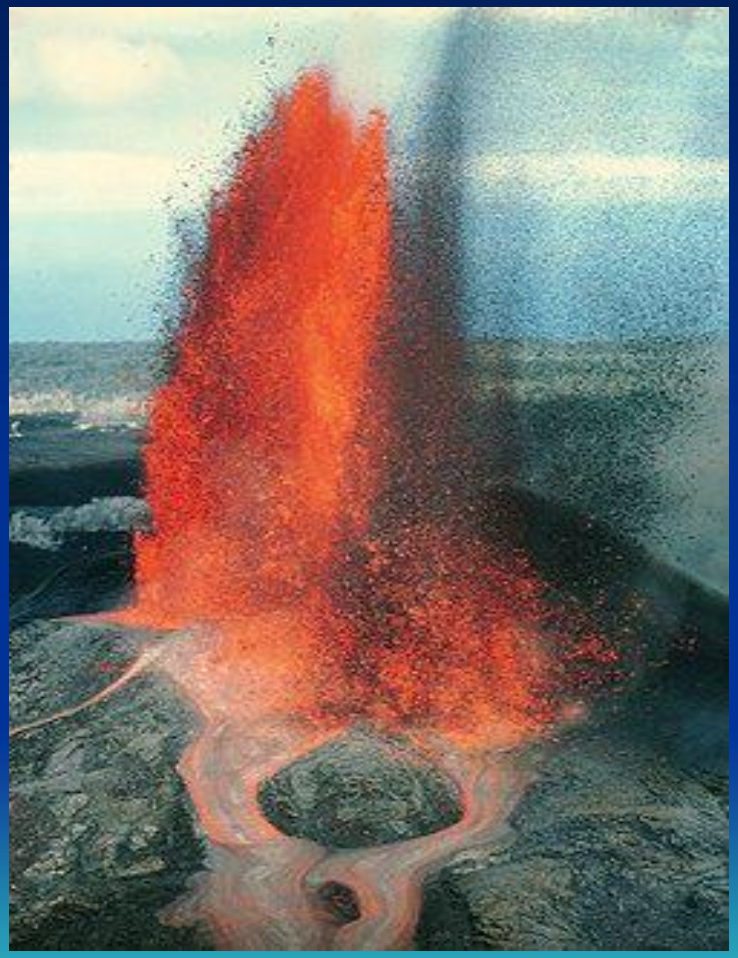
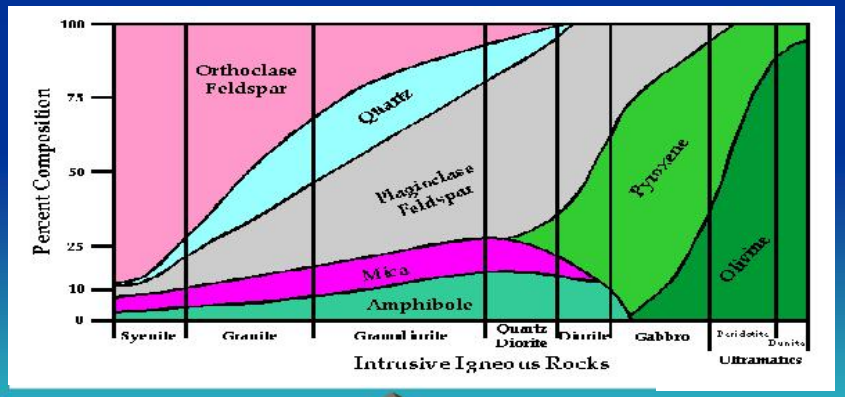
Igneous Rock Processes and Identification





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

http://earthsci.org/education/teacher/basicgeol/igneous/igneous.html#KindsofIgneousRocks

Major Concepts

1) Igneous rocks form directly from the crystallization of a magma or lava
2) Three primary tectonic settings of global-scale magmatization are divergent boundaries, subduction-related convergent boundaries, and hot spots.
3) Tectonic environment controls the type of magmas generated, and hence the types of igneous rocks that form at each of the three tectonic settings.
4) Magma reaching the surface is termed lava, typically forming a volcano.
5) The type of igneous rock formed is controlled by two factors: magma composition and cooling history; also determines naming of igneous rocks
6) Magma compositions vary from mafic to intermediate to silicic-felsic.
7) Texture controlled by cooling history; Mineralogy by magma composition
8) Coarse-grained igneous rocks that cooled very slowly at depth are termed intrusive or plutonic
9) Fine-grained igneous rocks that cooled quickly at or near surface are termed extrusive or volcanic.
10) Identification of igneous rocks based on two criteria: texture and composition

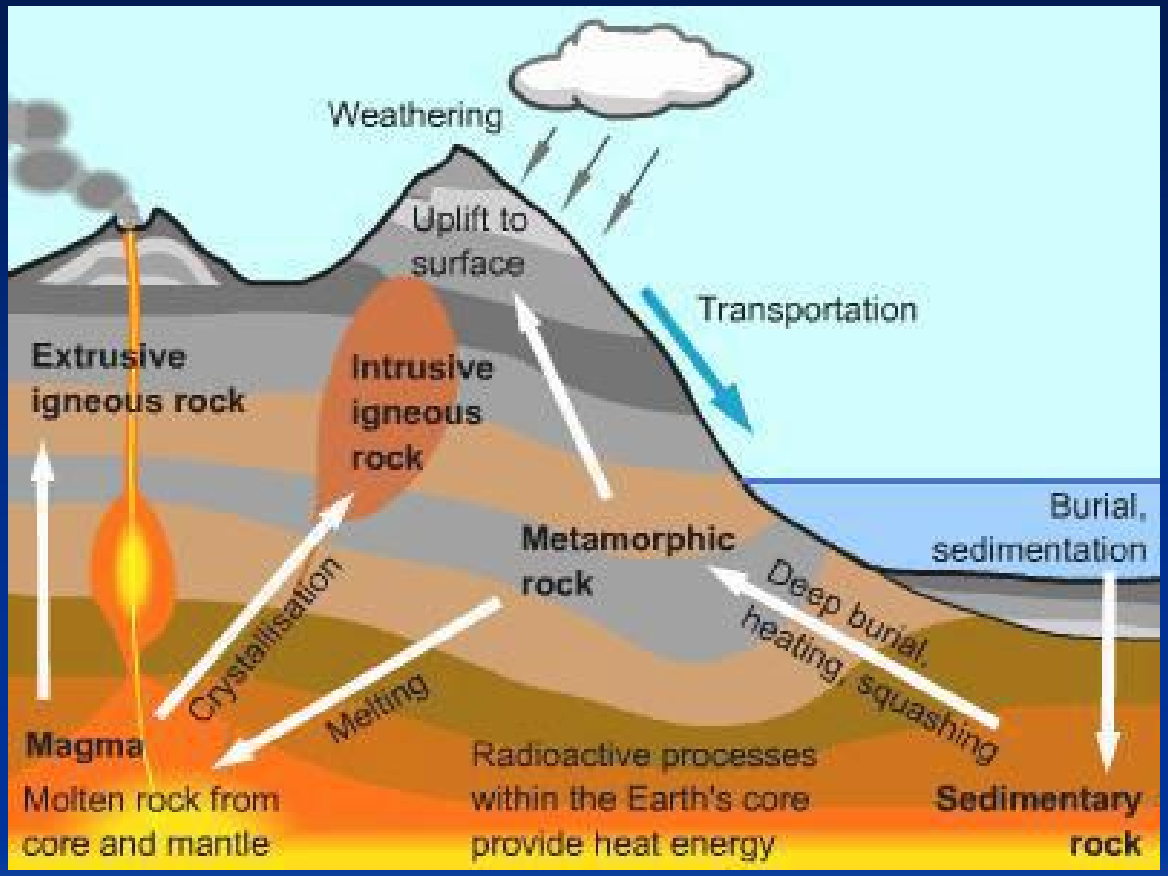
The Rock Cycle

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

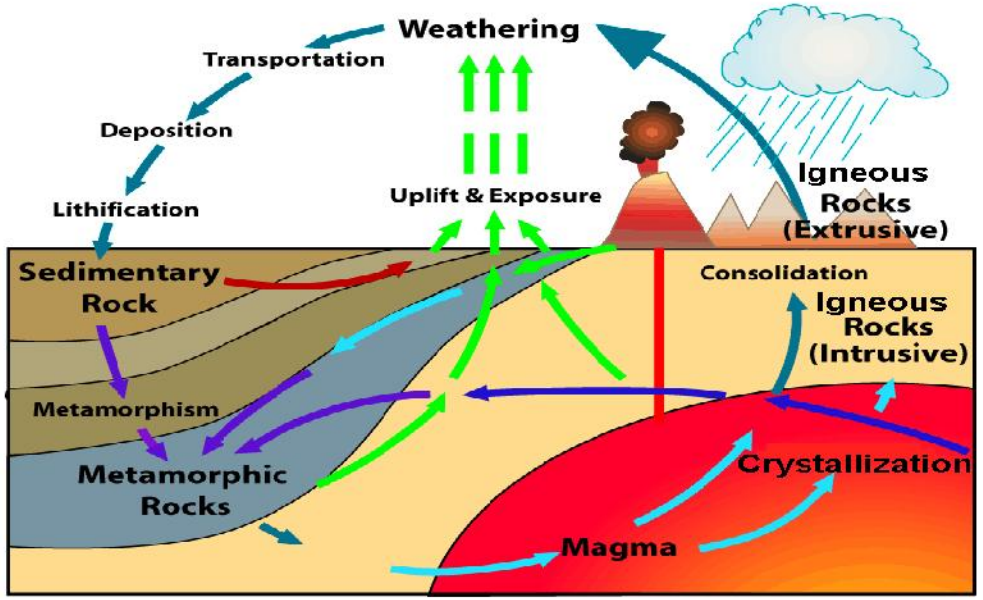
The Rock Cycle

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:

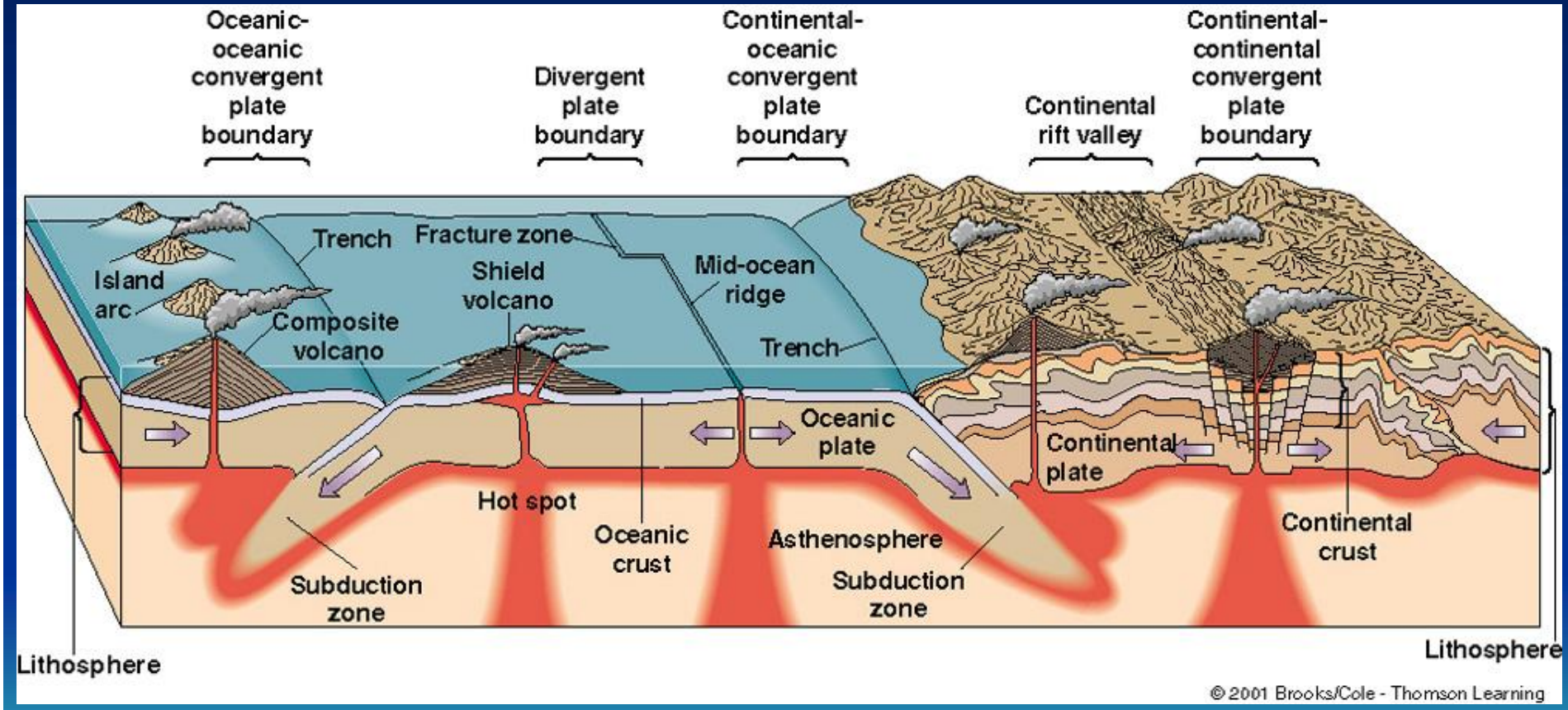
1) *Type and % of minerals* 2) *Crystal size & arrangement*

Magma and Lava = Mother Igneous

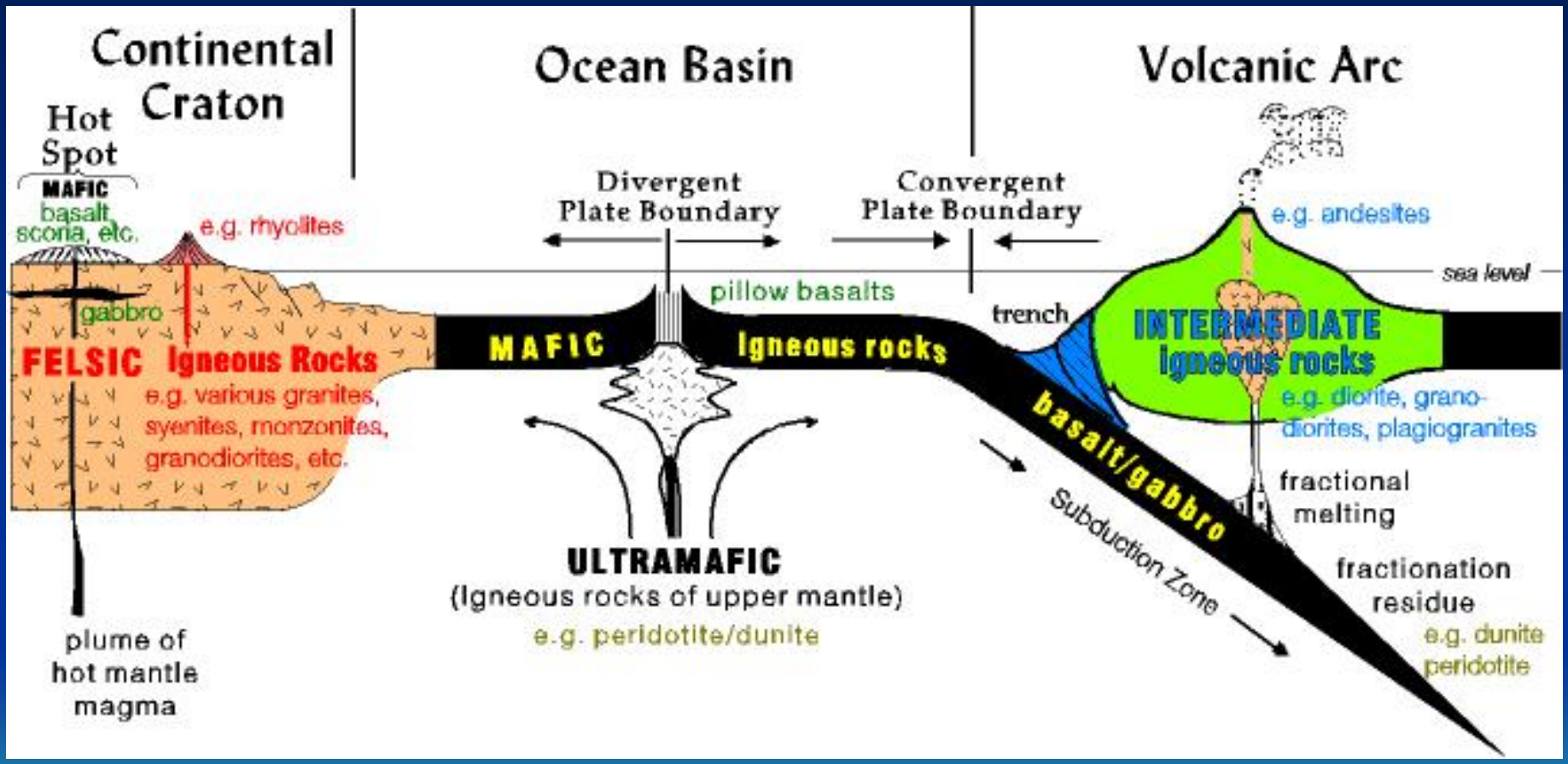
The mineralogy of an igneous rock is *primarily controlled* by the composition of the magma or lava that it cooled from.

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

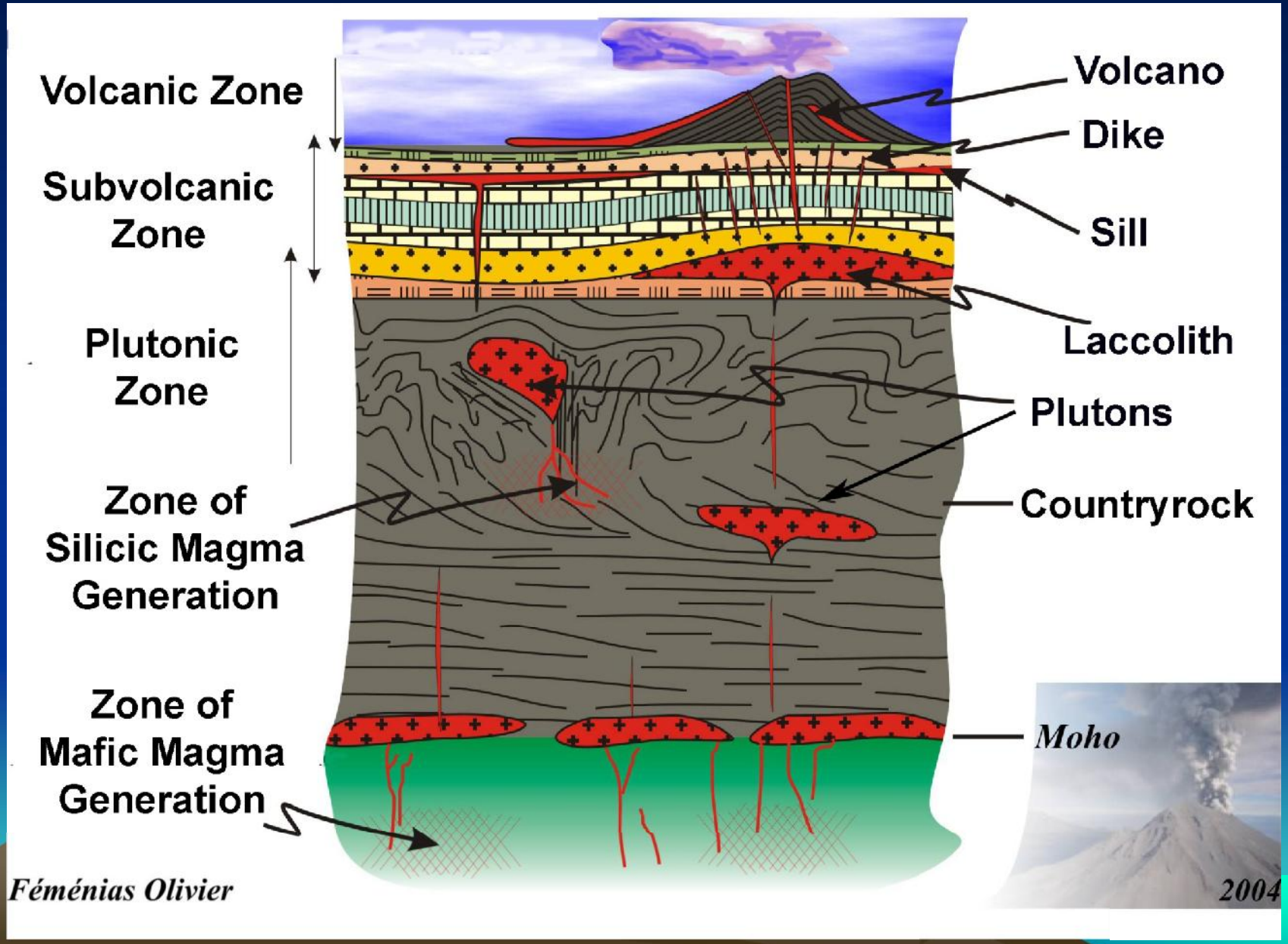
Tectonic Environments for Magma Generation



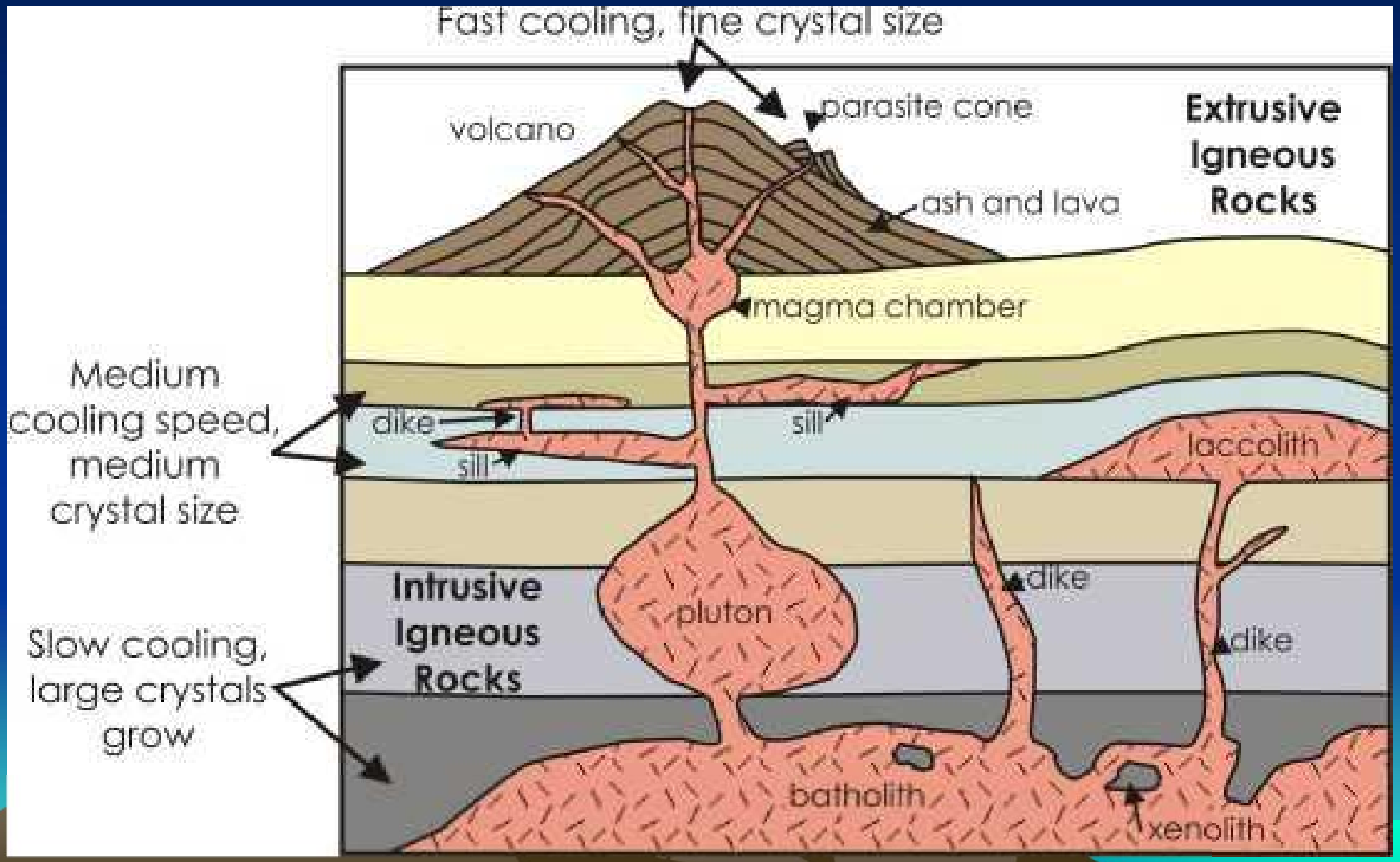
Predominant Igneous Rock Types at Specific Tectonic Settings



Igneous Environments



Affects of Cooling Rates on Crystal Size in Various Igneous Environment



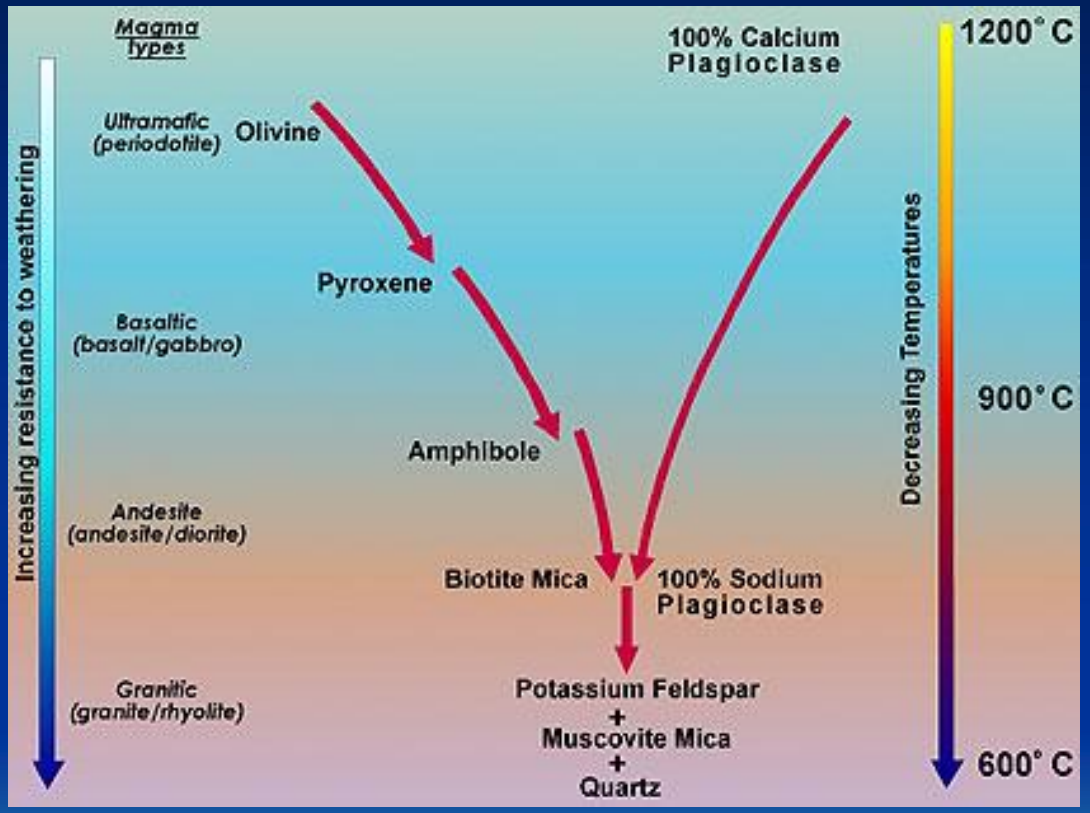
Common Rock-Forming Minerals

1) Plagioclase
2) K-Feldspar
3) Quartz
4) Muscovite
5) Clay
6) Calcite
7) Gypsum
8) Halite
9) Biotite
10) Hornblende
11) Pyroxene
12) Olivine
13) Tourmaline
14) Garnet
15) Magnetite
16) Hematite

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.

- http://www.rockhounds.com/rockshop/rockkey/index.html

Igneous 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**

Sub-Mafic:

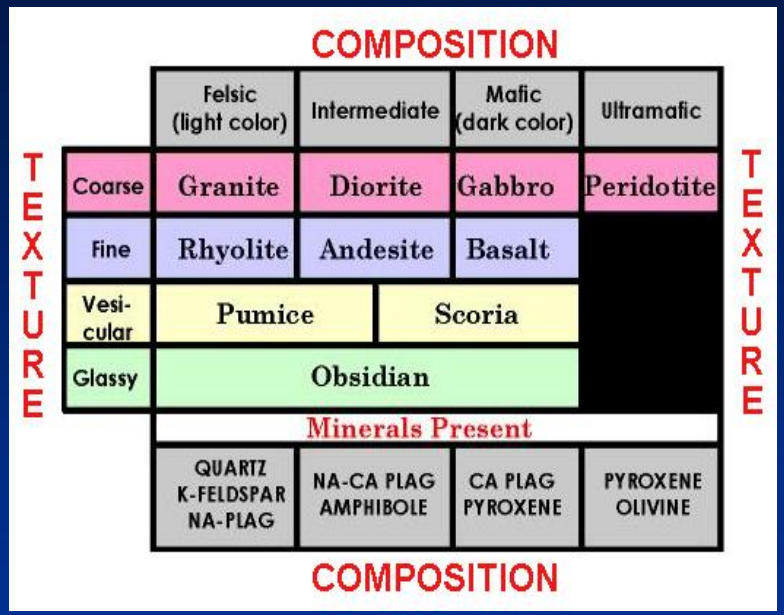
- ✓ Between Mafic and Sub-Felsic/Silicic
- ✓ Saturated in silica
- ✓ Volcanic Arc rocks = **Diorite** and **Andesite**

Sub-Felsic/Silicic:

- ✓ Between Sub-Mafic and Felsic/Silicic
- ✓ Saturated in silica
- ✓ Volcanic Arc rocks = **Granodiorite** and **Dacite**

Felsic/Silicic:

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

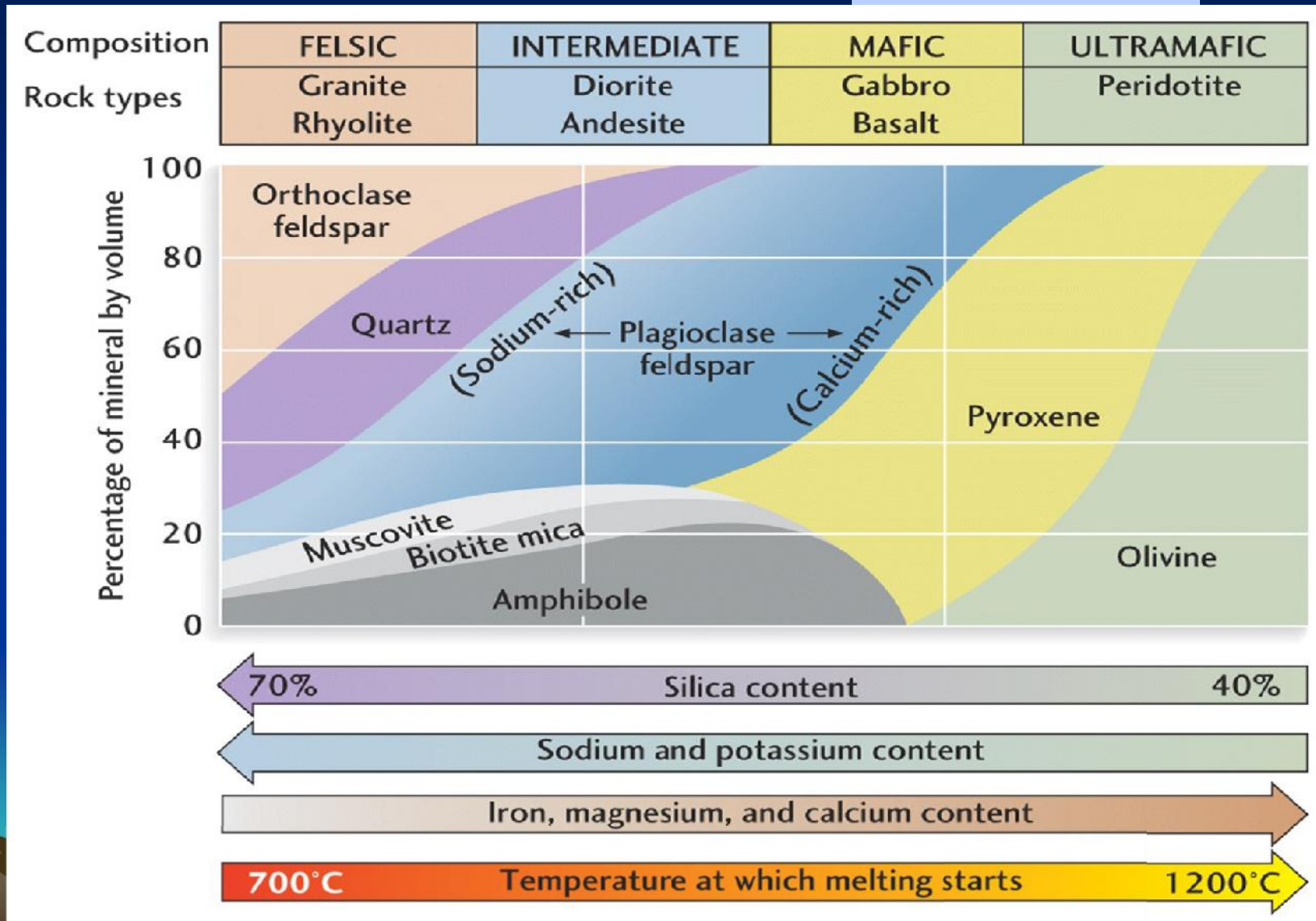


- http://www.rockhounds.com/rockshop/rockkey/index.ht

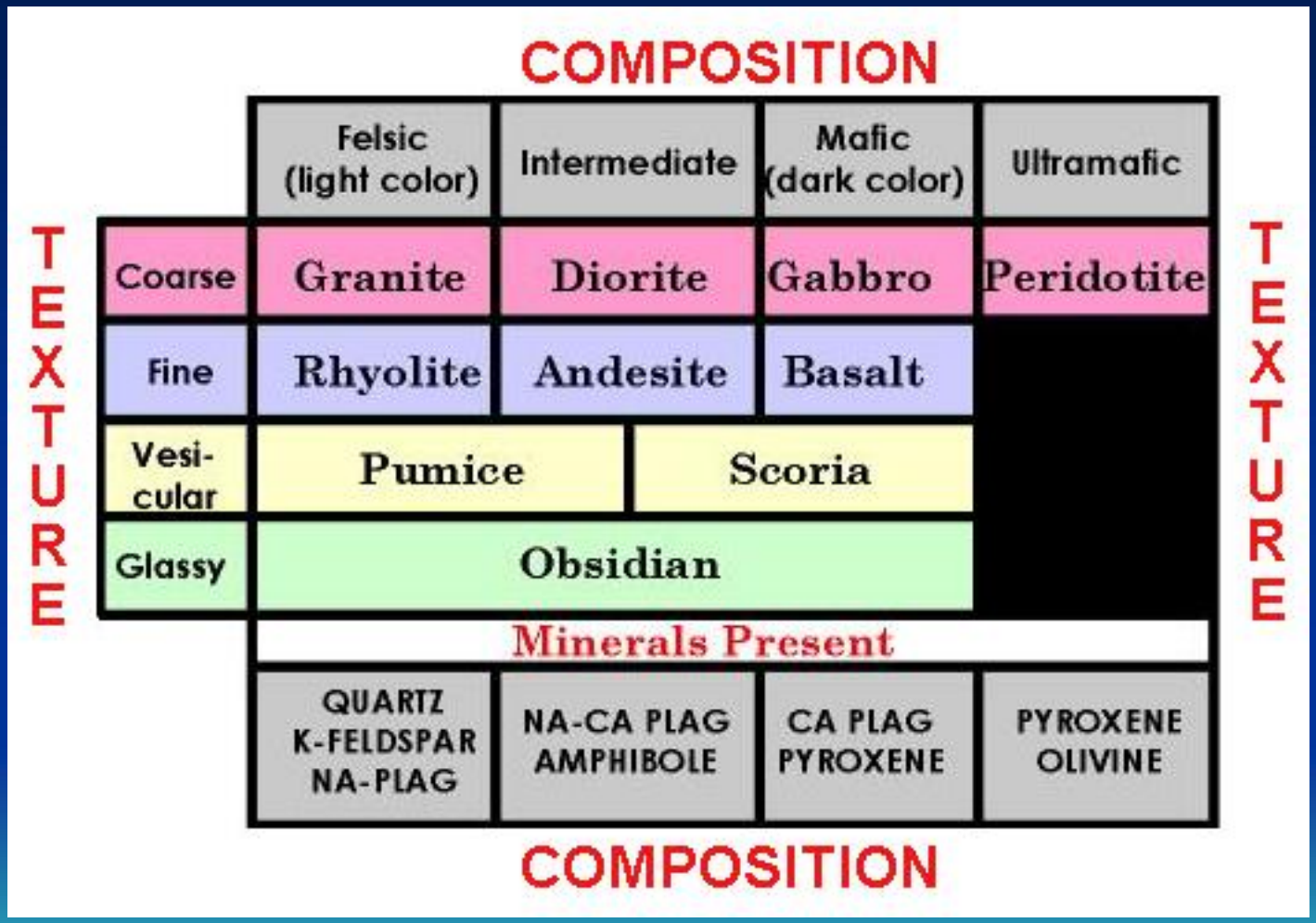
Mineral Assemblages of Igneous Rock

Light-Colored

Dark-Colored



Igneous Rock Classification



- http://geology.csupomona.edu/alert/igneous/igclass.htm

Igneous Rock Textures

Phaneritic Texture:

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

Aphanitic Texture:

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

Porphyritic Texture:

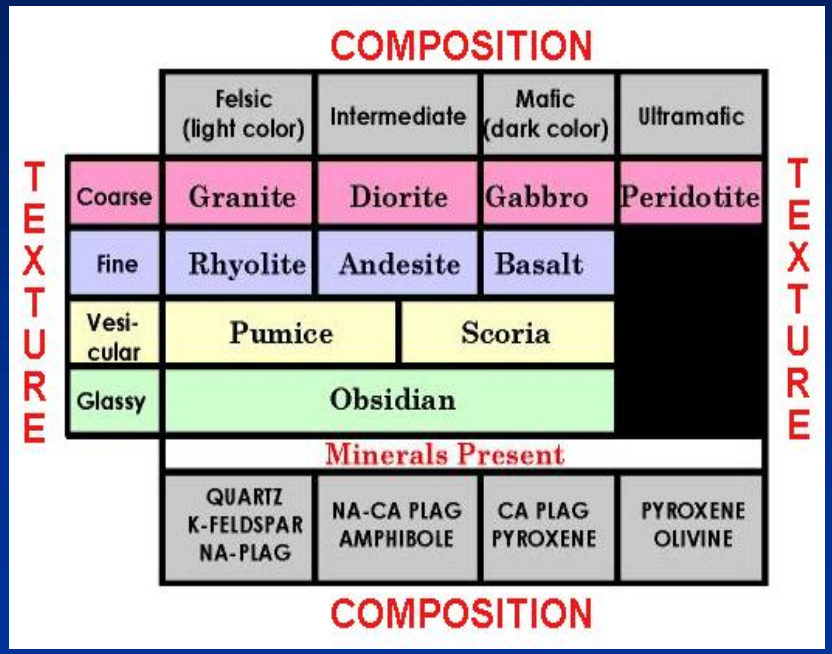
- ✓ Large crystals in aphanitic groundmass = slow cooling followed by rapid cooling
- ✓ **Porphyry Rocks** = Mixed-grain

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



- http://www.rockhounds.com/rockshop/rockkey/index.html

Igneous Rock Pairs

Classification by texture

Extrusive	*Intrusive*
Fine grained	*Coarse grained*
Basalt	gabbro
Andesite	diorite
Rhyolite	granite

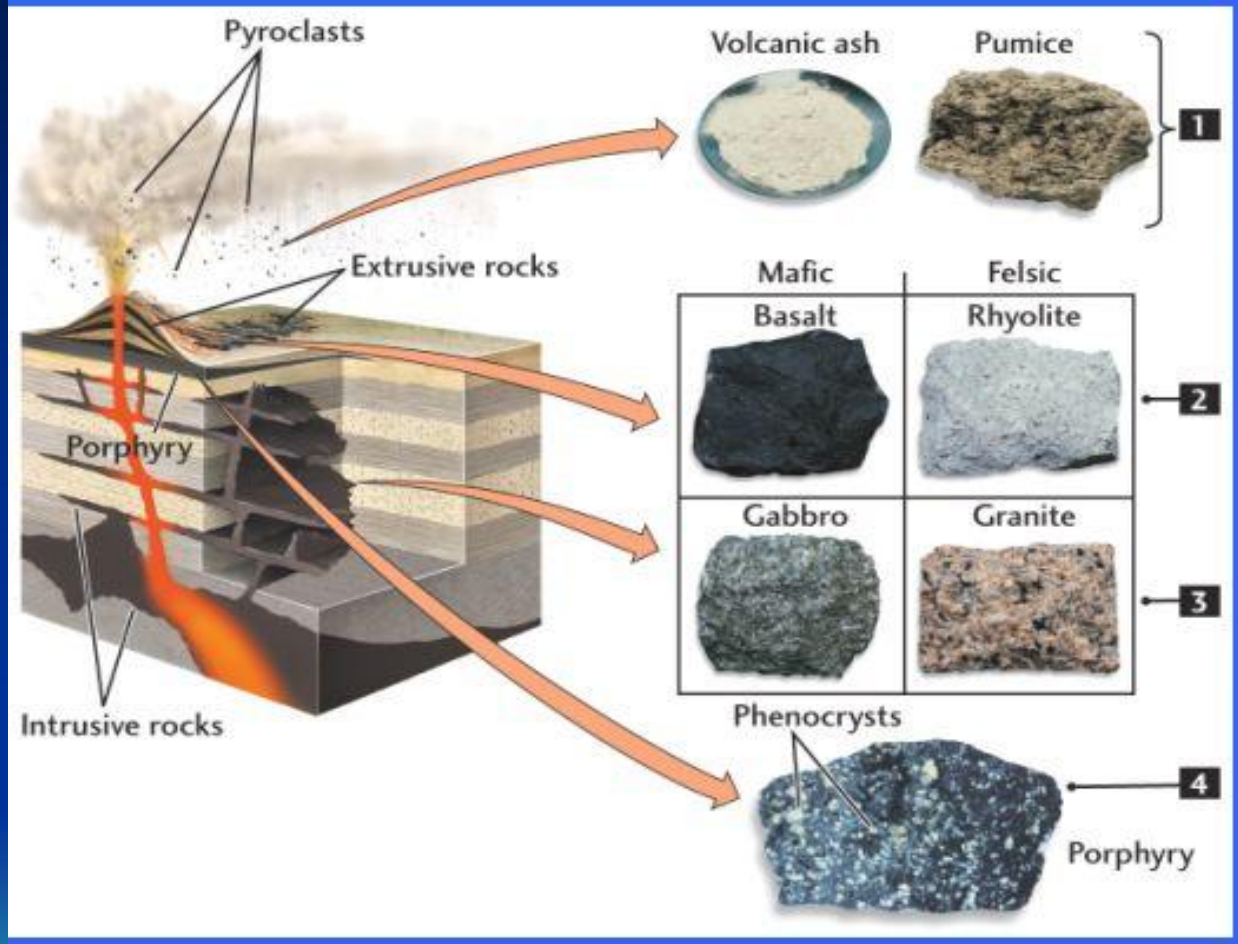
Classification by composition

- magnesium (Mg) + iron (Fe) = mafic
- feldspar + quartz (Si) = felsic

Fast Cooling

Slow Cooling

Formation and texture



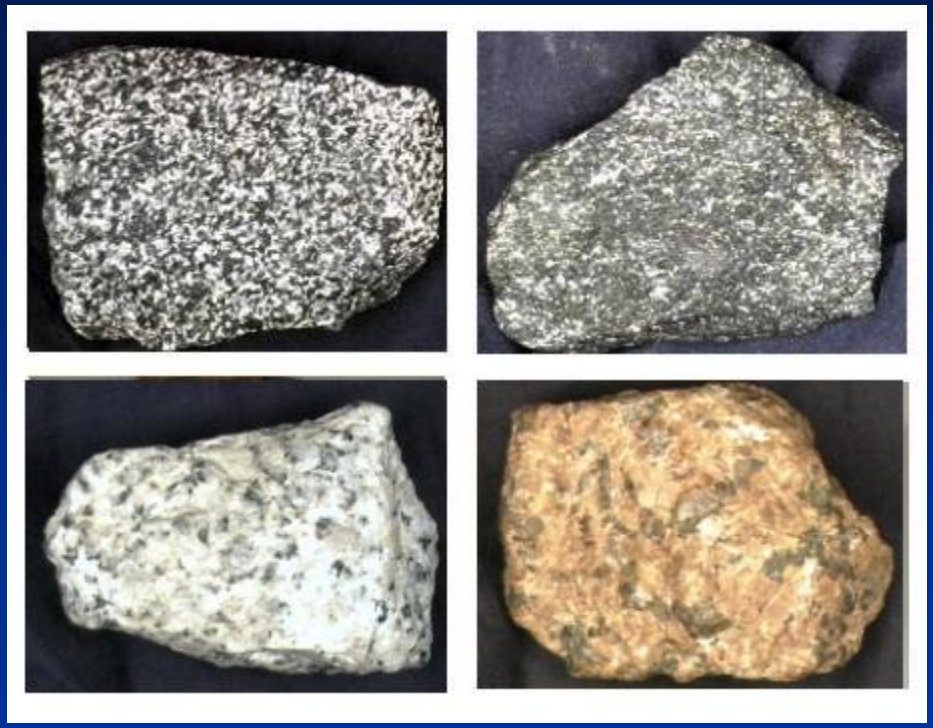
1. **Pyroclasts** form from airborne lava in violent eruption

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

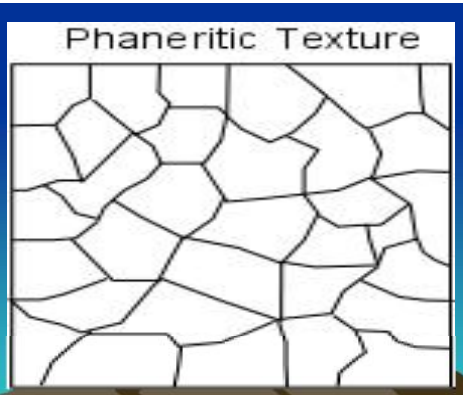
3. **Intrusive igneous rocks**. Cool slowly in the Earth's interior allowing large crystals to form

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

Plutonic Rock Textures



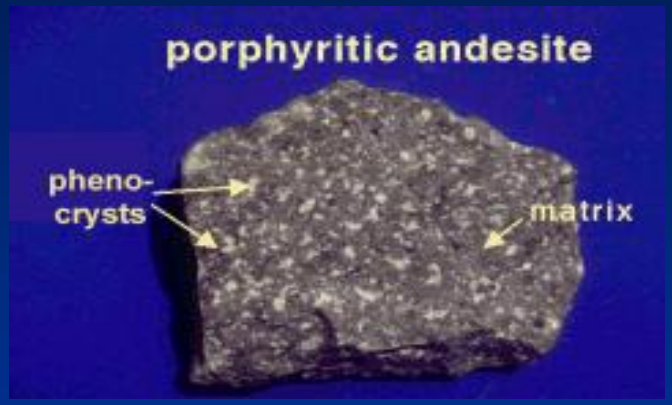
Field Outcrops of Plutonic Rocks

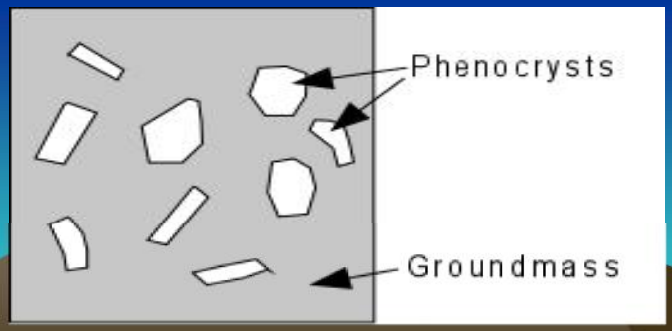


- ✓ Intrusive -Plutonic
- ✓ Coarse-grained
- ✓ Cooled Slowly

Volcanic Rock Textures

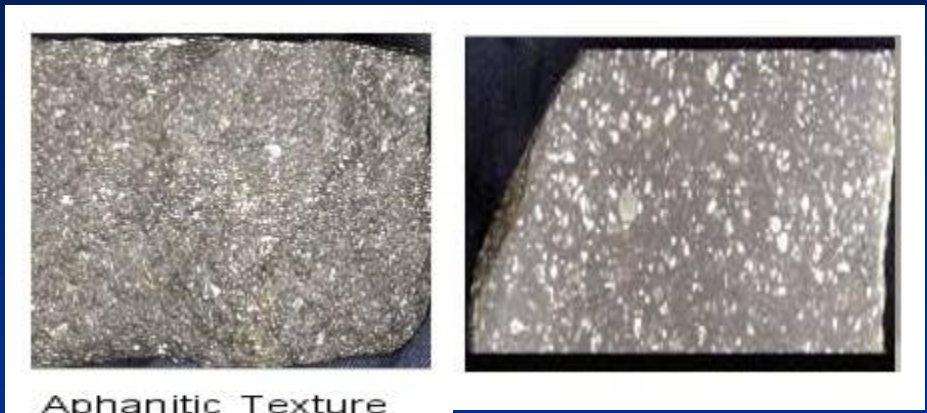
Porphyritic

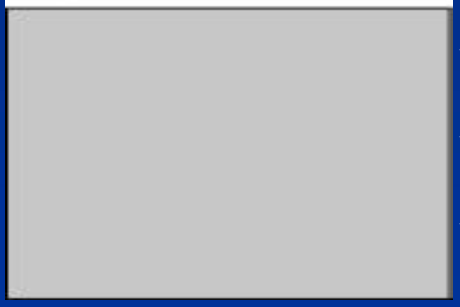




- ✓ Combo Plutonic -Volcanic
- ✓ Coarse-grained phenocrysts in a fine-grained groundmass
- ✓ First cooled Slow, then Fast

Aphanitic

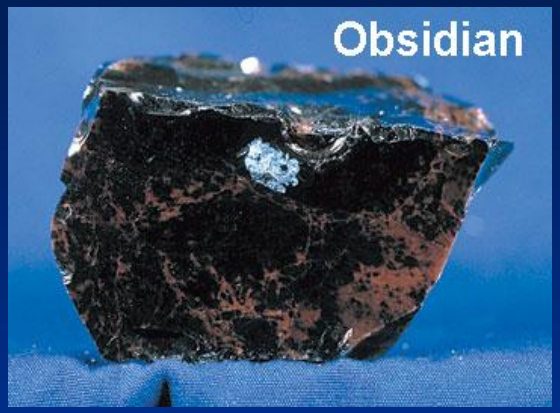




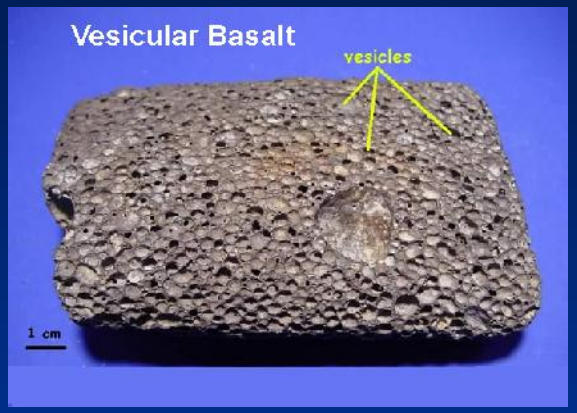
- ✓ Extrusive -Volcanic
- ✓ Fine-grained
- ✓ Cooled Rapidly

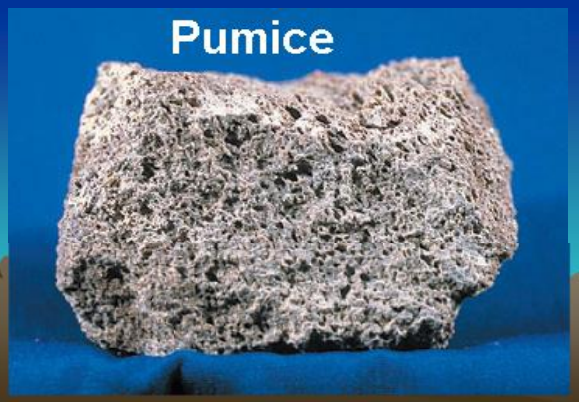
Other Volcanic Rock Textures

Glassy



Vesicular





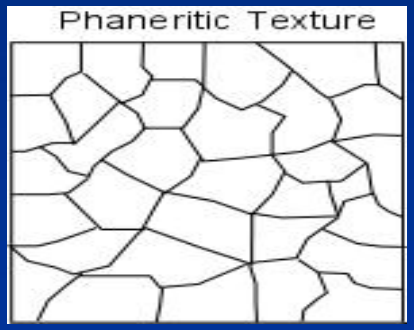
Fragmental

Igneous Rocks Under a Microscope

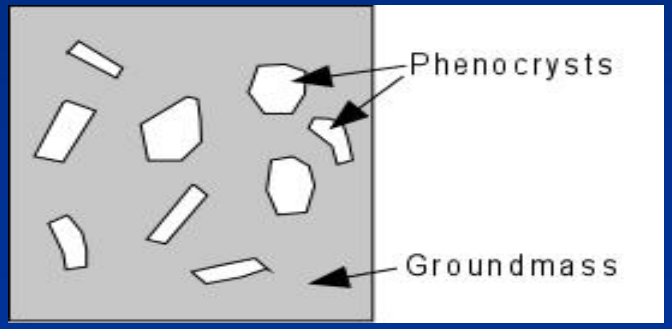
Granite

Rhyolite

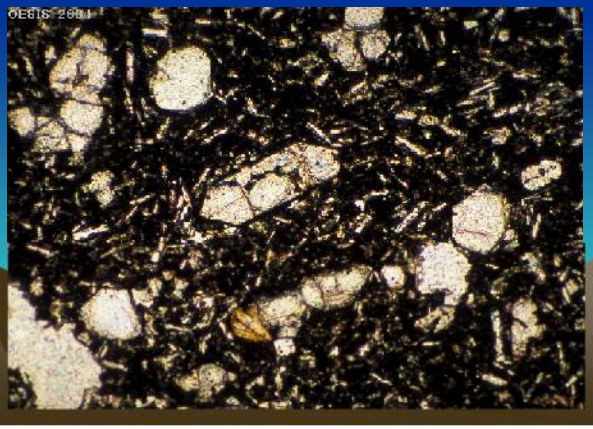
Obsidian

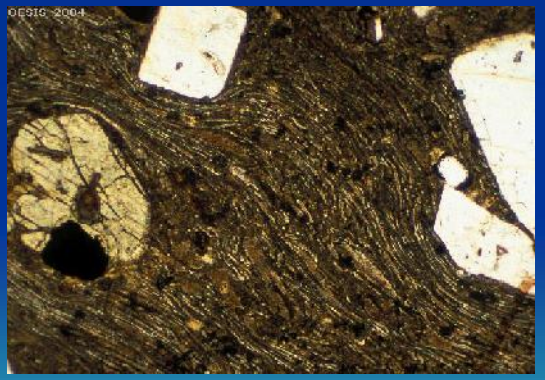


Gabbro



Basalt

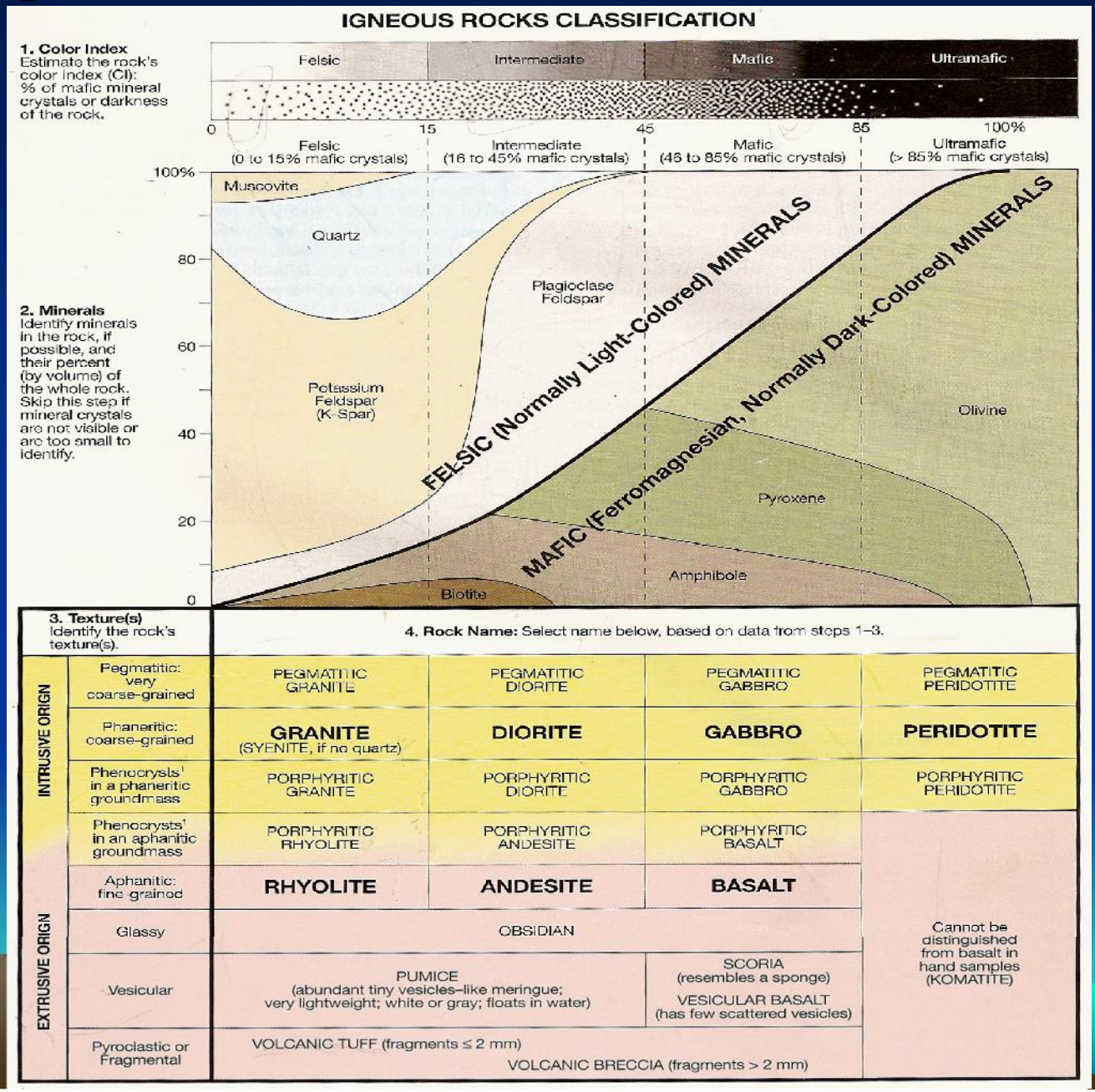




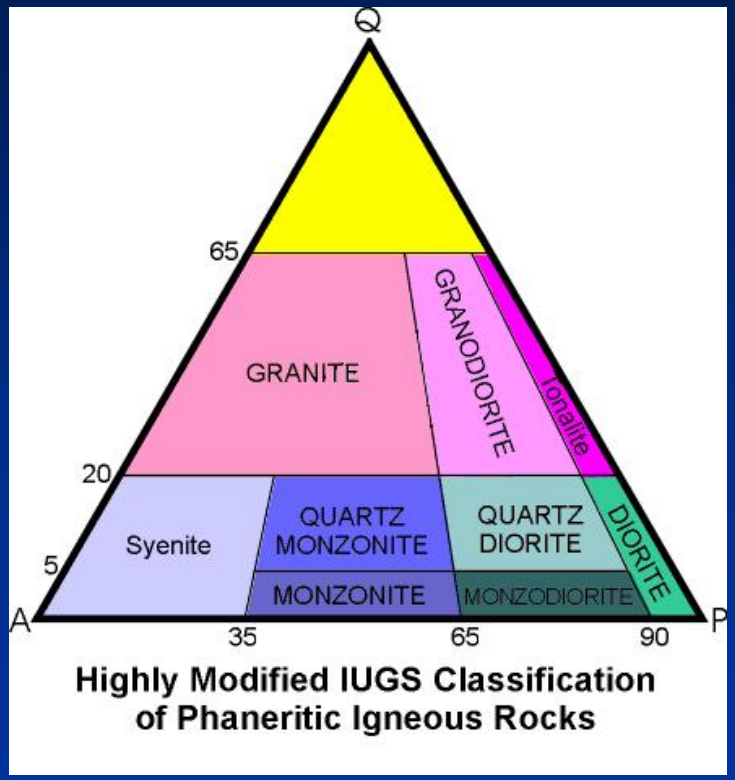
Welded Tuff

Color Index of Plutonic Rocks

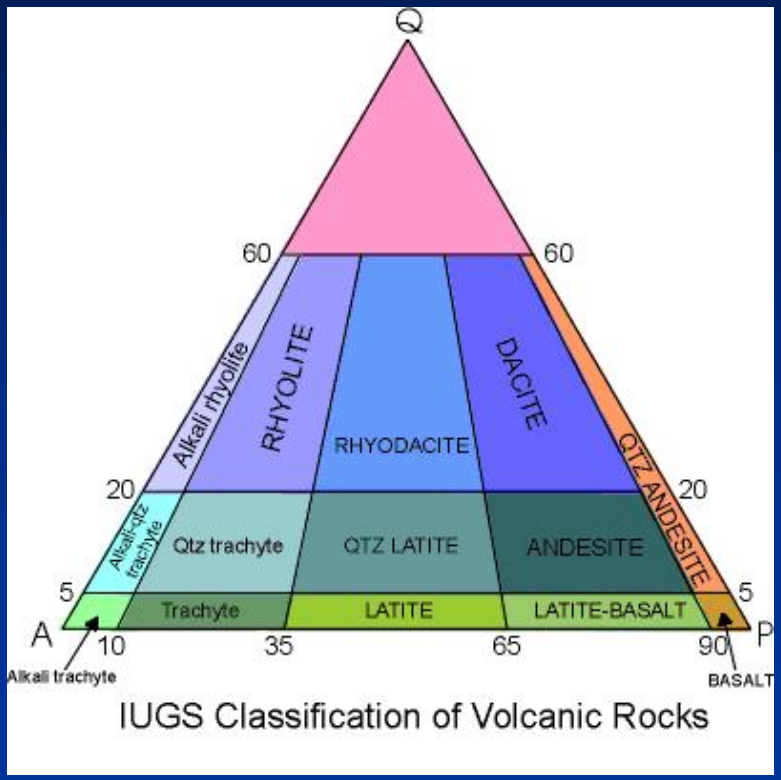
Igneous Rock Classification



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)

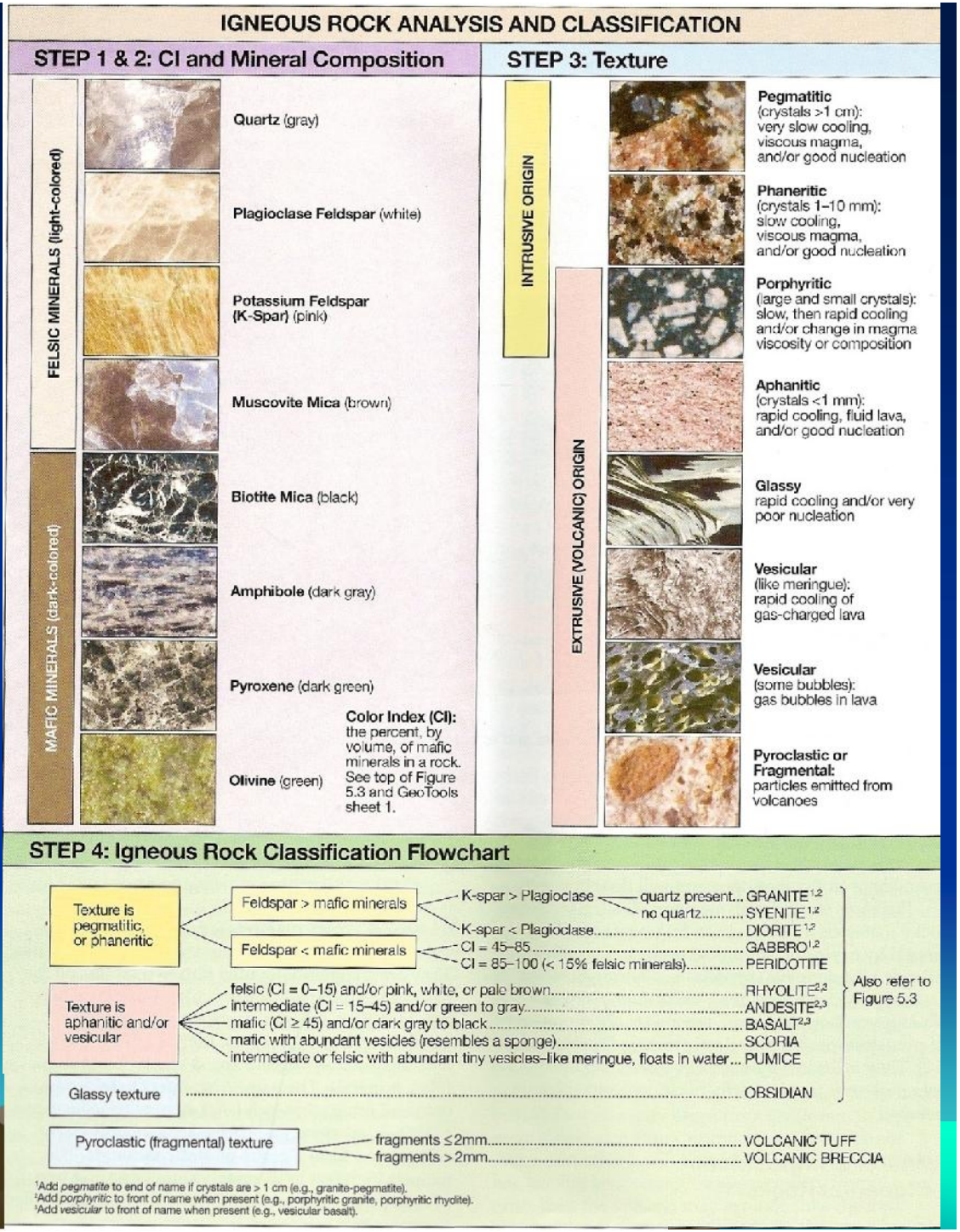
2) Determine Texture

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

3) Name the Rock

- ✓ Use Flowchart

Practical Use for Rock?



Igneous Rock Classification

A Three Step Process

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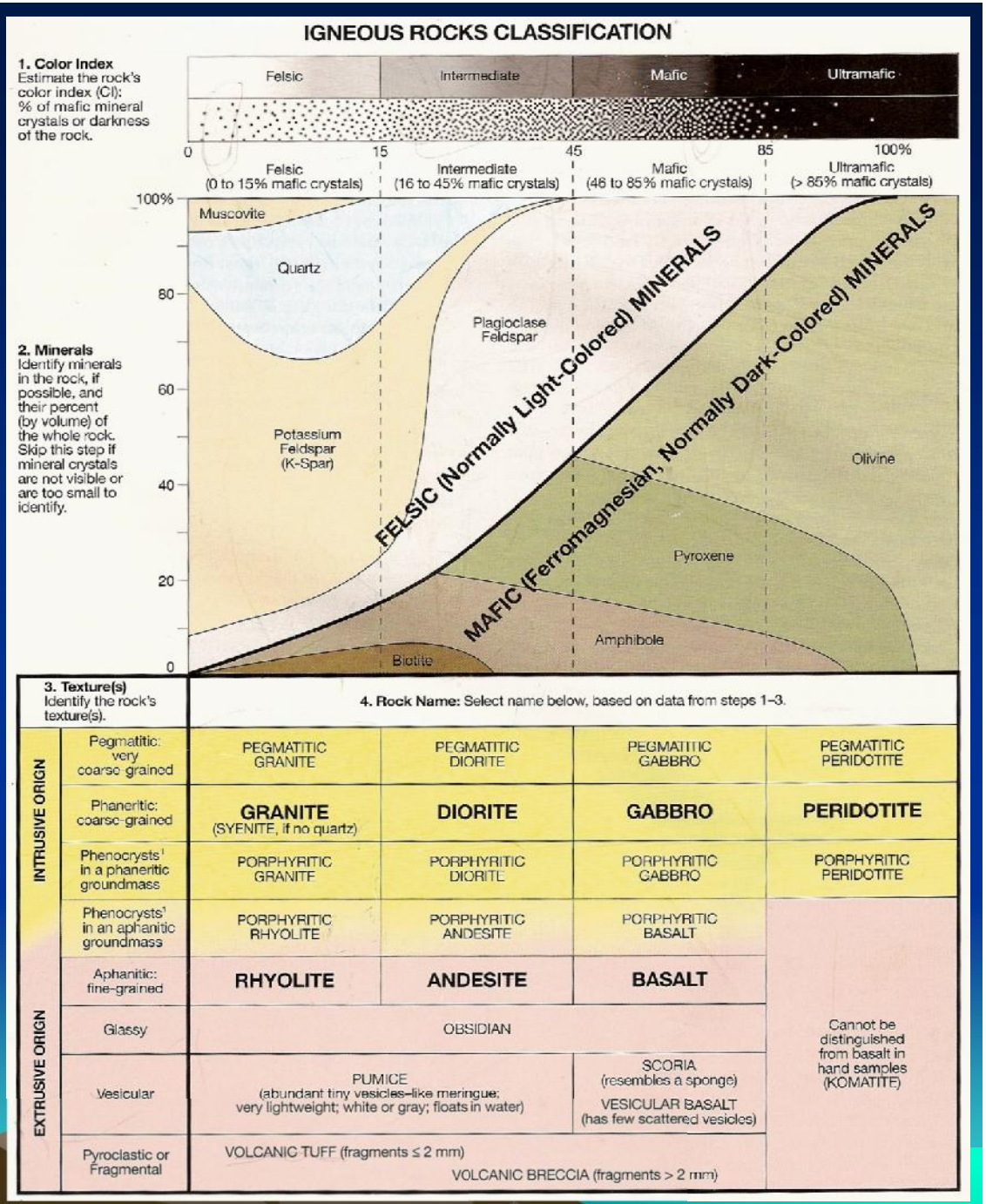


Igneous Rock Identification Procedure

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/silisic, "medium" = intermediate, and "dark" = mafic).

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

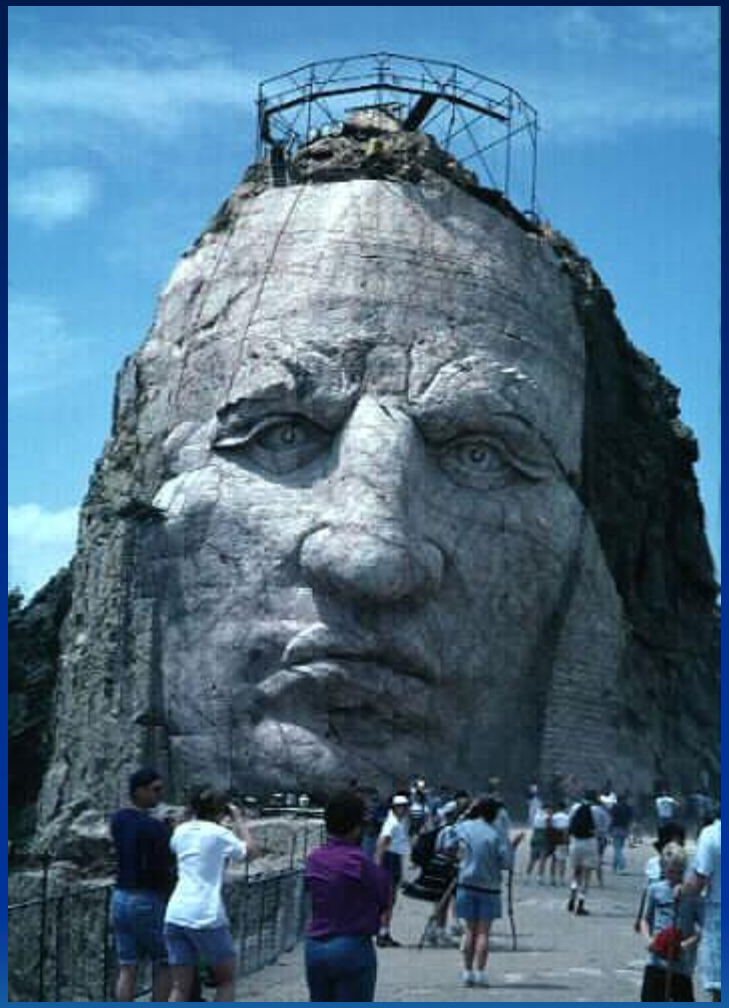
Applications

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

Volcanic Rock - used for various landscaping applications

http://www.stonecontact.com/library.asp

Igneous Rock References

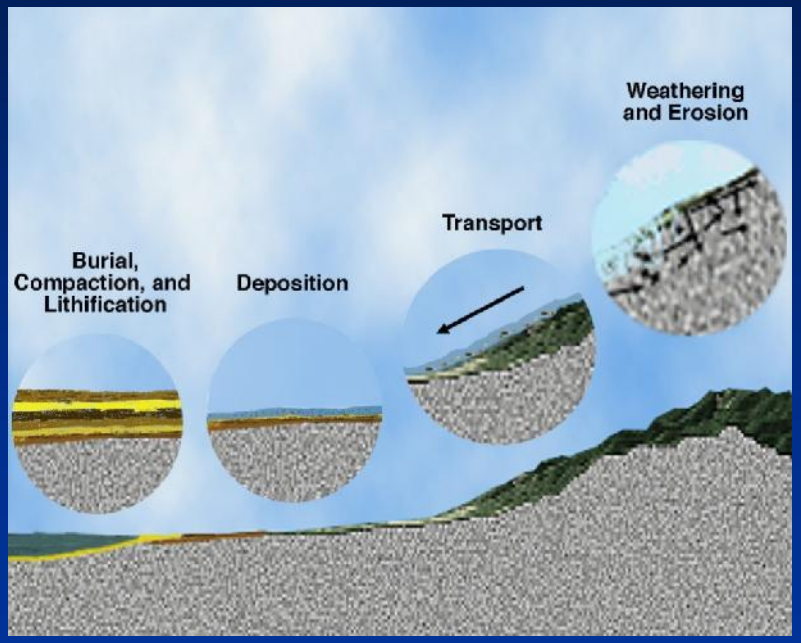


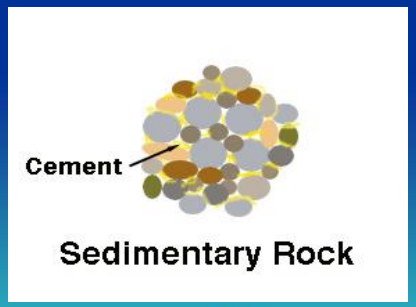
http://www.cobweb.net/~bug2/mineral.htm
http://www.rockhounds.com/rockshop/rockkey/index.html
http://www.union.edu/PUBLIC/GEODEPT/COURSES/geo-10/mineral.htm

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

Sedimentary Rocks

Origin, Properties and Identification

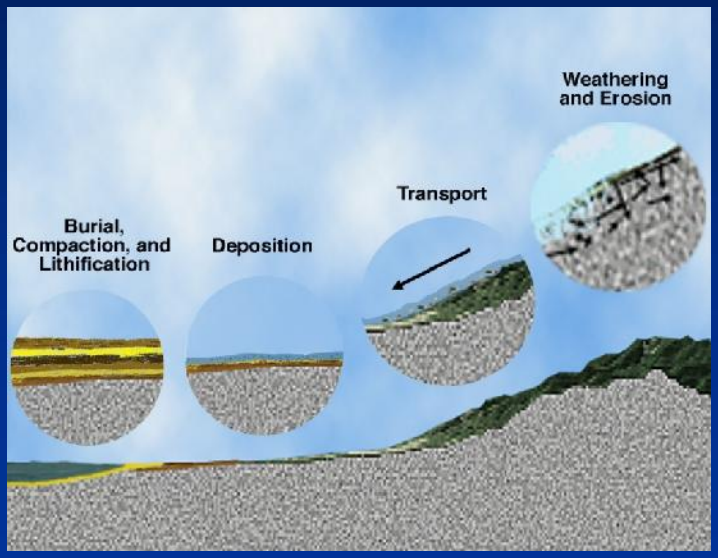


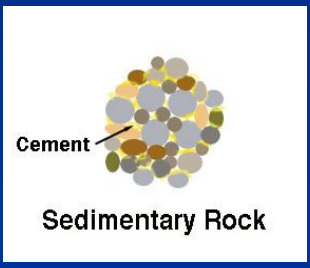


Intro to Earth Systems
ENVI 110 Lab

Ray Rector - Instructor

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

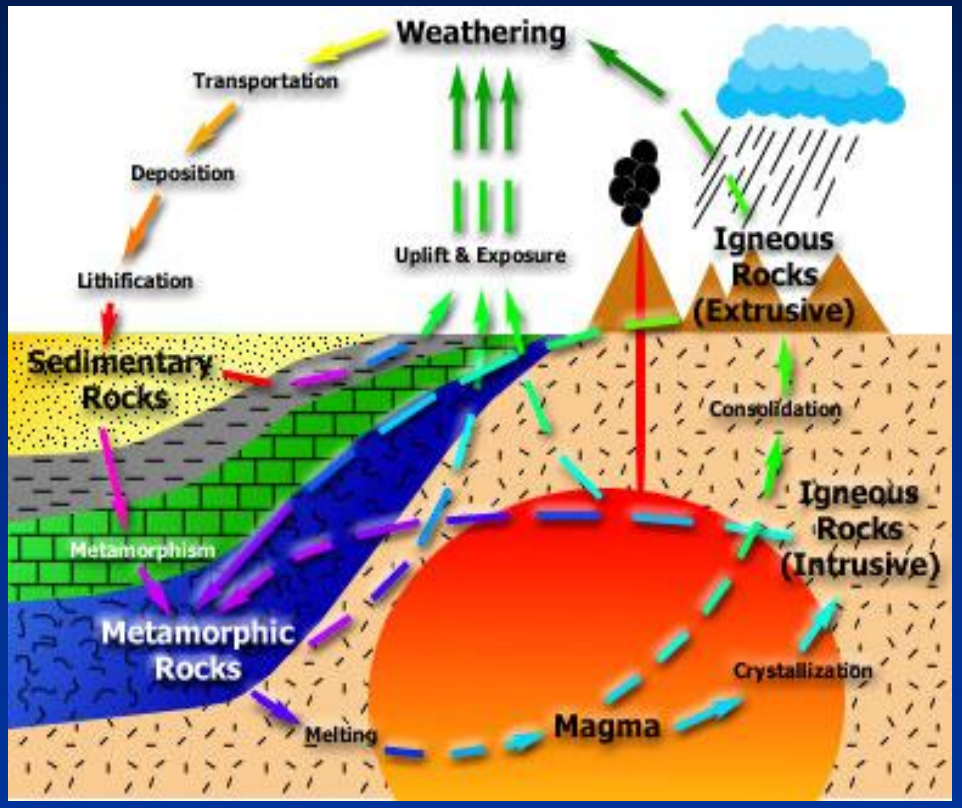
Major Sedimentary Concepts

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

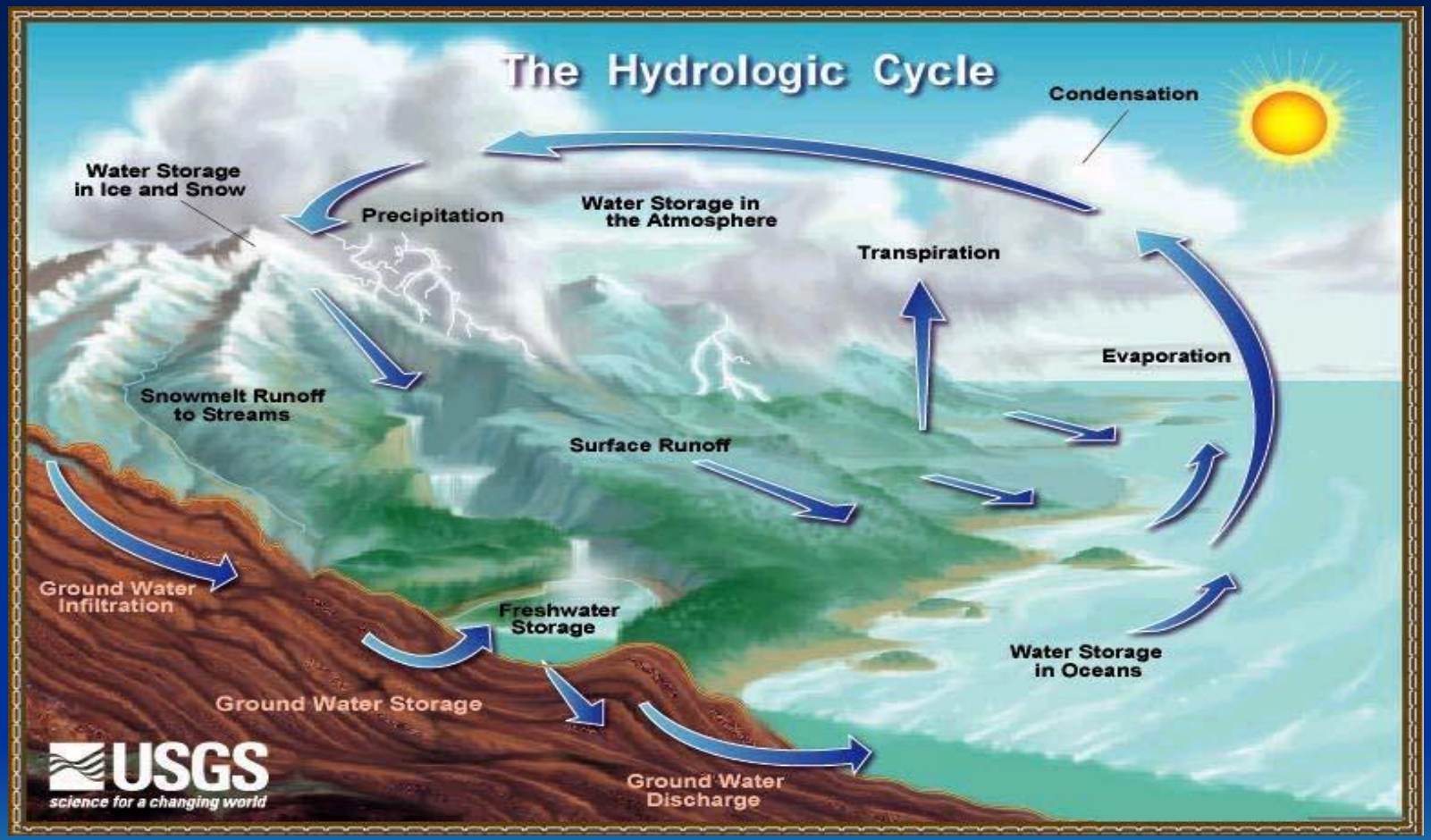
Key Points:

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

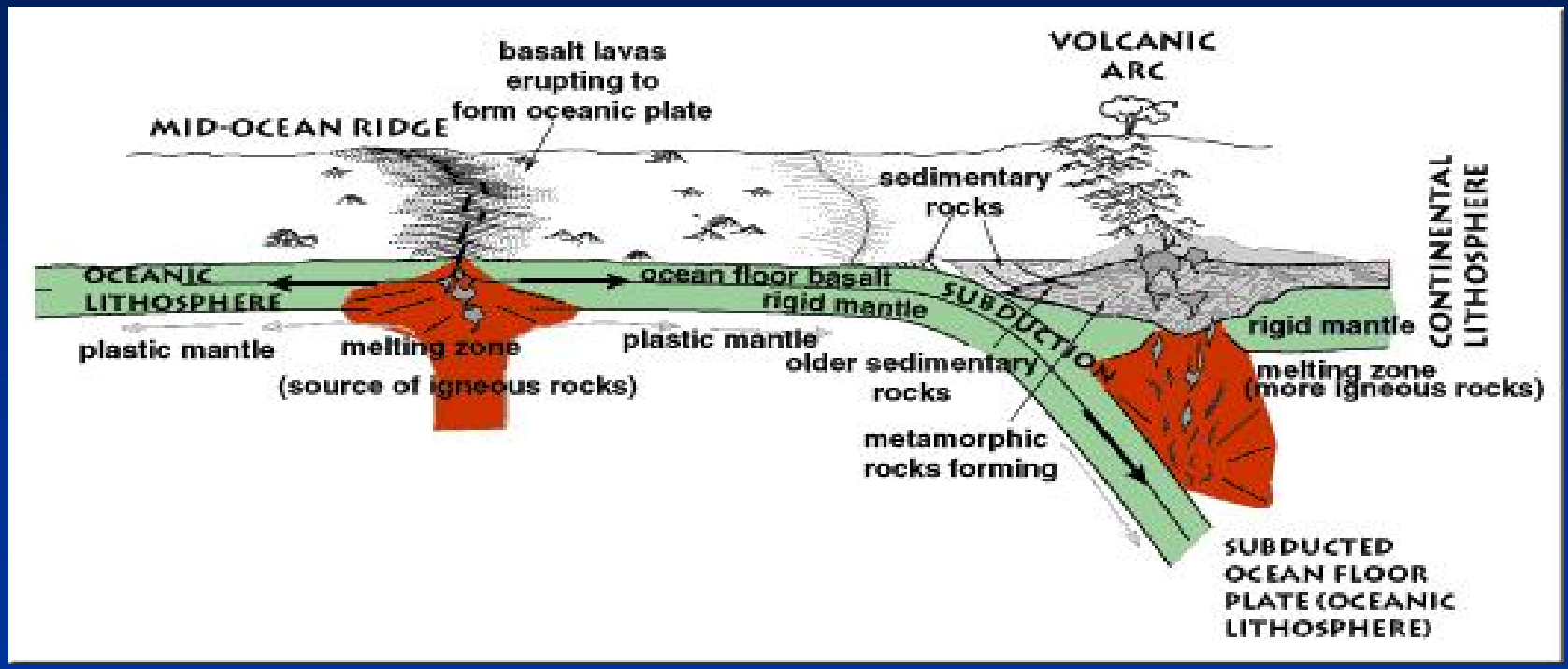
Water Cycle = Mother Sedimentary



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

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

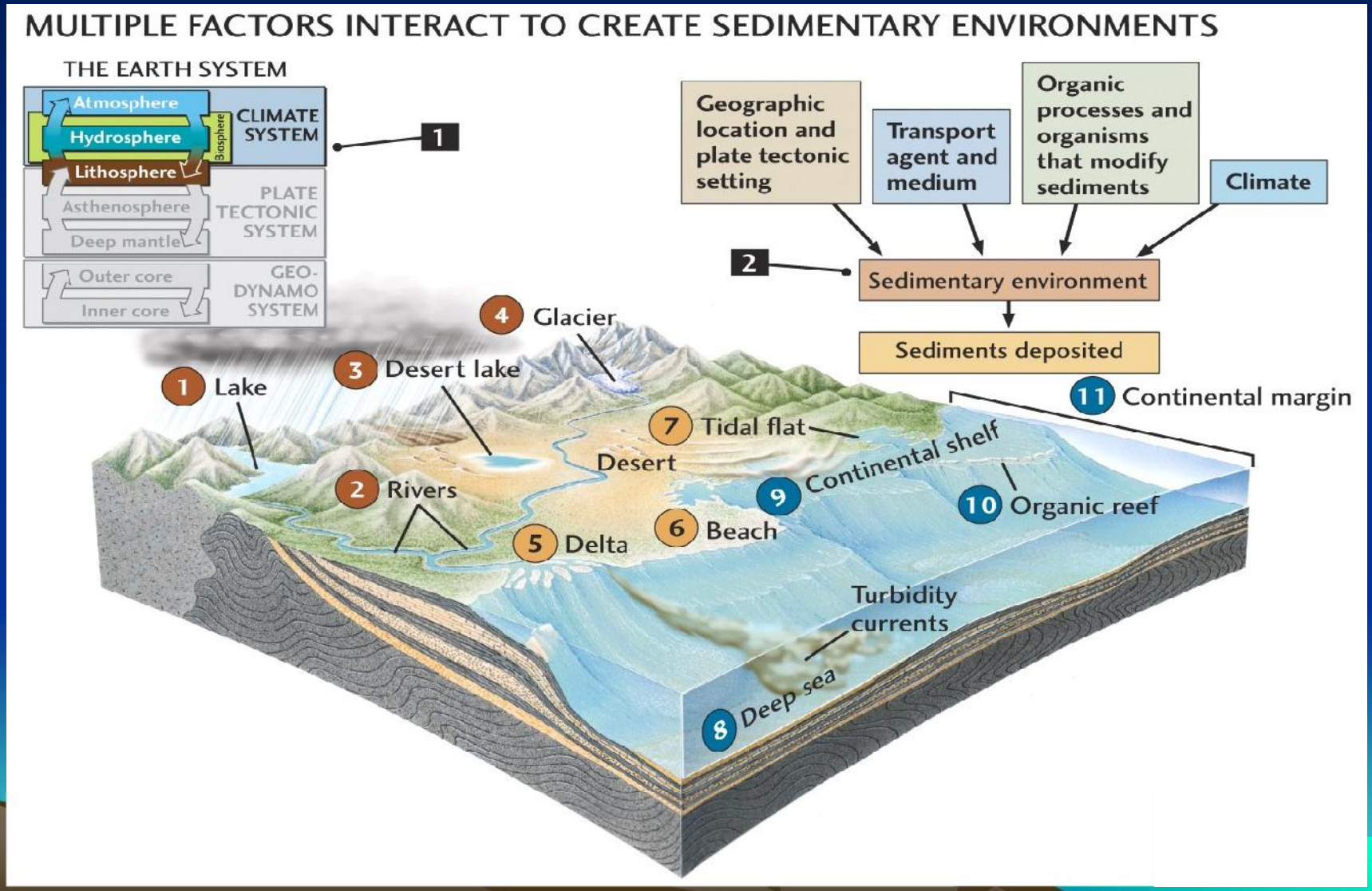
Tectonic Environments and Sedimentary Rock Formation



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



Predominant Sediment Clast Types at Specific Depositional Settings

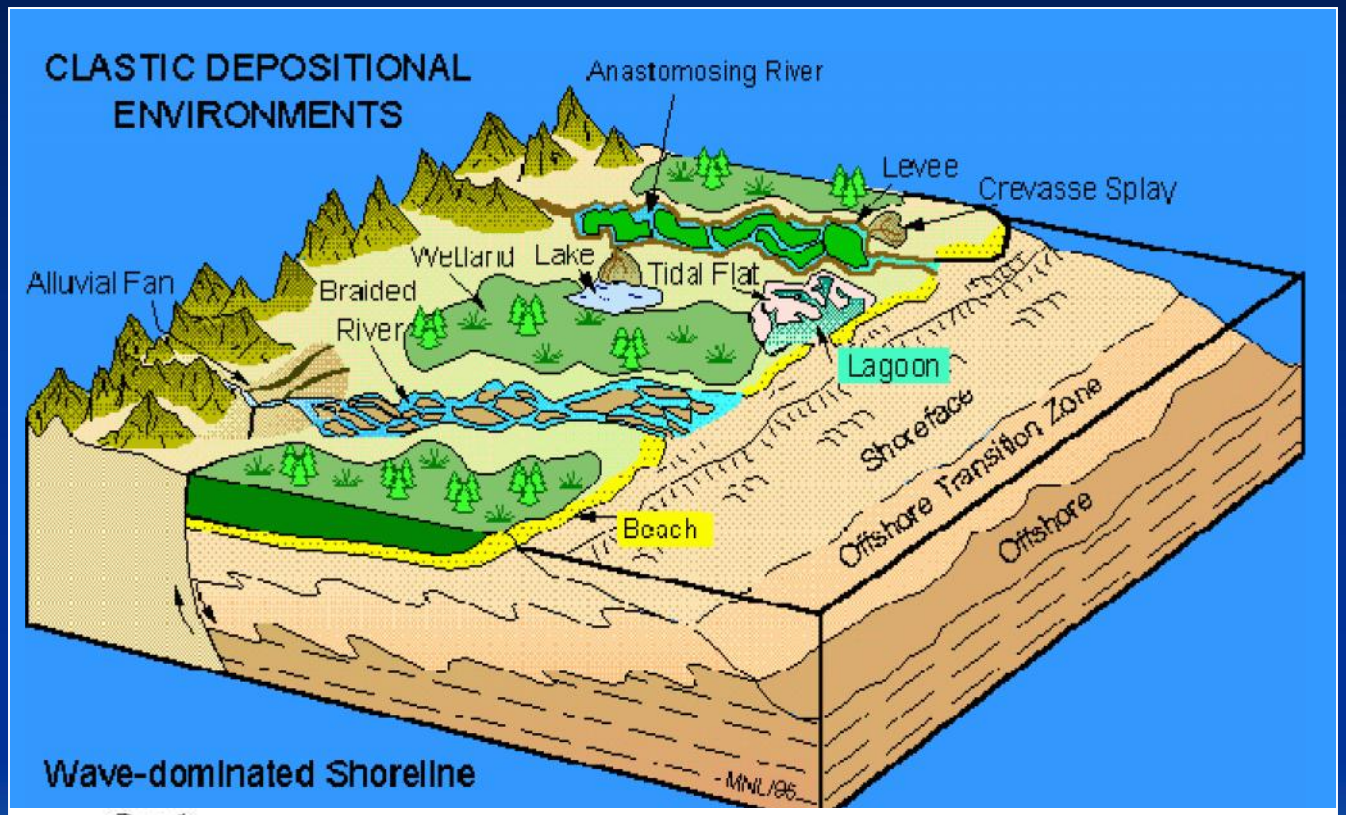
Gravel-size

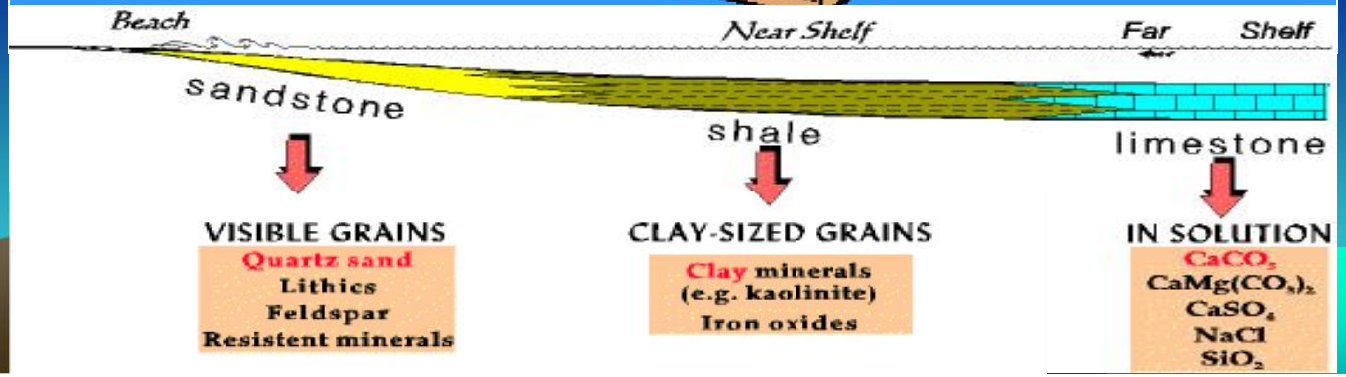
Sand-size

Silt-size

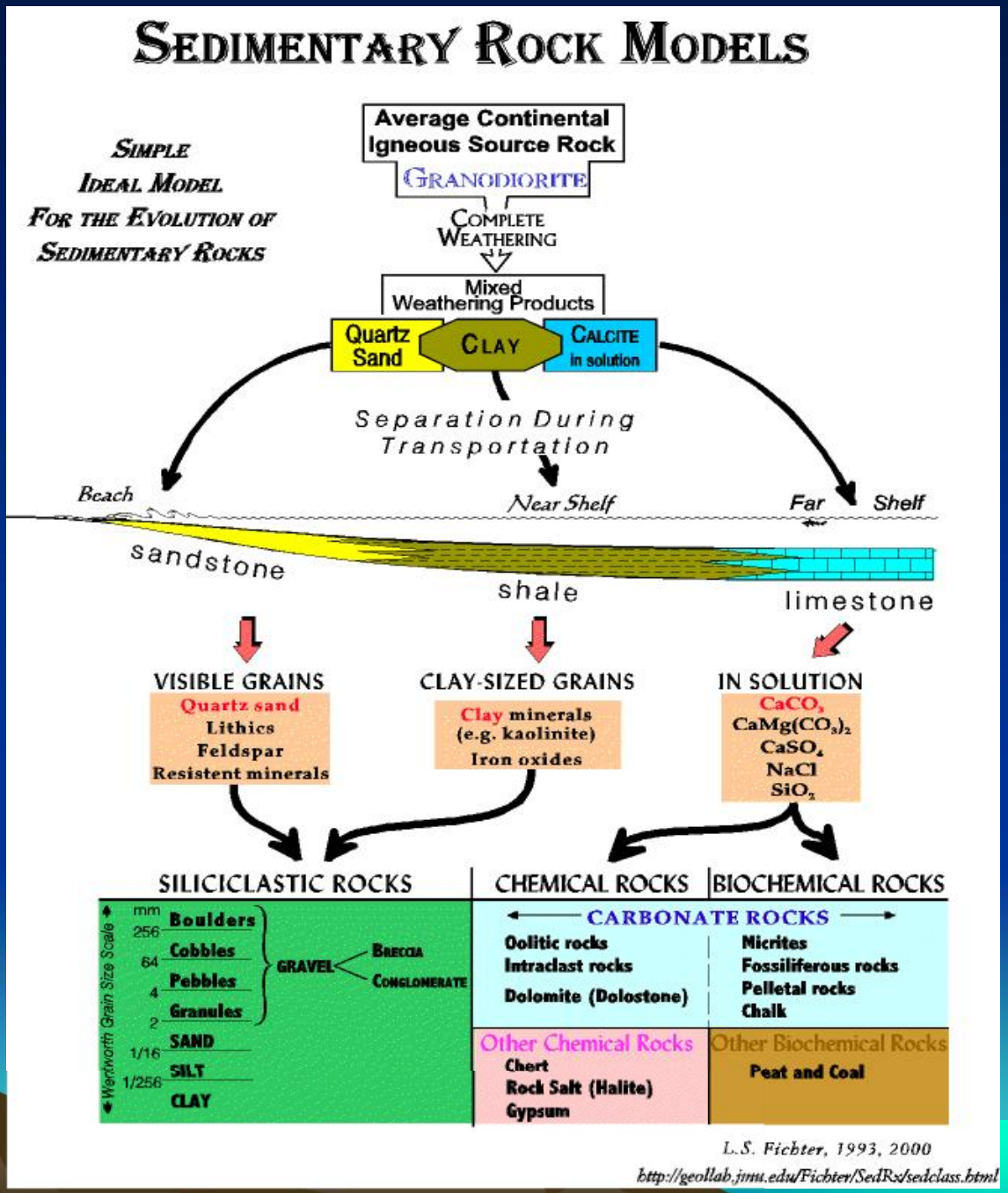
Clay-size

Clast Size





Sedimentary Rock Models



L.S. Fichter, 1993, 2000

http://geollab.jmu.edu/Fichter/SedRx/sedclass.html

Sediment Clast Types

Clast Size

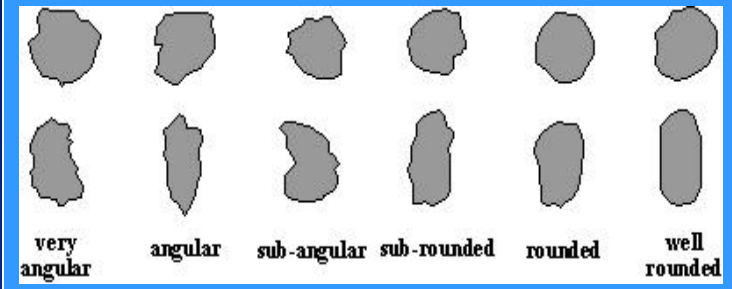
Gravel-size

Sand-size

Silt-size

Clay-size

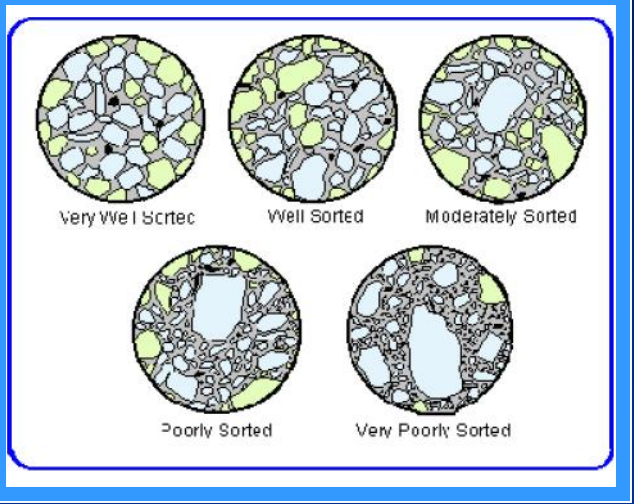
Clast Shape



Near-to-source

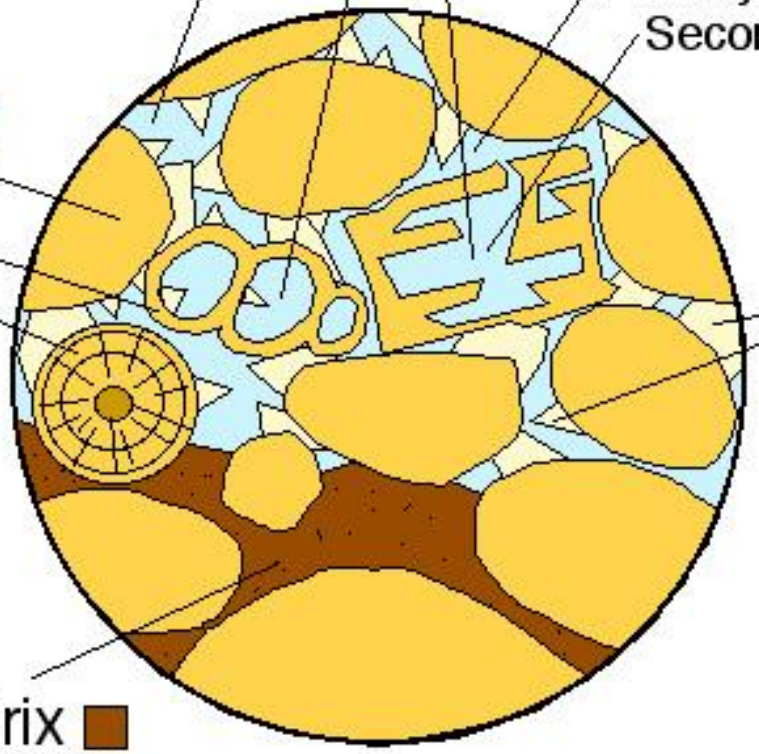
Far-from-source

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



Porosity (Space with no mineral matter; commonly filled with water)

Intergranular porosity

Intragranular porosity

Primary porosity

Secondary porosity

Grains (Sand grains, fossils, ooids, etc.)

Cement (Chemically precipitated mineral material)

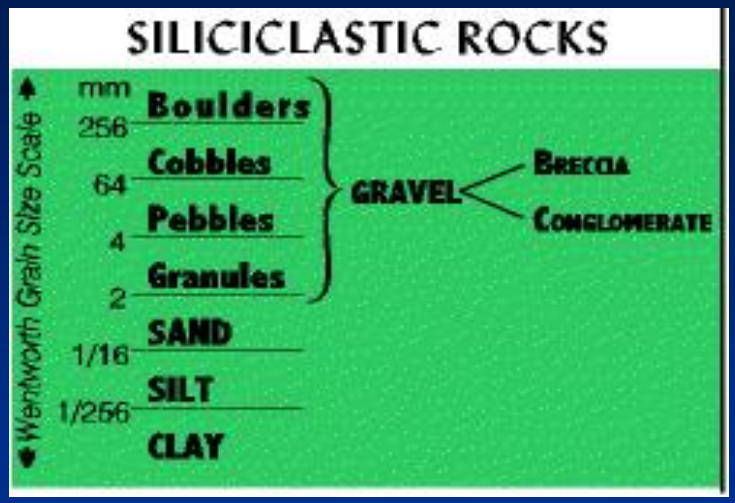
Matrix (Fine-grained (clay-sized) sediment)

LBR 6/2002

Three Major Groups of Sedimentary Rocks

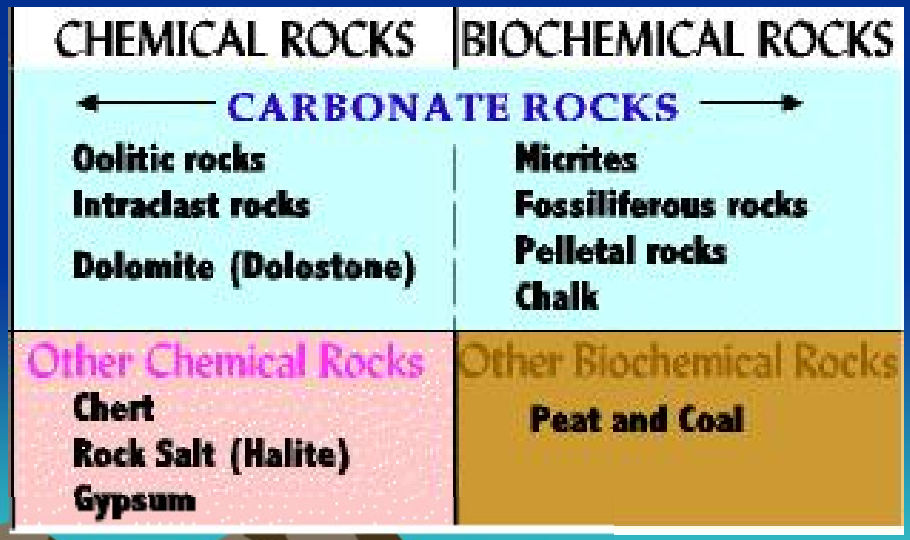
1) Siliciclastic

- ✓ 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

http://earthsci.org/mineral/mineral.html

Sedimentary Detrital Rock Textures

Breccia Texture:

- ✓ Very coarse-grained
- ✓ Angular fragments
- ✓ Deposits lose 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:

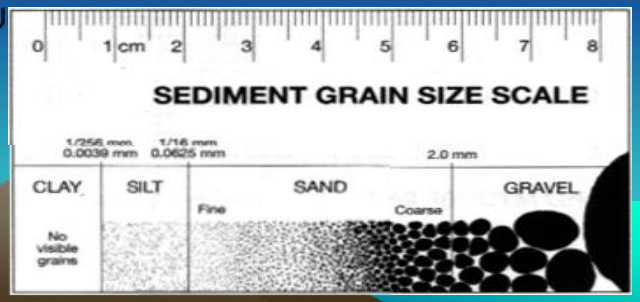
- ✓ Fine-grained = silt-sized
- ✓ Mostly quartz and feldspar
- ✓Deposits in fairly quiet waters

Shale Texture:

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

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

*U



Sedimentary (Bio)Chemical Textures

Clastic and Crystalline

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

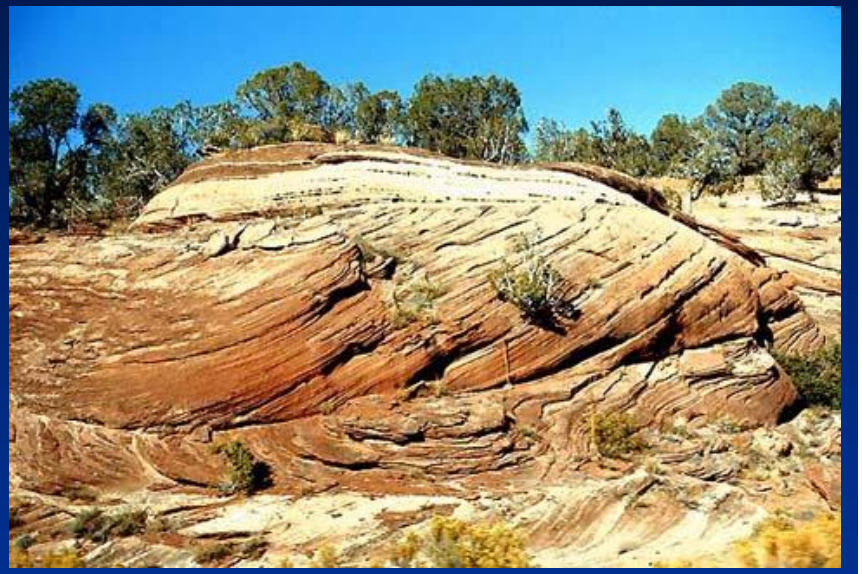
Fossiliferous Texture:

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

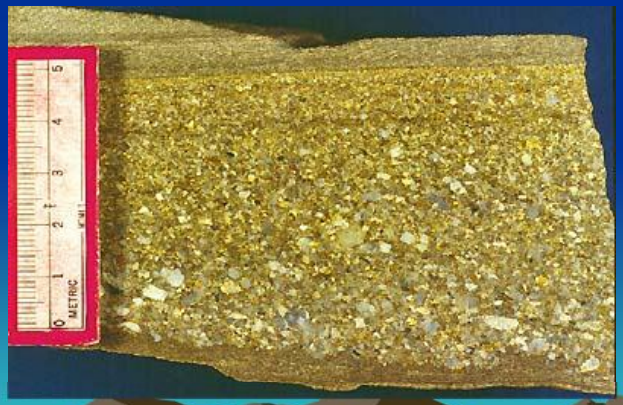
Sedimentary Rock Structures

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

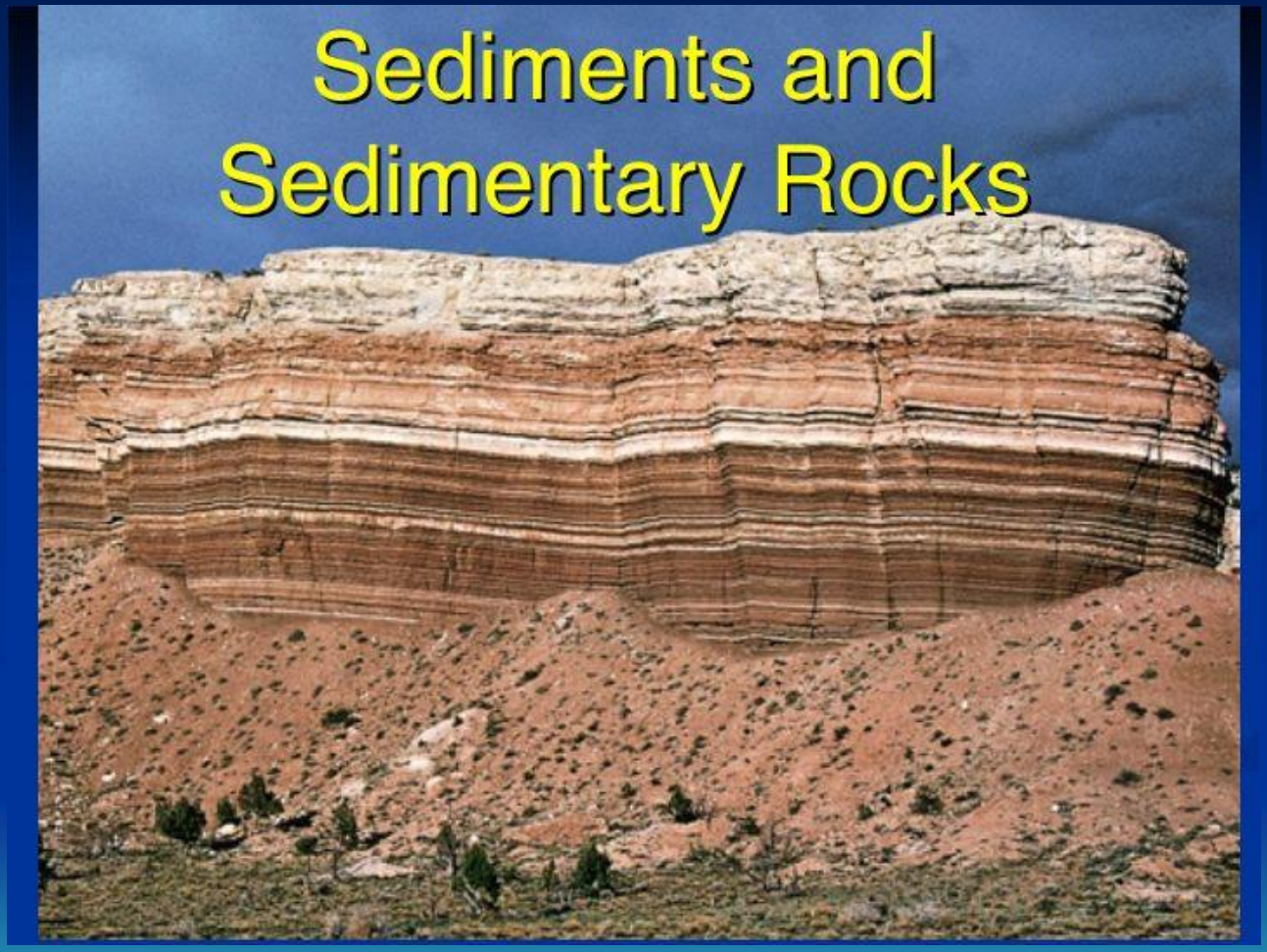
- ✓ Grain size?
- ✓ Shape?
- ✓ Fossils?

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 (≥ 2 mm)	Rounded grains	CONGLOMERATE	
			Angular grains	BRECCIA	
		Mainly sand (1/16 – 2 mm)	Mostly quartz grains	QUARTZ SANDSTONE	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	MUDSTONE
		Mainly Mud (< 1/16 mm): Mostly clay (< 1/256 mm)	Crumbles or breaks into blocks	CLAYSTONE	
			Fissile (splits easily)	SHALE	
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	LIMESTONE
		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, $CaCO_3$. 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 $CaMg(CO_3)_2$	Microcrystalline	Effervesces in dilute HCl only if powdered	DOLOSTONE	
	Mainly varieties of quartz, 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, $CaSO_4 \cdot 2H_2O$	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

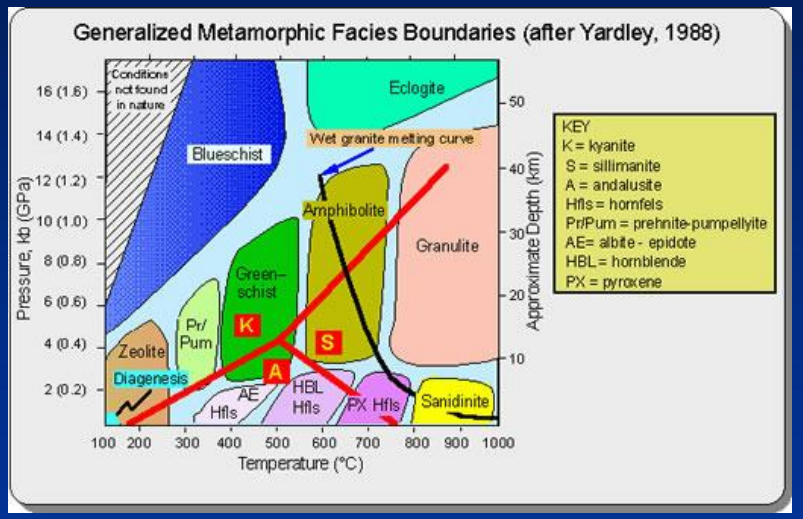


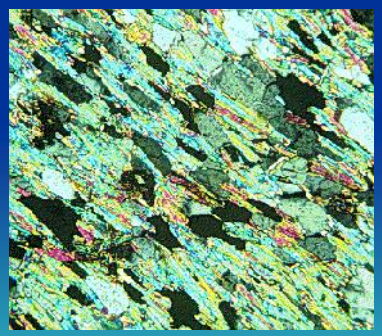
http://www.cobweb.net/~bug2/mineral.htm

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/Metaalphab.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 neocystallization.
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.

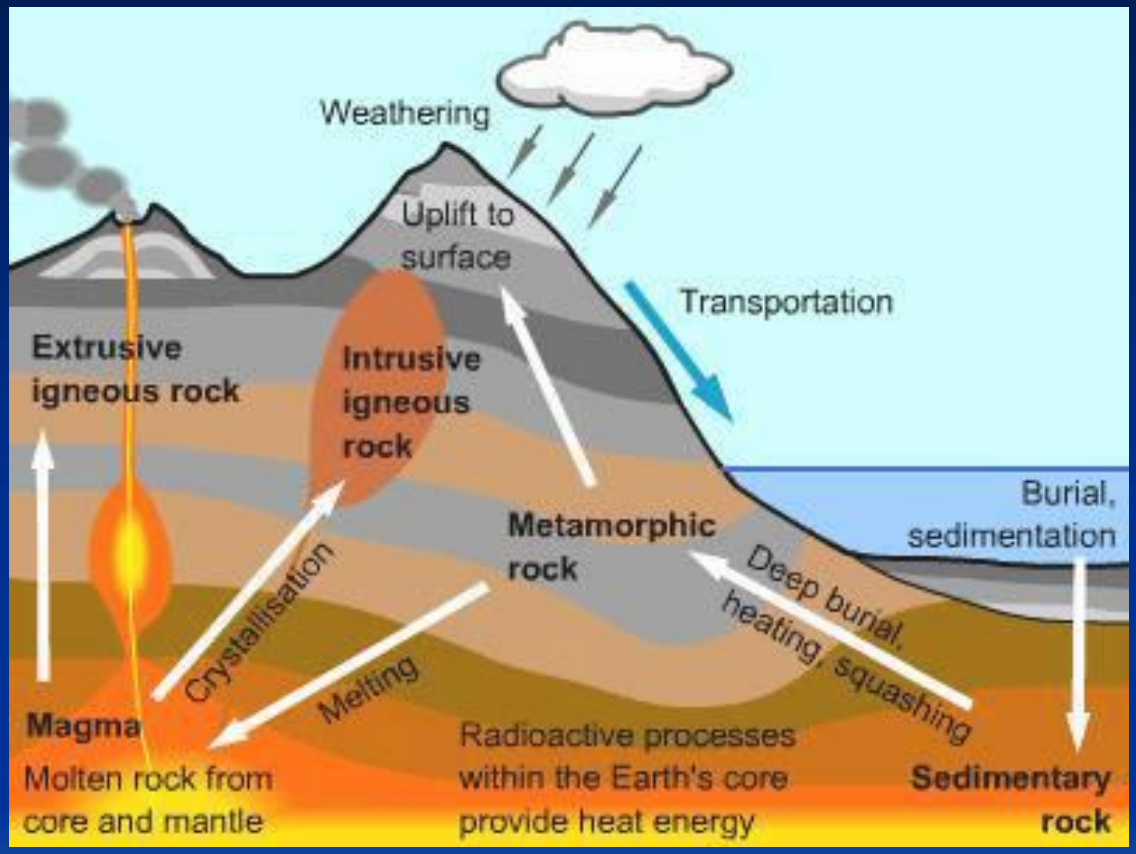
The Rock Cycle

Three Primary Rock Types

1) **Igneous**

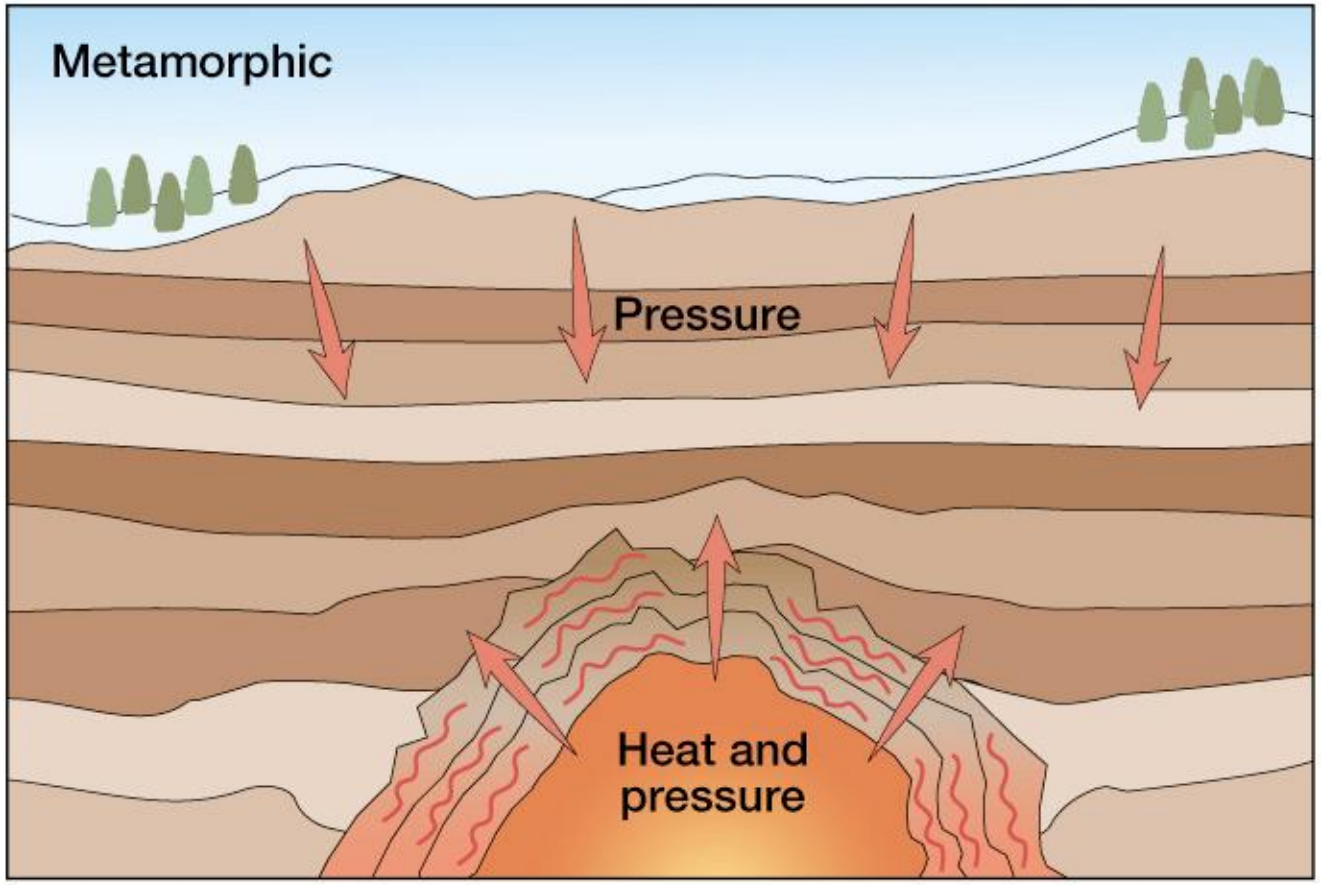
2) **Metamorphic**

3) **Sedimentary**



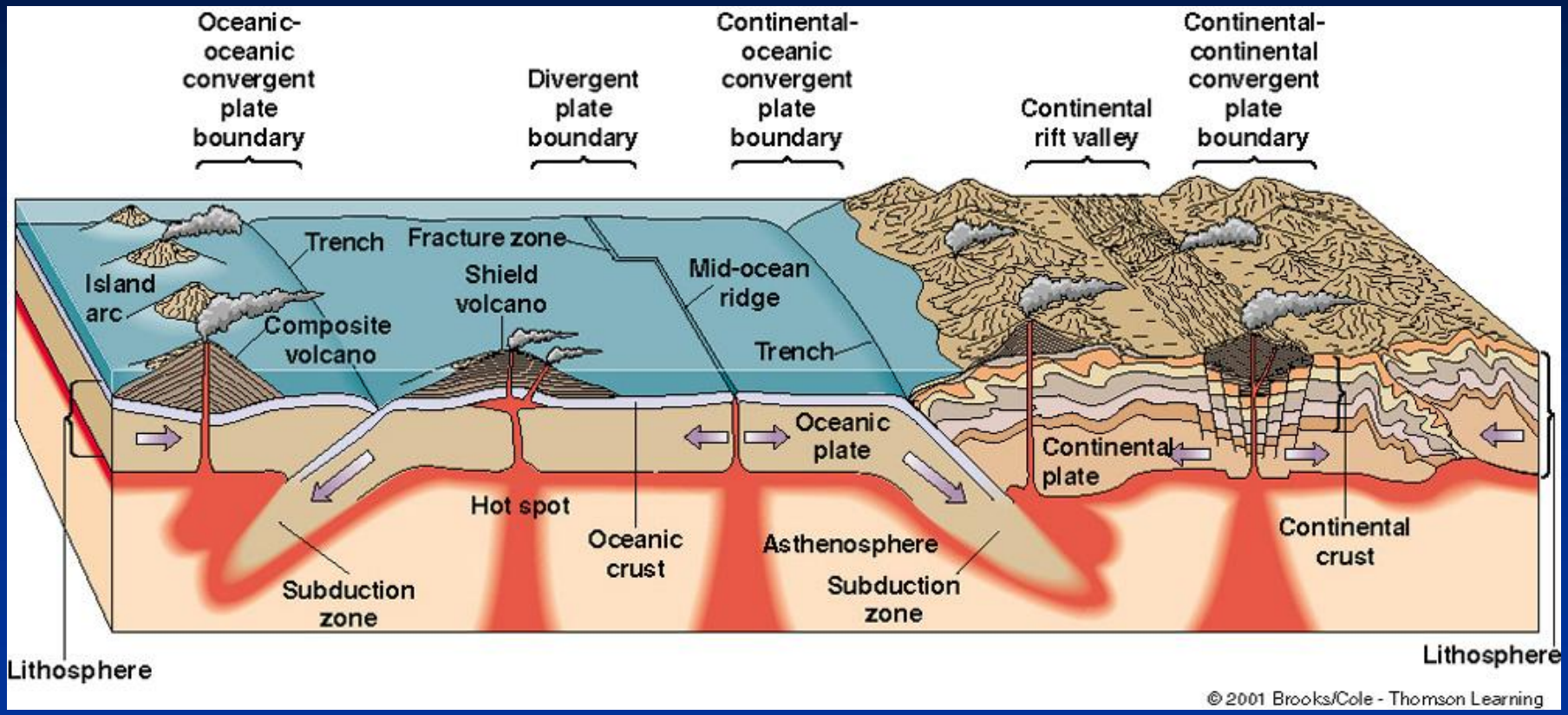
Focus of this presentation is on Metamorphic Rocks

Heat + Pressure = Mother Metamorphic



Hot Chemically-Reactive Fluids and Tectonic Stresses Too!

Environments for Metamorphism



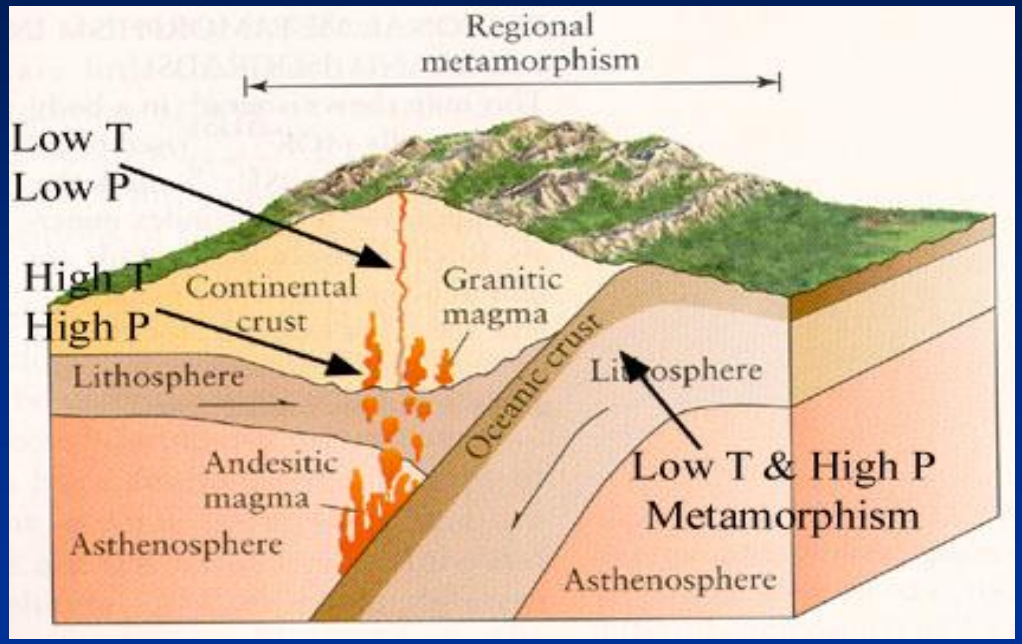
Vast majority of metamorphism takes place at plate boundaries – Why?

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

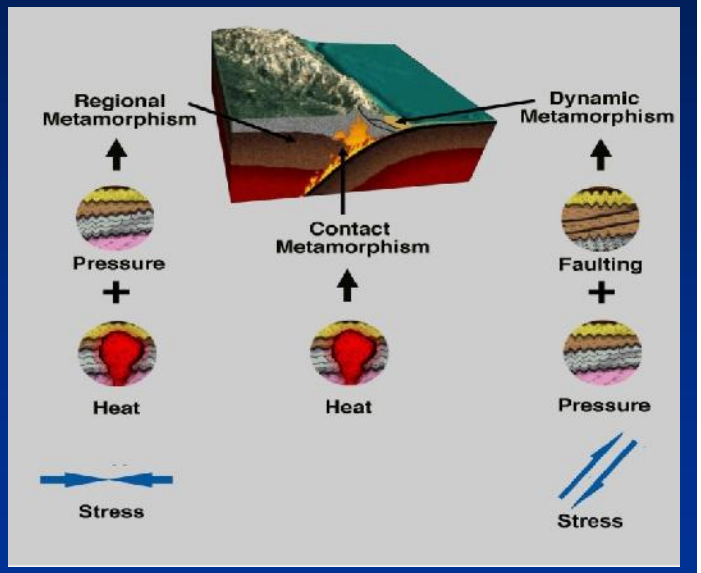
Metamorphic Processes and Grade

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

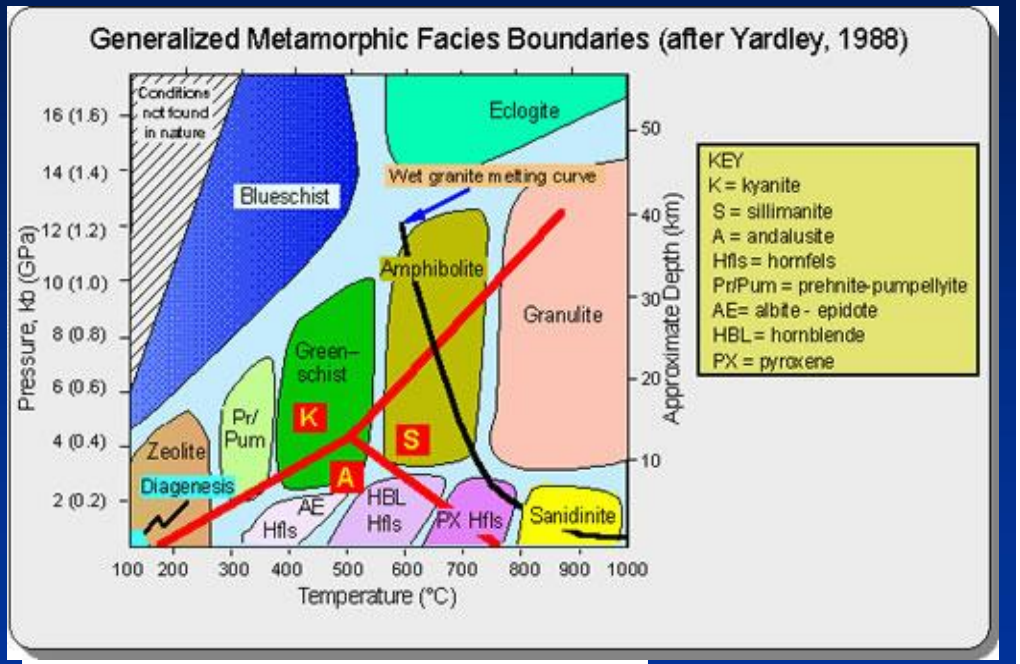
Parent	Low Grade		High Grade
Limestone	Marble		Marble
Sandstone	Quartzite		Quartzite
Shale	Slate	Schist	Gneiss
Granite	-----	Schist	Gneiss
Basalt	Greenschist		Amphibolite

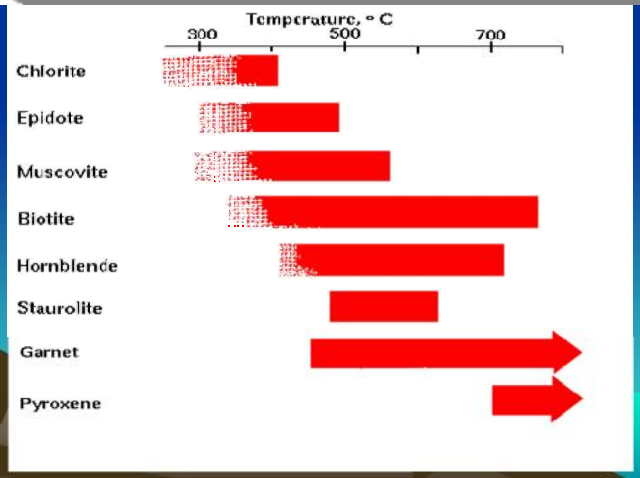
Metamorphic Grade and Mineral Facies

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

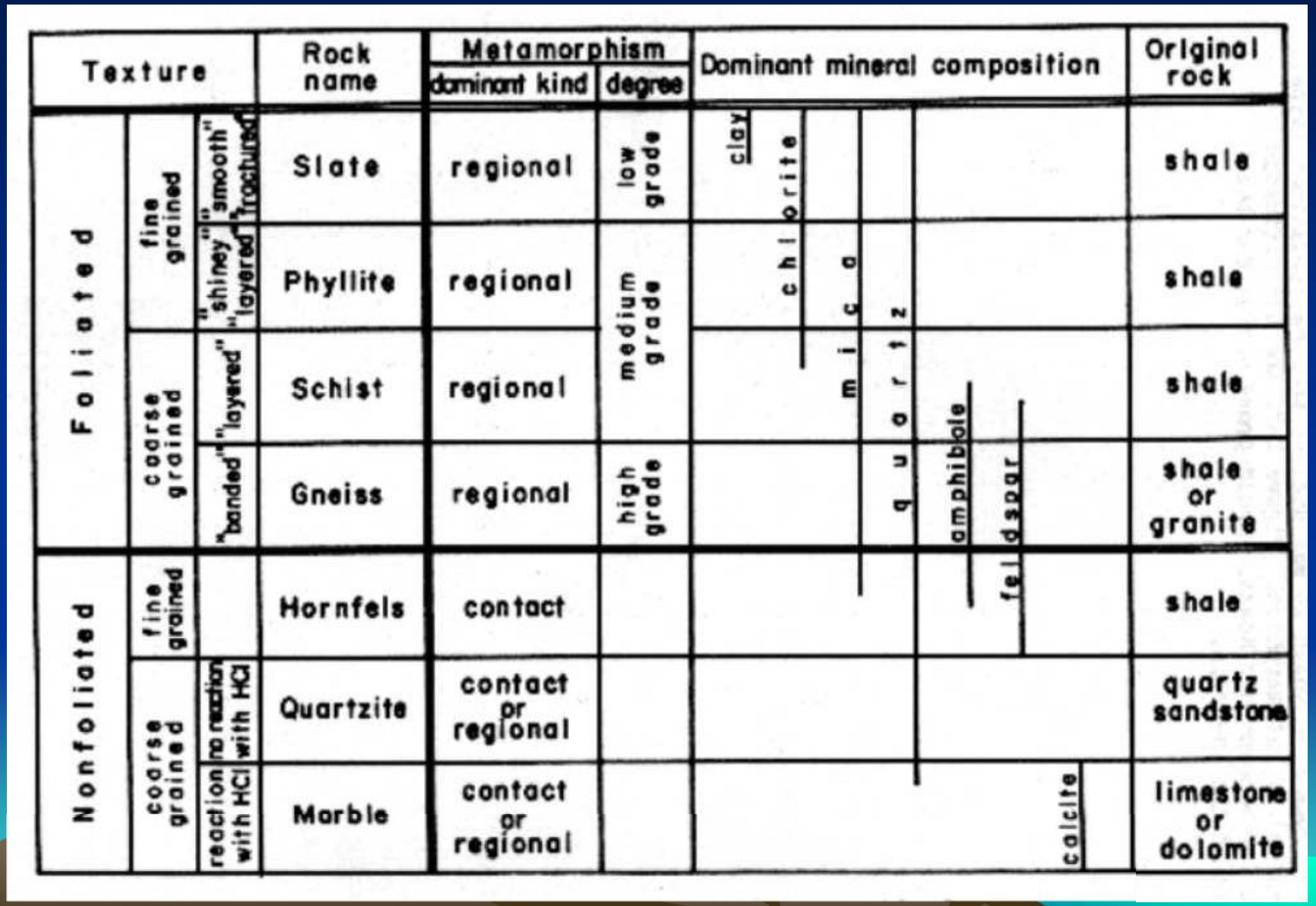
Metamorphic rocks are classified according to several criteria:

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

Parent Rock → Metamorphic Rock Pairs

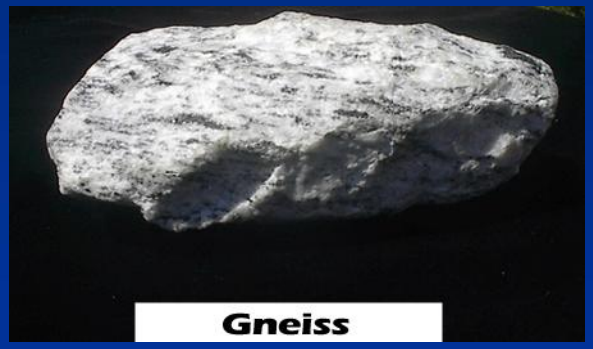
Parent	Grd	Rock	Foliation	Comments
Shale	Low	Slate	cleavage	v fine
		Phyllite	cleavage	'sheen' from fine mica
		Schist	schistocity	mica coarse/visible
	Hi	Gneiss	banding	v coarse
Basalt	Med	Green schist	schistocity	green chlorite
		Ampholite	Banding	black amphibole
	Hi	Blue-schist	schistocity	blue amphibole
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 kind	Metamorphism: degree	Dominant mineral composition	Original rock
Foliated	fine grained	"smooth" fractured	Slate	regional	low grade	clay	shale
		"shiney" "layered"	Phyllite	regional	medium grade	chlorite, mica, quartz	shale
	coarse grained	"layered"	Schist	regional		mica, quartz, amphibole, feldspar	shale
		"banded"	Gneiss	regional	high grade	quartz, amphibole, feldspar	shale or granite
Nonfoliated	fine grained		Hornfels	contact		mica, amphibole, feldspar	shale
	coarse grained	no reaction with HCl	Quartzite	contact or regional		quartz	quartz sandstone
		reaction with HCl	Marble	contact or regional		calcite	limestone or dolomite

Common Metamorphic Rocks In Hand Samples



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

Schistose

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

Mica Schist

Close-Up

Gneissic

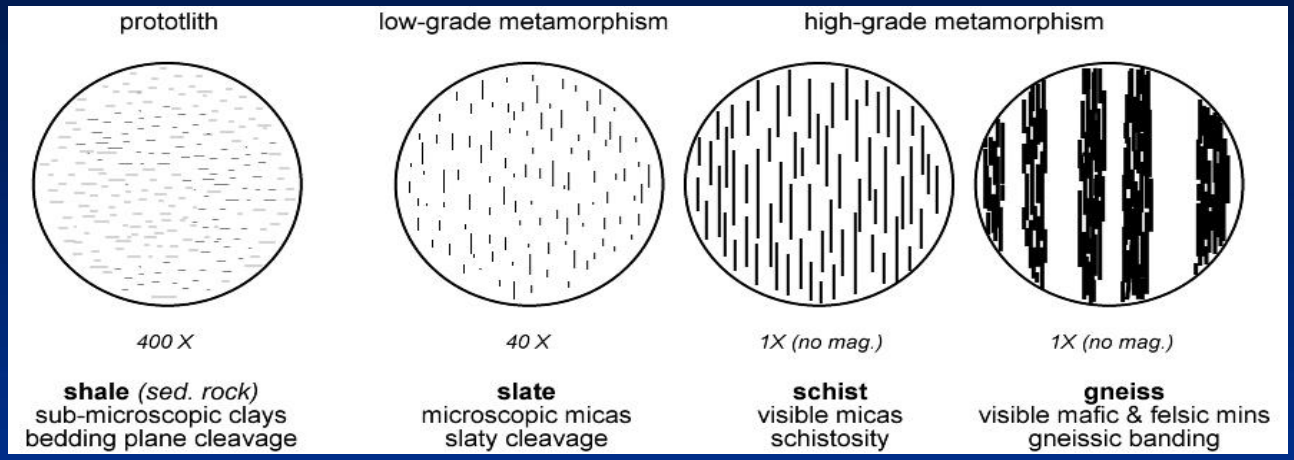
- ✓ Foliated = dark and light mineral bands
- ✓ Medium to course grained
- ✓ Observable mineralogy
- ✓ Quartz, feldspar, biotite, and amphibole

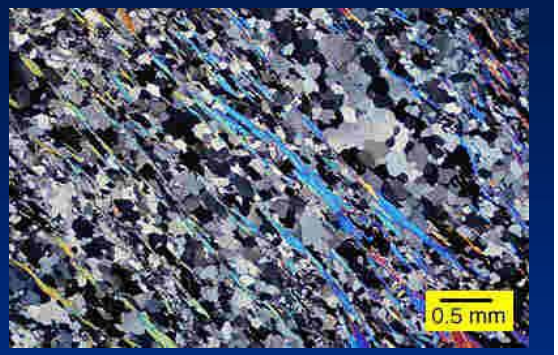
Garnet Gneiss

Close-Up

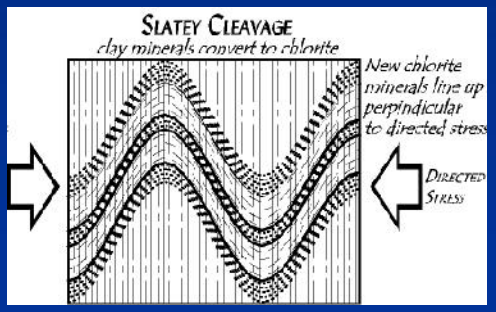
- http://www.rockhounds.com/rockshop/rockkey/index.html

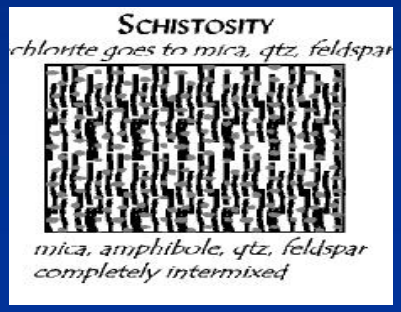
Foliated Metamorphic Textures

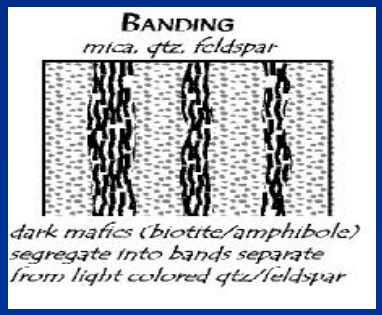




Foliated Textures







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

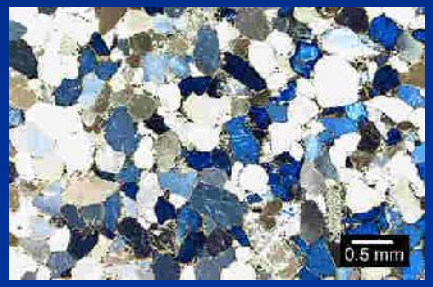
Microgranular

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

Macrogranular

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

Hornfels

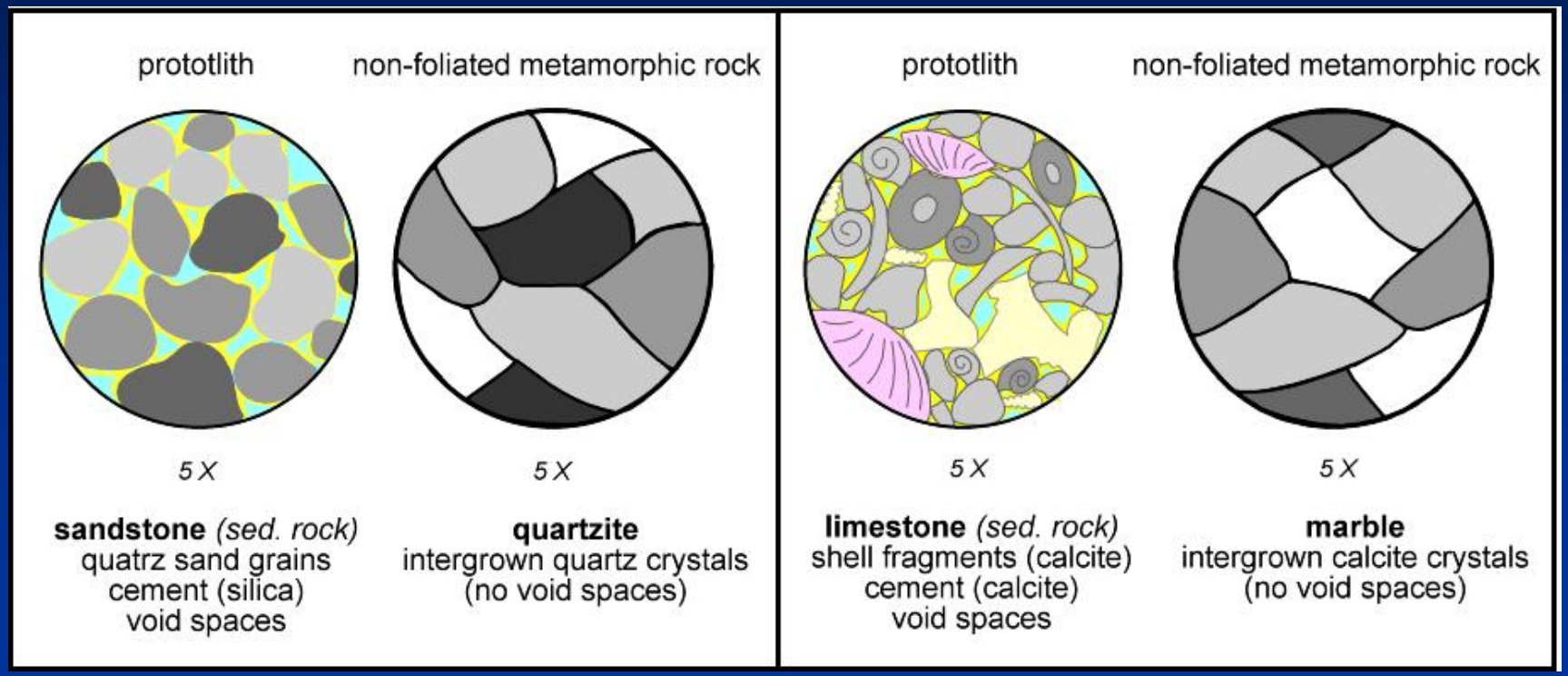


Granular Fabric

Marble

Metamorphism of Parent Rocks

Textural Changes in Mono-Minerallic Metamorphism



Quartz-rich Rocks

Calcite-rich Rocks

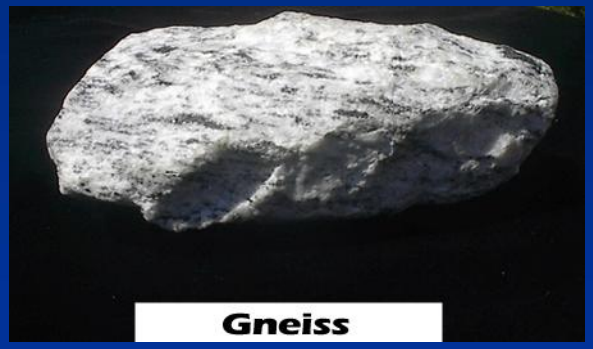
- ✓ **Mono-minerallic rocks are typically non-foliated.**
- ✓ **Texture described as "polygonal granular"**

Most Common Types of Metamorphic Rocks

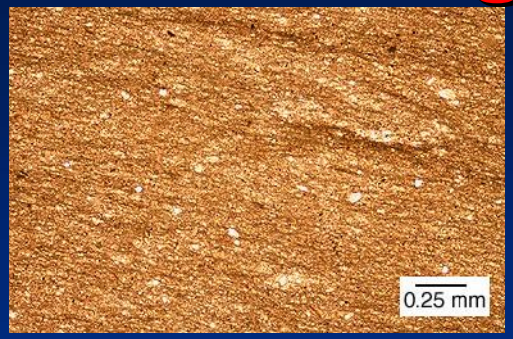
Questions:

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

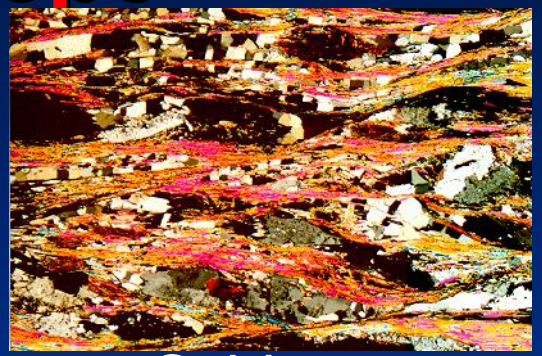


Common Metamorphic Rocks Under a Microscope

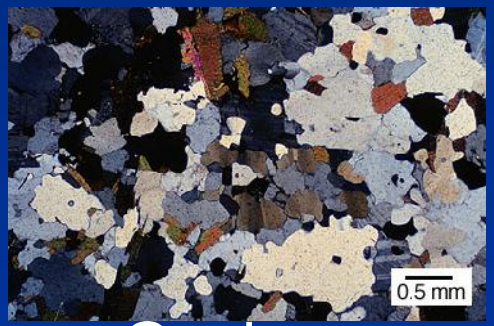


Slate

Phyllite



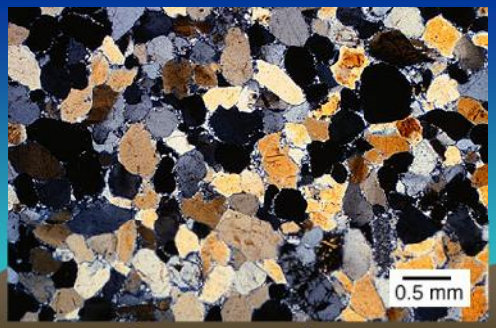
Schist



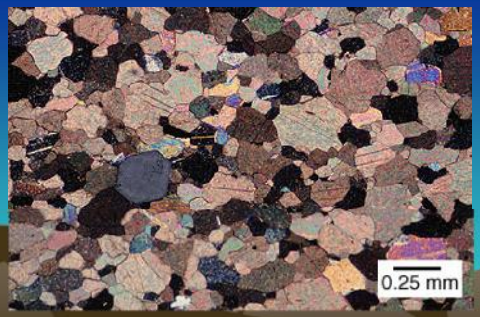
Gneiss

Amphibolite

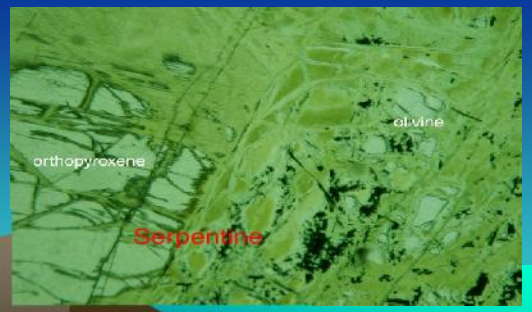
Hornfels



Quartzite



Marble



Serpentinite

Metamorphic Rock Classification

A Three Step Process

1) Determine Texture

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

2) Determine Composition

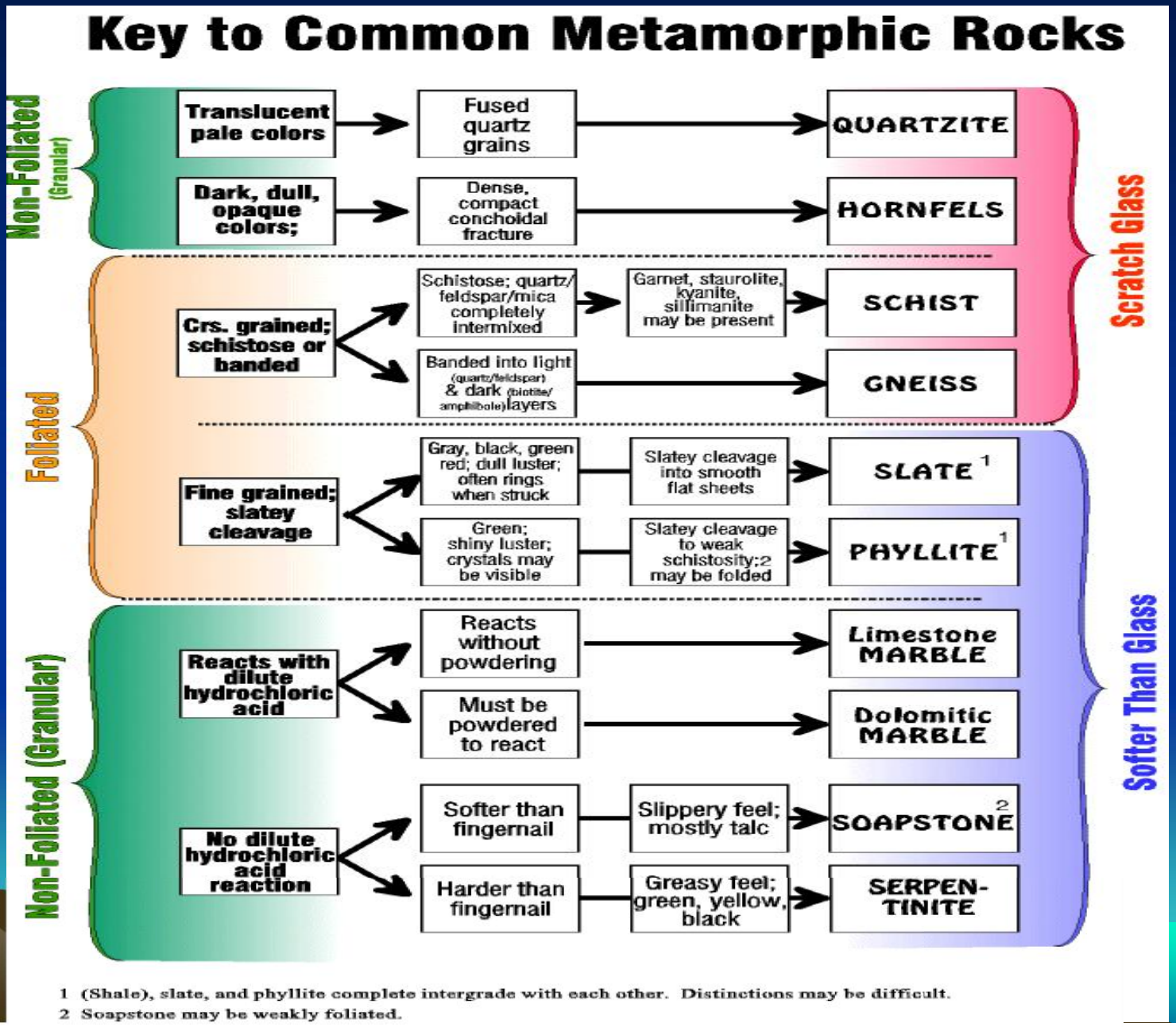
- ✓ Mineralogy?

3) Name the Meta Rock and its Parent Rock

Scheme for Metamorphic Rock Identification

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	
FOLIATED – MINERAL ALIGNMENT	Fine to medium	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET, PYROXENE	Regional (Heat and pressure increase with depth)	Foliation surfaces shiny from microscopic mica crystals	Phyllite	
FOLIATED – MINERAL ALIGNMENT	Fine to medium	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET, PYROXENE	Regional (Heat and pressure increase with depth)	Platy mica crystals visible from metamorphism of clay or feldspars	Schist	
FOLIATED – BAND-ING	Medium to coarse	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET, PYROXENE	Regional (Heat and pressure increase with depth)	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	
NONFOLIATED	Fine to coarse	Quartz	Regional or Contact	Metamorphism of quartz sandstone	Quartzite	
NONFOLIATED	Fine to coarse	Calcite and/or dolomite	Regional or Contact	Metamorphism of limestone or dolostone	Marble	
NONFOLIATED	Coarse	Various minerals in particles and matrix	Regional or Contact	Pebbles may be distorted or stretched	Metaconglomerate	

Classification of Metamorphic Rocks



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

2 Soapstone may be weakly foliated.

Metamorphic Rocks

Discussion and Examination