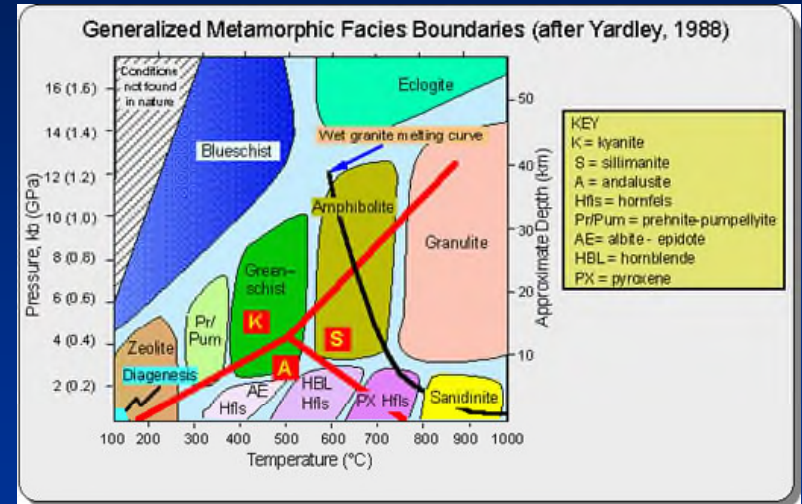
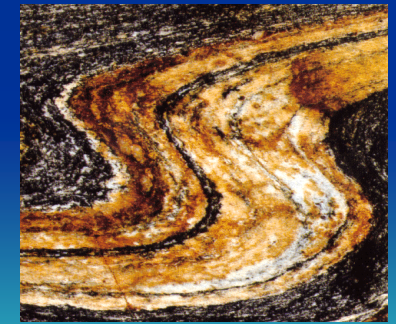
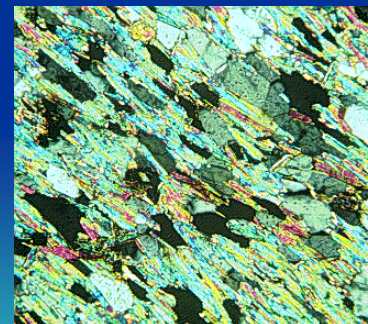




# Metamorphic Rock Origin, Processes and Identification



Physical Geology  
GEOL 100 Lecture  
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>

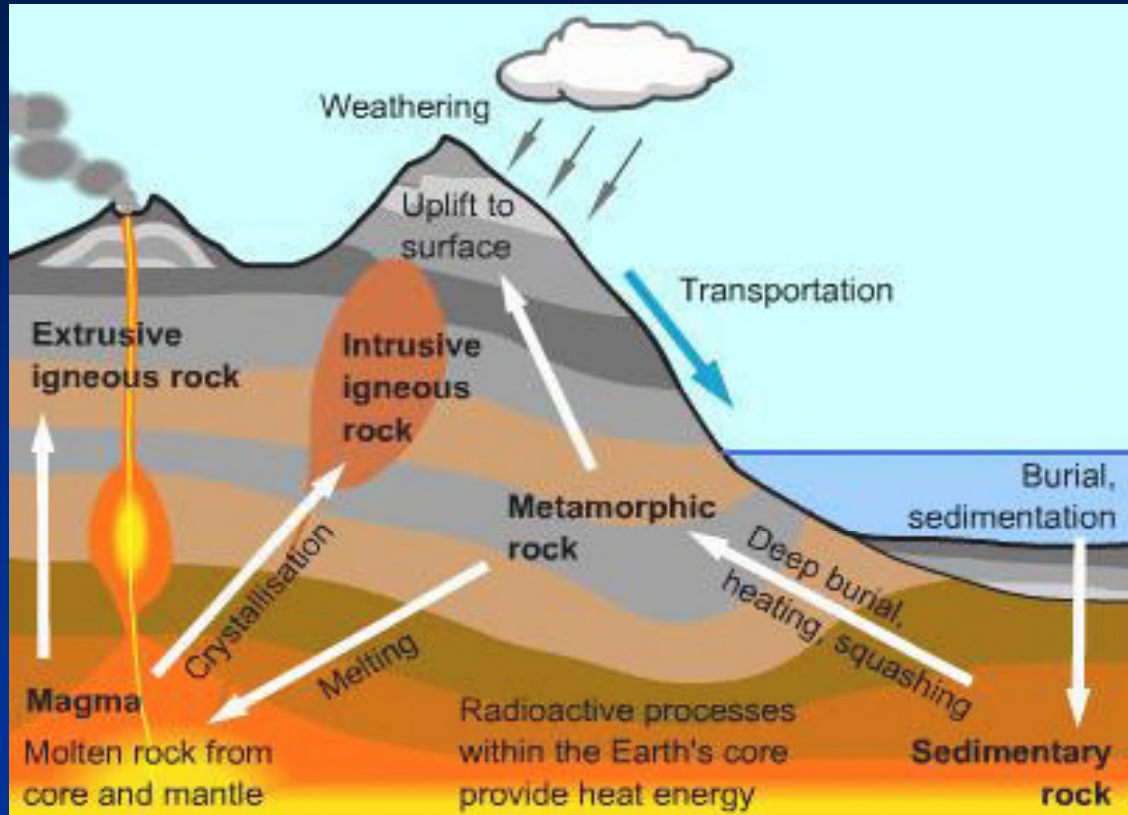
# Major Concepts

- 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 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**



Metamorphic rocks form by changing the texture and/or mineralogy of a parent/source rock into another rock in the solid-state under elevated temperatures, pressure, stress and/or fluids activity

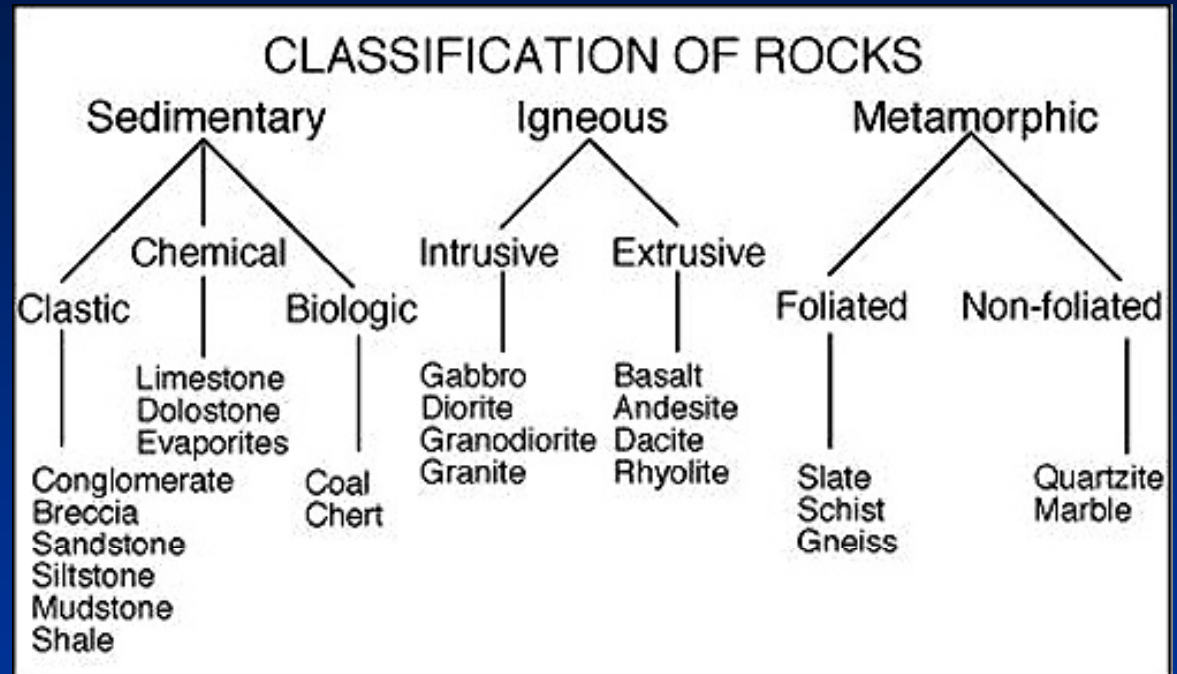


# Classification of Metamorphic Rocks

1) **Igneous**

2) **Metamorphic**

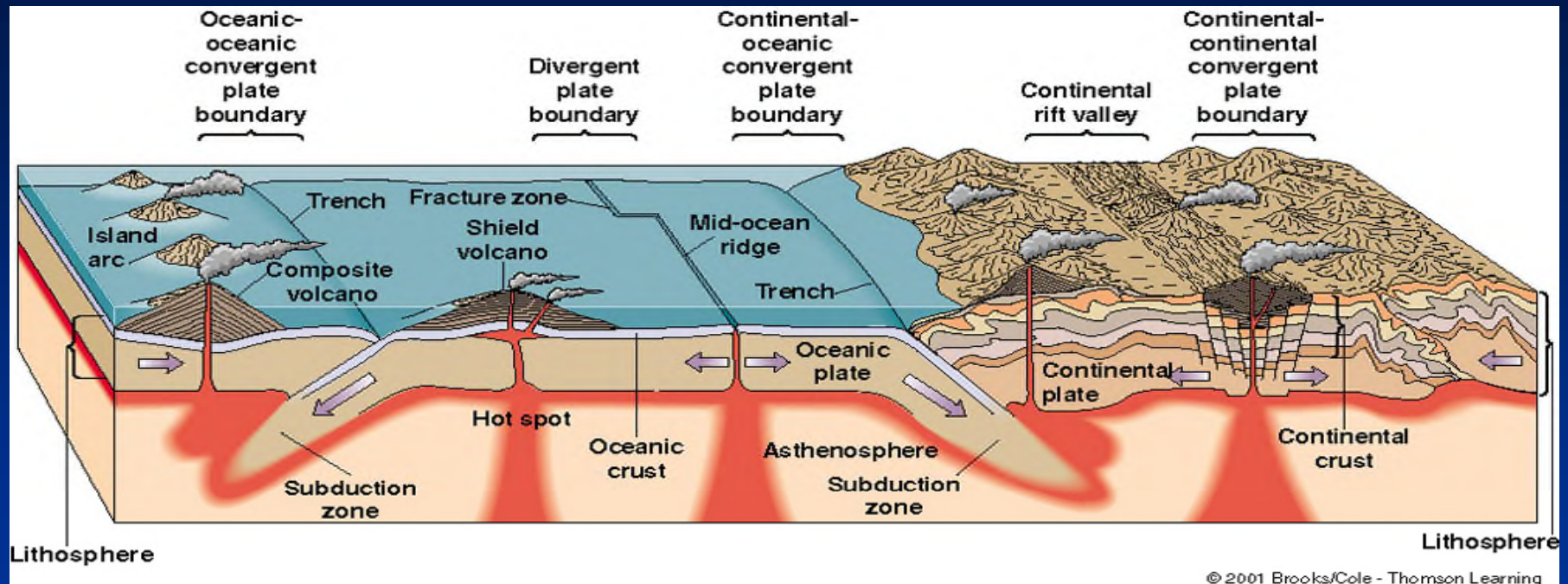
3) **Sedimentary**



Like the other rock types, metamorphic rocks are classified based on both Texture and Composition

The primary division on metamorphic rock classification is whether a metamorphic rock is foliated (layered) or nonfoliated

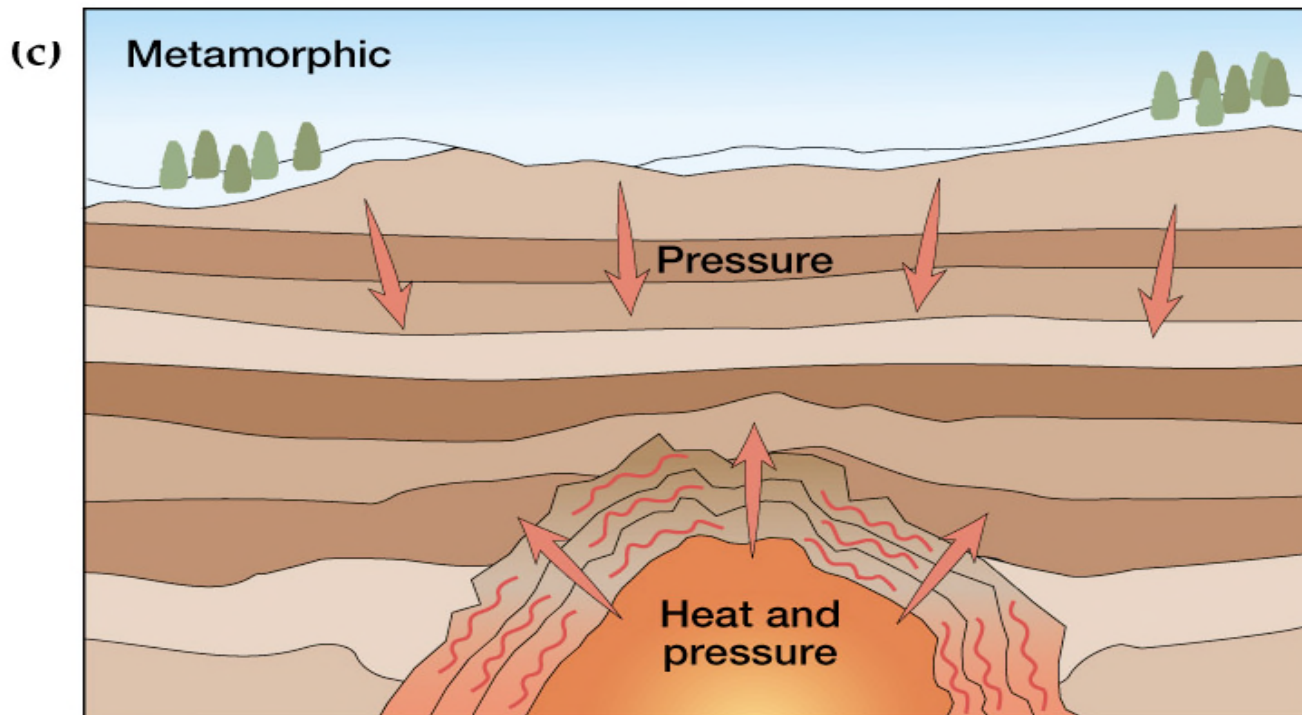
# Environments for Metamorphism



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

- 1) Regions of elevated **heat energy** (deep crustal burial, hot magmas/ fluids)
- 2) Regions of elevated lithostatic **pressure** (crustal burial & thickening)
- 3) Regions of magma production with associated chemically-reactive fluids
- 4) Regions of great tectonic **stresses** (tectonic plate interactions)

# Four General Types of Metamorphism Agents of Change



**Hot Chemically-Reactive Fluids and Tectonic Stresses Too!**

# 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)

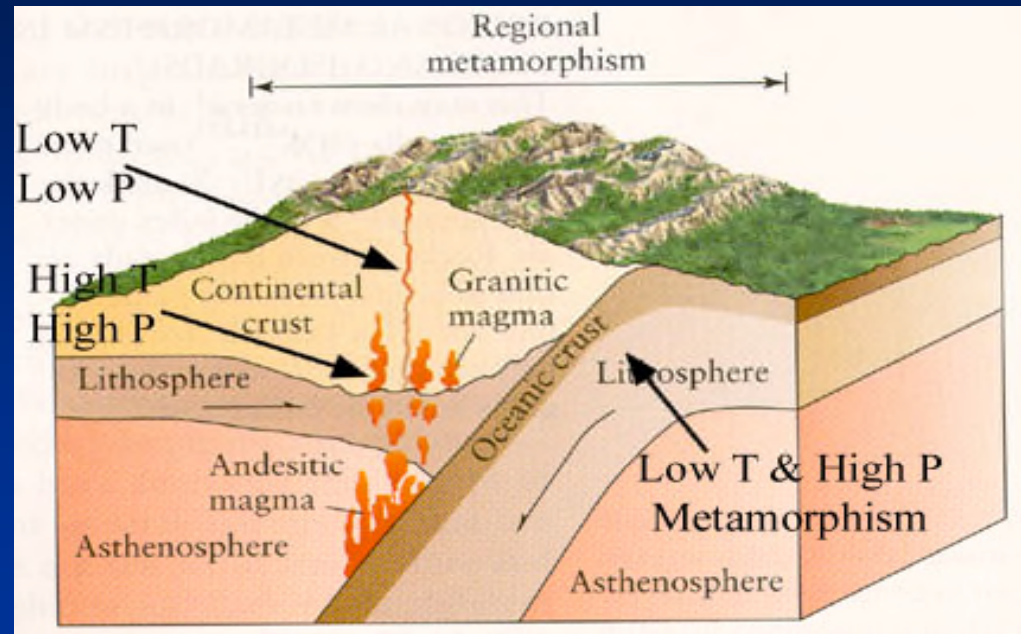
- ✓ Due to deep burial
- ✓ From Low T + Low P to High T + High P

### 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





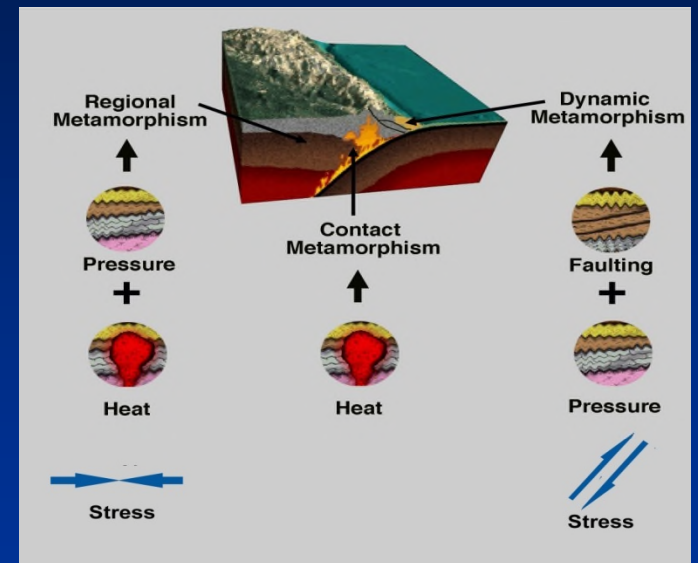
# Metamorphic Processes and Grade

## 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
Granite	-----	Schist
Basalt	Greenschist	Amphibolite



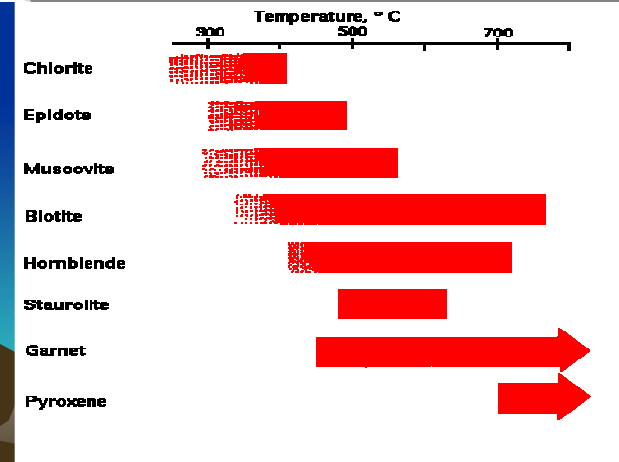
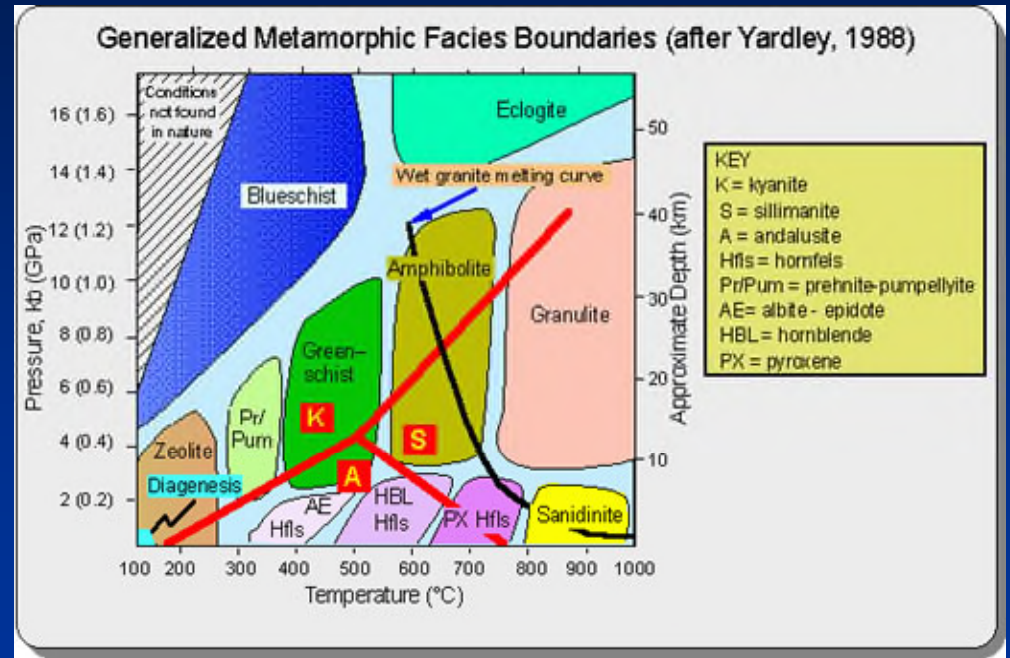


# Metamorphic Grade and Mineral Facies

## 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

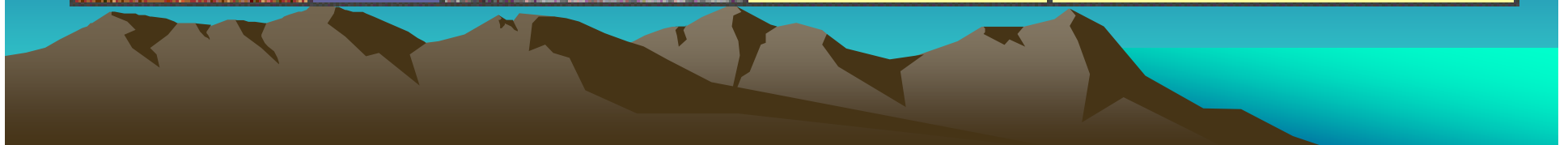
Original Rock	Texture	Rock Name	Metamorphic Process	Metamorphic Grade	Comments
mudstone	Foliated	slate	regional	lower	breaks into plates (slaty cleavage)
mudstone	Foliated	phyllite	regional	moderate	more shiny and crenulated than slate
mudstone	Foliated	schist	regional	mod-high	different schists recognized 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
	 Hi	Phyllite	cleavage	'sheen' from fine mica
		Schist	schistosity	mica coarse/visible
		Gneiss	banding	v coarse
Basalt	Med	Green schist	schistosity	green chlorite
	 Hi	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	"shiny smooth"	Slate	regional	low grade	clay			shale
		"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	shale or granite
Nonfoliated	fine grained		Hornfels	contact				shale	
	coarse grained	reaction no reaction with HCl	Quartzite	contact or regional				feldspar	quartz sandstone
		reaction with HCl	Marble	contact or regional				calcite	limestone or dolomite

# Common Metamorphic Rocks In Hand Samples



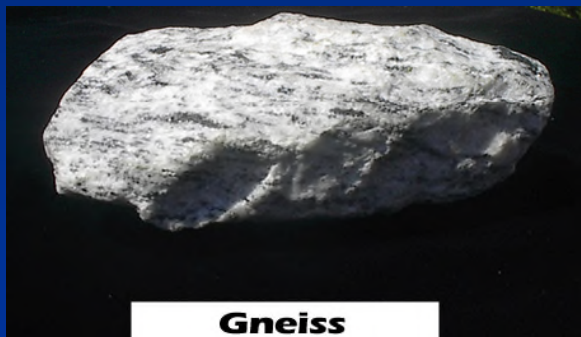
**Slate**



**Phyllite**



**Schist**



**Gneiss**



**Amphibolite**



**Hornfels**



**Quartzite**



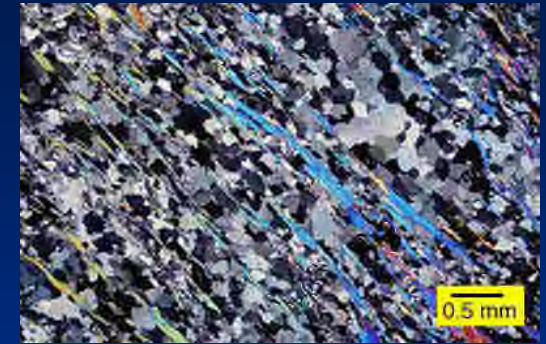
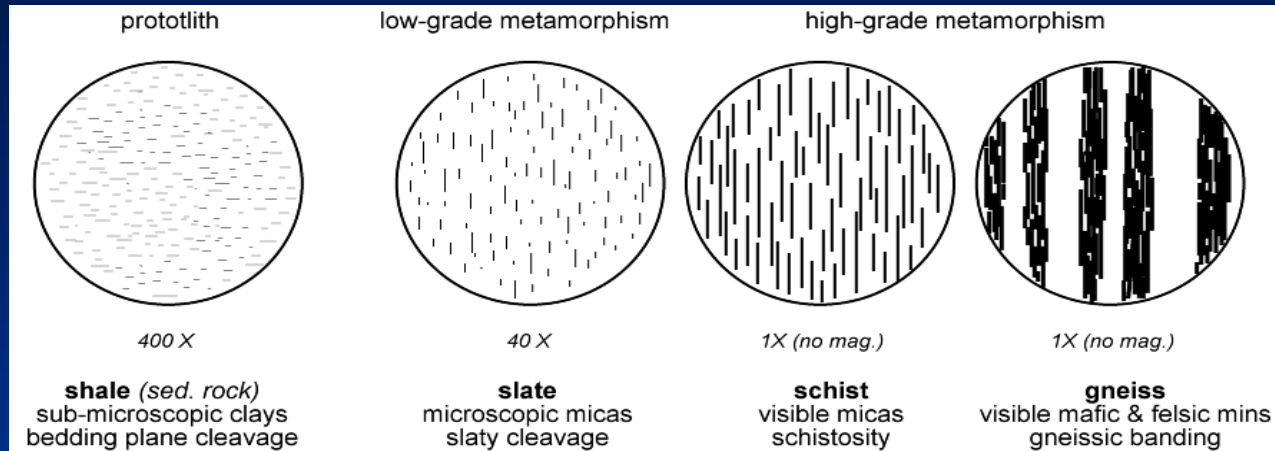
**Marble**



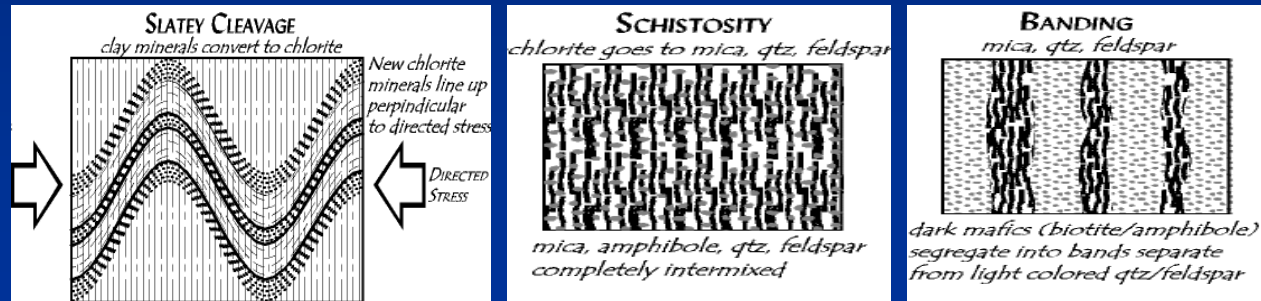
**Serpentine**



# Foliated Metamorphic Textures



**Foliated Textures**



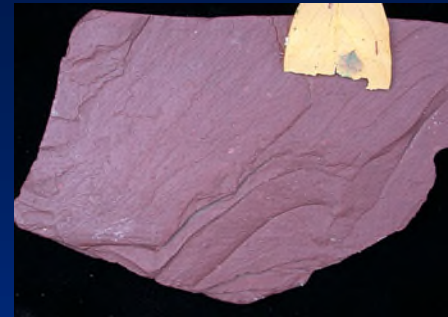
- 1) Foliated textures result from deviatoric tectonic stresses
- 2) The type of foliated rock fabric is a function of metamorphic grade
  - ✓ Foliation character changes with intensity and duration of metamorphism
- 3) The type of foliated rock fabric is also a function of rock composition



# 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 course grained
- ✓ Observable mineralogy
- ✓ Lots of mica and quartz



Garnet Gneiss



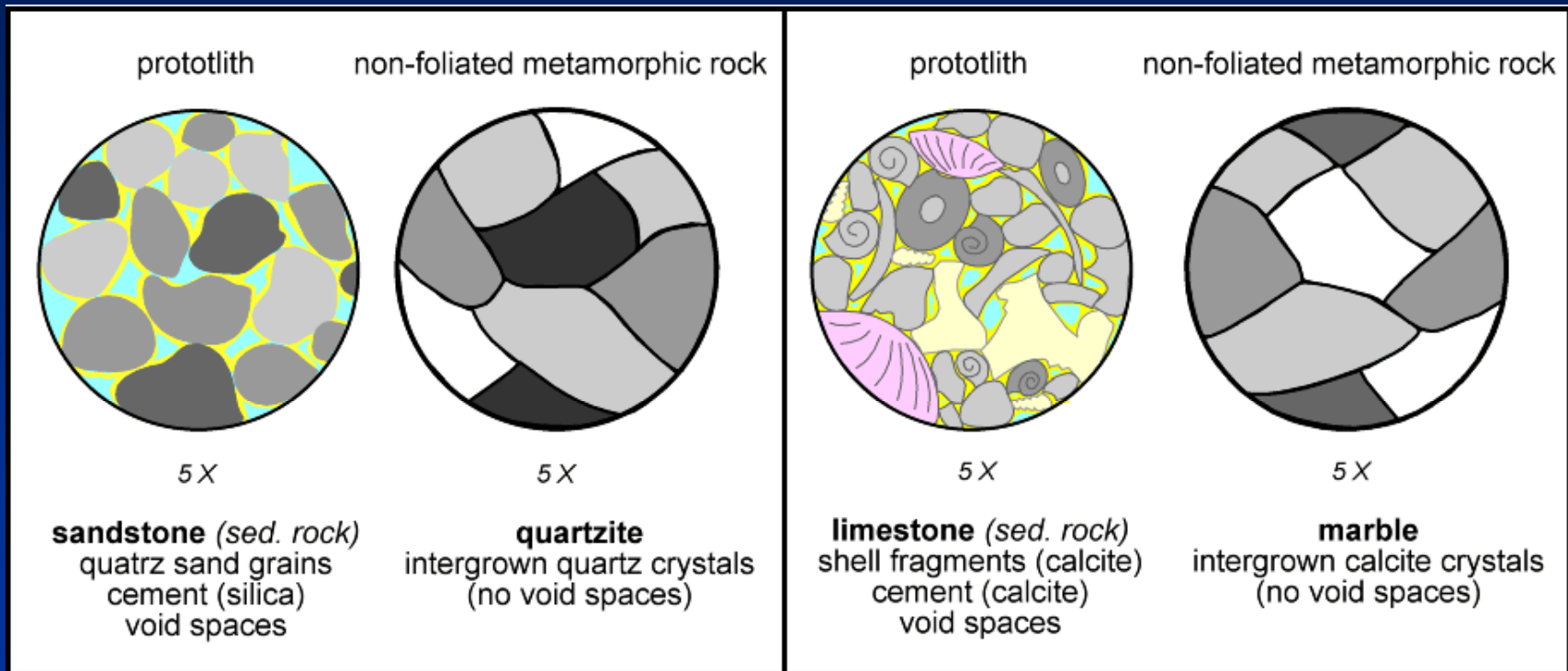
Close-Up

## Gneissic

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

# 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”

# 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

## Macrogranular

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



Granular Fabric



Marble



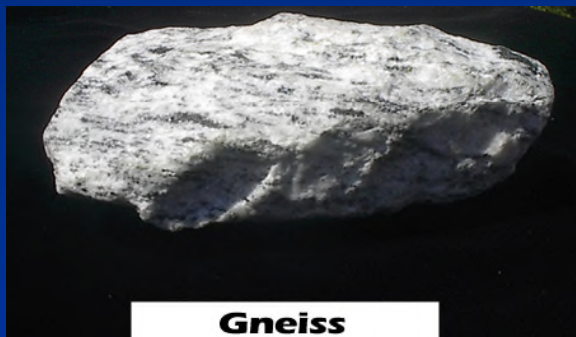
# Most Common Types of Metamorphic Rocks

## 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?

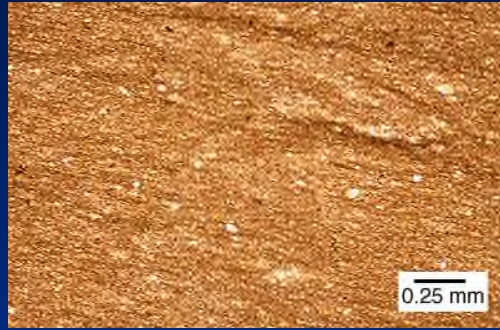


# Common Metamorphic Rocks In Hand Samples

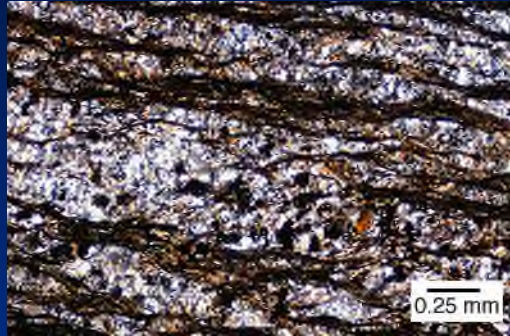




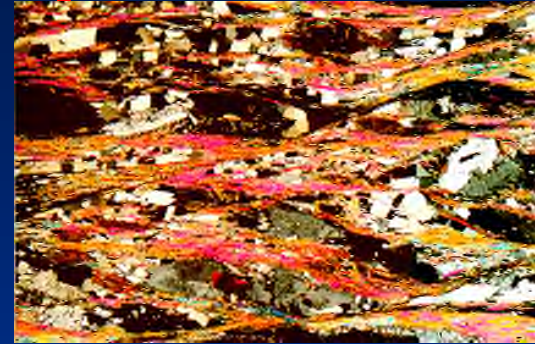
# Common Metamorphic Rocks Under a Microscope



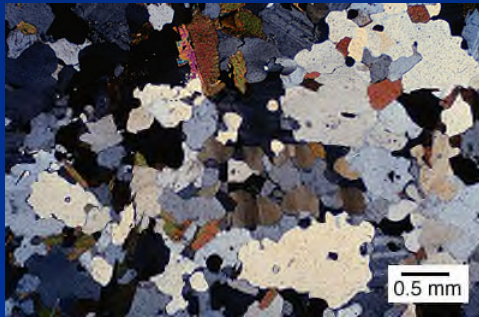
Slate



Phyllite



Schist



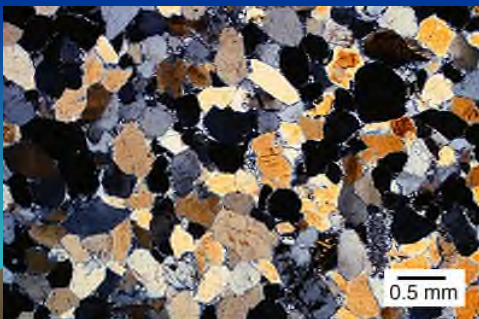
Gneiss



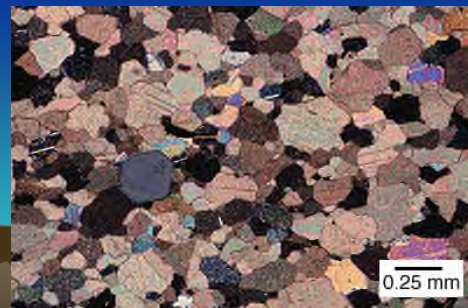
Amphibolite



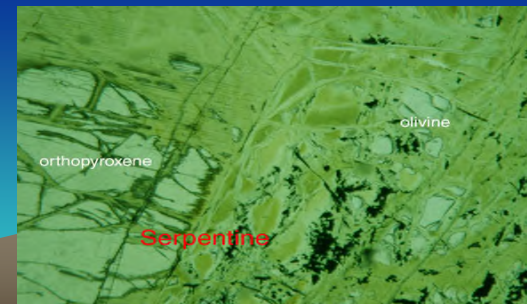
Hornfels



Quartzite



Marble



Serpentinite



# Metamorphic Rock Classification

## A Three Step Process

### 1) Determine Texture

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

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	
		Fine to medium			Foliation surfaces shiny from microscopic mica crystals	Phyllite	
	BANDING	Medium to coarse			Platy mica crystals visible from metamorphism of clay or feldspars	Schist	
					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 dolomite	Marble		
	Coarse	Various minerals in particles and matrix		Pebbles may be distorted or stretched	Metaconglomerate		

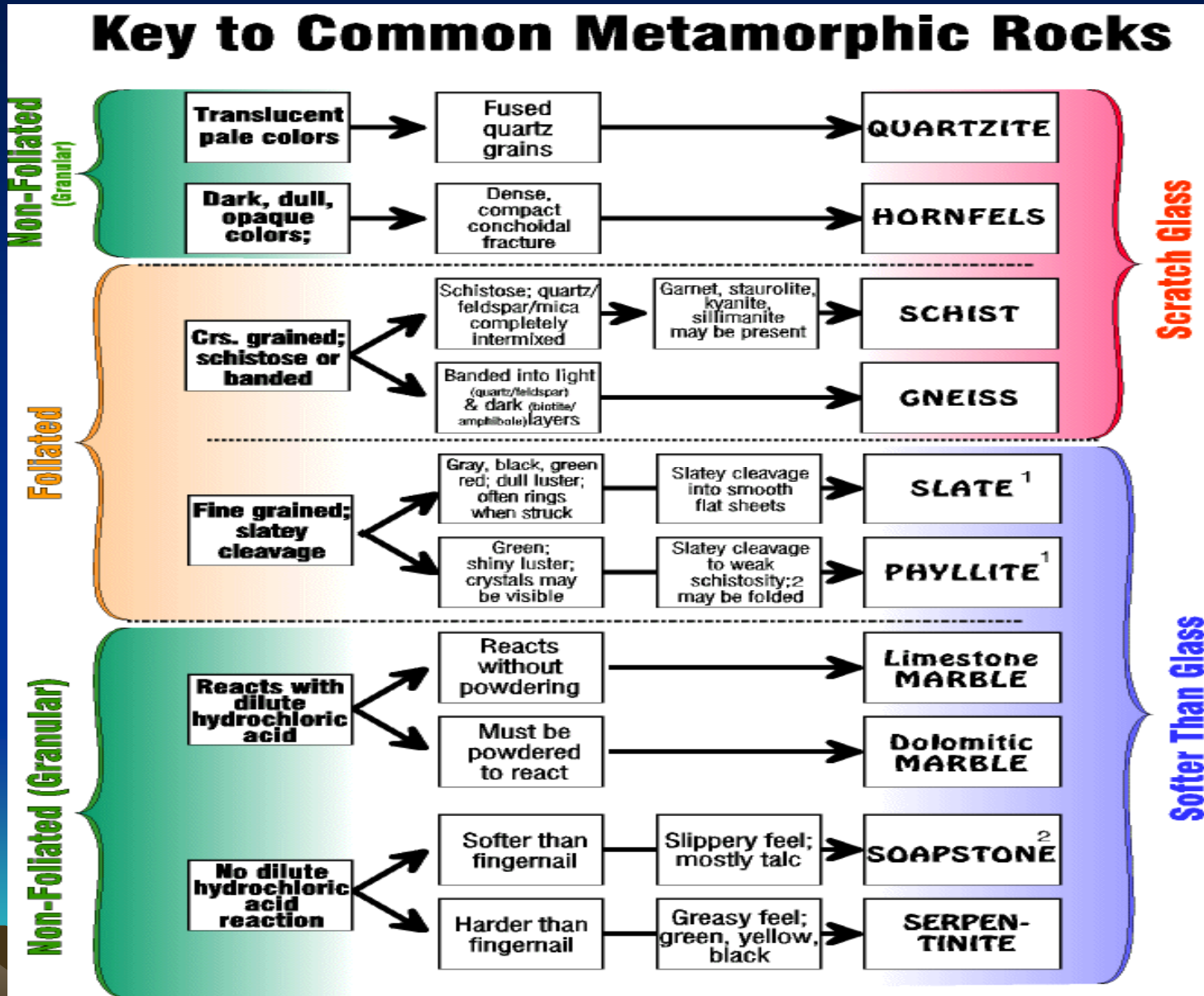
### 2) Determine Composition

- ✓ Mineralogy?

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



# Classification of Metamorphic Rocks



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



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