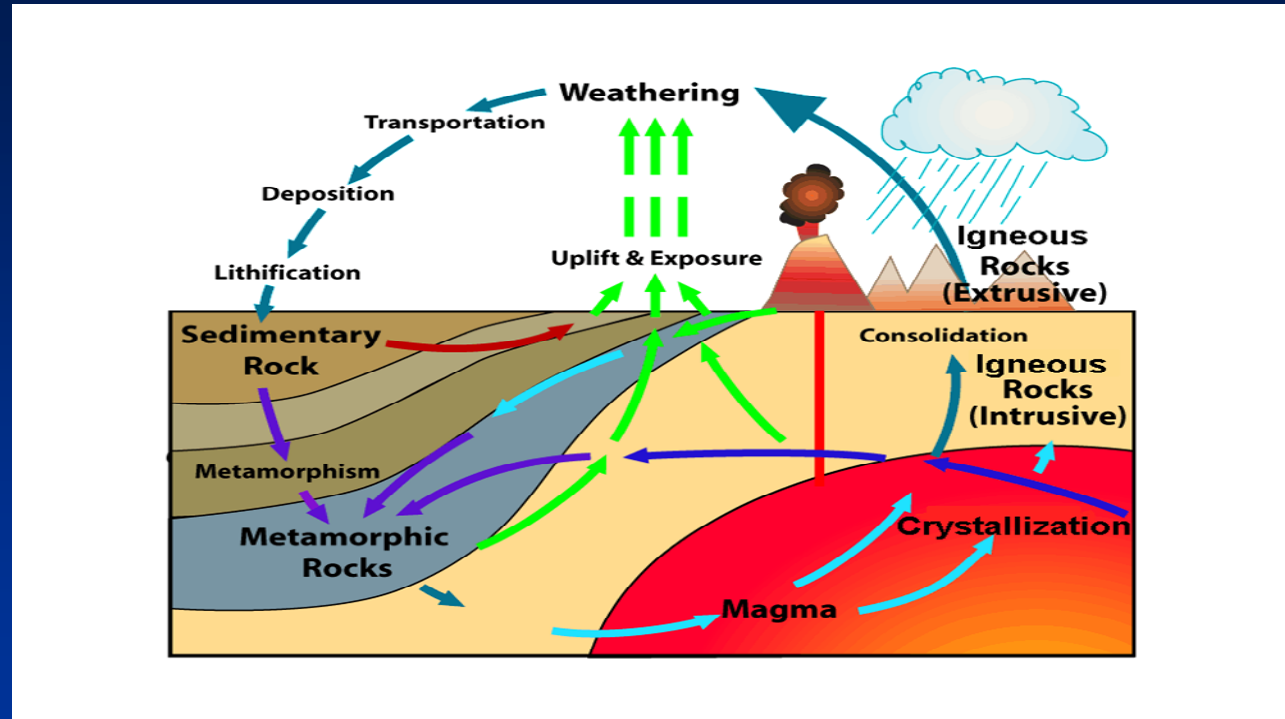




# The Rock Cycle

## Three Primary Rock Types

- 1) **Igneous**
- 2) **Metamorphic**
- 3) **Sedimentary**



Igneous rocks form by the *cooling* and *crystallization* of underground *magmas* and erupted *lavas*.

Igneous rocks are classified by two mineral criteria:

- 1) *Type and % of minerals*
- 2) *Crystal size & arrangement*

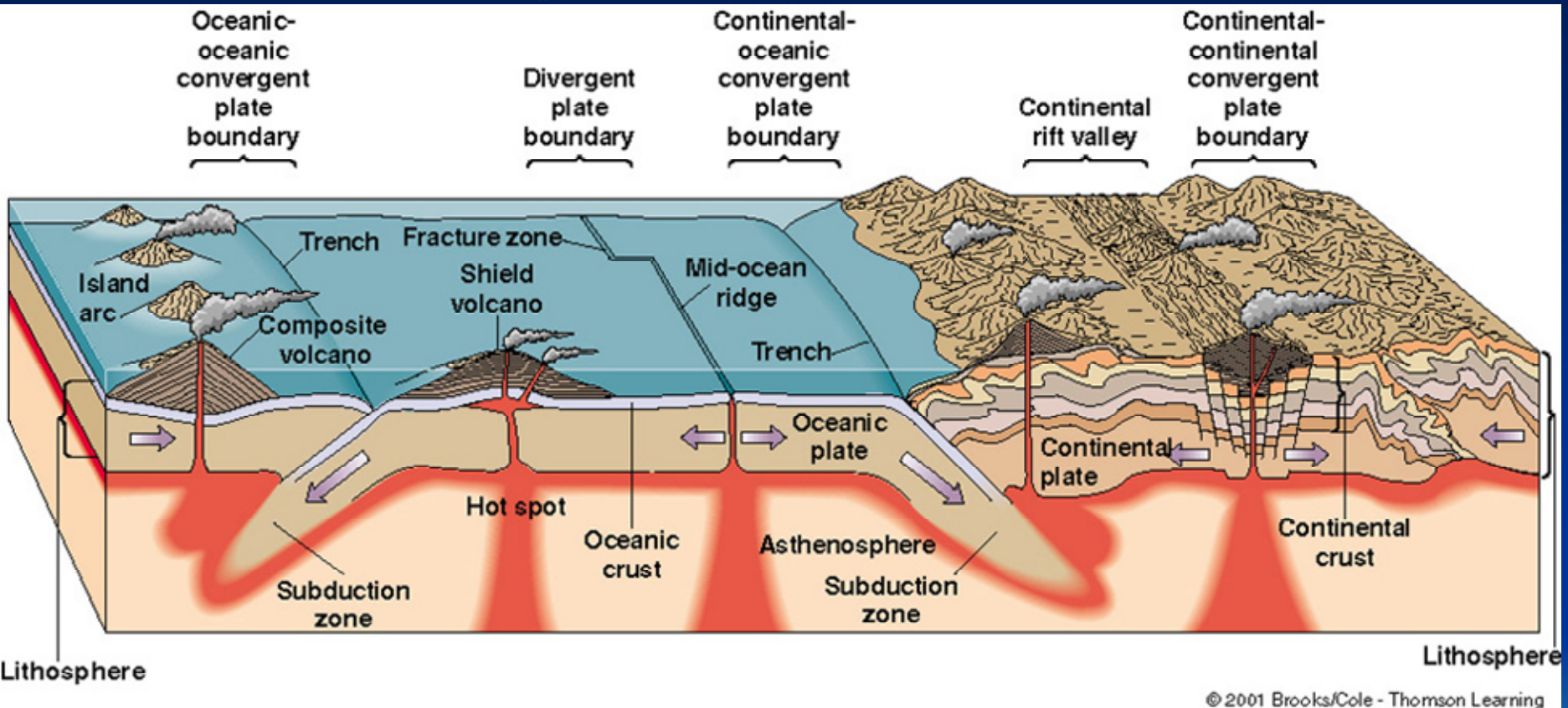
# Magma and Lava = Mother Igneous



The **mineralogy** of an igneous rock is *primarily controlled* by the **composition of the magma** or lava that it cooled from.

The **texture** of an igneous rock is *primarily controlled* by the **cooling rate** of its parent crystallizing magma or lava.

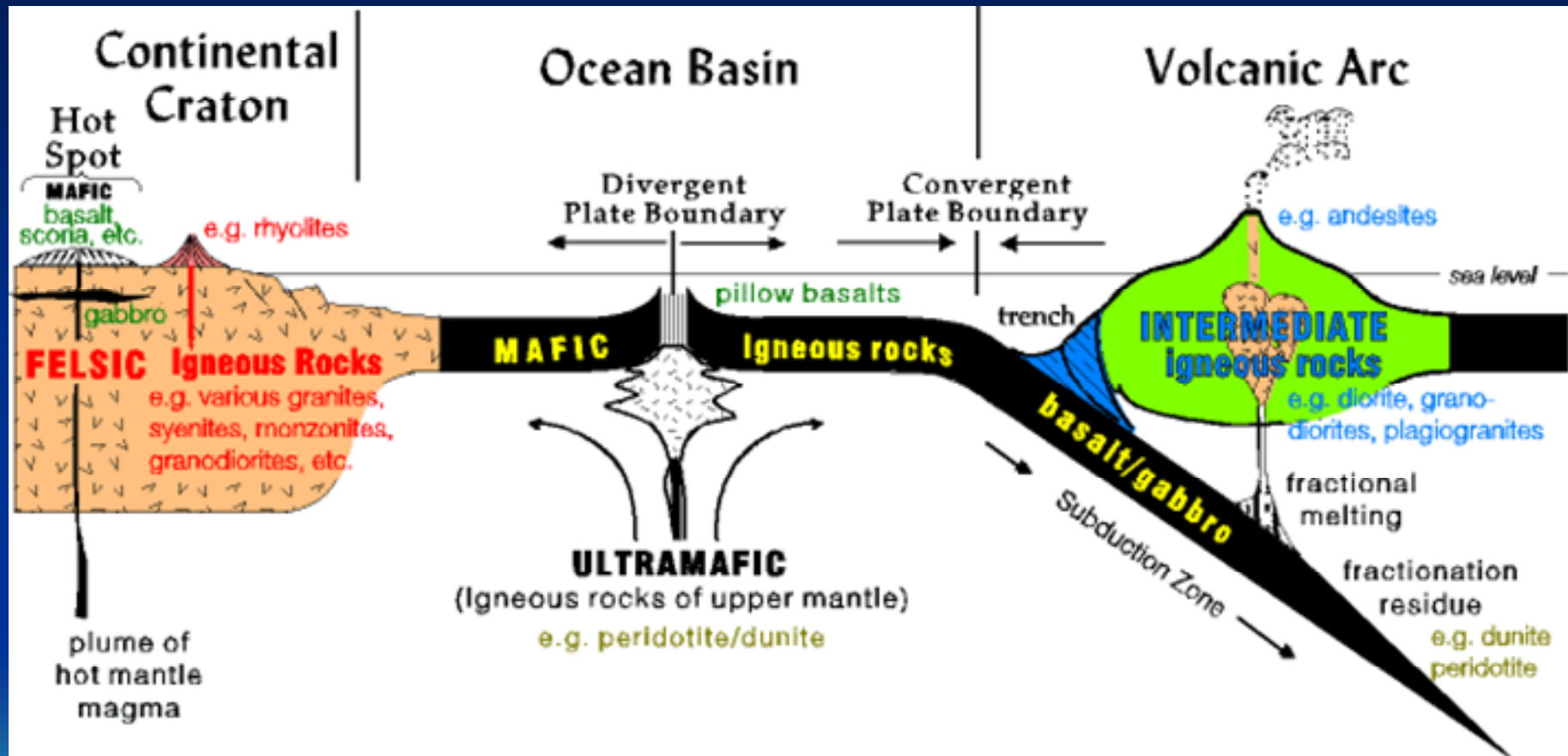
# Tectonic Environments for Magma Generation



Most Igneous Rocks Form at Plate Boundaries

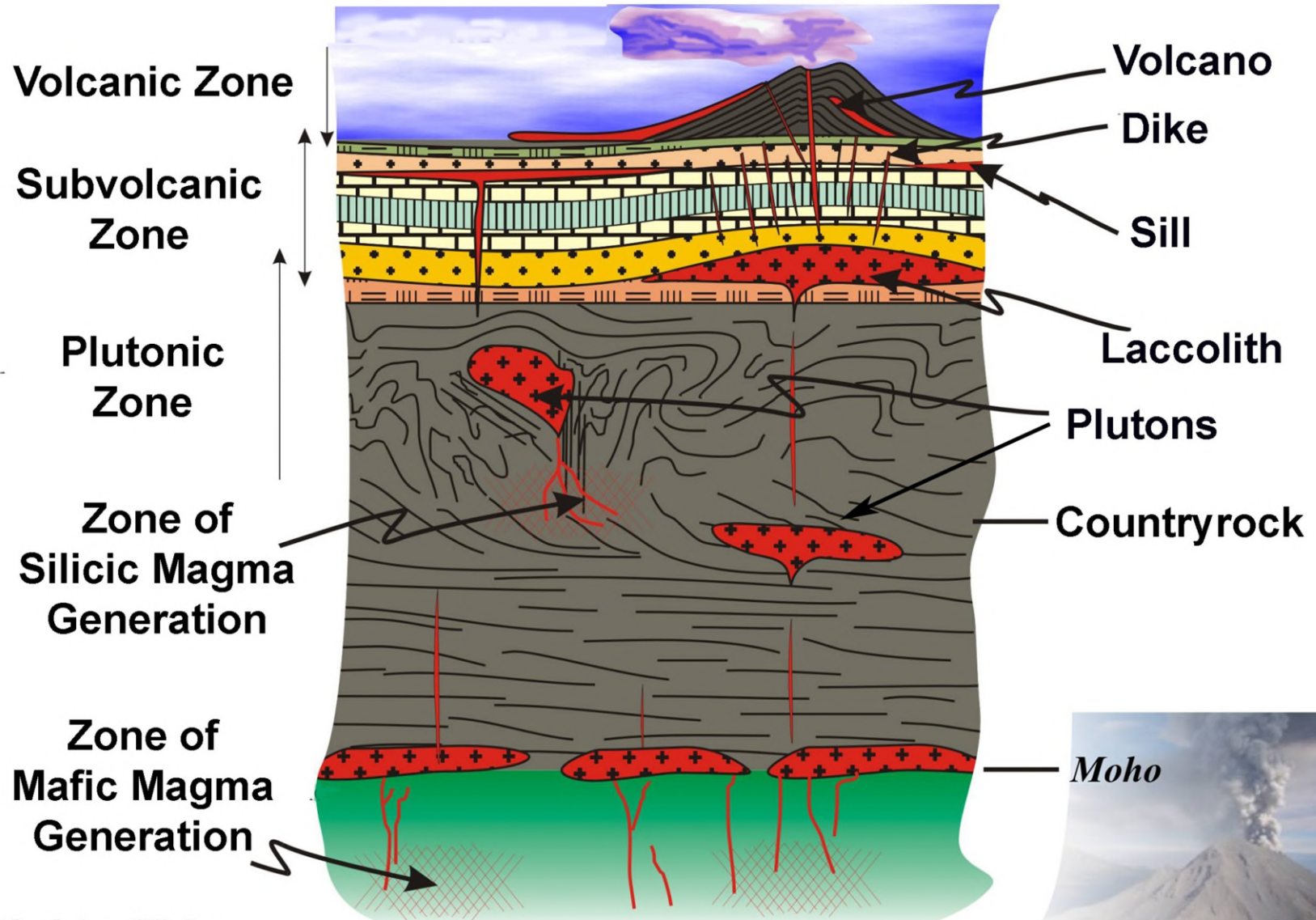


# Predominant Igneous Rock Types at Specific Tectonic Settings



Specific Types of Igneous Rocks Form at Specific Types of Plate Boundaries

# Igneous Environments



# Basaltic Volcanic Eruptions





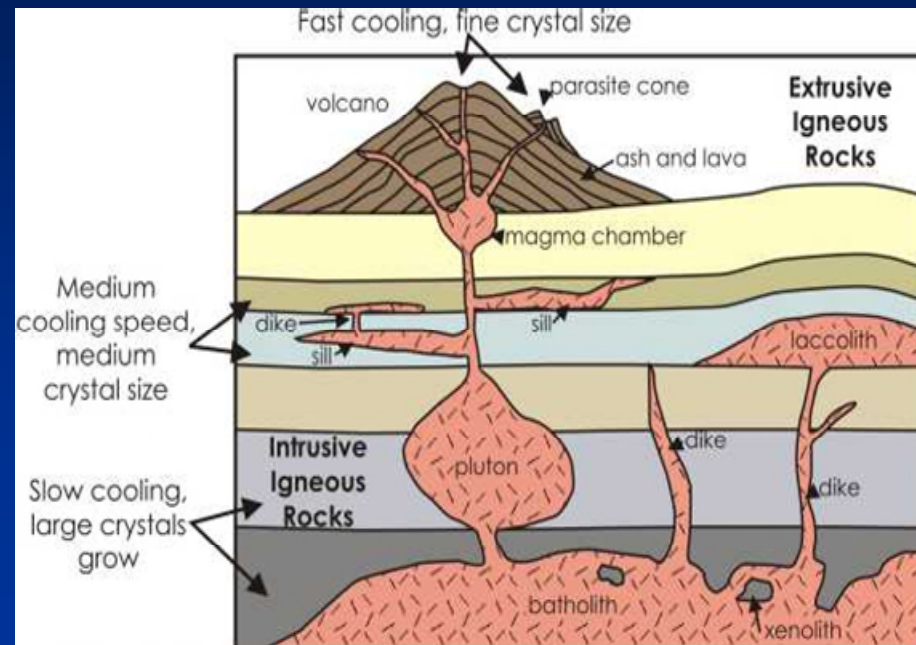
# Andesitic Volcanic Eruptions



# Cooling Rates of Magmas and Lavas Affect Crystal Size

Cooling rates are fast in shallow crust and at surface; this causes magmas and lavas to cool quickly. **Fast-cooling** rates create fine-grained igneous rocks = **Extrusive/Volcanic**

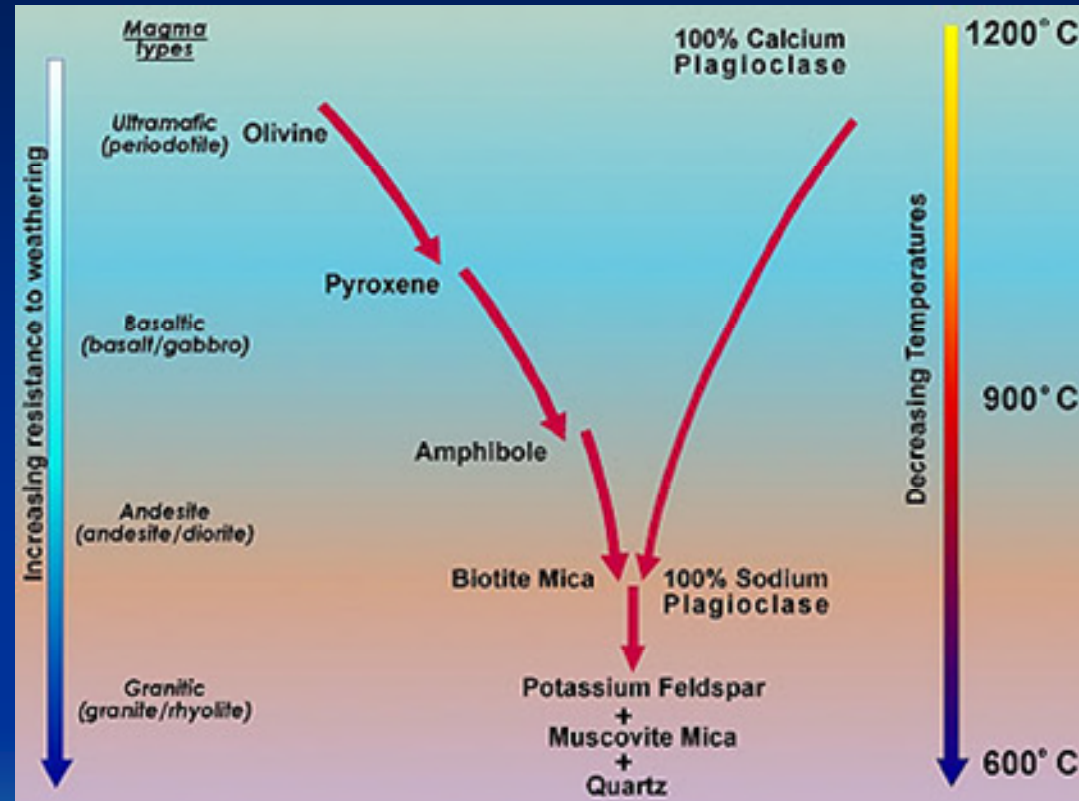
Cooling rates are slow in middle and deep crust and cause magmas and lavas to cool slowly. **Slow-cooling** rates create coarse-grained igneous rocks = **Intrusive/Plutonic**



# Cooling and Crystallization of a Magma

## Bowen's Reaction Series

- ✓ Early forming minerals are Fe-Mg-Ca rich and silica poor @ high temps
- ✓ Later forming minerals become more richer in Na and silica @ mod temps
- ✓ Last forming minerals are most rich in K and silica @ low temps
- ✓ Final rock type depends mostly on initial magma composition
- ✓ Crystal fractionation processes can also affect magma comp.





# Igneous Rock Classification

Igneous Rocks are classified based on two criteria:

- ✓ Mineral - Chemical Composition
- ✓ Texture/Grain Size

		COMPOSITION				
		Felsic (light color)	Intermediate	Mafic (dark color)	Ultramafic	
TEXTURE	Coarse	Granite	Diorite	Gabbro	Peridotite	TEXTURE
	Fine	Rhyolite	Andesite	Basalt		
	Vesicular	Pumice		Scoria		
	Glassy	Obsidian				
		Minerals Present				
		QUARTZ K-FELDSPAR NA-PLAG	NA-CA PLAG AMPHIBOLE	CA PLAG PYROXENE	PYROXENE OLIVINE	
		COMPOSITION				

# Igneous Chemical Compositions

## Ultramafic:

- ✓ Very Iron – Magnesium Rich
- ✓ Super undersaturated in silica
- ✓ Mantle rocks = **Peridotite**

## Mafic:

- ✓ Iron–Magnesium–Calcium Rich
- ✓ Undersaturated in silica
- ✓ Oceanic rocks = **Gabbro** and **Basalt**

## Intermediate:

- ✓ Between Mafic and Felsic/Silicic
- ✓ Saturated in silica
- ✓ Volcanic Arc rocks = **Diorite** and **Andesite**

## Felsic/Silicic:

- ✓ Sodium – Potassium - Aluminum Rich
- ✓ Oversaturated in silica
- ✓ Continental rocks = **Granite** and **Rhyolite**

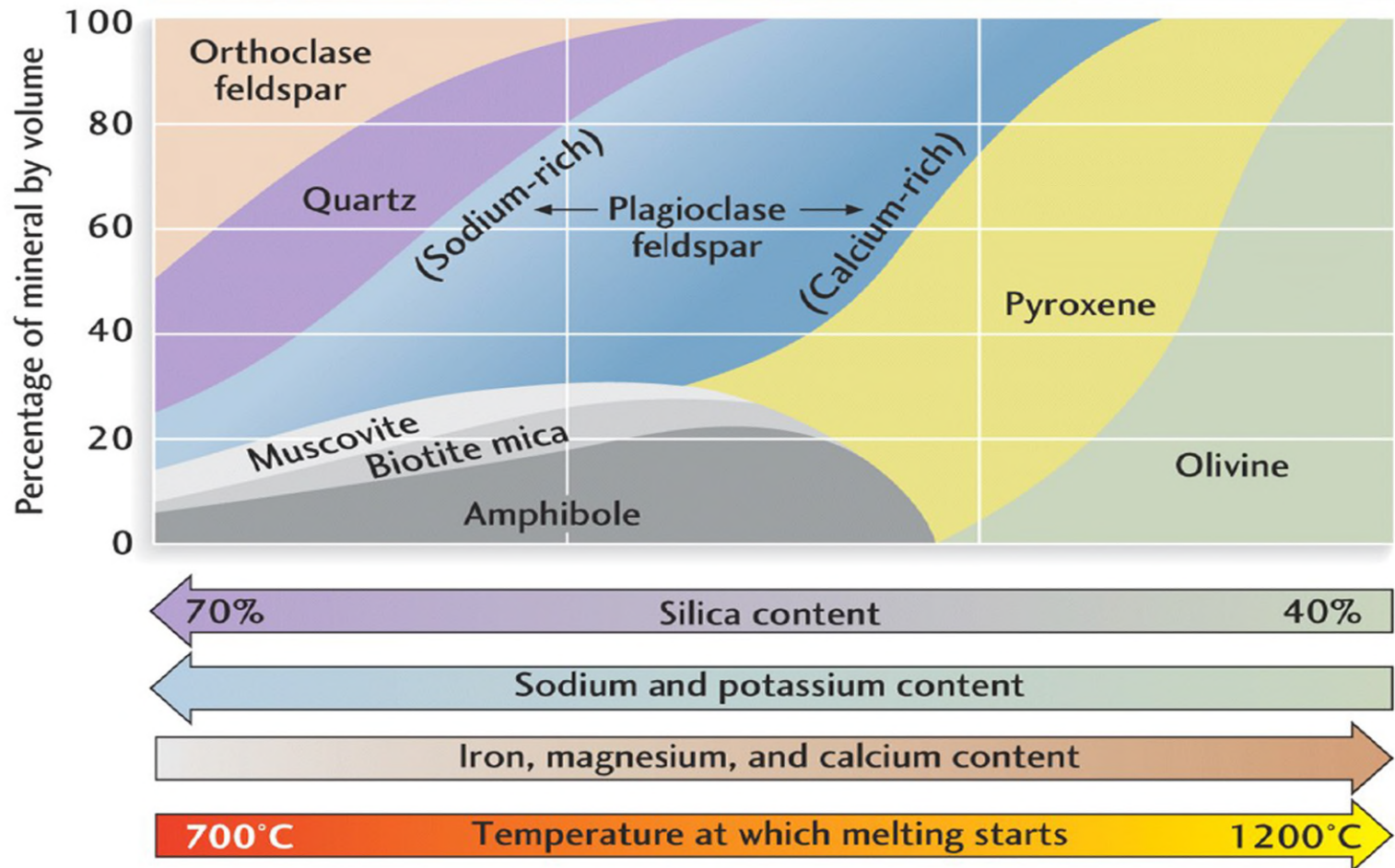
		COMPOSITION				
		Felsic (light color)	Intermediate	Mafic (dark color)	Ultramafic	
TEXTURE	Coarse	Granite	Diorite	Gabbro	Peridotite	TEXTURE
	Fine	Rhyolite	Andesite	Basalt		
	Vesicular	Pumice		Scoria		
	Glassy	Obsidian				
	Minerals Present					
		QUARTZ K-FELDSPAR NA-PLAG	NA-CA PLAG AMPHIBOLE	CA PLAG PYROXENE	PYROXENE OLIVINE	
		COMPOSITION				

# Mineral Assemblages of Igneous Rock

Light-Colored

Dark-Colored

Composition	FELSIC	INTERMEDIATE	MAFIC	ULTRAMAFIC
Rock types	Granite Rhyolite	Diorite Andesite	Gabbro Basalt	Peridotite





## Phaneritic Texture:

- ✓ Coarse Grain Size = Slow Cooling
- ✓ Plutonic Rocks = Coarse-grained

## Aphanitic Texture:

- ✓ Fine Grain Size = Fast Cooling
- ✓ Volcanic Rocks = Fine-grained

## Porphyritic Texture:

- ✓ Large crystals in aphanitic groundmass = slow cooling followed by rapid cooling
- ✓ Porphyry Rocks = Mixed-grain

## Vesicular Texture:

- ✓ Fine-grained to glassy with Cavities
- ✓ Lots of tiny vesicles = pumice
- ✓ Fewer larger vesicles = scoria

## Glassy Texture:

- ✓ Little to no crystals = natural glass
- ✓ Super rapid cooling
- ✓ Obsidian is dark in color
- ✓ Pumice is light in color

# Igneous Rock Textures

		COMPOSITION				TEXTURE
		Felsic (light color)	Intermediate	Mafic (dark color)	Ultramafic	
TEXTURE	Coarse	Granite	Diorite	Gabbro	Peridotite	TEXTURE
	Fine	Rhyolite	Andesite	Basalt		
	Vesicular	Pumice		Scoria		
	Glassy	Obsidian				
	Minerals Present					
		QUARTZ K-FELDSPAR NA-PLAG	NA-CA PLAG AMPHIBOLE	CA PLAG PYROXENE	PYROXENE OLIVINE	
		COMPOSITION				

# Igneous Rock Pairs

## Classification by texture

*Extrusive*

*Fine grained*

Basalt

Andesite

Rhyolite

*Intrusive*

*Coarse grained*

gabbro

diorite

granite

## Classification by composition

•magnesium (Mg) + iron (Fe) = mafic

•feldspar + quartz (Si) = felsic

Basalt

Gabbro

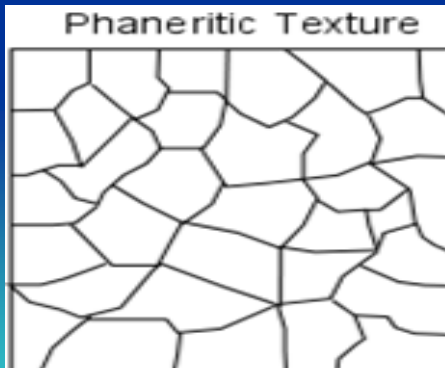
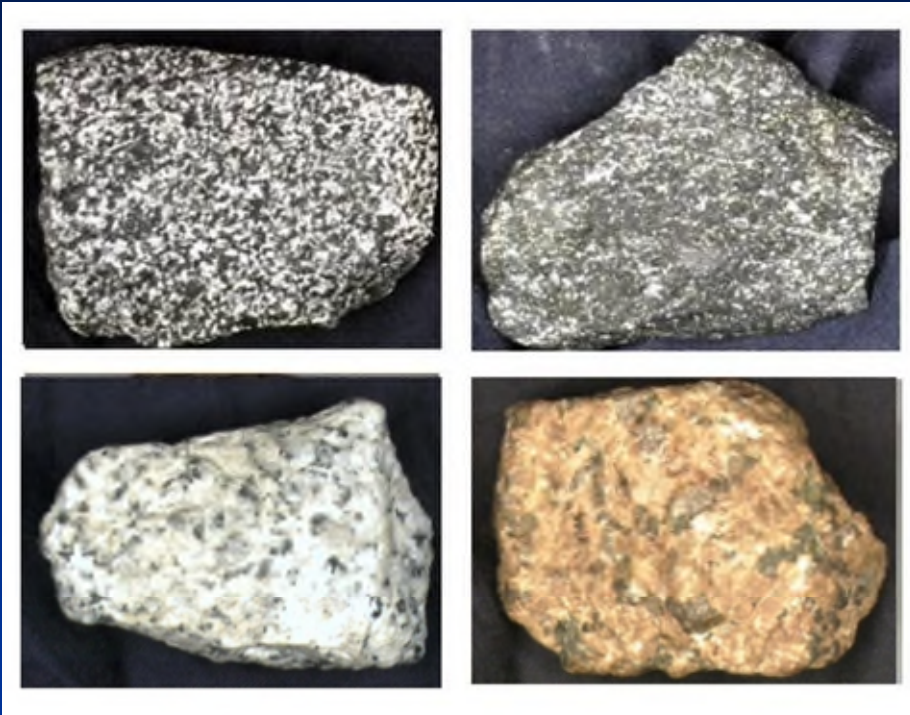
Rhyolite

Granite





# Plutonic Rock Textures



- ✓ Intrusive -Plutonic
- ✓ Coarse-grained
- ✓ Cooled Slowly



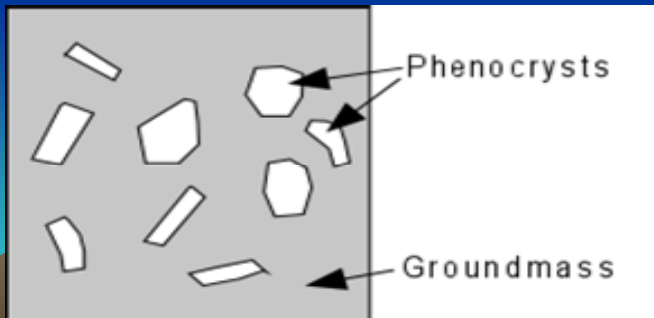
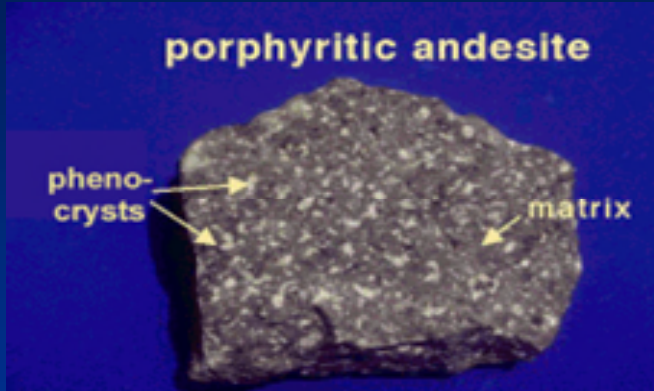
Field Outcrops of Plutonic Rocks



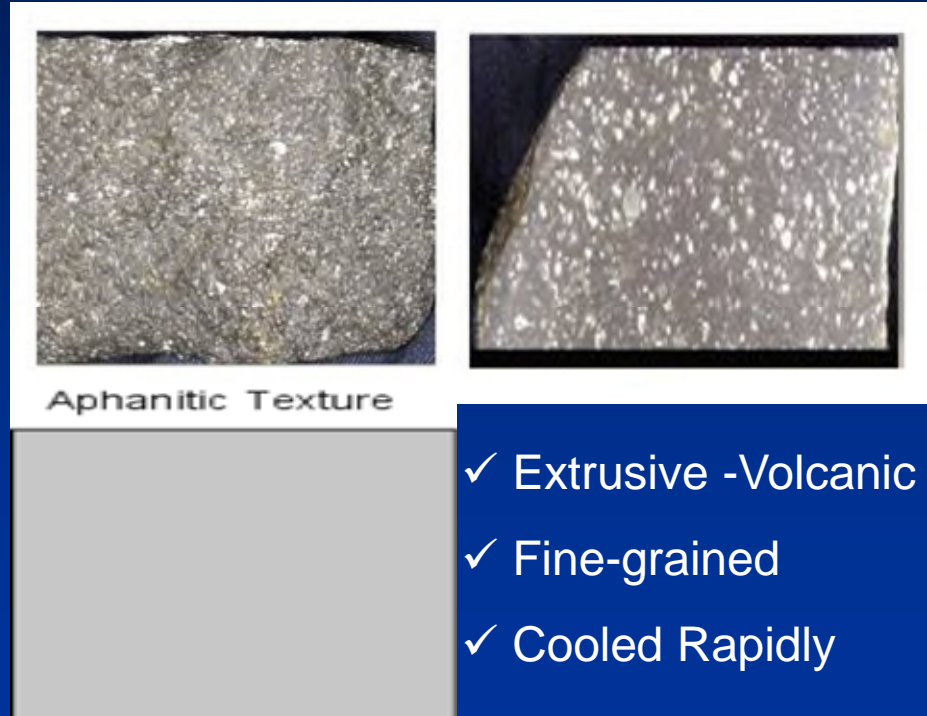


# Volcanic Rock Textures

## Porphyritic



## Aphanitic



- ✓ Extrusive -Volcanic
- ✓ Fine-grained
- ✓ Cooled Rapidly

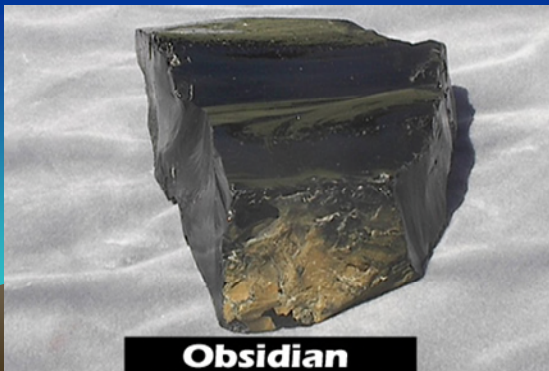
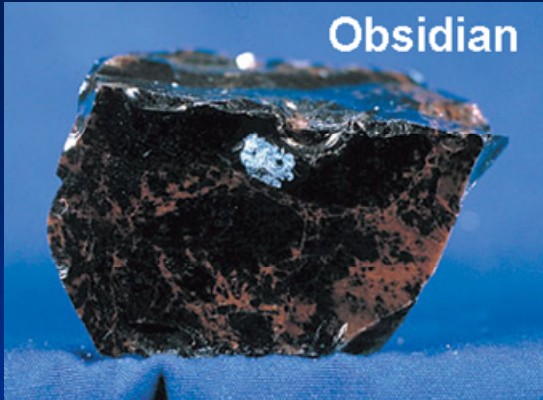
- ✓ Combo Plutonic -Volcanic
- ✓ Coarse-grained phenocrysts in a fine-grained groundmass
- ✓ First cooled Slow, then Fast



# Other Volcanic Rock Textures

## Glassy

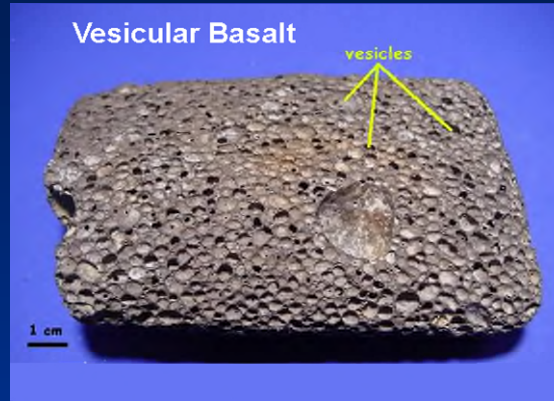
Obsidian



Obsidian

## Vesicular

Vesicular Basalt



Scoria

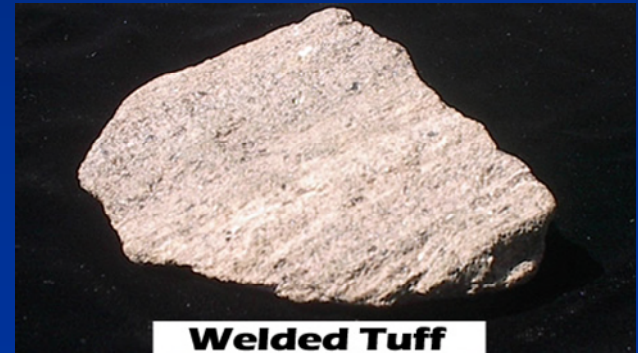


Pumice

## Fragmental



Tuff



Welded Tuff



Tuff Breccia



# Igneous Rocks Under a Microscope



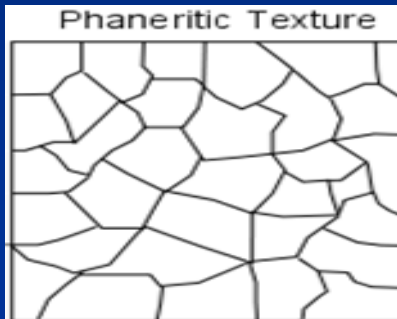
Granite



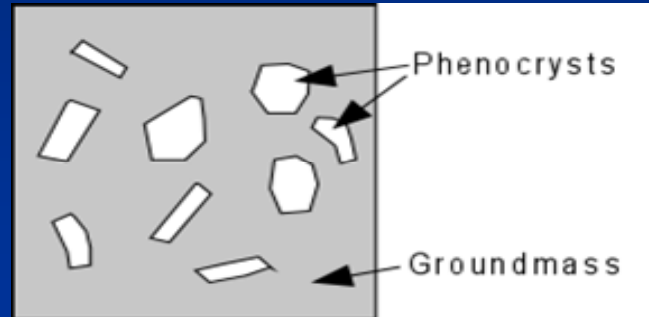
Rhyolite



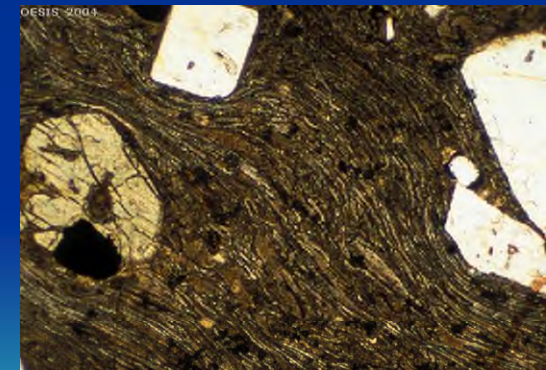
Obsidian



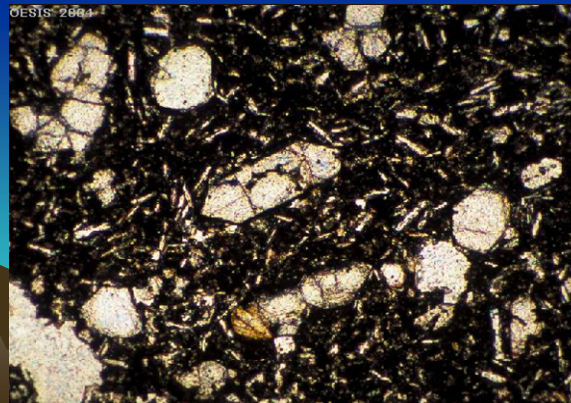
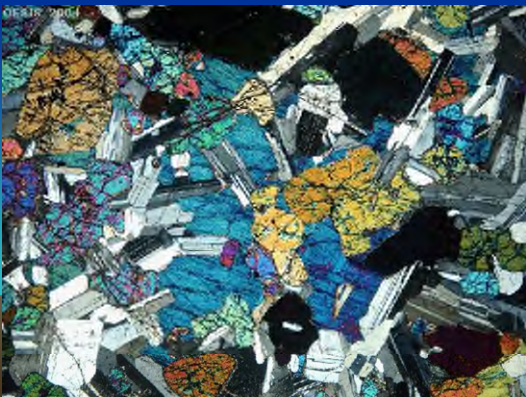
Gabbro



Basalt

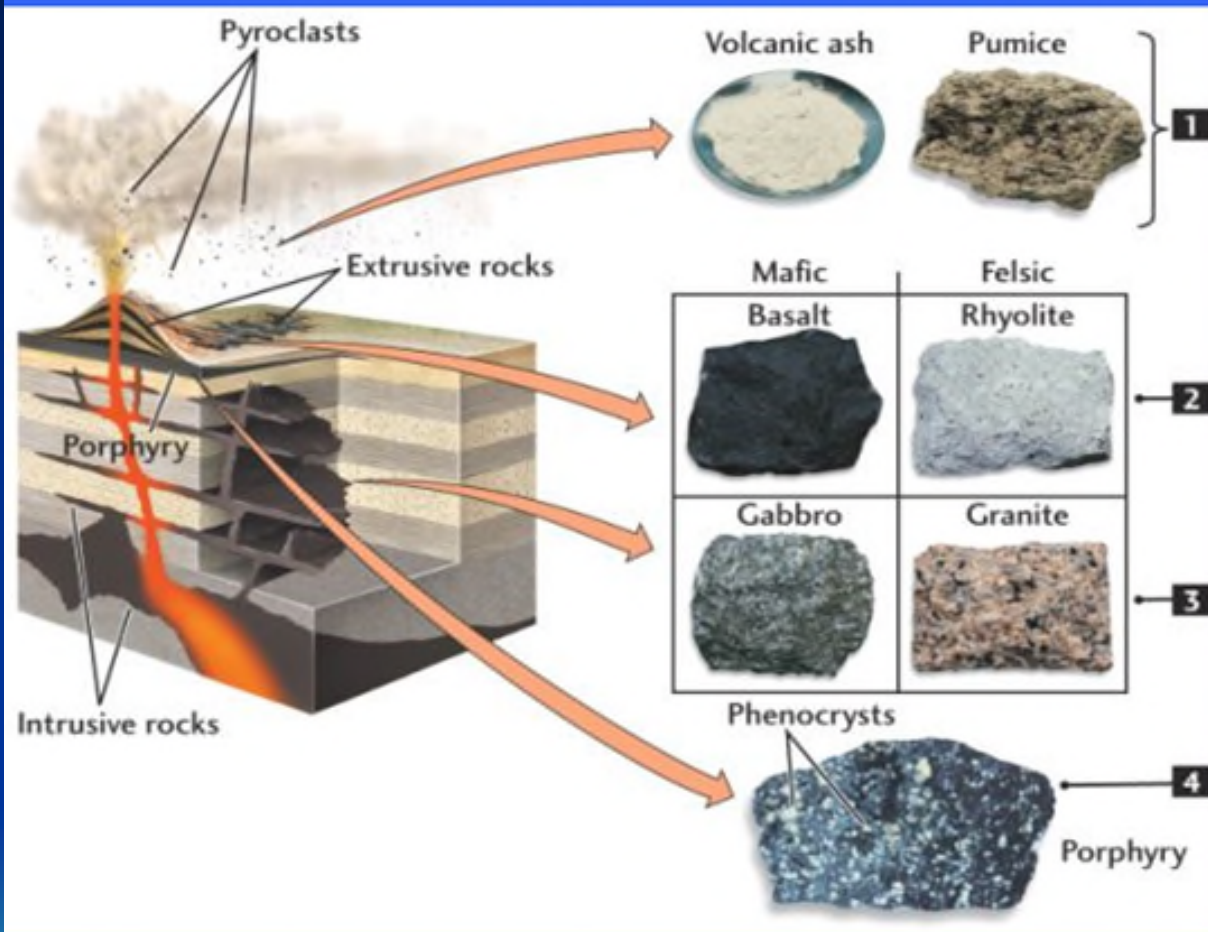


Welded Tuff





# Formation and texture



1. **Pyroclasts** form from airborne lava in violent eruption

2. **Extrusive igneous rocks.** Cool rapidly on the Earth's surface

3. **Intrusive igneous rocks.** Cool slowly in the Earth's interior allowing large crystals to form

4. **Porphyry** starts to grow below the surface but before solidification is brought to the surface

# Color Index of Plutonic Rocks

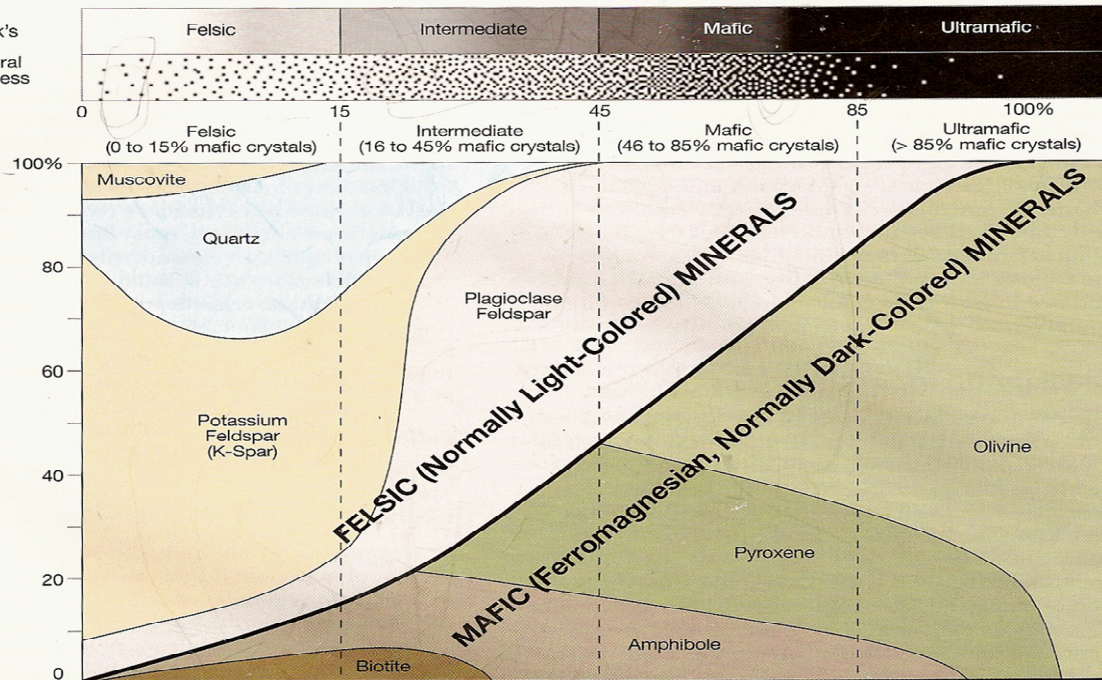




# Igneous Rock Classification

## 1. Color Index

Estimate the rock's color index (CI): % of mafic mineral crystals or darkness of the rock.



## 2. Minerals

Identify minerals in the rock, if possible, and their percent (by volume) of the whole rock. Skip this step if mineral crystals are not visible or are too small to identify.

## 3. Texture(s)

Identify the rock's texture(s).

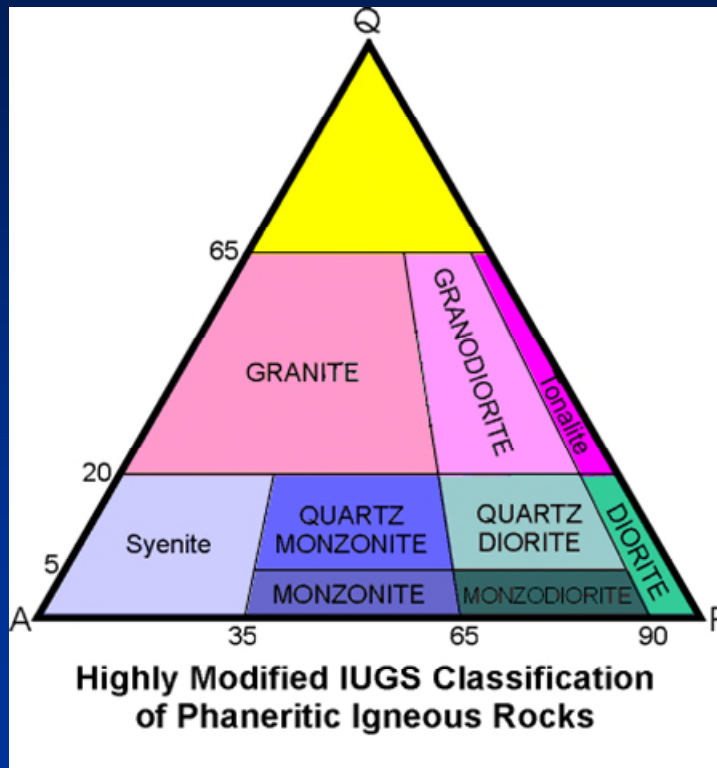
## 4. Rock Name:

Select name below, based on data from steps 1–3.

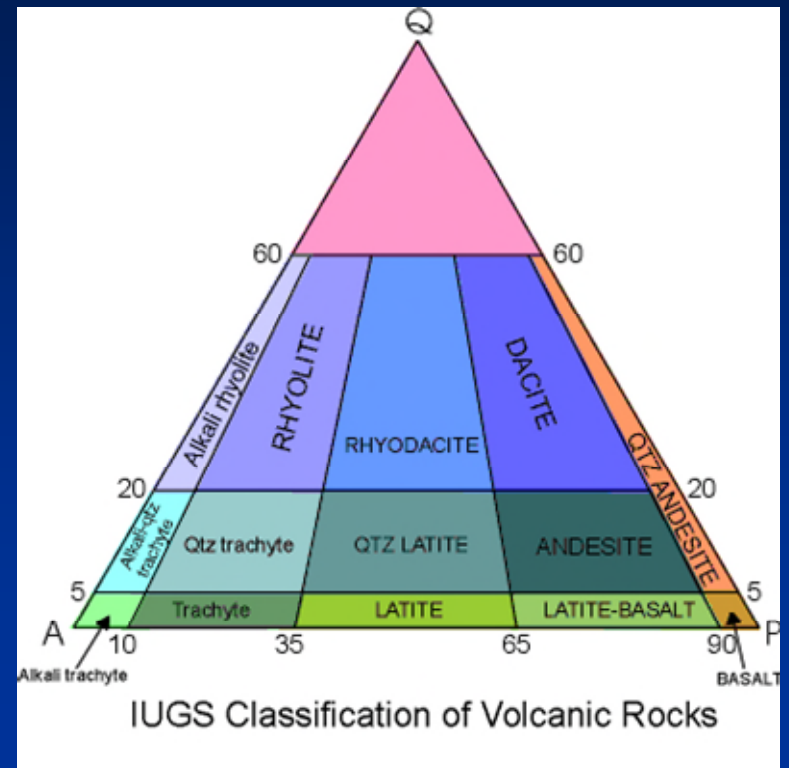
INTRUSIVE ORIGIN	Pegmatitic: very coarse-grained	PEGMATITIC GRANITE	PEGMATITIC DIORITE	PEGMATITIC GABBRO	PEGMATITIC PERIDOTITE
	Phaneritic: coarse-grained	<b>GRANITE</b> (SYENITE, if no quartz)	<b>DIORITE</b>	<b>GABBRO</b>	<b>PERIDOTITE</b>
	Phenocrysts <sup>1</sup> in a phaneritic groundmass	PORPHYRITIC GRANITE	PORPHYRITIC DIORITE	PORPHYRITIC GABBRO	PORPHYRITIC PERIDOTITE
	Phenocrysts <sup>1</sup> in an aphanitic groundmass	PORPHYRITIC RHYOLITE	PORPHYRITIC ANDESITE	PORPHYRITIC BASALT	Cannot be distinguished from basalt in hand samples (KOMATITE)
EXTRUSIVE ORIGIN	Aphanitic: fine-grained	<b>RHYOLITE</b>	<b>ANDESITE</b>	<b>BASALT</b>	
	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)			



# Igneous Rock Classification



Granitic Plutonic Rocks



Volcanic Rocks



# Igneous Rock Classification

## A Three Step Process

### 1) Determine Composition

- ✓ Color Index (plutonic only)
- ✓ Color darkness (volcanic)
- ✓ Mineralogy (observable)

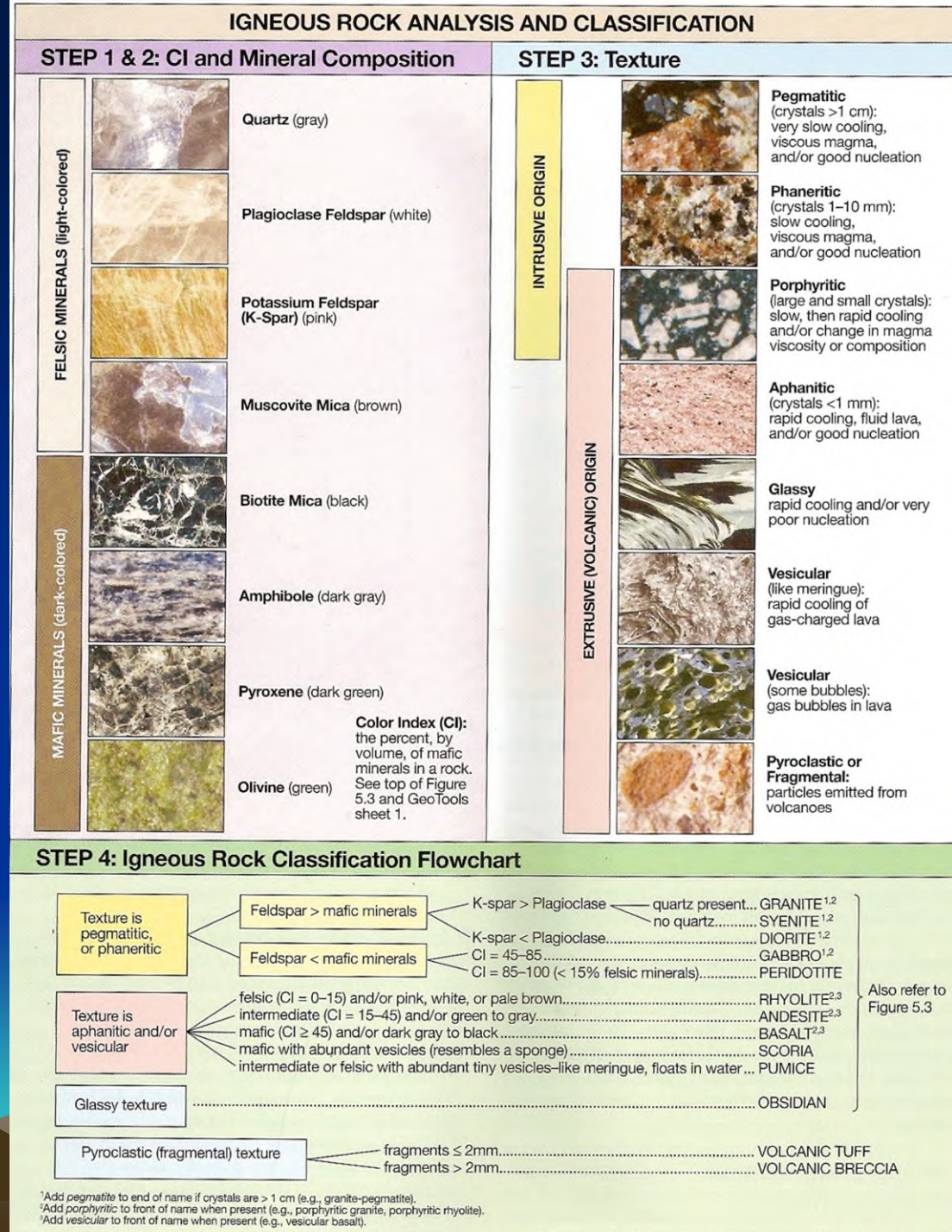
### 2) Determine Texture

- ✓ Specific intrusive texture?
- ✓ Specific extrusive texture?

### 3) Name the Rock

- ✓ Use Flowchart

Practical Use for Rock?





# Igneous Rock Classification

## A Three Step Process

### 1) Determine Texture

- ✓ Specific intrusive texture?
- ✓ Specific extrusive texture?

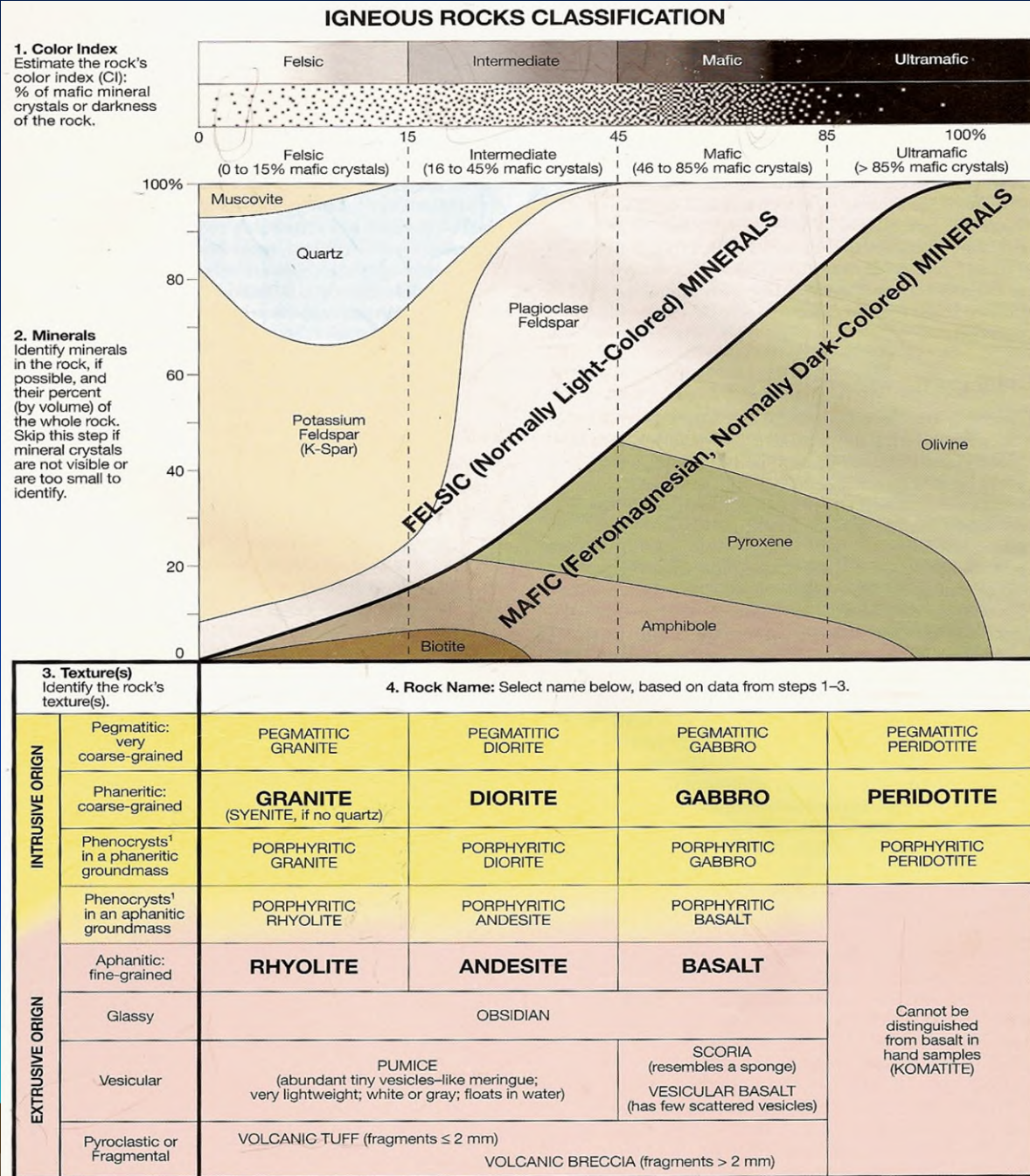
### 2) Determine Composition

- ✓ Color Index (plutonic only)
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- ✓ Mineralogy (observable)

### 3) Name the Rock

- ✓ Use Flowchart

Practical Use for Rock?





# Igneous Rock Identification Procedure

**Step 1:** Observe and record the rock's **TEXTURE**

- ✓ Pegmatitic
- ✓ Phaneritic
- ✓ Aphanitic
- ✓ Porphyritic
- ✓ Fragmental
- ✓ Others = vesicular or glassy

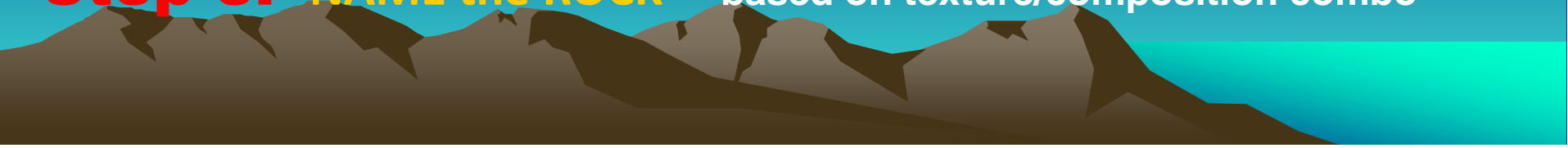
**Step 2:** IF *Phaneritic* or *Pegmatitic*- Identify and record the minerals and the volume % of dark minerals = **COLOR INDEX**.

**Note:** Color index applicable for course-grained rocks ONLY! **OR**

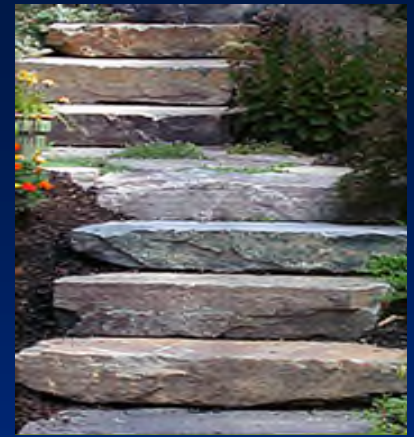
IF *Aphanitic* or *Porphyritic* = no to some observable minerals, then estimate composition by the **OVERALL ROCK COLOR**.

**Note:** ("light" = felsic/silicic, "medium" = intermediate, and "dark" = mafic).

**Step 3:** **NAME the ROCK** — based on texture/composition combo



# Applications



Granite, Diorite and Gabbro - used for flooring, countertops, walls, steps, cobblestone paving, gravestones, and various landscaping applications

Volcanic Rock - used for various landscaping applications



# Igneous Rock References



<http://www.cobweb.net/~bug2/mineral.htm>

<http://www.rockhounds.com/rockshop/rockkey/index.html>

<http://www.union.edu/PUBLIC/GEODEPT/COURSES/geo-10/mineral.htm>

- <http://academic.brooklyn.cuny.edu/geology/grocha/mineral/mineral.html>



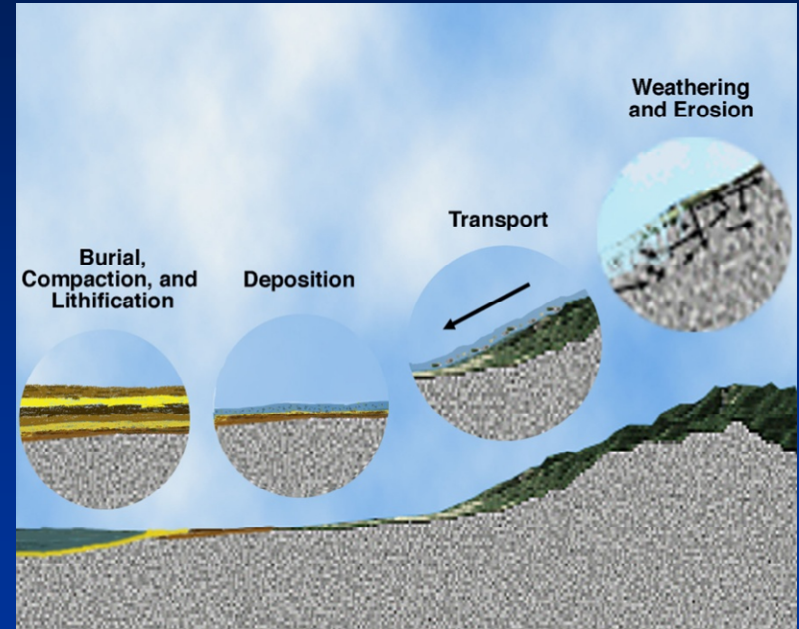


# Sedimentary Rocks

## Origin, Properties and Identification

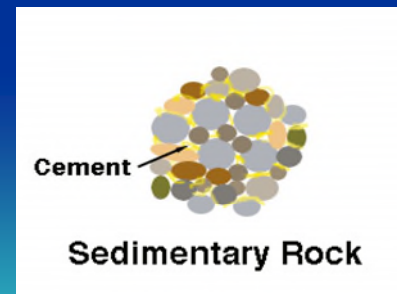


From: "Earth" by Tarbuck and Lutgens



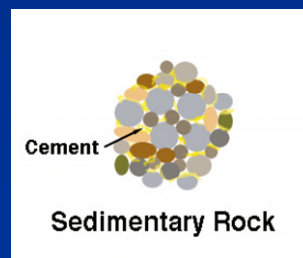
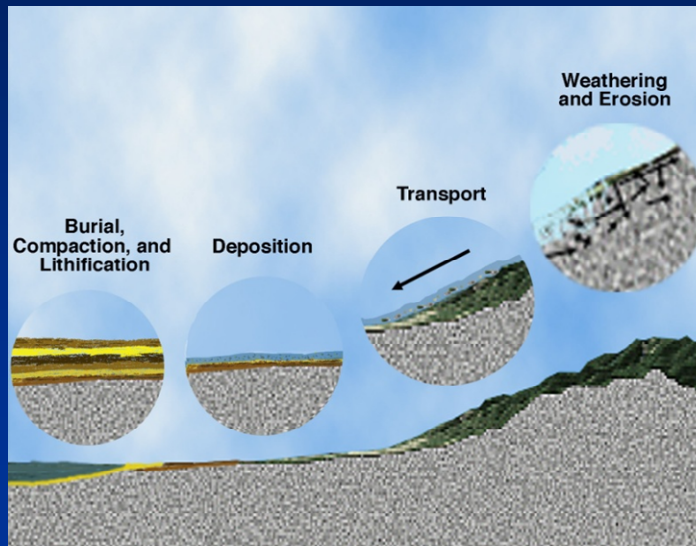
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ENVI 110 Lab

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# Sedimentary Rock Origin and Identification Lab



## Pre-Lab Internet Link Resources

1) <http://www.rockhounds.com/rockshop/rockkey/index.html>

2) <http://earthsci.org/education/teacher/basicgeol/sed/sed.html#top>



# Major Sedimentary Concepts

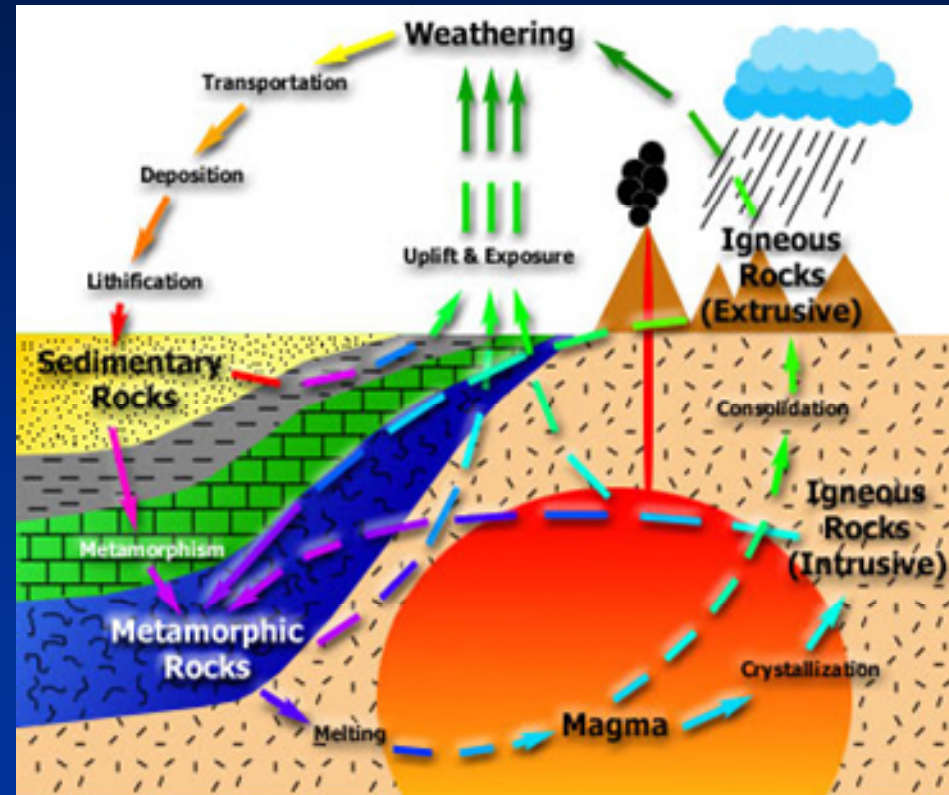
- 1) Sedimentary rocks form by depositing, compaction, and cementing of sediment grains, and/or precipitation of crystals from an aqueous solution
- 2) The type of sedimentary rock formed is controlled by two factors: **1)** type of sediment and **2)** depositional environment
- 3) The **five primary depositional environments** of sedimentation worldwide are **1)** lakes and river systems, **2)** alluvial fans and deserts, **3)** shorelines, **4)** continental margins (shelves, slopes and rises) , and **5)** deep ocean floor.
- 4) Source rock, climate, weathering, erosion, and deposition conditions control the nature of the deposited sediments, and hence the types of sedimentary rocks that form at each of the five sedimentary sites described above.
- 5) Sedimentary rocks formed by cementing of clastic grains are called **detrital** rocks.
- 6) Sedimentary rocks formed by the precipitation and/or cementing of shell, skeleton, or plant material are called **biochemical** rocks.
- 7) Sedimentary rocks formed by the precipitation and cementing of material directly from an aqueous solution like seawater are called **chemical** rocks.
- 8) Identification of sedimentary rocks based on two criteria:
  - ✓ **Texture**
  - ✓ **Composition**



# Sedimentary Rocks in The Rock Cycle

## Key Points:

- 1) Part of rock cycle involving materials, conditions and processes *at or near Earth's surface*
- 2) Begins with weathering of uplifted, exposed rock
- 3) Continues with the erosion (removal and transportation) of weathered sediment
- 4) Finishes with the deposition and lithification of sediment

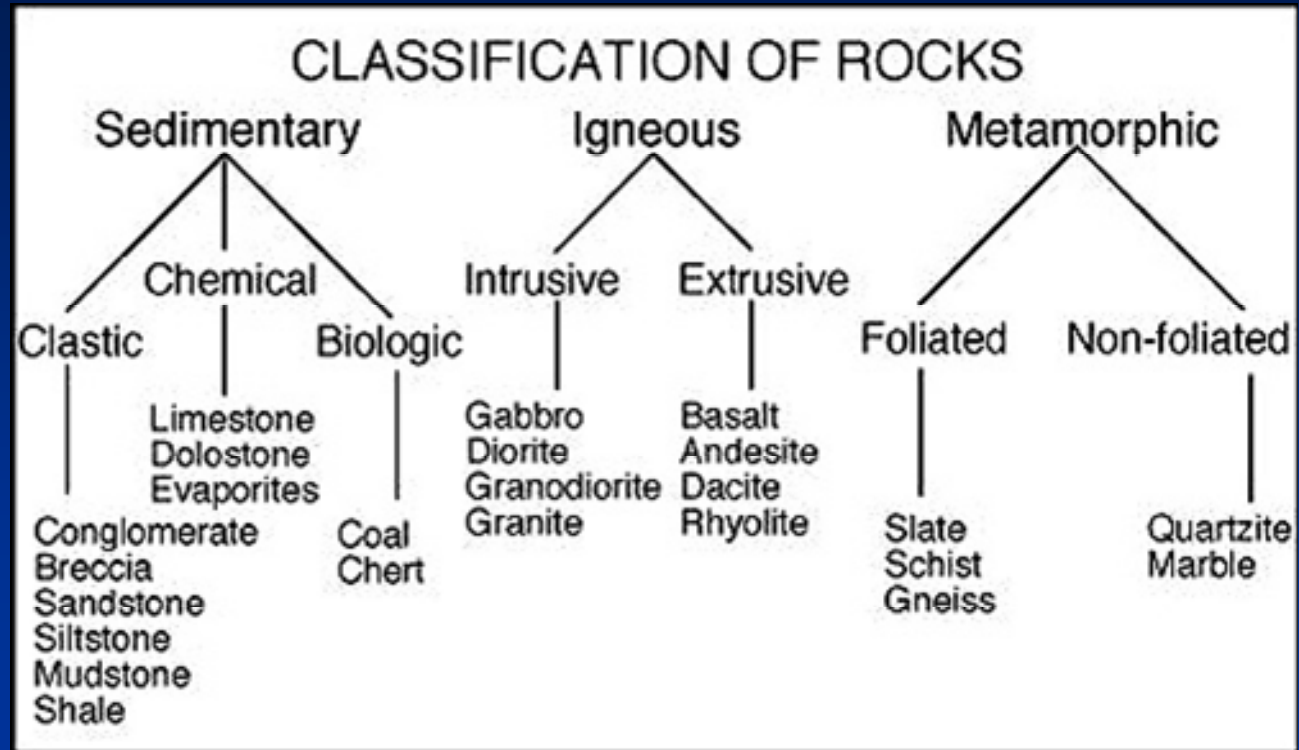


The Rock Cycle

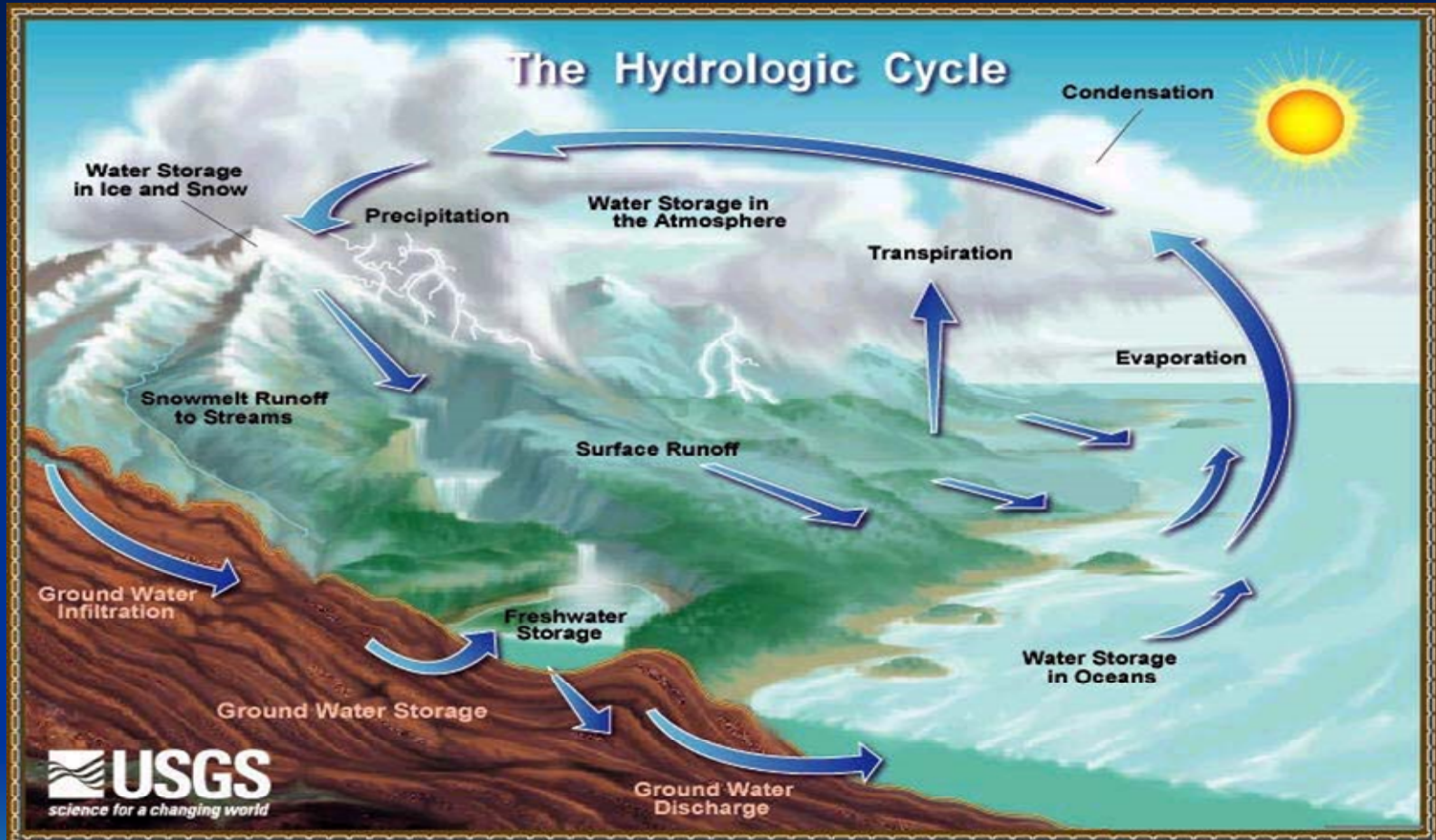


# Three Primary Rock Types

- 1) **Igneous**
- 2) **Metamorphic**
- 3) **Sedimentary**



# Water Cycle = Mother Sedimentary

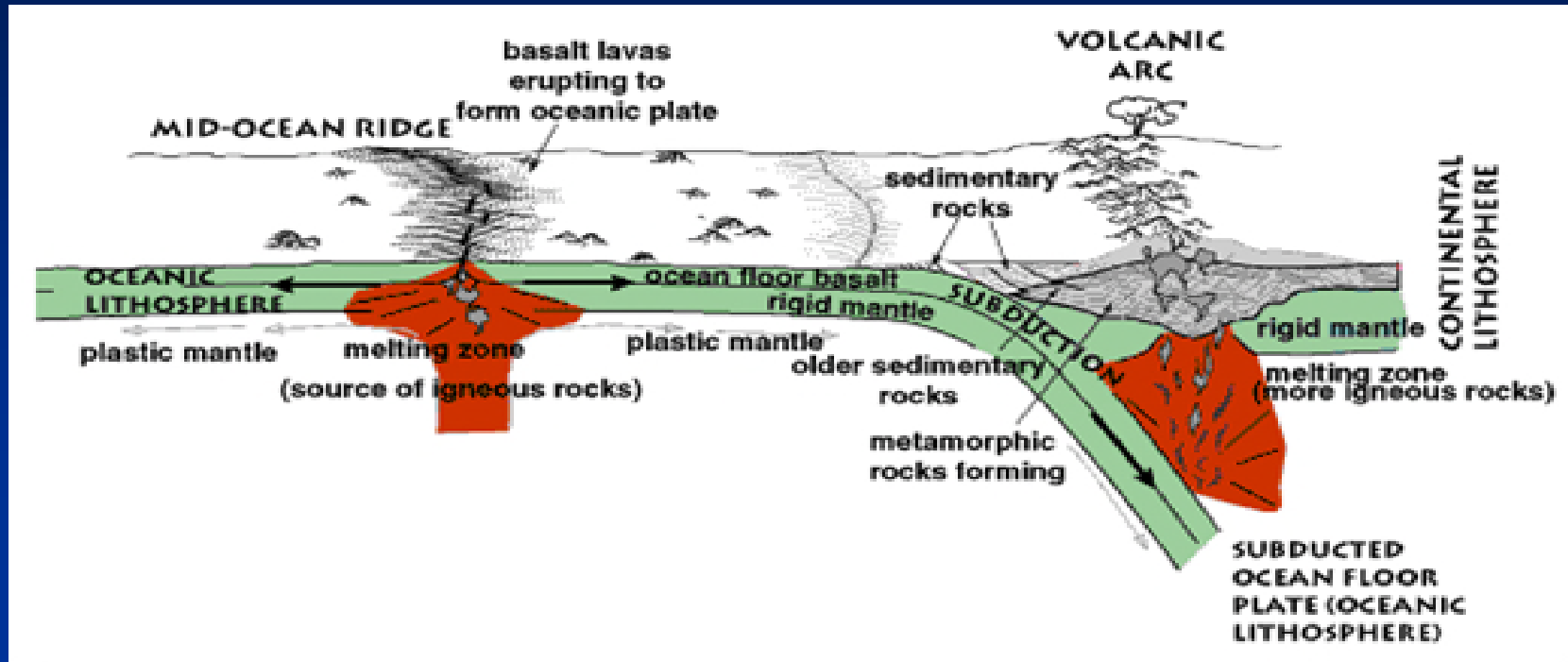


1) **Agents** = Sun, Water, Air and Gravity

2) **Processes** = Weathering, Erosion and Deposition



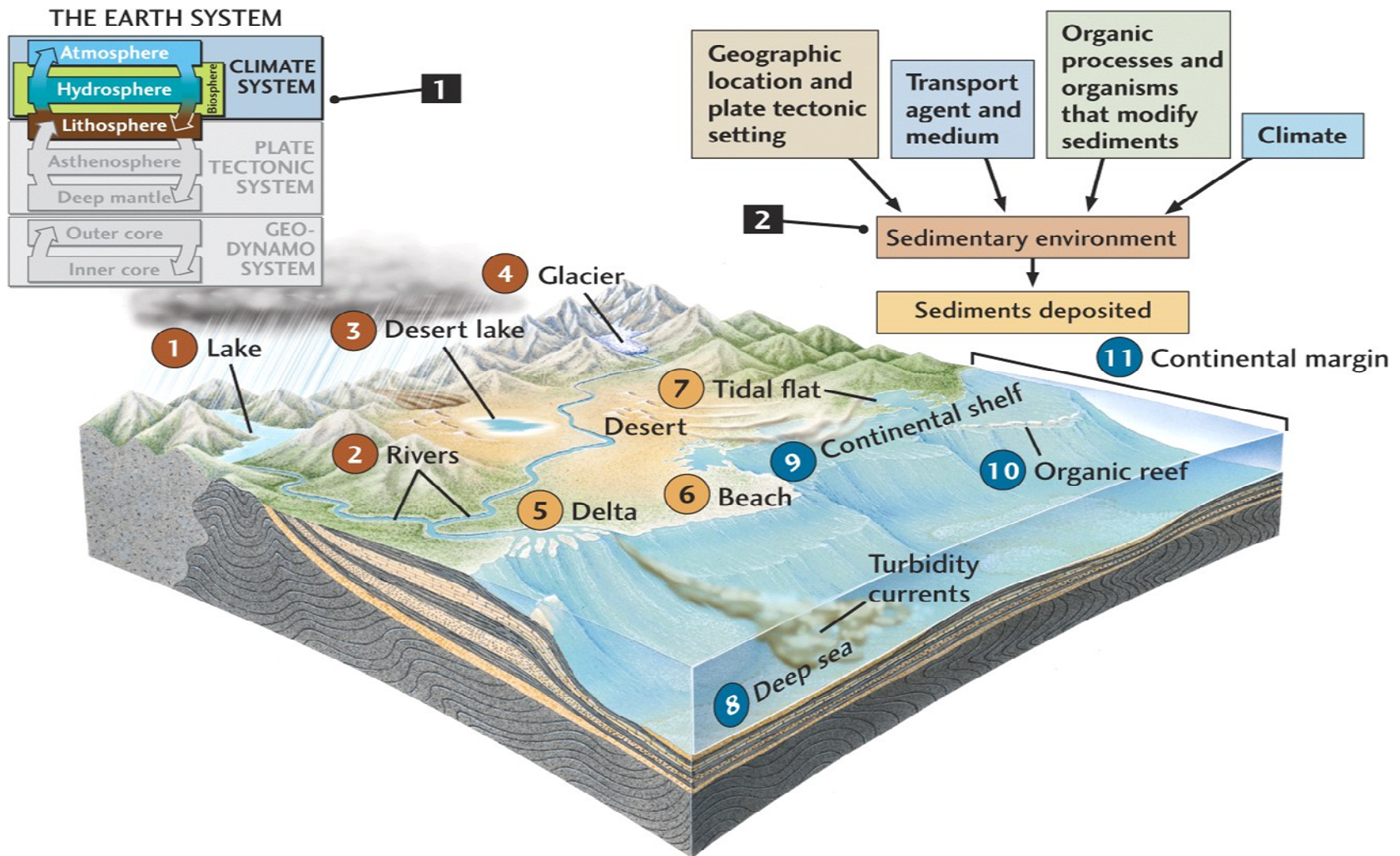
# Tectonic Environments and Sedimentary Rock Formation



- 1) *Source regions* for sediments are primarily convergent plate boundaries
- 2) *Depositional sites* for sediments are primarily the edges of ocean basins

# Sedimentary Environments Where Sedimentary Rocks Form

MULTIPLE FACTORS INTERACT TO CREATE SEDIMENTARY ENVIRONMENTS





# Predominant Sediment Clast Types at Specific Depositional Settings



Gravel-size



Sand-size

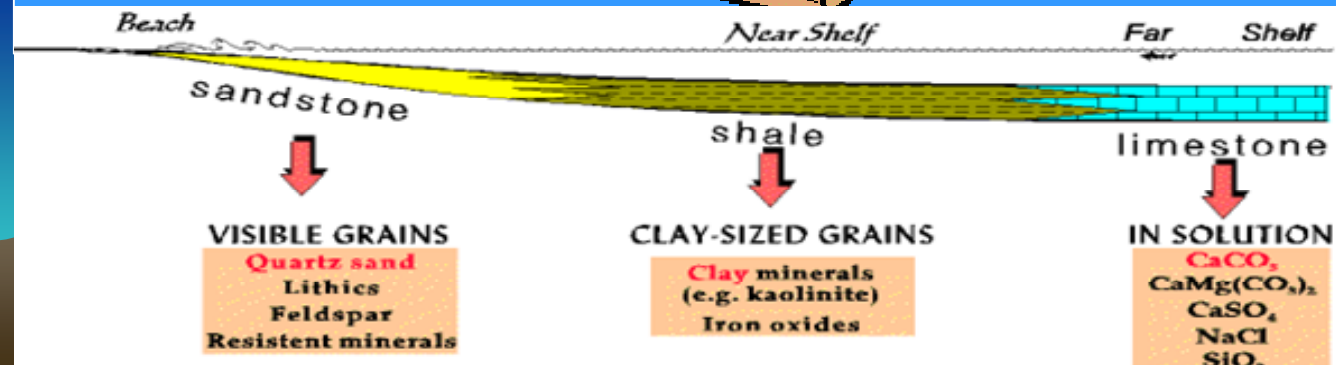
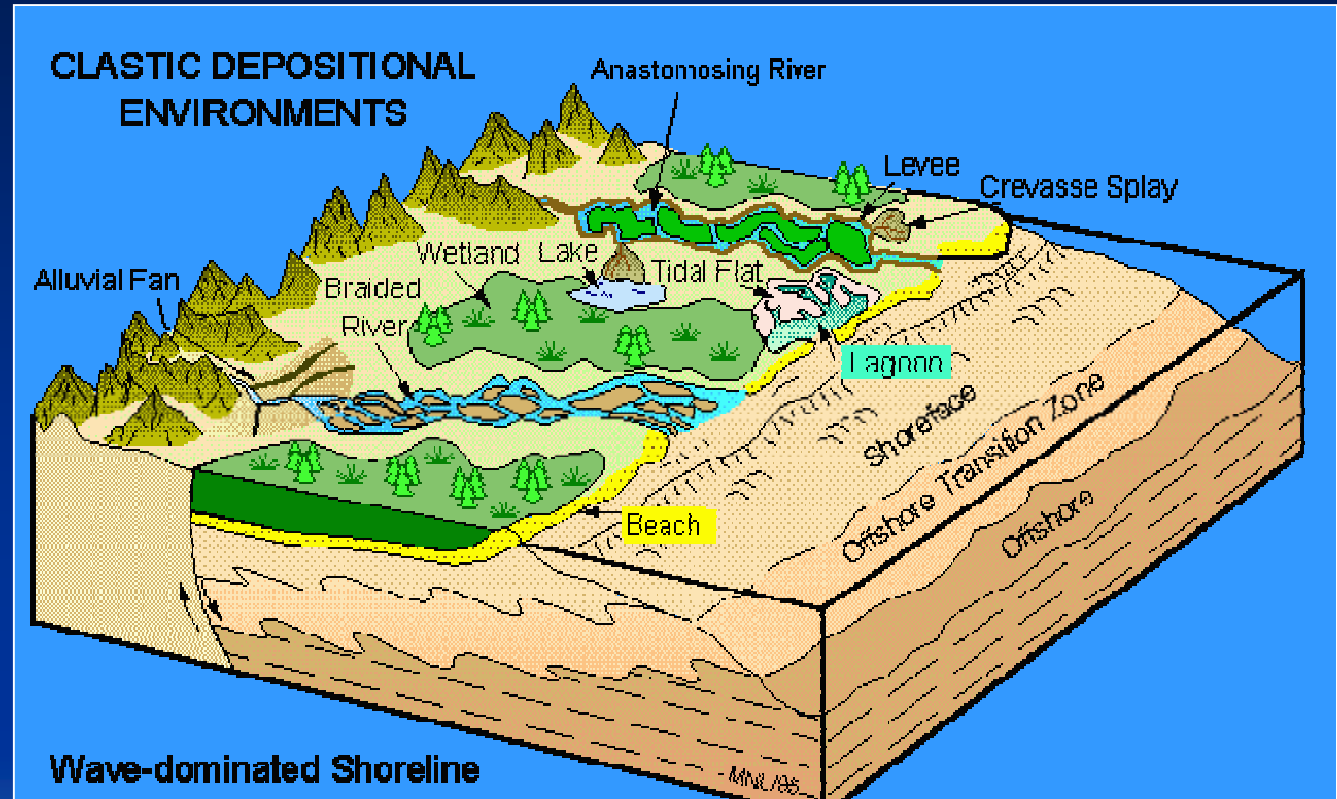


Silt-size



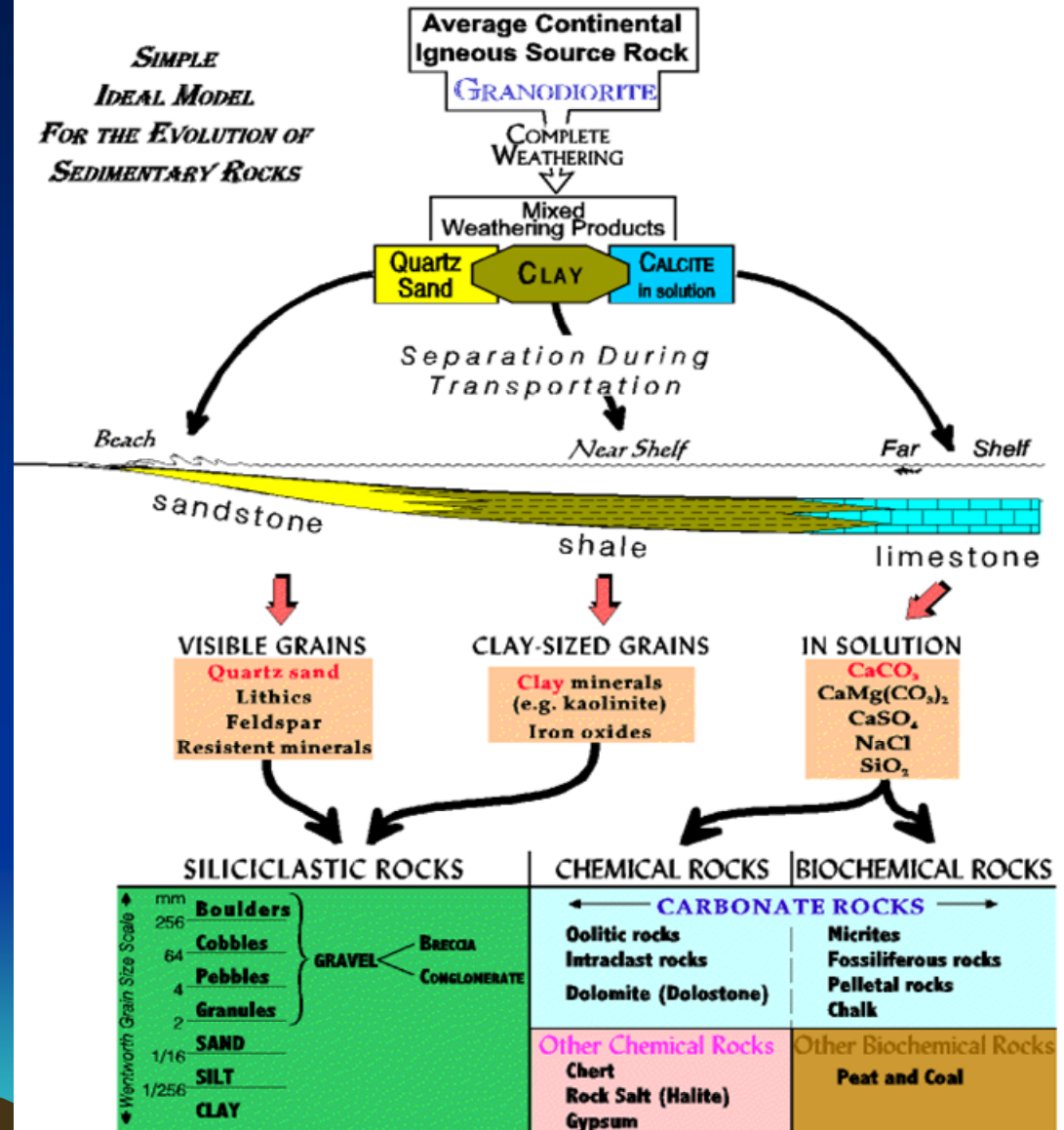
Clay-size

**Clast Size**



# SEDIMENTARY ROCK MODELS

*SIMPLE  
IDEAL MODEL  
FOR THE EVOLUTION OF  
SEDIMENTARY ROCKS*



L.S. Fichter, 1993, 2000

<http://geolab.jmu.edu/Fichter/SedRs/sedclass.html>



# Sediment Clast Types

## Clast Size



Gravel-size



Sand-size

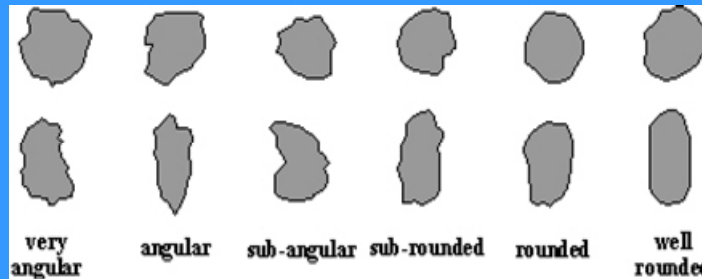


Silt-size



Clay-size

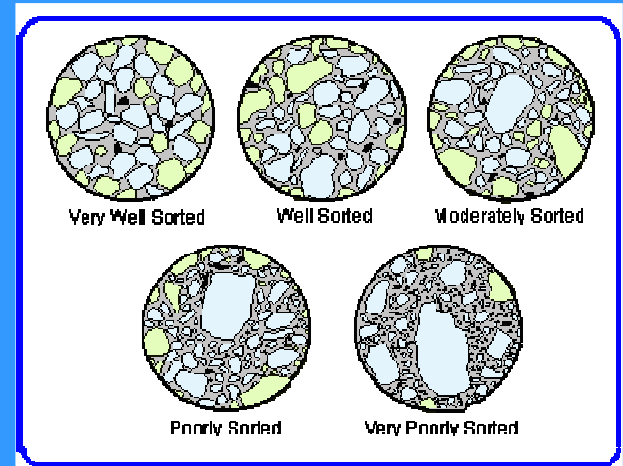
## Clast Shape



Near-to-source

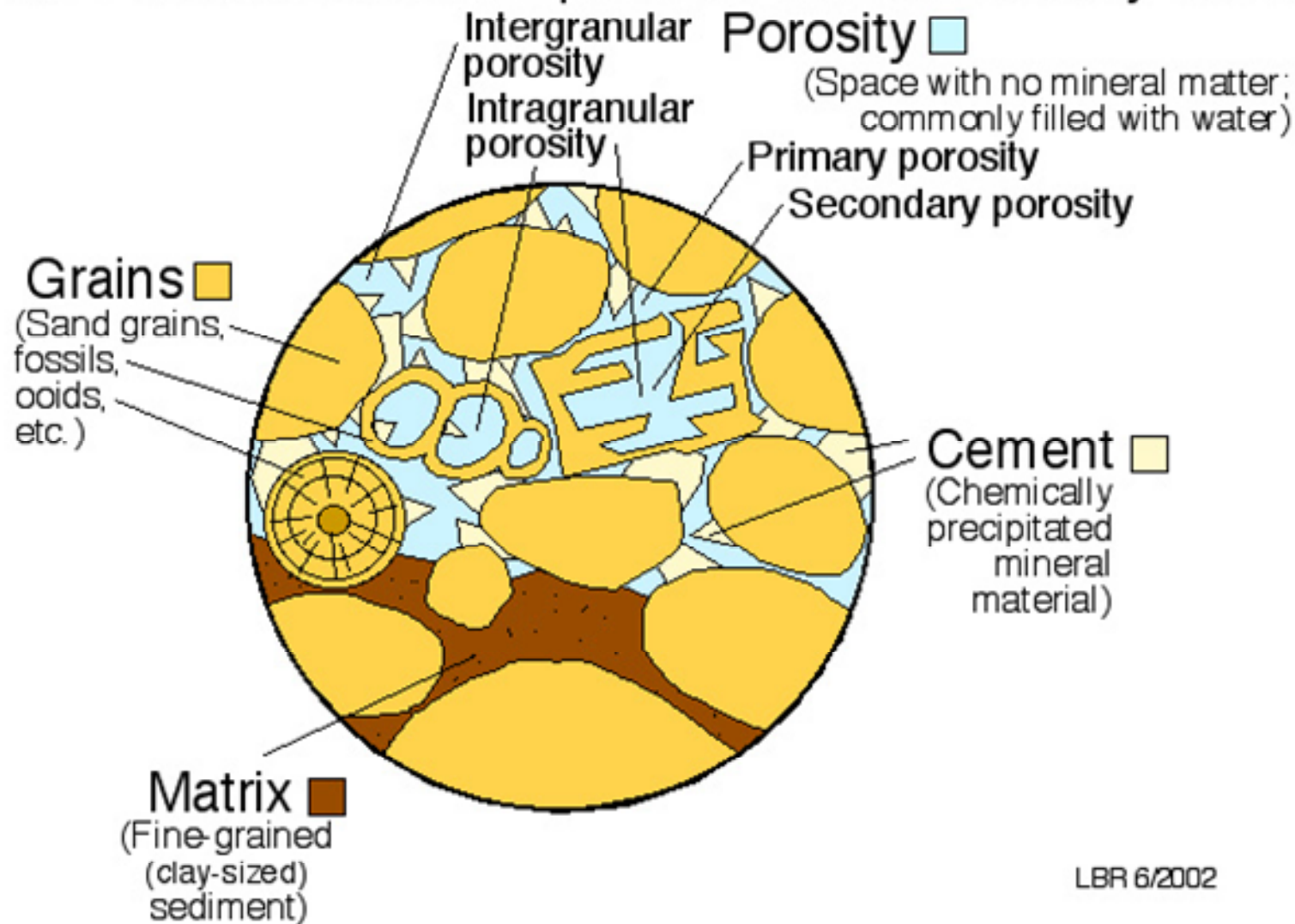
Far-from-source

## Clast Sorting



- 1) **Clast size** is a function of transport time and medium
  - ✓ An indicator of depositional environment
- 2) **Clast shape** is a function of transport distance and time
  - ✓ An indicator of sediment “maturity”
- 3) **Clast sorting** is a function of transport medium
  - ✓ An indicator of depositional environment

# Four Fundamental Components of Sedimentary Rocks

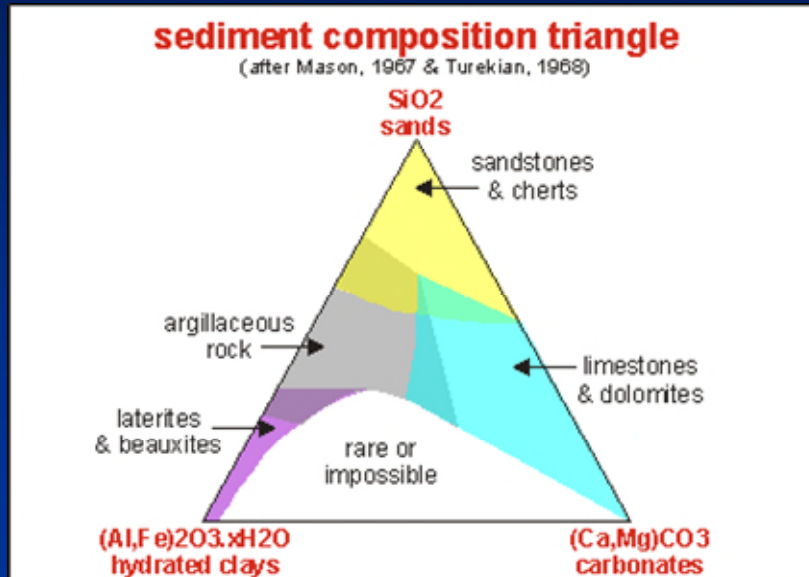


LBR 6/2002



# Sediment Composition Classification

## Three Most Common Sediment Types Forming Sedimentary Rock



## Sediments Type Chart

## Sediment Mineral Types

- ✓ Quartz Silts & Sands
- ✓ Clays
- ✓ Carbonates

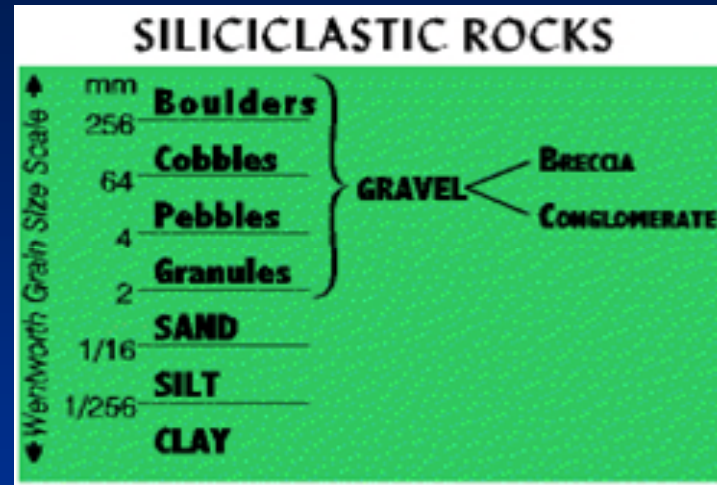
## Sediment Rock Types

- ✓ Siltstone, Sandstone & Chert
- ✓ Shales & Mudstones
- ✓ Limestones & Dolostones

# Three Major Groups of Sedimentary Rocks

## 1) Siliciclastic

- ✓ Breccia and Conglomerate
- ✓ Sandstone
- ✓ Siltstone
- ✓ Shale



## 2) Biochemical

- ✓ Limestone and Coal
- ✓ Biogenic origin
- ✓ Clastic and Crystalline

## 3) Chemical

- ✓ Chert, Rock Salt, and Gypsum
- ✓ Inorganic origin
- ✓ Crystalline

CHEMICAL ROCKS	BIOCHEMICAL ROCKS
← CARBONATE ROCKS →	
Oolitic rocks	Micrites
Intraclast rocks	Fossiliferous rocks
Dolomite (Dolostone)	Pelletal rocks
	Chalk
Other Chemical Rocks	Other Biochemical Rocks
Chert	Peat and Coal
Rock Salt (Halite)	
Gypsum	



## Breccia Texture:

- ✓ Very coarse-grained
- ✓ Angular fragments
- ✓ Deposits close to source region



## Conglomerate Texture:

- ✓ Very coarse-grained
- ✓ Rounded Fragments
- ✓ Deposits far from source region



## Sandstone Texture:

- ✓ Coarse to medium-grained
- ✓ Mostly quartz and feldspar
- ✓ Deposits in moving waters



## Siltstone texture:

- ✓ Fine-grained = silt-sized
- ✓ Mostly quartz and feldspar
- ✓ Deposits in fairly quiet waters



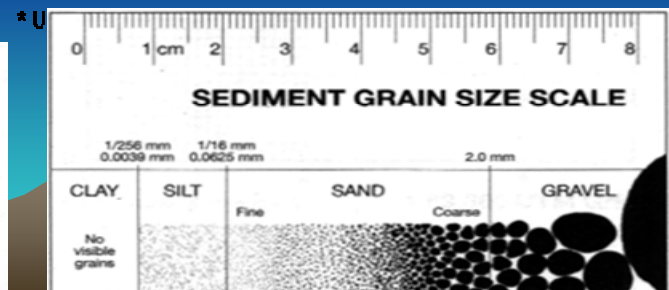
## Shale Texture:

- ✓ Very fine-grained = clay-sized
- ✓ Mostly clay
- ✓ Deposits in very quiet waters



# Sedimentary Detrital Rock Textures

Phi Units*	Size	Wentworth Size Class	Sediment/Rock Name
-8	256 mmr	Boulders	Sediment: GRAVEL Rock: RUDITES: (conglomerates, breccias)
-6	64 mmr	Cobbles	
-2	4 mmr	Pebbles	
-1	2 mmr	Granules	Sediment: SAND Rocks: SANDSTONES (arenites, wackes)
0	1 mmr	Very Coarse Sand	
1	1/2 mmr	Coarse Sand	
2	1/4 mmr	Medium Sand	
3	1/8 mmr	Fine Sand	
4	1/16 mmr	Very Fine Sand	Sediment: MUD Rocks: LUTITES (mudrocks)
3	1/256 mmr	Silt	
		Clay	



## Sparite Texture:

- ✓ Coarse-grained crystalline
- ✓ Carbonate minerals
- ✓ Halite and Gypsum
- ✓ With or without fossils



## Micrite Texture:

- ✓ Fine-grained crystalline
- ✓ Carbonate minerals
- ✓ With or without fossils



## Coquina Texture:

- ✓ Coarse-grained
- ✓ Mostly shell material
- ✓ Carbonate minerals



## Microcrystalline texture:

- ✓ Extremely fine-grained
- ✓ Smooth, massive looking
- ✓ Deposits in quiet waters
- ✓ Chert and Travertine



# Sedimentary (Bio)Chemical Textures

Clastic and Crystalline

## Fossiliferous Texture:

- ✓ Abundant fossils
- ✓ Either crystalline or clastic groundmass
- ✓ Usually carbonate rich





# Sedimentary Rock Structures



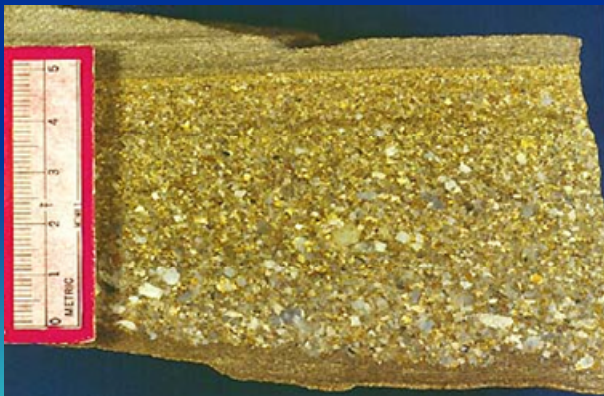
Mud Cracks



Ripple Marks



Cross Bedding



Graded Bedding



Layering



Bioturbation



# Sedimentary Rock Classification

## • A Three Step Process

### 1) Find Rock Composition

- ✓ Detrital? Crystalline?
- ✓ Mineralogy?

### 2) Find Texture

- ✓ Grain size?
- ✓ Shape?
- ✓ Fossils?

### 3) Name the Rock

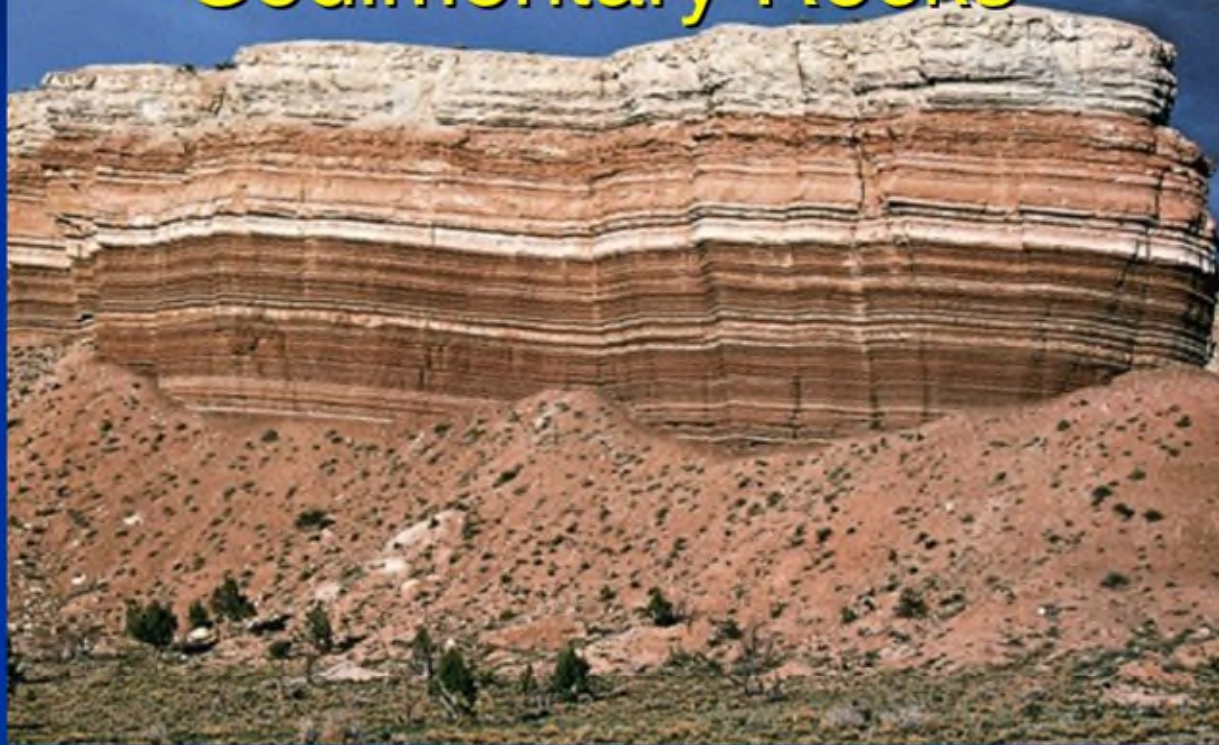
SEDIMENTARY ROCK ANALYSIS AND CLASSIFICATION						
STEP 1: What is the rock's composition?		STEP 2: What are the rock's textural and other distinctive properties?			STEP 3: Rock Name(s)	
DETRITAL (CLASTIC)	Mainly rock fragments or mineral grains (quartz, feldspar, clay) weathered from other rocks	Mainly gravel ( $\geq 2$ mm)		Rounded grains	CONGLOMERATE	
				Angular grains	BRECCIA	
		Mainly sand ( $1/16 - 2$ mm)		Mostly quartz grains	QUARTZ SANDSTONE	
				Mainly feldspar and quartz	ARKOSE	
				Sand is mixed with much silt and/or clay (mud)	GRAYWACKE	
		Mainly Mud ( $< 1/16$ mm)	Mostly silt ( $1/256 - 1/16$ mm)	Breaks into blocks or layers	SILTSTONE	
			Mostly clay ( $< 1/256$ mm)	Crumbles or breaks into blocks	CLAYSTONE	
				Fissile (splits easily)	SHALE	
					SANDSTONE	
					MUDSTONE	
BIOCHEMICAL: Mainly fossil shells or plant fragments	Mainly plant fragments or charcoal	Dull brown with visible plant fragments		Porous and easy to break apart the plant fragments	PEAT	
		Black		Dense and brittle or porous and sooty	BITUMINOUS COAL	
	Mainly fossil shells, shell fragments, or microfossils  Effervesces in dilute HCl	Mostly visible shells and shell fragments cemented into a dense mass			CALCIRUDITE	
		Mostly sand-sized fragments. May have a few larger shells.			CALCARENITE	
		Mostly very fine grained to microcrystalline mass of calcite and microfossils			MICRITE	
		Porous, poorly cemented mass of shells and shell fragments			COQUINA	
		Mostly very fine grained, earthy, chalky, light-colored mass of microfossils			CHALK	
CHEMICAL (INORGNIC): Chemically precipitated crystals	Mainly crystals of calcite or aragonite, $\text{CaCO}_3$  Effervesces in dilute HCl	Crystalline to microcrystalline bands of calcite crystals			TRAVERTINE	
		Spherical grains like tiny beads ( $< 2$ mm) with concentric laminations			OOLITIC LIMESTONE	
	Mainly dolomite $\text{CaMg}(\text{CO}_3)_2$	Microcrystalline		Effervesces in dilute HCl only if powdered	DOLOSTONE	
	Mainly varieties of quartz, $\text{SiO}_2$ (chalcedony, flint, chert, opal, jasper, etc.)	Microcrystalline, conchoidal fracture		Scratches glass	CHERT	
	Mainly halite, NaCl	Crystals formed as inorganic chemical precipitates		Salty taste	ROCK SALT	
	Mainly gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	Crystals formed as inorganic chemical precipitates		Can be scratched with your fingernail	ROCK GYPSUM	
	Mostly iron-bearing minerals, like limonite and hematite	Amorphous or microcrystalline		Dark-colored, usually brown or red-gray	IRONSTONE	



# Discussion and Examination



## Sediments and Sedimentary Rocks



<http://www.cobweb.net/~bug2/mineral.htm>

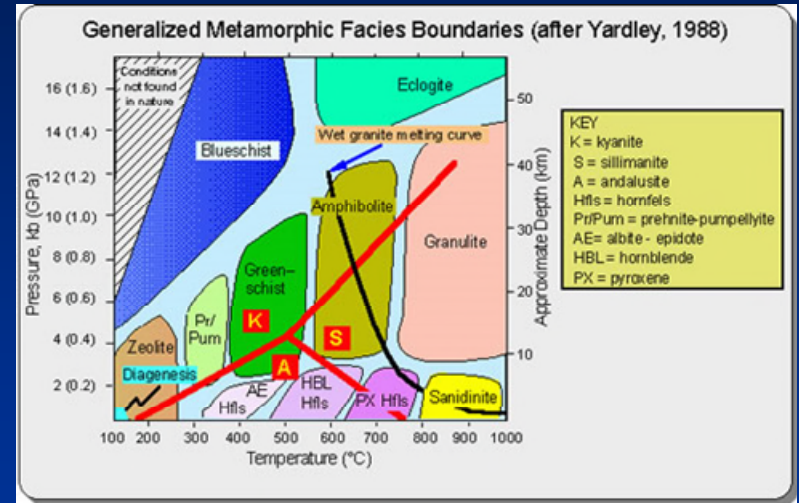
<http://www.rockhounds.com/rockshop/rockkey/index.html>

<http://www.union.edu/PUBLIC/GEODEPT/COURSES/geo-10/mineral.htm>



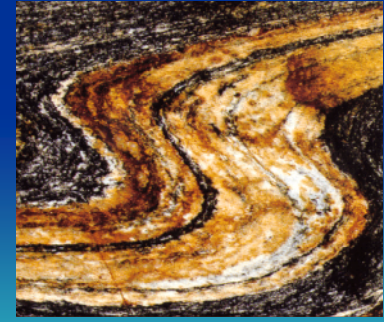
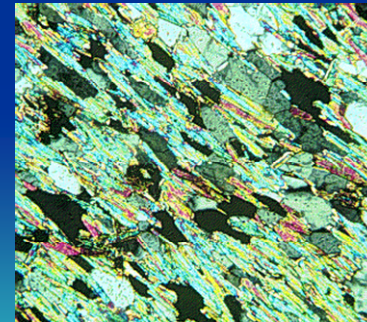


# Metamorphic Rock Origin and Identification



Intro to Earth Systems  
ENVI 110 Lab

Ray Rector - Instructor




<http://www.rockhounds.com/rockshop/rockkey/index.html>

<http://earthsci.org/education/teacher/basicgeol/meta/meta.html>

<http://csmres.jmu.edu/geollab/Fichter/MetaRx/Metaalphanb.html>

# Major Concepts

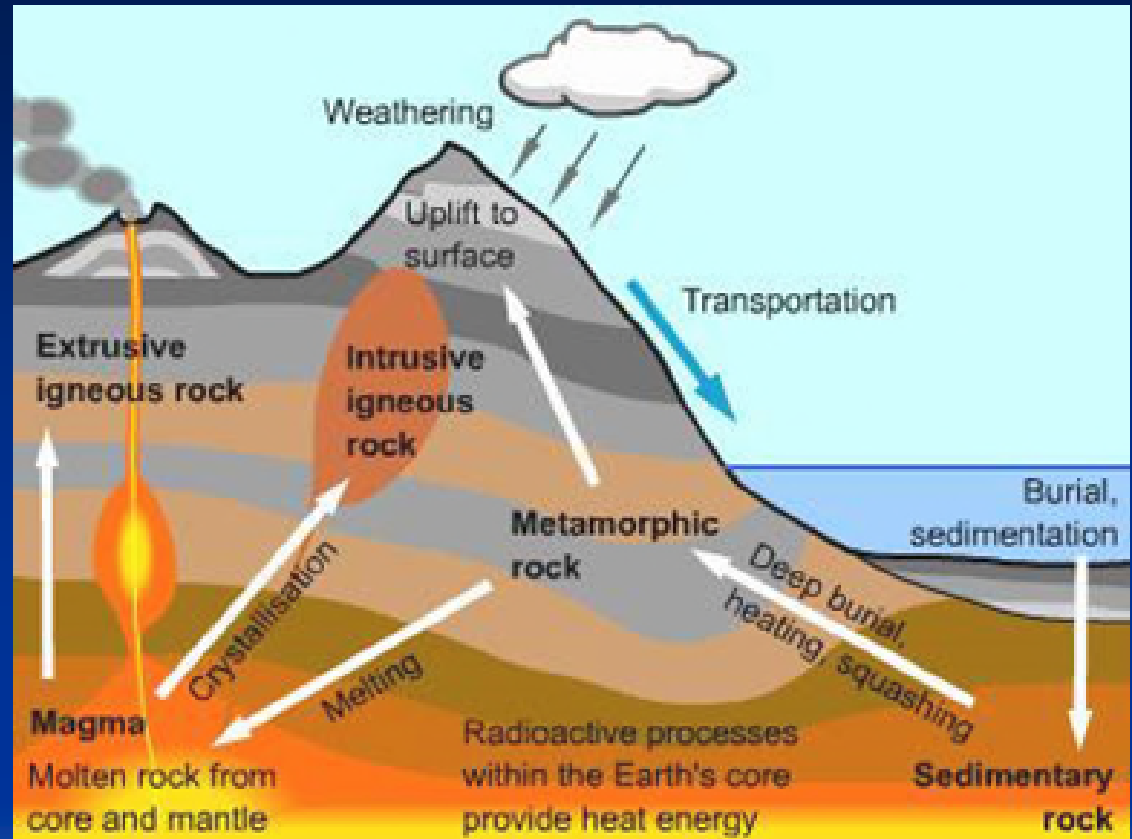
- 1) Metamorphic rocks form by recrystallization and/or neocrystallization of preexisting rock (parent rock) in the solid state.
  - 2) Most cases of metamorphism occur at or near tectonic plate boundaries.
  - 3) Agents of metamorphism include heat, pressure, reactive fluids, and stress.
  - 4) Two metamorphic processes are recrystallization and neocrystallization.
  - 5) Three major types of metamorphism is regional, contact and dynamic.
  - 6) The two primary criteria for classifying and identifying metamorphic rocks are composition (mineralogy) and texture (grain size and grain orientation).
  - 7) Two major metamorphic rock groups are 1) foliated and 2) nonfoliated.
  - 8) Metamorphic rock composition controlled by parent rock composition.
  - 9) Texture controlled by combination of metamorphic agents (foliated includes stress; nonfoliated no stress involved).
  - 10) Slate, phyllite, schist and gneiss are the foliated metamorphic rocks.
  - 11) Marble, quartzite, hornfels, and granofels are the nonfoliated meta rocks.
- 



# The Rock Cycle

## Three Primary Rock Types

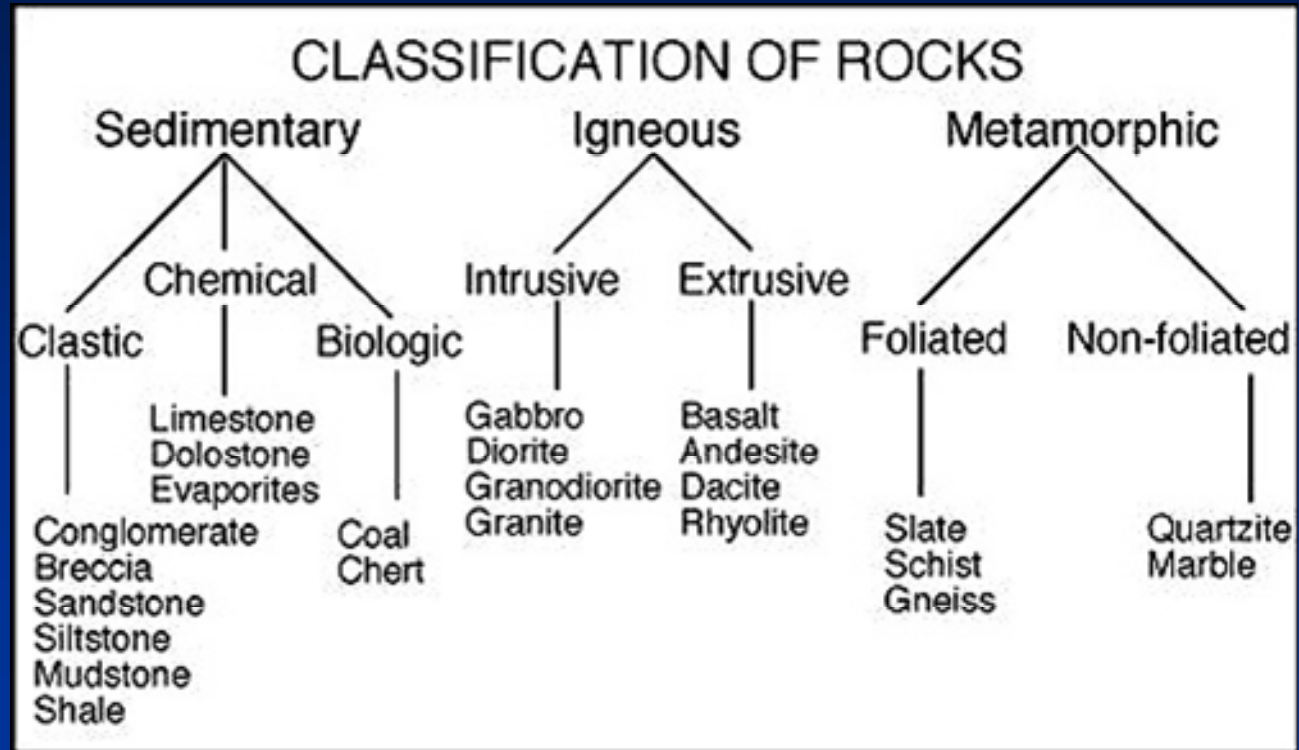
- 1) **Igneous**
- 2) **Metamorphic**
- 3) **Sedimentary**



Focus of this presentation is on Metamorphic Rocks

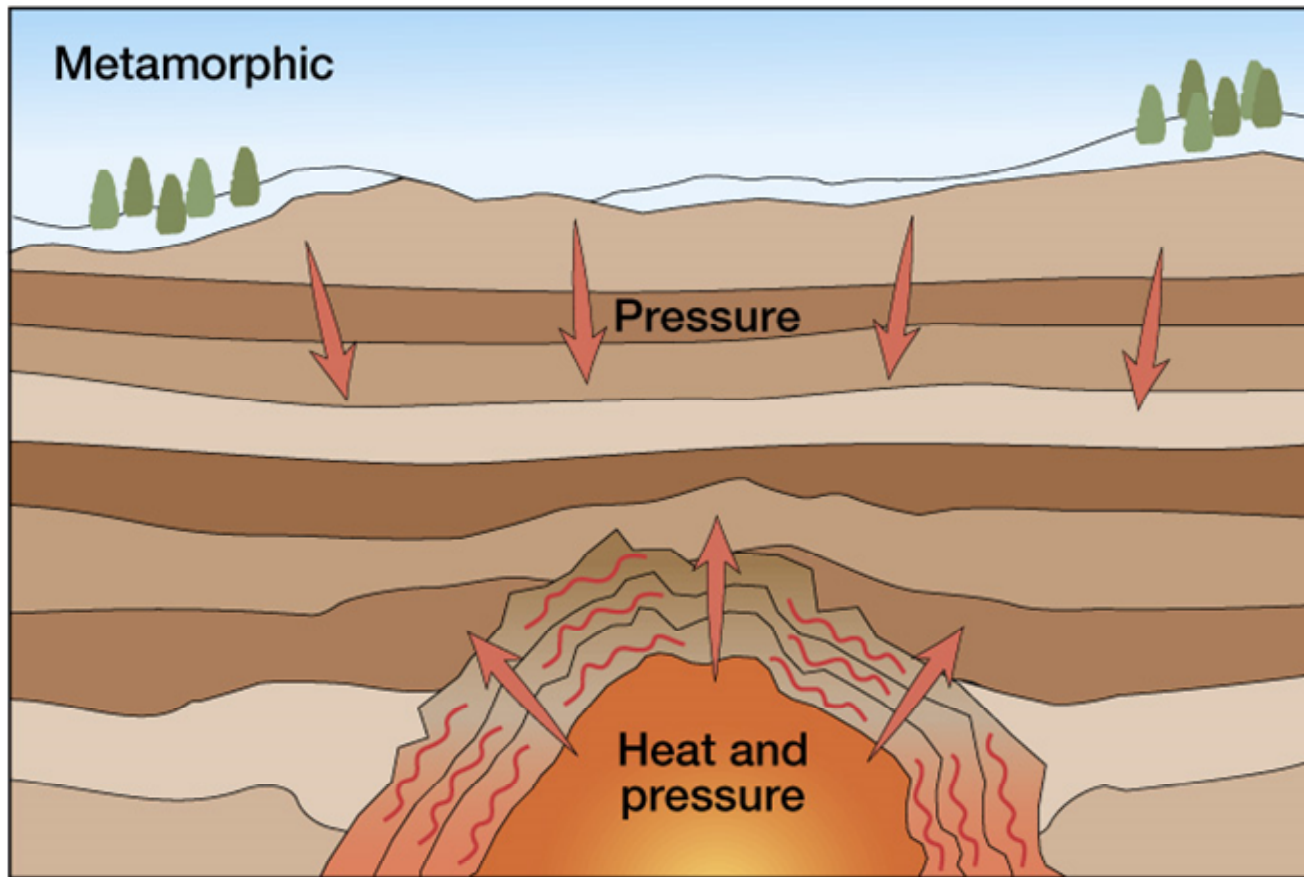
# Three Primary Rock Types

- 1) **Igneous**
- 2) **Metamorphic**
- 3) **Sedimentary**



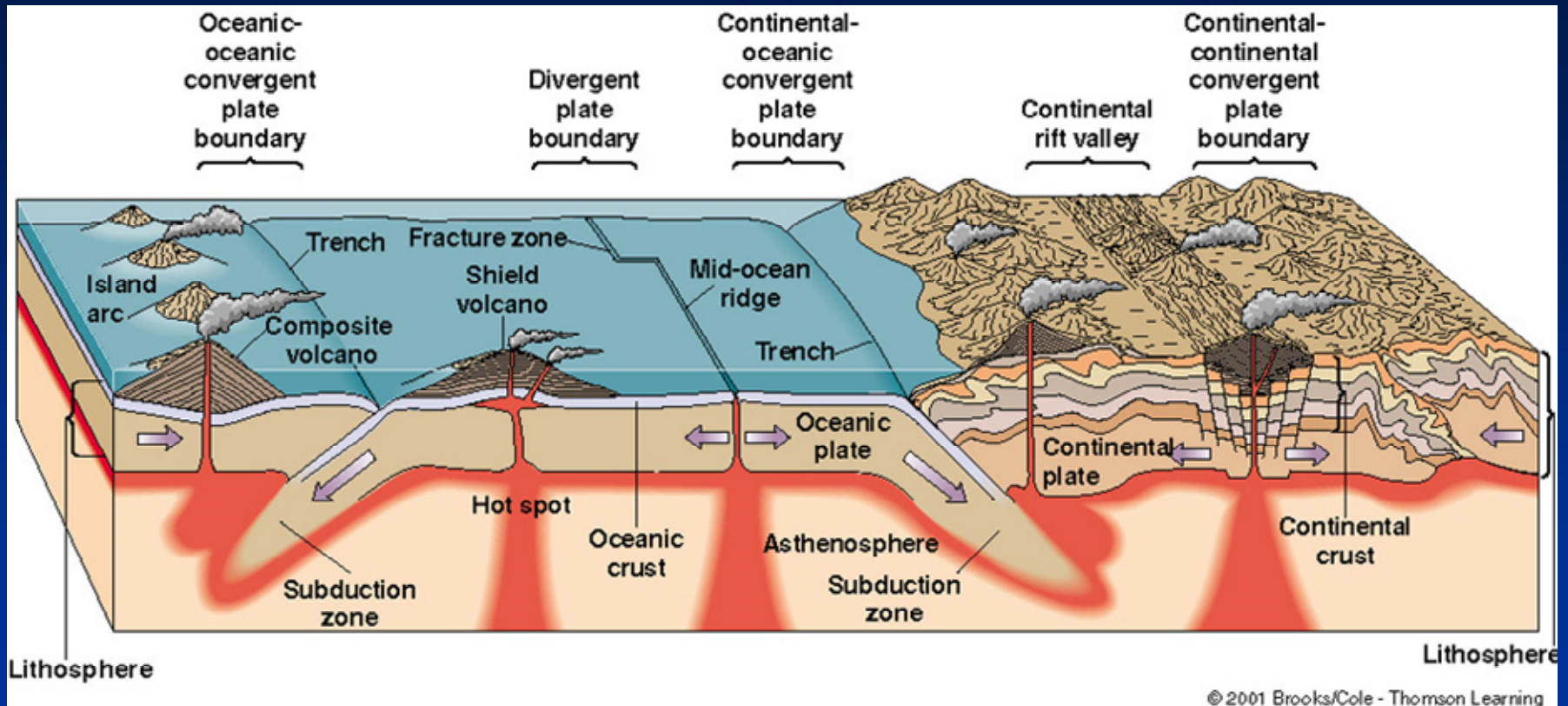


# Heat + Pressure = Mother Metamorphic



Hot Chemically-Reactive Fluids and Tectonic Stresses Too!

# Environments for Metamorphism



**Vast majority of metamorphism takes place at plate boundaries – Why?**

- 1) Heat
- 2) Elevated Pressure
- 3) Magma and Hot Fluids
- 4) Tectonic Stresses



# Tectonic Settings and Types of Metamorphism

## Tectonic Settings of Metamorphism

- 1) All types of plate boundaries
- 2) Hot spots
- 3) Any other region undergoing mountain building and/or magmatic activity

## Types of Metamorphism

### 1) Regional Metamorphism (RM)

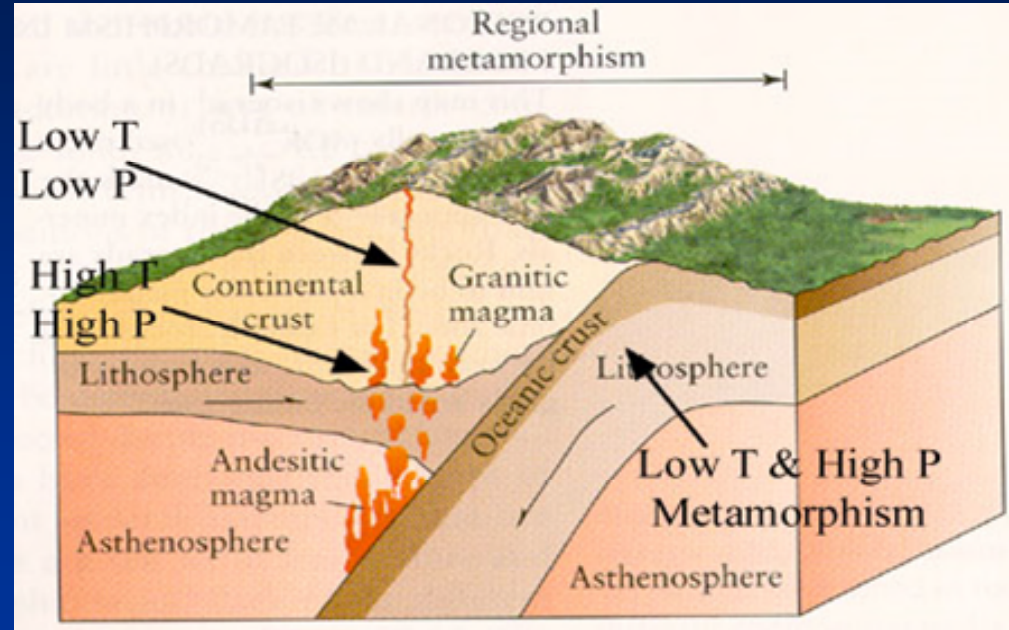
- ✓ Due to deep burial
- ✓ From Low T + Low P to High T + High P

### 2) Contact Metamorphism (CM)

- ✓ Caused by close proximity to magma and/or very hot fluids
- ✓ From High T + Low P to High T + High P

### 3) Dynamic Metamorphism (DM)

- ✓ Caused by shearing forces in active fault zones
- ✓ From Low T + Low P to Mod T + Mod P



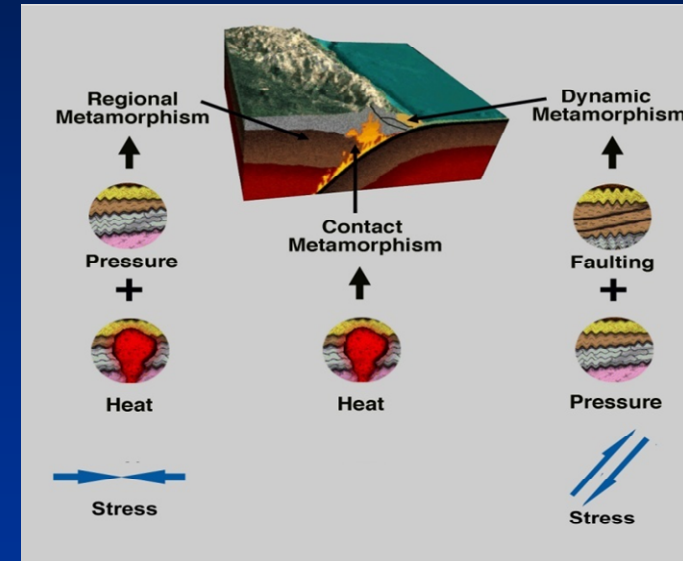
# Metamorphic Processes and Grade

## 1) Deep Burial = Pressure + Heat + Tectonic Stresses

- ✓ Process termed **Regional Metamorphism**
- ✓ Metamorphic conditions = Low to High grade
- ✓ Produces foliated textures
- ✓ Slates, schist, and gneisses

## 2) Magma Contact = High Heat + Fluids

- ✓ Process termed **Contact Metamorphism**
- ✓ Metamorphic conditions = Low to High grade
- ✓ Produces non-foliated textures
- ✓ Quartzite, Marble, and Hornfels



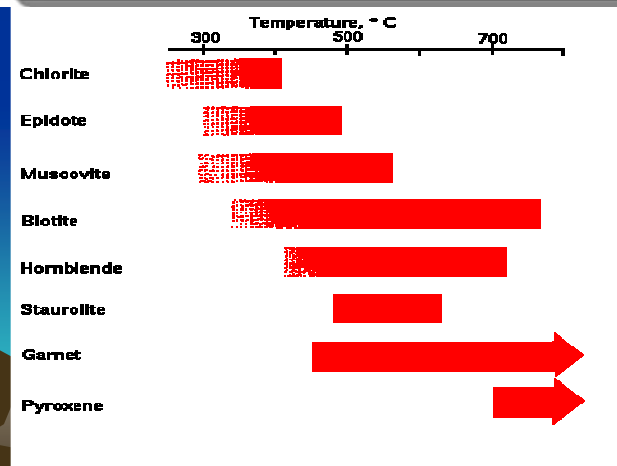
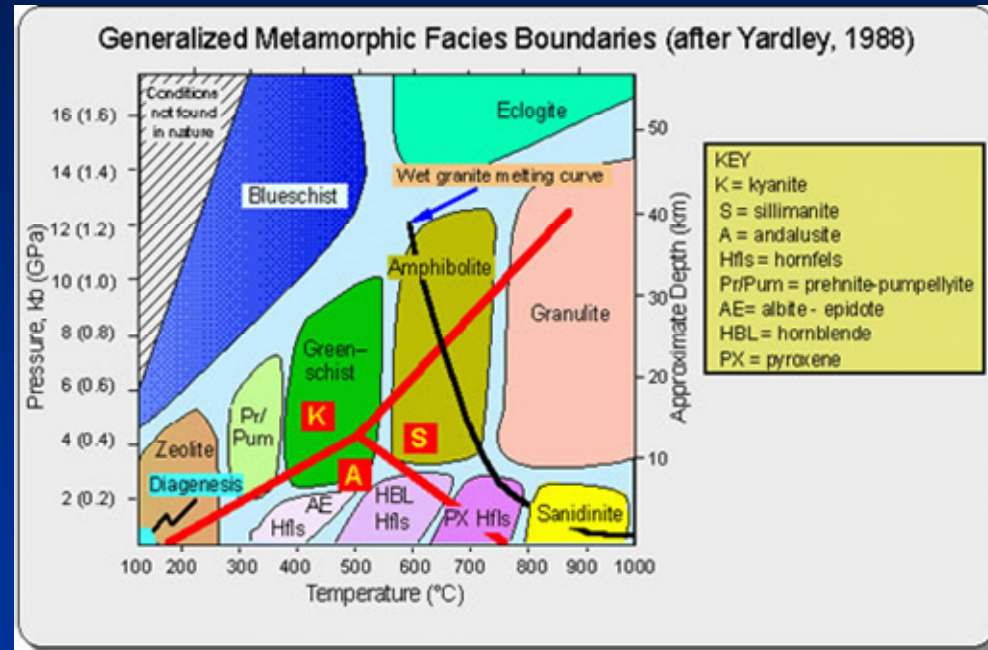
Metamorphic Grade			
Parent	Low Grade	High Grade	
Limestone	Marble	Slate	Marble
Sandstone	Quartzite	Schist	Quartzite
Shale	Slate	Gneiss	Gneiss
Granite	-----	Schist	Gneiss
Basalt	Greenschist	Amphibolite	Amphibolite

# Metamorphic Grade and Mineral Facies

## Temperature-Pressure Chart

### The Facies Concept

- 1) The presence of a Key Mineral in a metamorphic rock indicates a unique set of Temperature-Pressure conditions
- 2) A specific range of temperature-pressure values constitutes a given Metamorphic Facies
- 3) Each Metamorphic Facies is associated with a unique tectonic setting
- 4) Low-grade metamorphism occurs at low temperatures and pressures
- 5) High-grade metamorphism occurs at high temperatures and pressures







# Metamorphic Rock Classification

Original Rock	Texture	Rock Name	Metamorphic Process	Metamorphic Grade	Comments
mudstone	Foliated	slate	regional	lower	breaks into plates (slaty cleavage)
mudstone	Foliated	phyllite	regional	moderate	more shiny and crenulated than slate
mudstone	Foliated	schist	regional	mod-high	different schists recognized on the basis of mineral content
mudstone granite	Foliated	gneiss	regional	high	well-developed light and dark banding
quartz sandstone	Non-foliated	quartzite	contact	low-high	sugary texture composed of interlocking quartz grains; relatively hard; won't fizz with acid
limestone	Non-foliated	marble	contact	low-high	sugary texture composed of interlocking calcite grains; relatively soft; may fizz with acid
basalt	Non-foliated	metabasalt	contact	low	greenish color due to chlorite

**Metamorphic rocks are classified according to several criteria:**

- 1) Origin = parent rock
- 2) Texture-Fabric
- 3) Composition-Mineralogy
- 4) Metamorphic process
- 5) Grade of metamorphism

# Parent Rock → Metamorphic Rock Pairs

Parent	Grd	Rock	Foliation	Comments
Shale	Low	Slate	cleavage	v fine
		Phyllite	cleavage	'sheen' from fine mica
		Schist	schistosity	mica coarse/visible
		Gneiss	banding	v coarse
Basalt	Med	Green schist	schistosity	green chlorite
		Ampholite	Banding	black amphibole
		Blue-schist	schistosity	blue amphibole
Lime-stone	All	Marble	None/ Banding	Calcite dominates minors give color
Sand-stone	All	Quartzite	None	Quartz dominates minors give color



# Metamorphic Rock Classification

Texture			Rock name	Metamorphism		Dominant mineral composition				Original rock
				dominant kind	degree					
Foliated	fine grained	"smooth"	Slate	regional	low grade	clay				shale
		"shiny" "layered"	Phyllite	regional	medium grade	chlorite				shale
	coarse grained	"layered"	Schist	regional	medium grade		m i c a			shale
		"banded"	Gneiss	regional	high grade			q u a r t z	amphibole feldspar	shale or granite
Nonfoliated	fine grained		Hornfels	contact						shale
	coarse grained	reaction with HCl	Quartzite	contact or regional						quartz sandstone
		no reaction with HCl	Marble	contact or regional					calcite	limestone or dolomite



# Common Metamorphic Rocks In Hand Samples



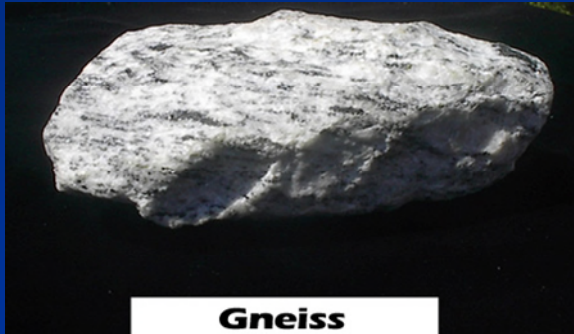
**Slate**



**Phyllite**



**Schist**



**Gneiss**



**Amphibolite**



**Hornfels**



**Quartzite**



**Marble**



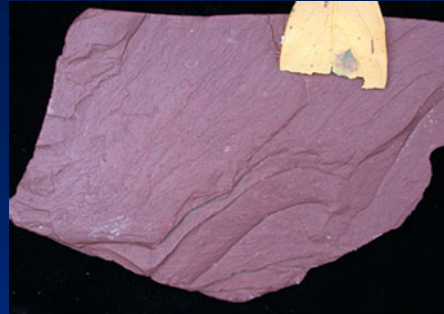
**Serpentine**



# Foliated Metamorphic Textures

## Slaty

- ✓ Foliated = Flat, tight-layered sheets
- ✓ Very Fine Grained
- ✓ Little to minerals observable



Red Slate



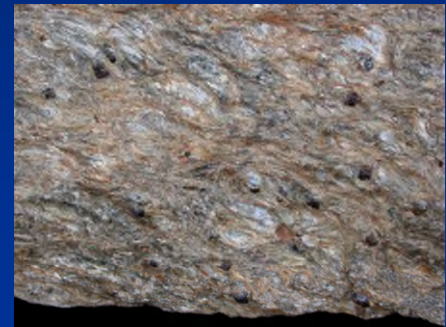
Close-Up

## Phyllitic

- ✓ Foliated = Mildly wavy, sheets
- ✓ Fine-grained
- ✓ Sheen-like luster = mica minerals



Mica Schist



Close-Up

## Schistose

- ✓ Foliated = wavy, flaky layers
- ✓ Medium to coarse grained
- ✓ Observable mineralogy
- ✓ Lots of mica and quartz



Garnet Gneiss

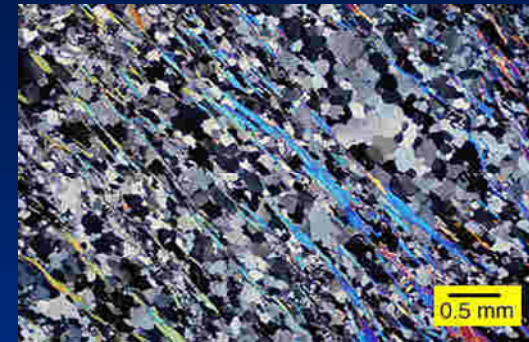
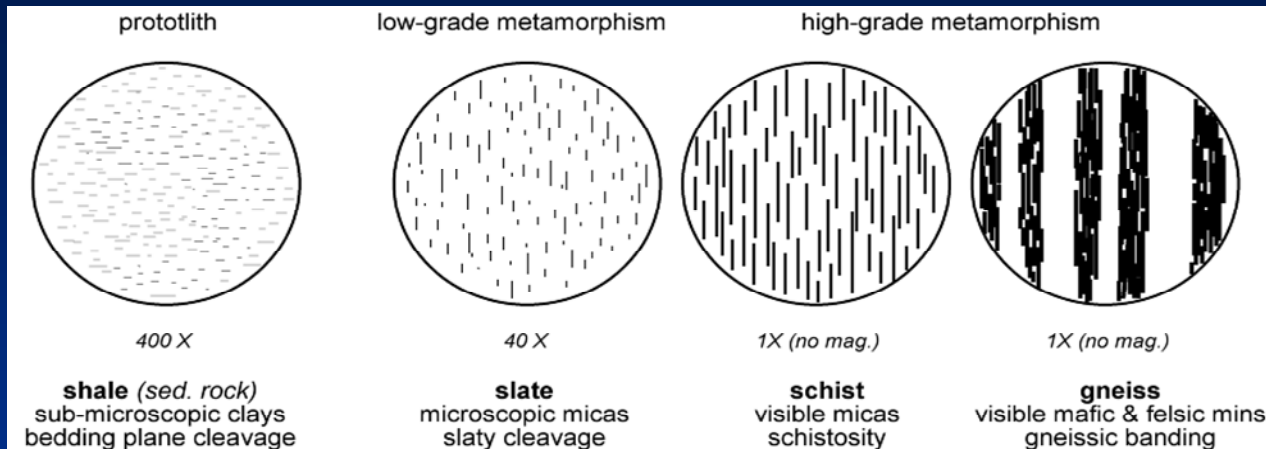


Close-Up

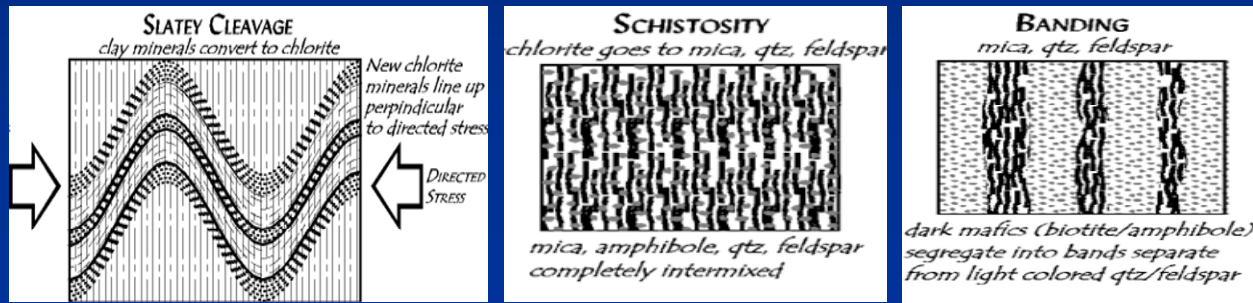
## Gneissic

- ✓ Foliated = dark and light mineral bands
- ✓ Medium to coarse grained
- ✓ Observable mineralogy
- ✓ Quartz, feldspar, biotite, and amphibole

# Foliated Metamorphic Textures



**Foliated  
Textures**



- 1) Foliated textures result from deviatoric tectonic stresses
- 2) The type of foliated rock fabric is a function of metamorphic grade
  - ✓ Foliation character changes with intensity and duration of metamorphism
- 3) The type of foliated rock fabric is also a function of rock composition



# Non-Foliated Metamorphic Textures

## Microgranular

- ✓ Crystalline
- ✓ Nonfoliated = Equant-shaped grains
- ✓ Very fine- to fine-grained
- ✓ Massive-looking rock
- ✓ Little to no minerals observable
- ✓ Example = Hornfels



Hornfels



Granular Fabric

## Macrogranular

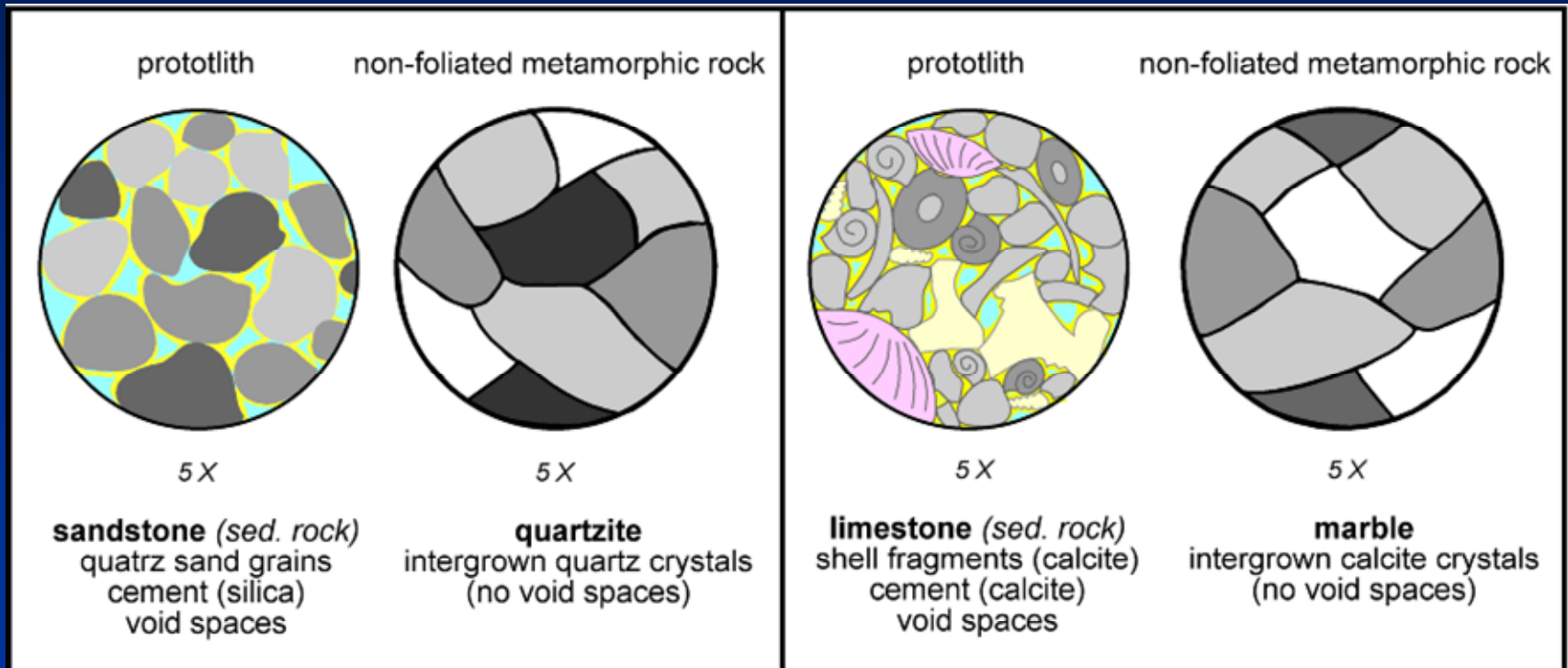
- ✓ Crystalline
- ✓ Nonfoliated = Equant-shaped grains
- ✓ Medium to coarse-grained
- ✓ Massive-looking rock
- ✓ Identifiable minerals
- ✓ Example: Marble



Marble

# Metamorphism of Parent Rocks

## Textural Changes in Mono-Minerallic Metamorphism



Quartz-rich Rocks

Calcite-rich Rocks

- ✓ Mono-minerallic rocks are typically non-foliated.
- ✓ Texture described as “polygonal granular”

# Most Common Types of Metamorphic Rocks

## Questions:

- 1) Which are foliated?
- 2) Which are nonfoliated?
- 3) Which are monomineralic?
- 4) Which are high grade?
- 5) Which are low grade?
- 6) Which looks mica-rich?
- 7) Which are hard?
- 8) Which are soft?





# Common Metamorphic Rocks In Hand Samples



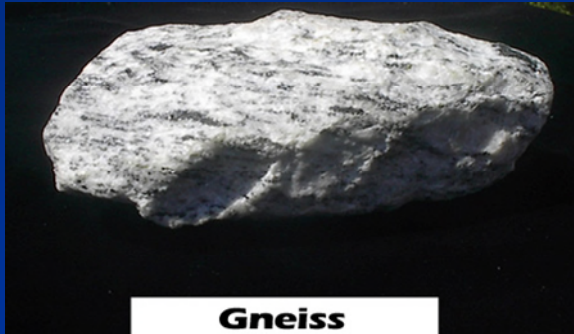
**Slate**



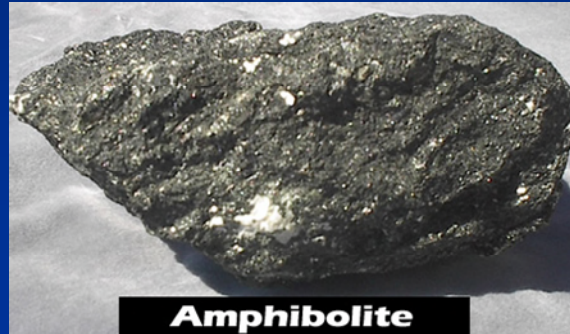
**Phyllite**



**Schist**



**Gneiss**



**Amphibolite**



**Hornfels**



**Quartzite**



**Marble**



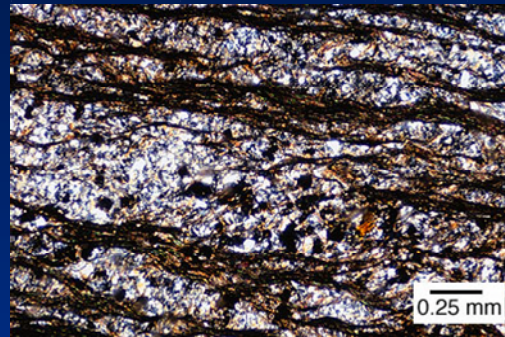
**Serpentine**



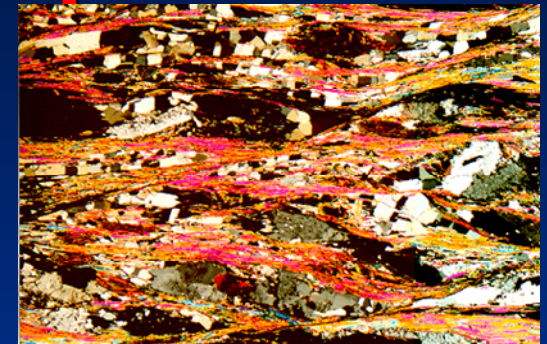
# Common Metamorphic Rocks Under a Microscope



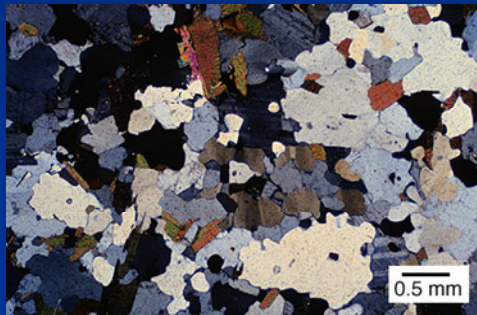
Slate



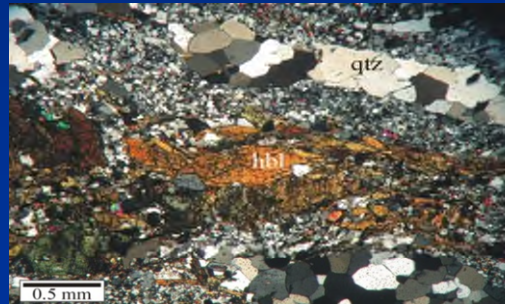
Phyllite



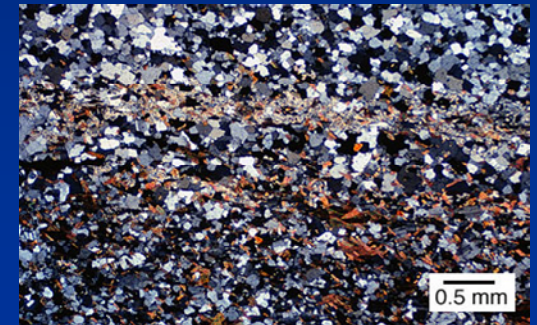
Schist



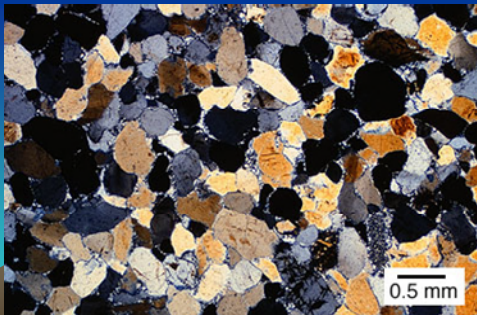
Gneiss



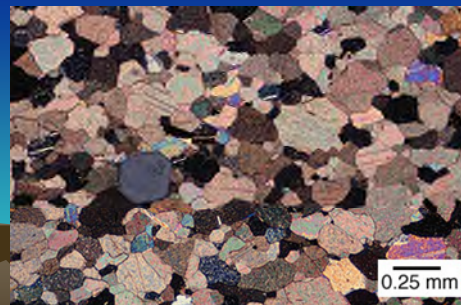
Amphibolite



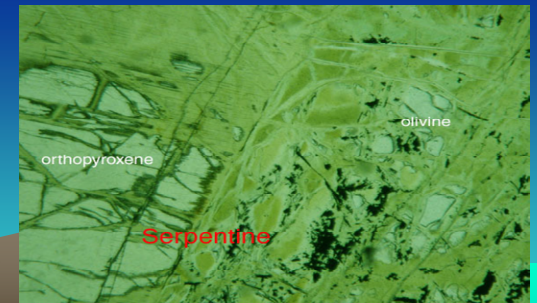
Hornfels



Quartzite



Marble




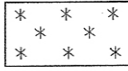

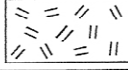



Serpentinite

# Metamorphic Rock Classification

## A Three Step Process

### 1) Determine Texture

- ✓ Foliated or Nonfoliated?
- ✓ Type of foliation?
- ✓ Grain size?

TEXTURE		GRAIN SIZE	COMPOSITION					TYPE OF METAMORPHISM	COMMENTS	ROCK NAME	MAP SYMBOL	
FOLIATED	MINERAL ALIGNMENT	Fine	MICA	QUARTZ	FELDSPAR	AMPHIBOLE	GARNET	PYROXENE	Regional  (Heat and pressure increase with depth) ↓	Low-grade metamorphism of shale	Slate	
		Fine to medium								Foliation surfaces shiny from microscopic mica crystals	Phyllite	
										Platy mica crystals visible from metamorphism of clay or feldspars	Schist	
	BAND-ING	Medium to coarse									High-grade metamorphism: some mica changed to feldspar; segregated by mineral type into bands	Gneiss
NONFOLIATED		Fine	Variable					Contact (Heat)	Various rocks changed by heat from nearby magma/lava	Hornfels		
	Fine to coarse	Quartz					Regional or Contact	Metamorphism of quartz sandstone	Quartzite			
		Calcite and/or dolomite						Metamorphism of limestone or dolostone	Marble			
		Coarse	Various minerals in particles and matrix						Pebbles may be distorted or stretched	Metaconglomerate		

### 2) Determine Composition

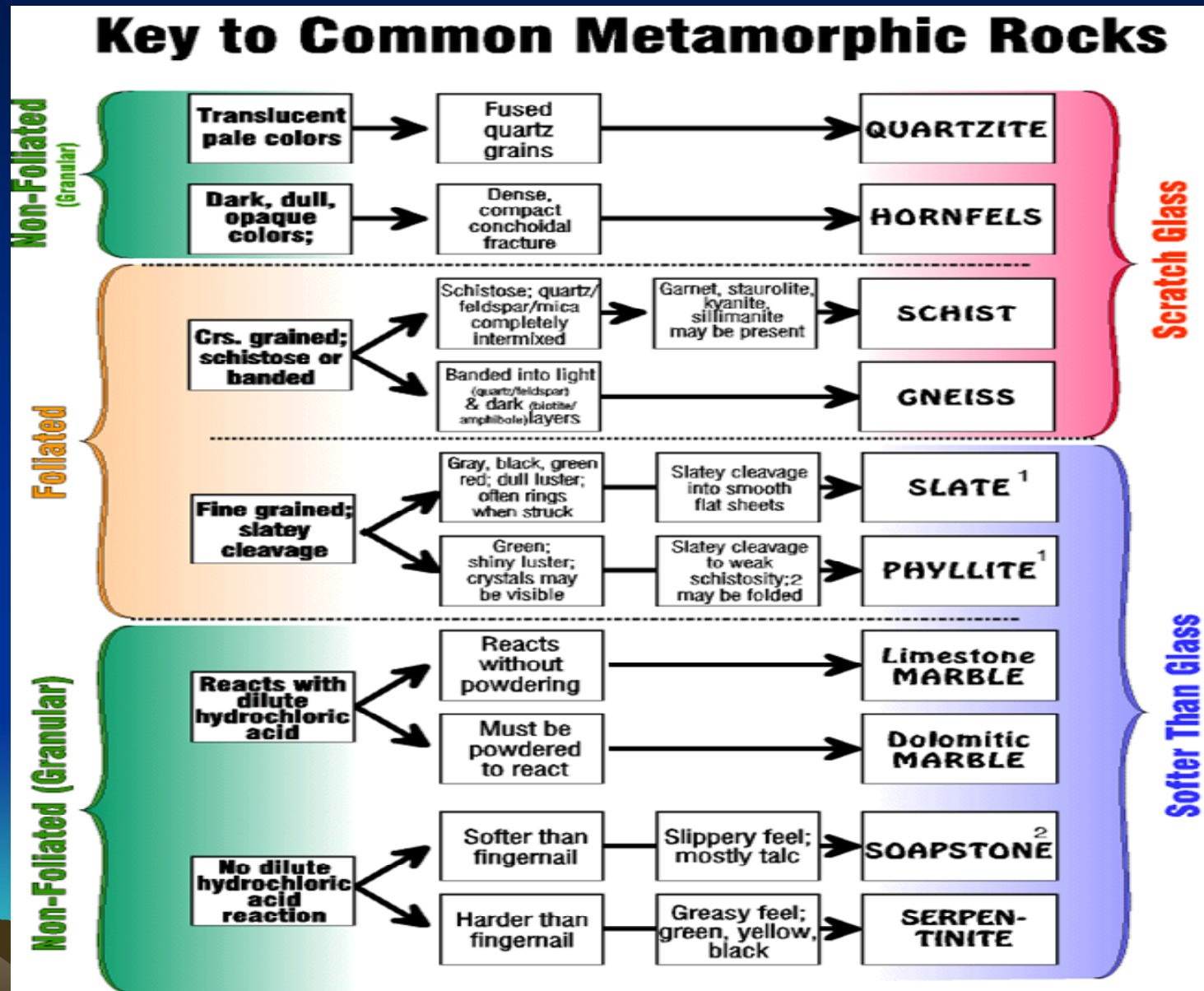
- ✓ Mineralogy?

### 3) Name the Meta Rock and its Parent Rock





# Classification of Metamorphic Rocks



<sup>1</sup> (Shale), slate, and phyllite complete intergrade with each other. Distinctions may be difficult.

<sup>2</sup> Soapstone may be weakly foliated.



# Metamorphic Rocks

## Discussion and Examination



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# Next Week's Lab Topics

## **Isostasy and Plate Tectonics**

- Definitions and Concepts
- Ocean and Continental Crustal Densities
- Modeling Isostasy
- Isostatic Equilibrium and Adjustment

## **Pre-lab Checklist**

- Reader: Lab 2 – Isostasy and Plate Tectonics
- Chapter in Lab Manual
- Do the Pre-lab Activities and Quiz BEFORE lab

Bring Lab Reader to class

**GeoTime Scale Quiz Next Week too!!!!**