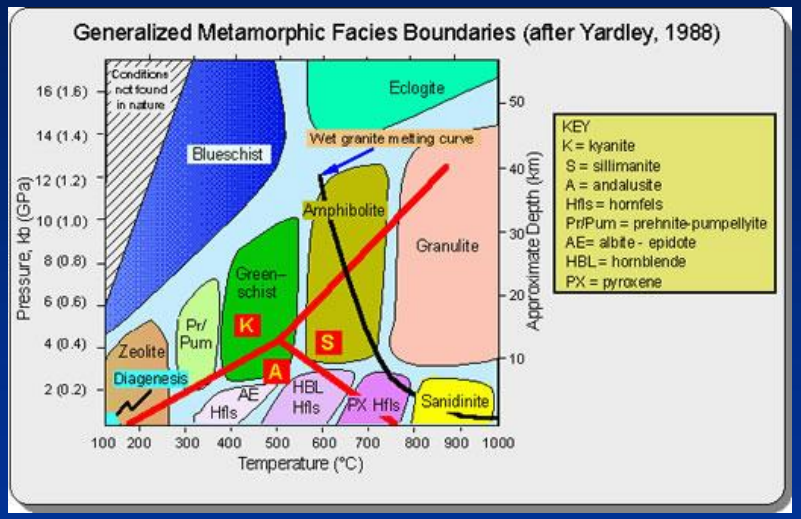
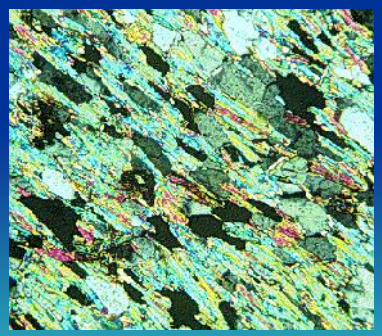
Metamorphic Rock Origin, Processes and Identification





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 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.

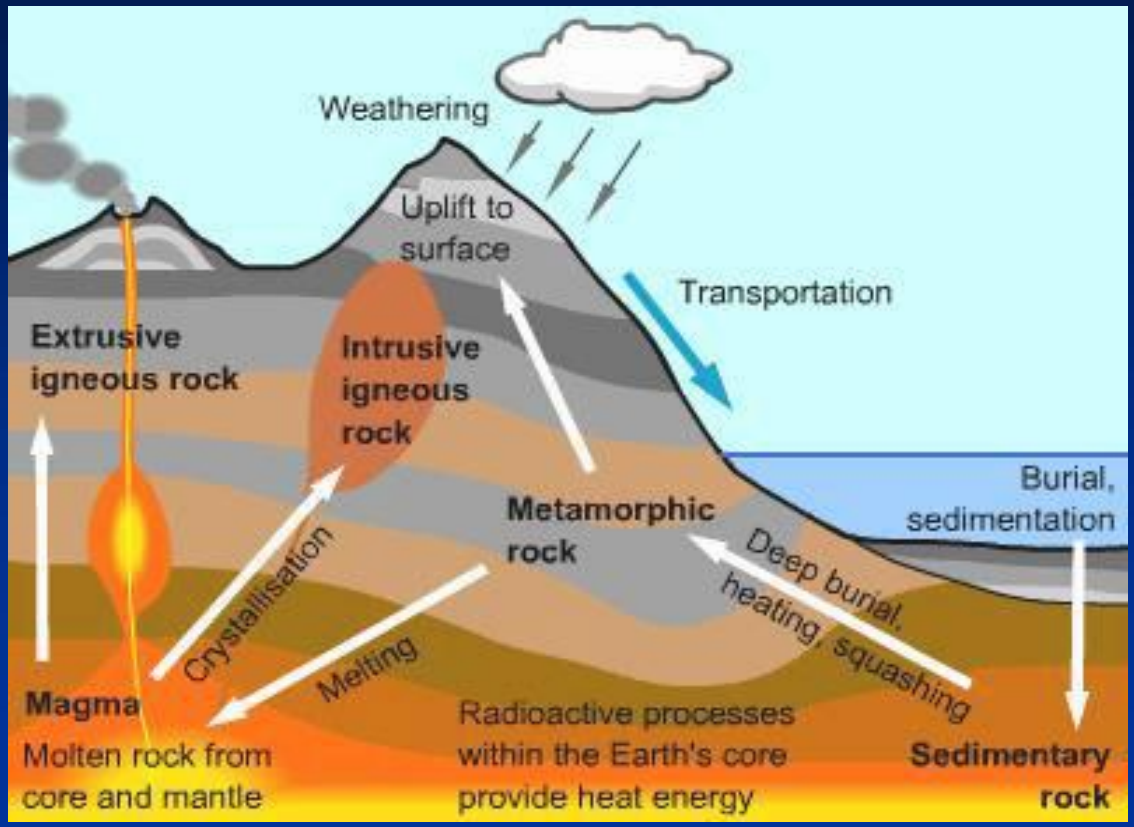
The Rock Cycle

Three Primary Rock Types

1) **Igneous**

2) **Metamorphic**

3) **Sedimentary**



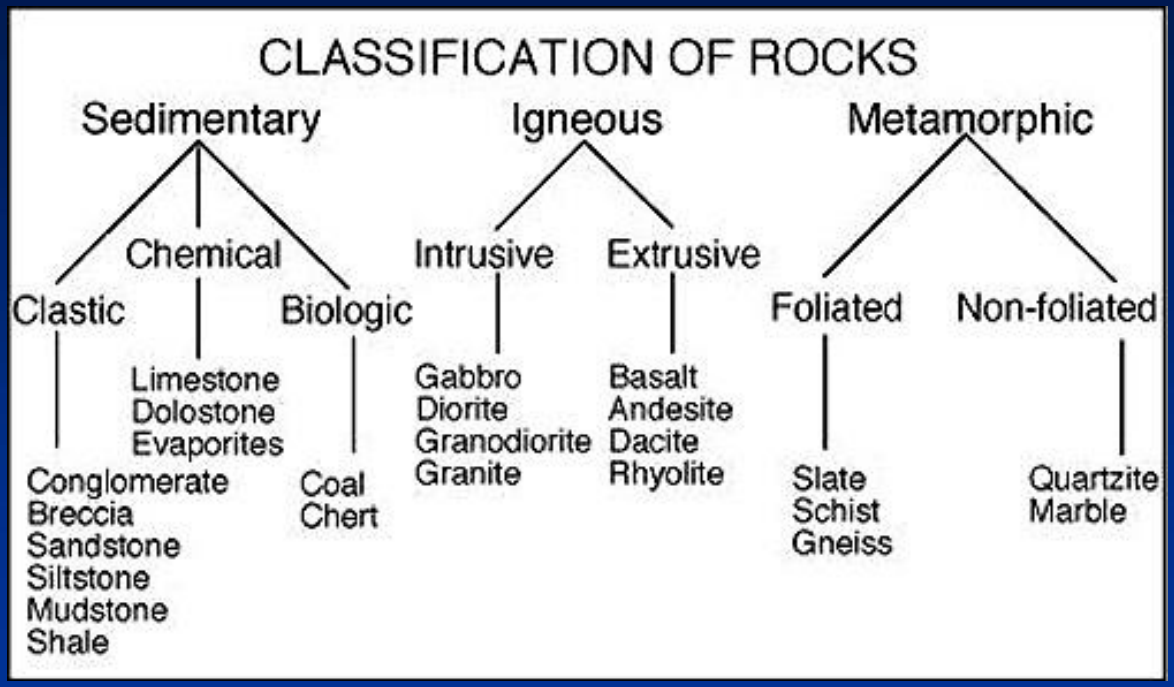
Metamorphic rocks form by changing the texture and/or mineralogy of a parent/source rock into another rock in the solid-state under elevated temperatures, pressure, stress and/or fluids activity

Classification of Metamorphic Rocks

1) **Igneous**

2) **Metamorphic**

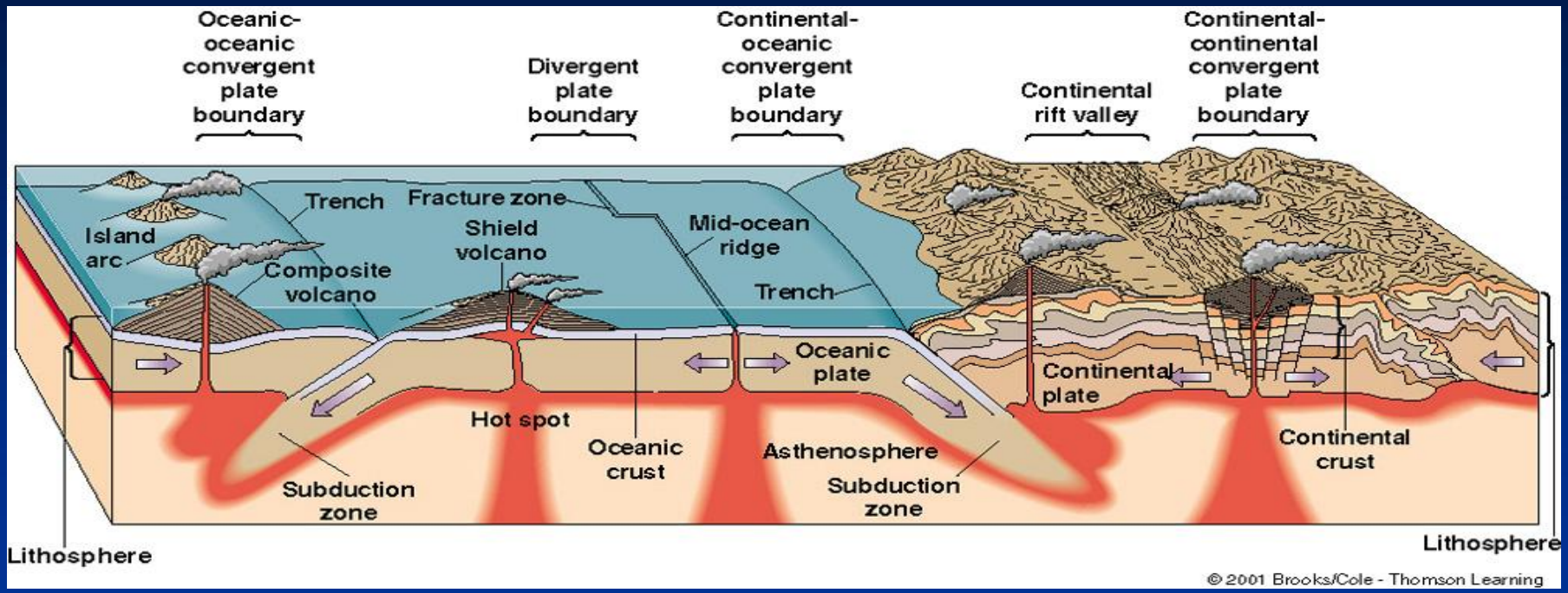
3) **Sedimentary**



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?

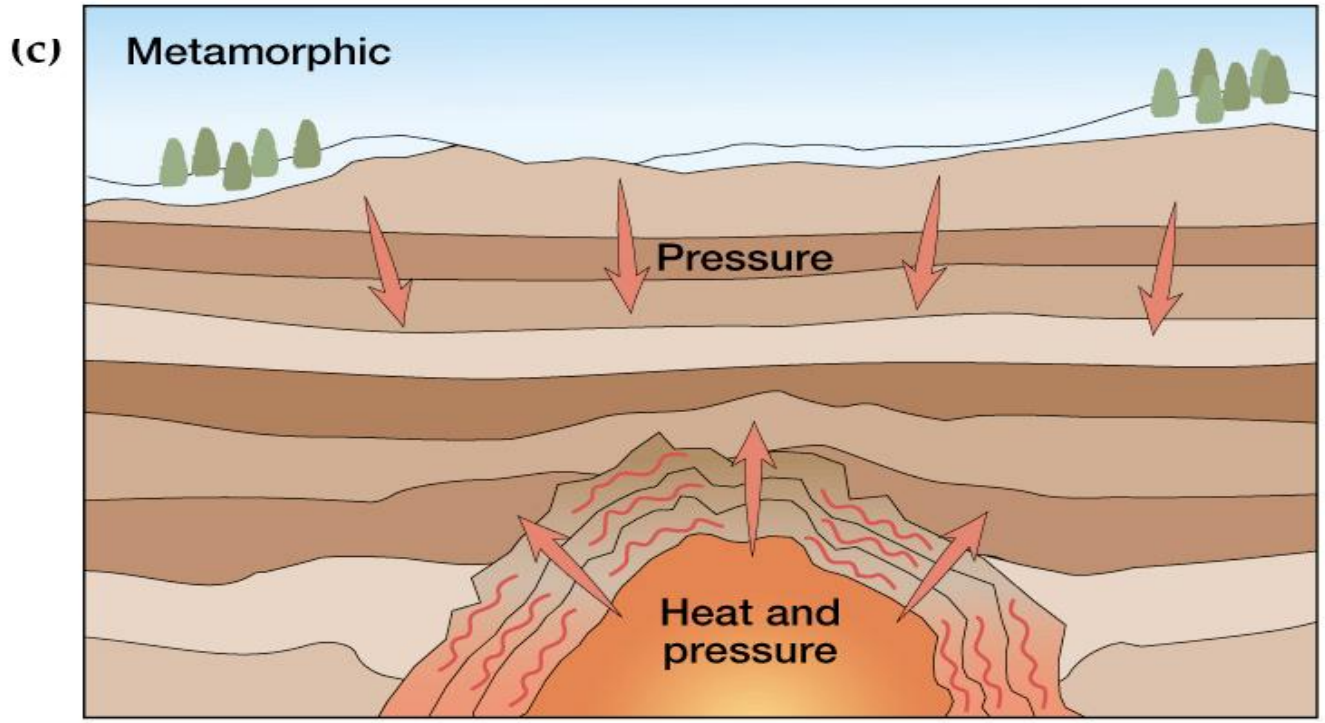
1) Regions of elevated **heat energy** (deep crustal burial, hot magmas/ fluids)

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

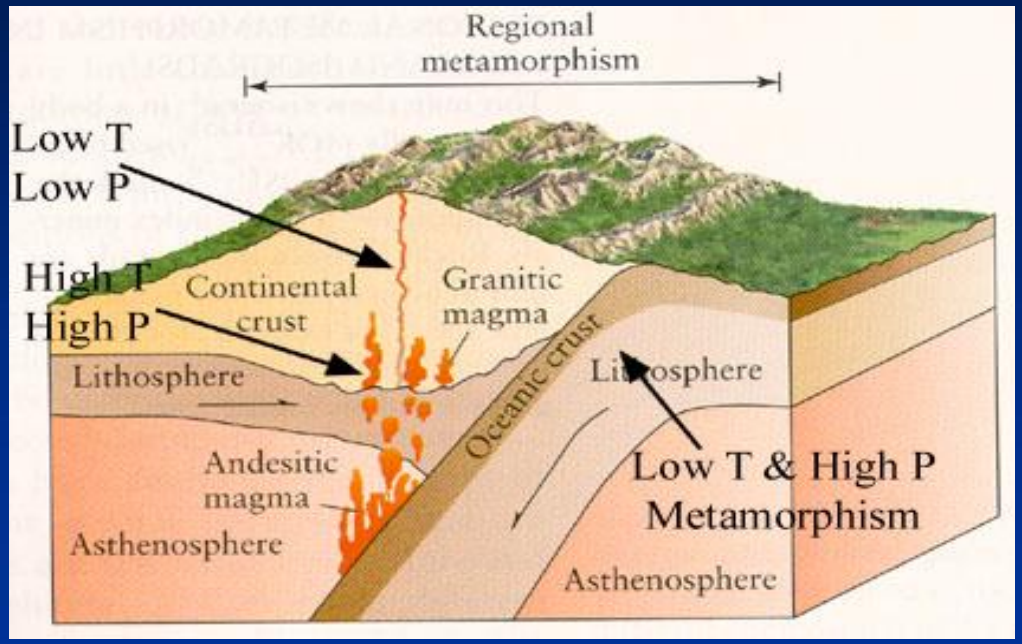


Hot Chemically-Reactive Fluids and Tectonic Stresses Too!

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

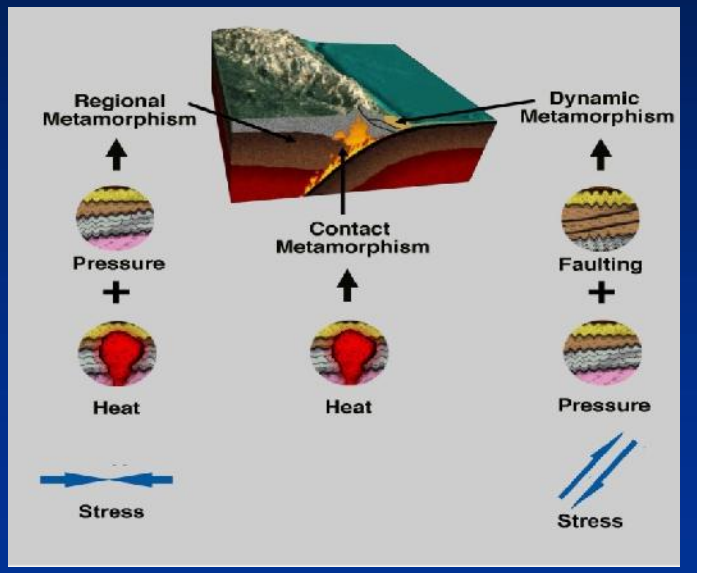
Metamorphic Processes and Grade

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

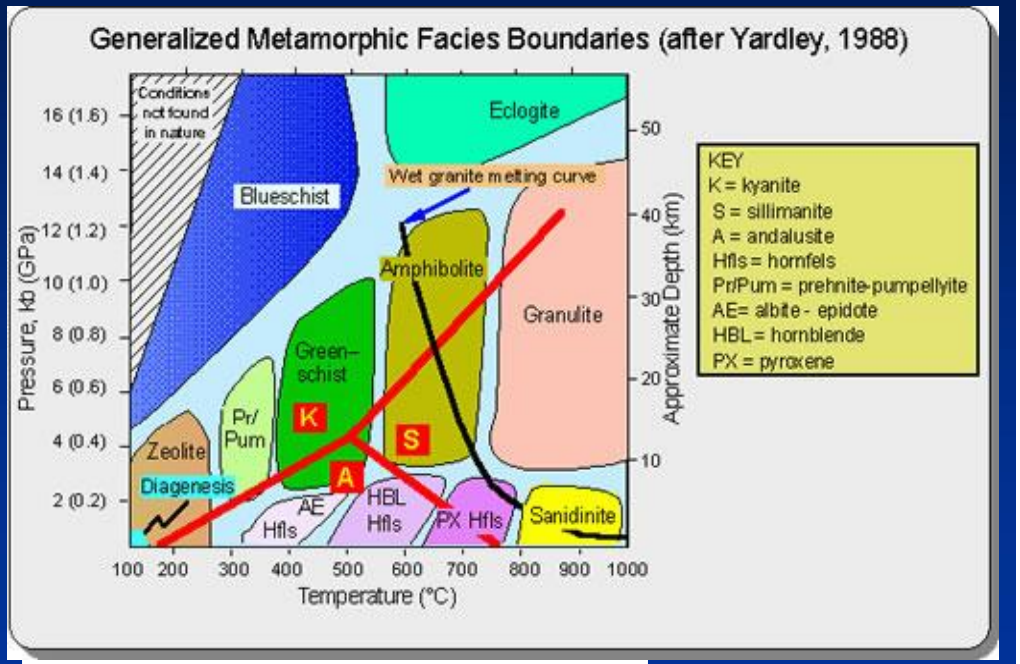
Parent	Low Grade		High Grade
Limestone	Marble		Marble
Sandstone	Quartzite		Quartzite
Shale	Slate	Schist	Gneiss
Granite	-----	Schist	Gneiss
Basalt	Greenschist		Amphibolite

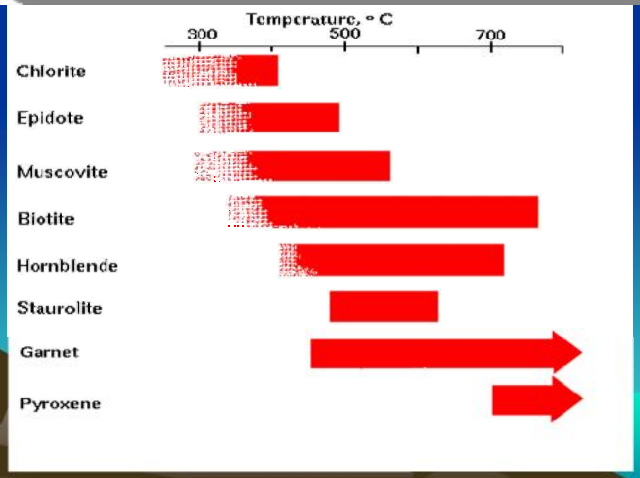
Metamorphic Grade and Mineral Facies

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

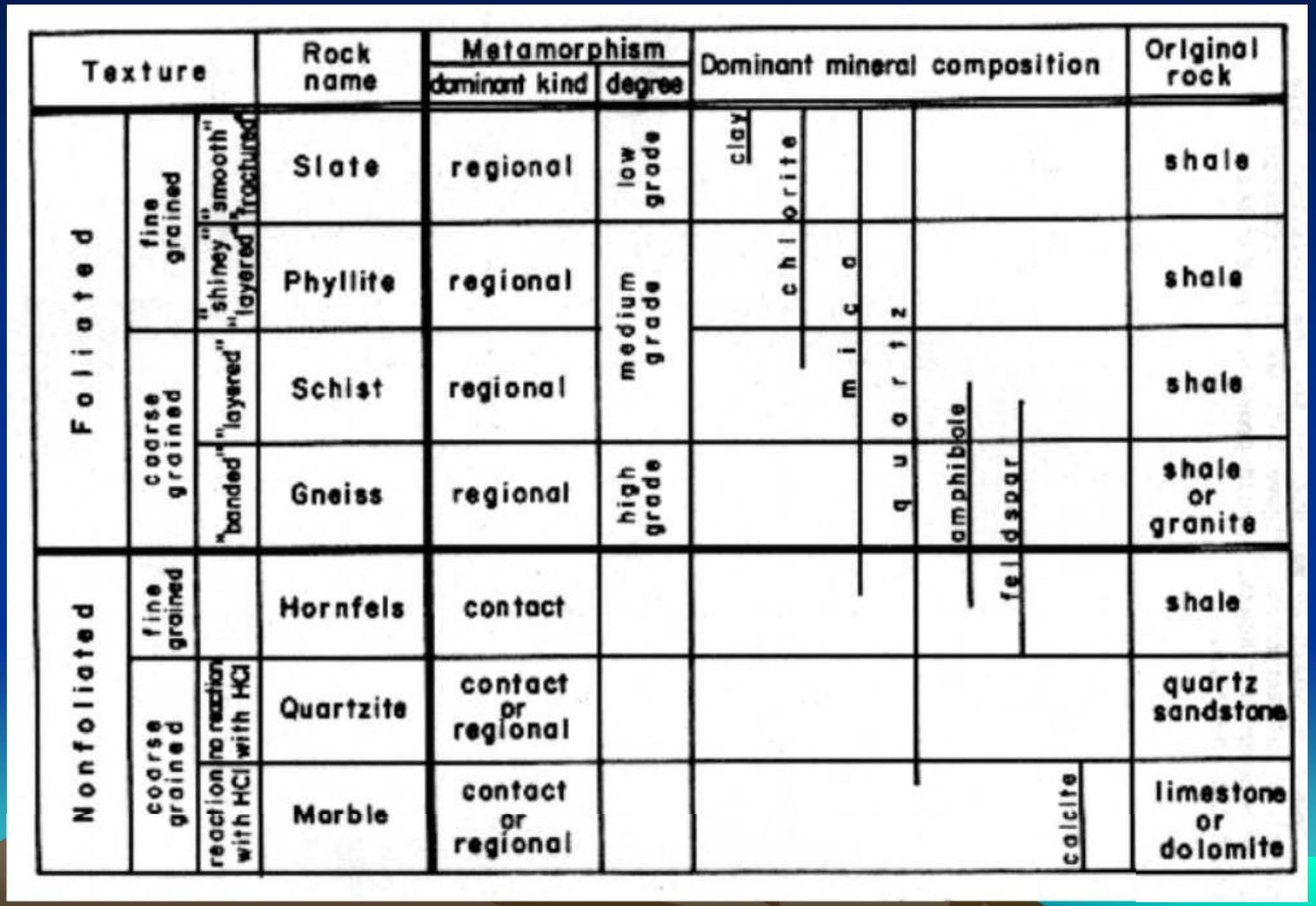
Metamorphic rocks are classified according to several criteria:

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

Parent Rock → Metamorphic Rock Pairs

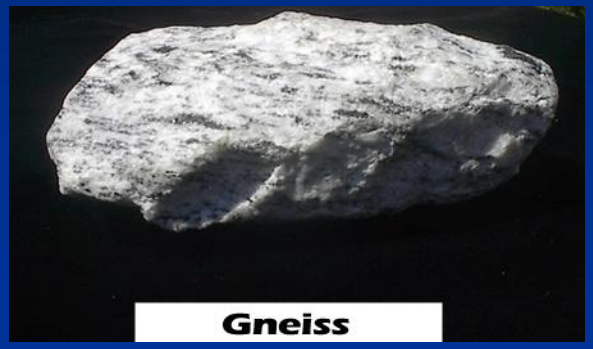
Parent	Grd	Rock	Foliation	Comments
Shale	Low	Slate	cleavage	v fine
		Phyllite	cleavage	'sheen' from fine mica
		Schist	schistocity	mica coarse/visible
	Hi	Gneiss	banding	v coarse
Basalt	Med	Green schist	schistocity	green chlorite
		Ampholite	Banding	black amphibole
	Hi	Blue-schist	schistocity	blue amphibole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

Metamorphic Rock Classification

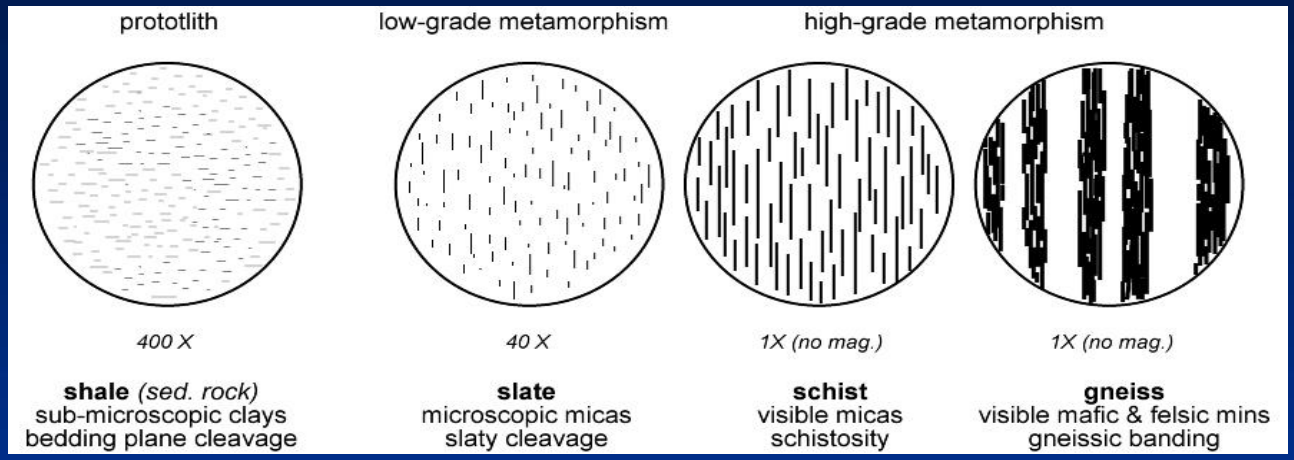


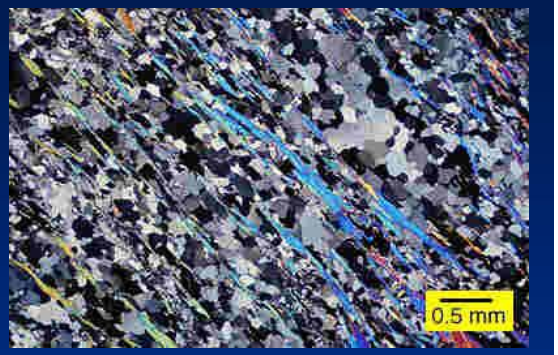
Texture			Rock name	Metamorphism: dominant kind	Metamorphism: degree	Dominant mineral composition	Original rock
Foliated	fine grained	"smooth" fractured	Slate	regional	low grade	clay	shale
		"shiney" "layered"	Phyllite	regional	medium grade	chlorite, mica, quartz	shale
	coarse grained	"layered"	Schist	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

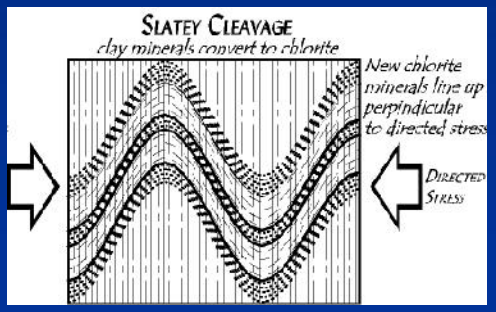


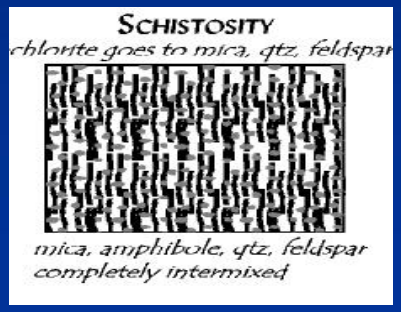
Foliated Metamorphic Textures

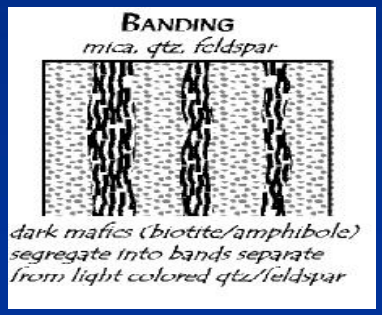




Foliated Textures







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

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

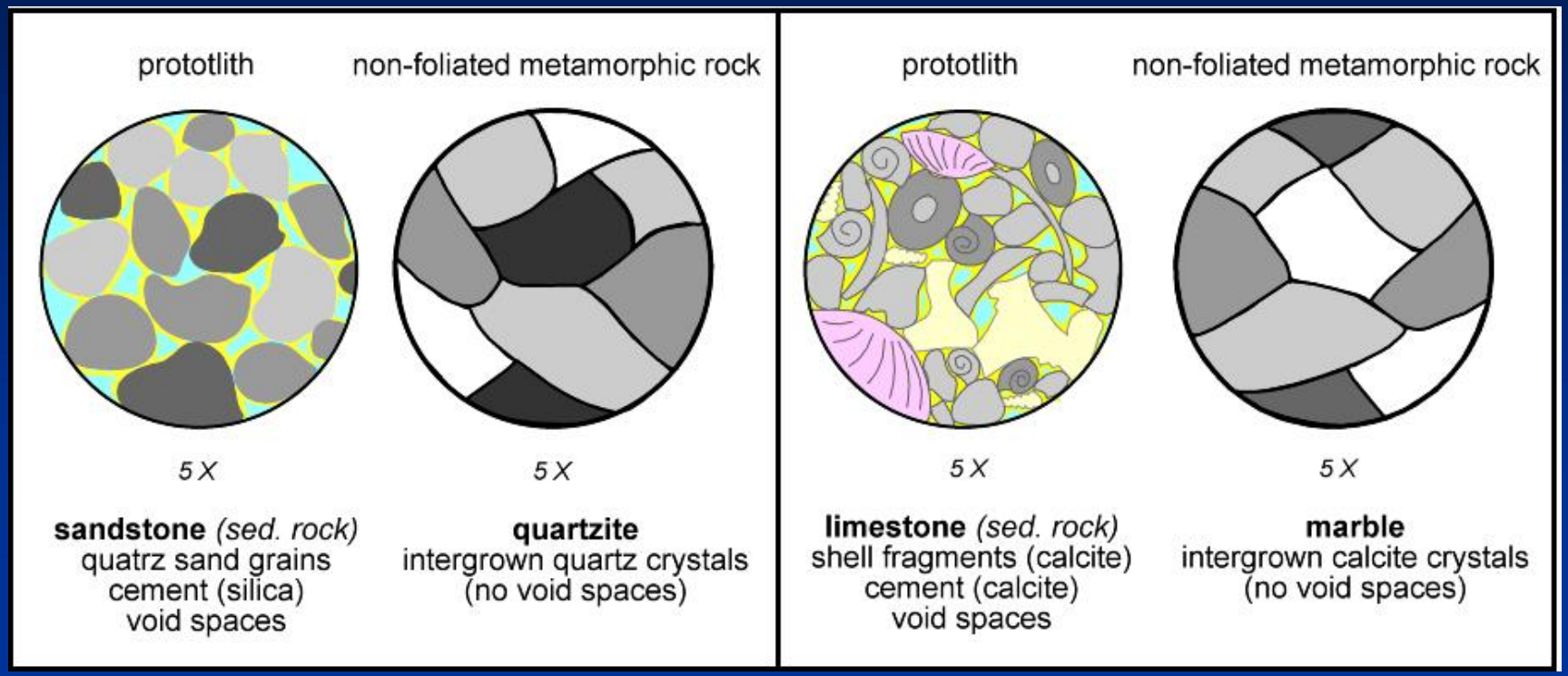
Garnet Gneiss

Close-Up

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

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

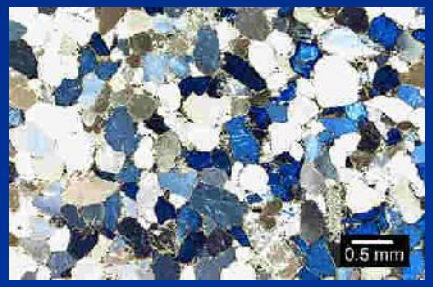
Microgranular

- ✓ **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

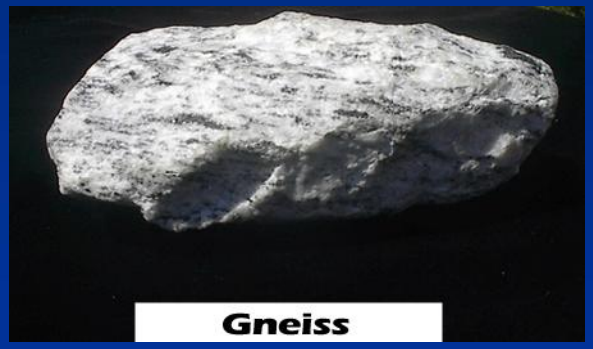
Marble

Most Common Types of Metamorphic Rocks

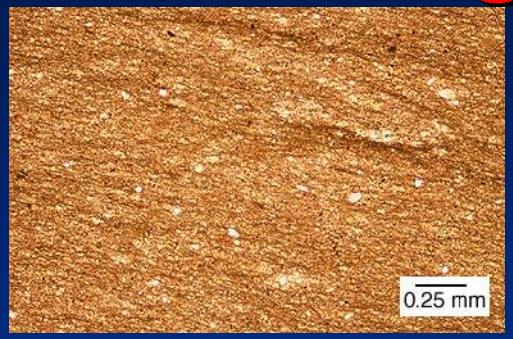
Questions:

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

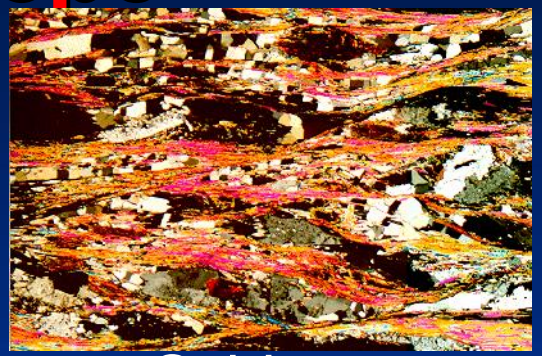


Common Metamorphic Rocks Under a Microscope

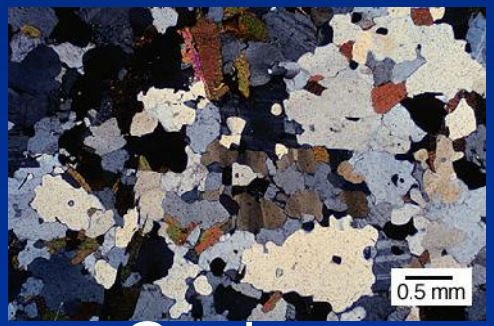


Slate

Phyllite



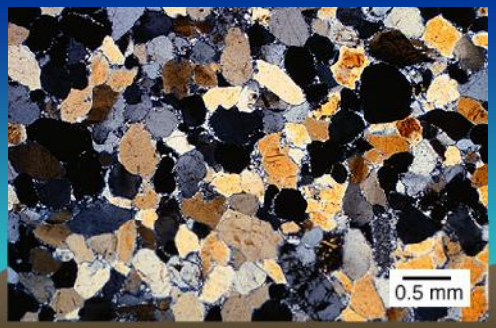
Schist



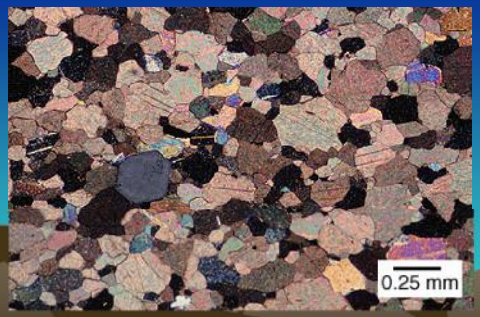
Gneiss

Amphibolite

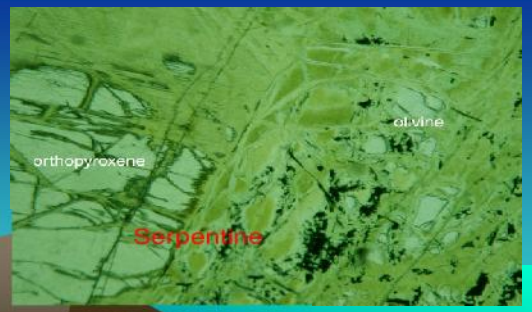
Hornfels



Quartzite



Marble



Serpentinite

Metamorphic Rock Classification

A Three Step Process

1) Determine Texture

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

2) Determine Composition

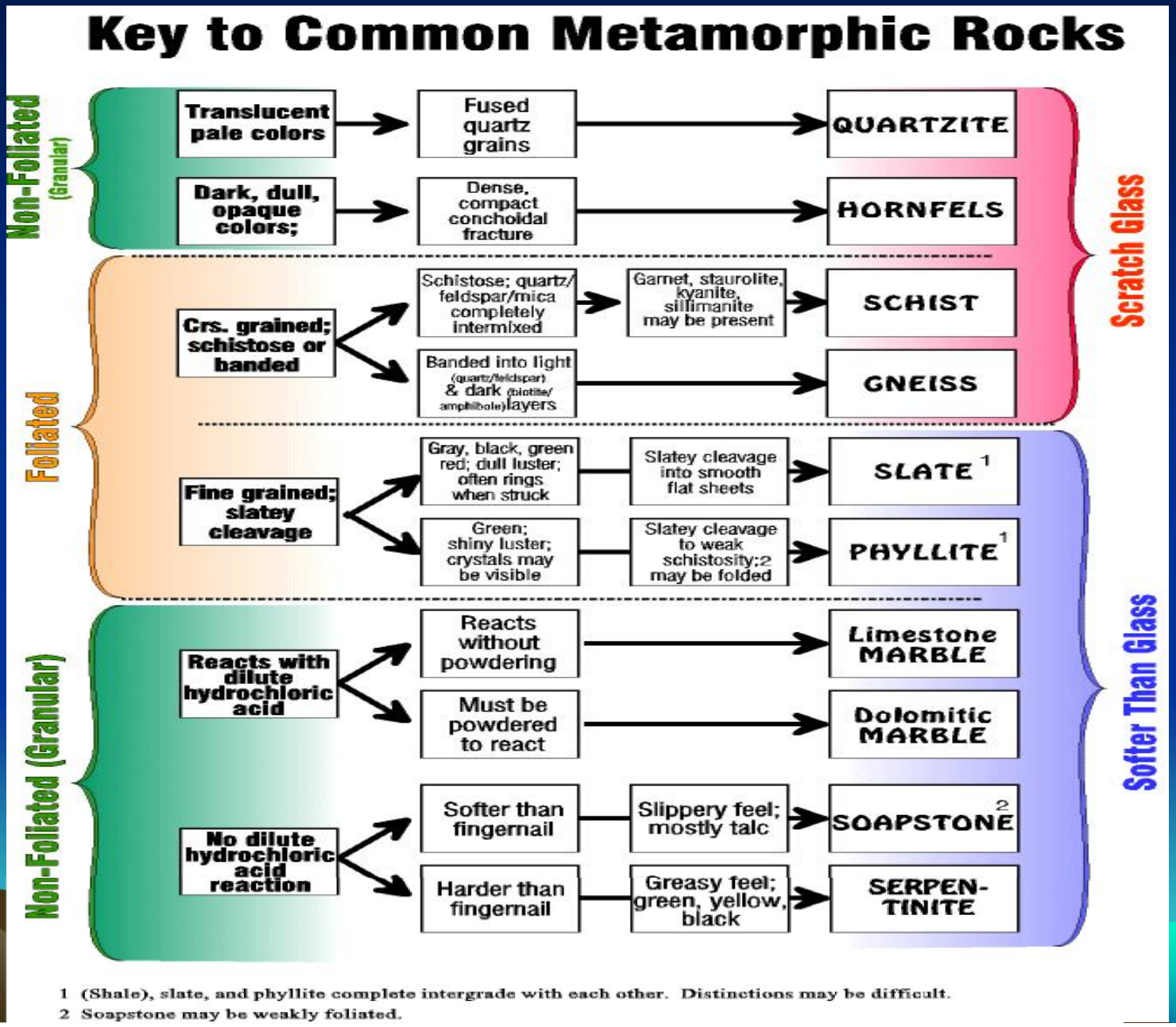
- ✓ Mineralogy?

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