Chapter 1
Minerals: Building Blocks of Rocks
Review

EARTH SCIENCE
GLY 1001
QUIZ 2

Name KEY ______________________ **Ed Meyers**

Match the following words with their definition and/or description:

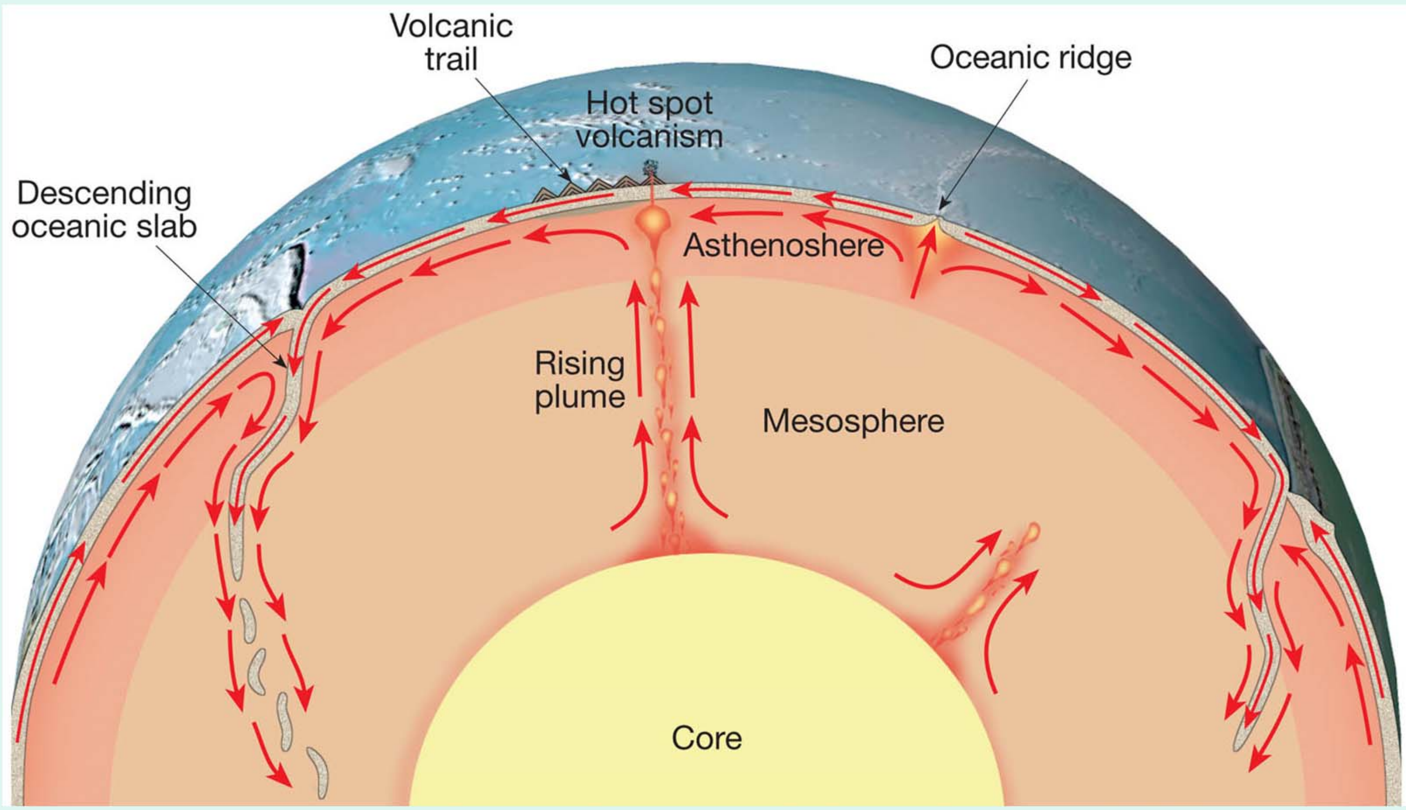
1. I Strata (beds)
2. J Weathering
3. C Magma
4. F Porphyritic Texture
5. G Chemical Sedimentary Rock
6. E Nonfoliated texture
7. H Rock Cycle
8. D Metamorphic Rock
9. A Lava
10. B Lithification

Minerals: Building Blocks of Rocks

- By definition a *mineral* is/has
  - Naturally occurring
  - Inorganic solid
  - Ordered internal molecular structure
  - Definite chemical composition

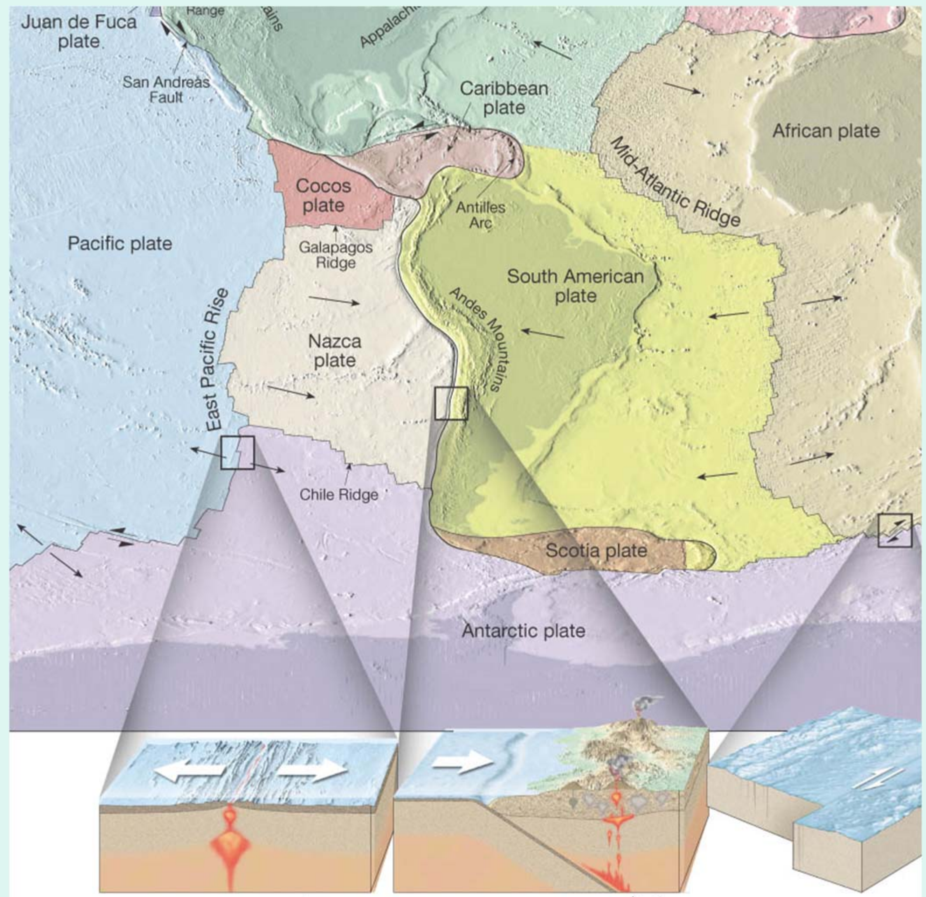


Plate Tectonics



Where do minerals form

Plate boundaries = Igneous and Metamorphic minerals
Oceans and water = Sedimentary minerals



Where do minerals form

Magma

Slow cooling = large crystals

Fast cooling = small crystals

Where do minerals form

Metamorphic Minerals

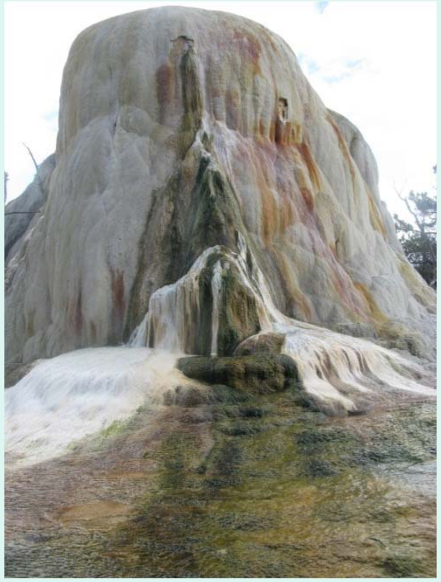
Heating and recrystallization

of existing rocks

Where do minerals form

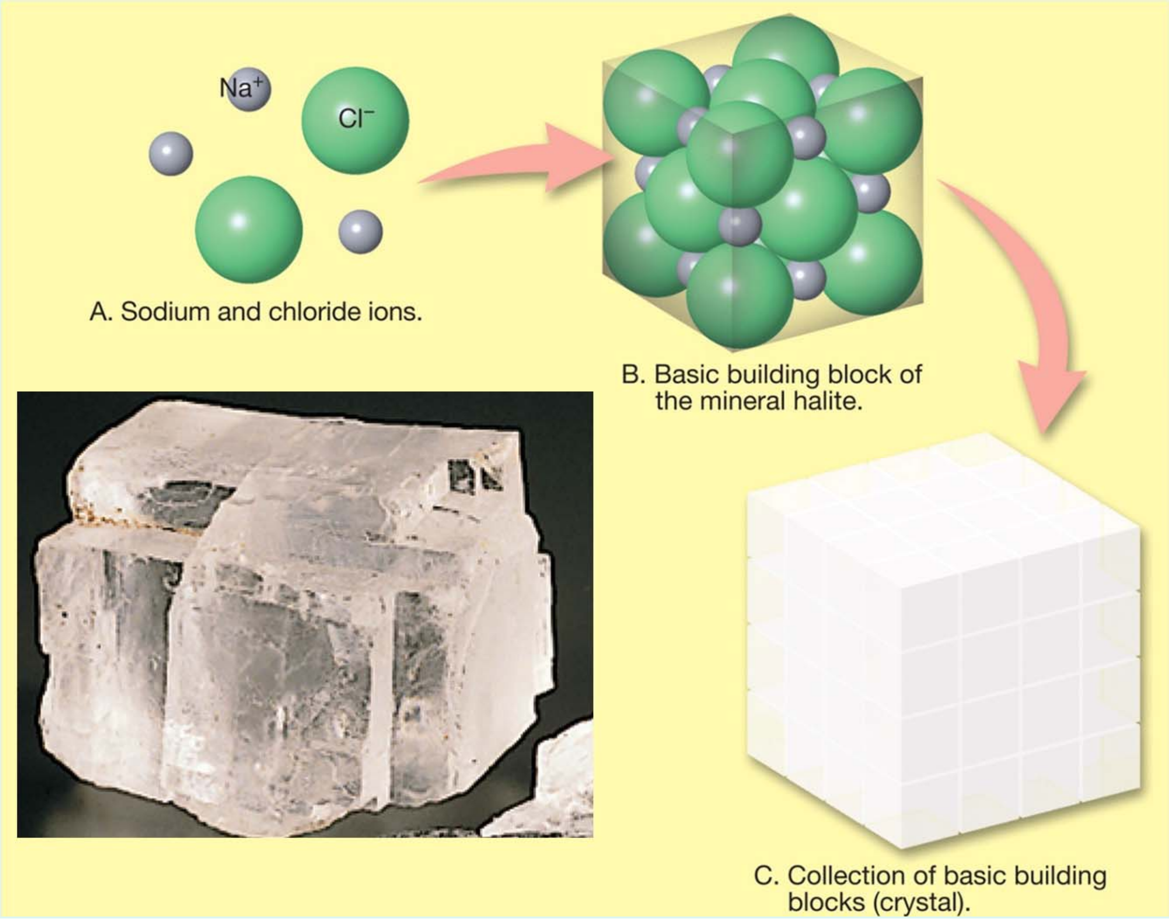
Sedimentary

Precipitation of minerals from water

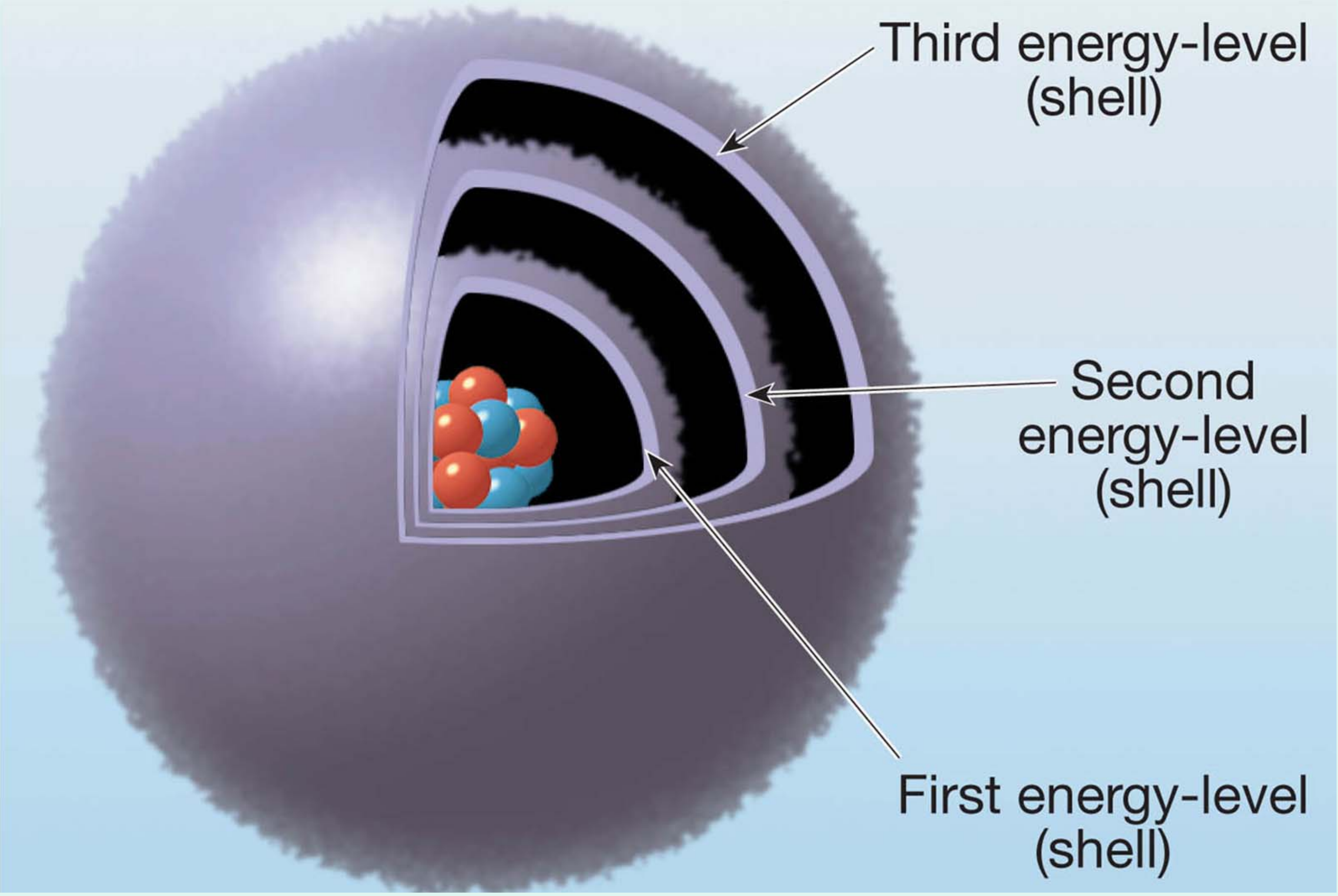


Composition and Structure of Minerals

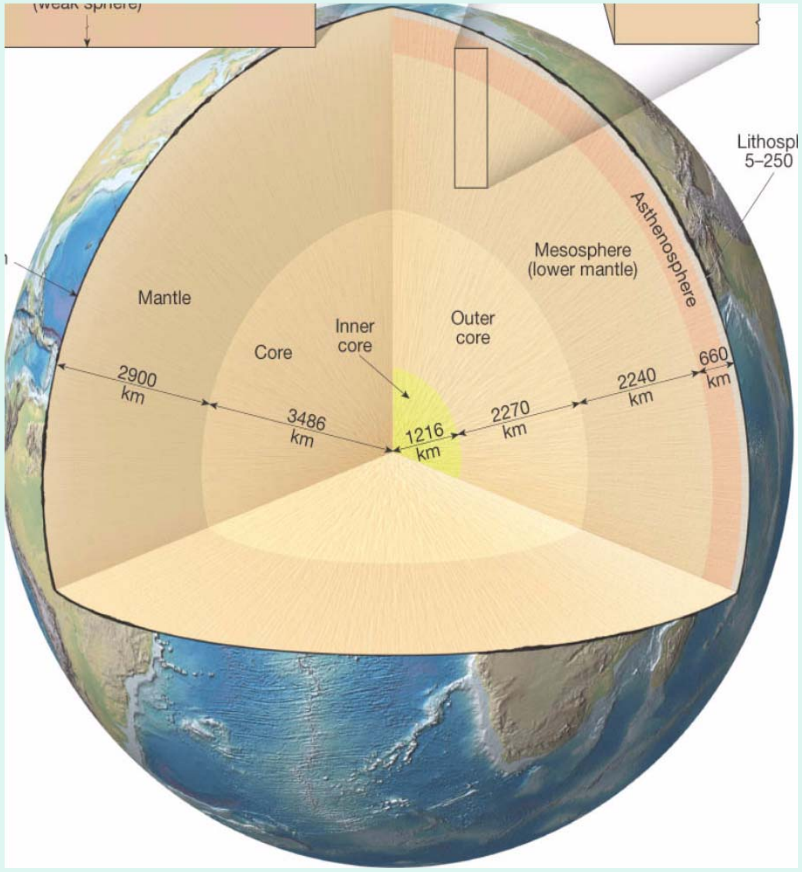
Atoms ⟶ Elements ⟶ Minerals ⟶ Rocks



Structure of an Atom



Earth Composition



Earth Consists of the Core, Mantle, and Crust

Elemental Abundances
Earth as a whole vs Crust

Earth		Crust	
Oxygen	35%	Oxygen	47%
Iron	24%	Iron	5.5%
Silicon	17%	Silicon	27%
Magnesium	14%	Magnesium	2.1%
Sulfur	6%	Sulfur	<1%
Aluminum	1%	Aluminum	8%
Calcium	1%	Calcium	3.7%

Identifying Minerals

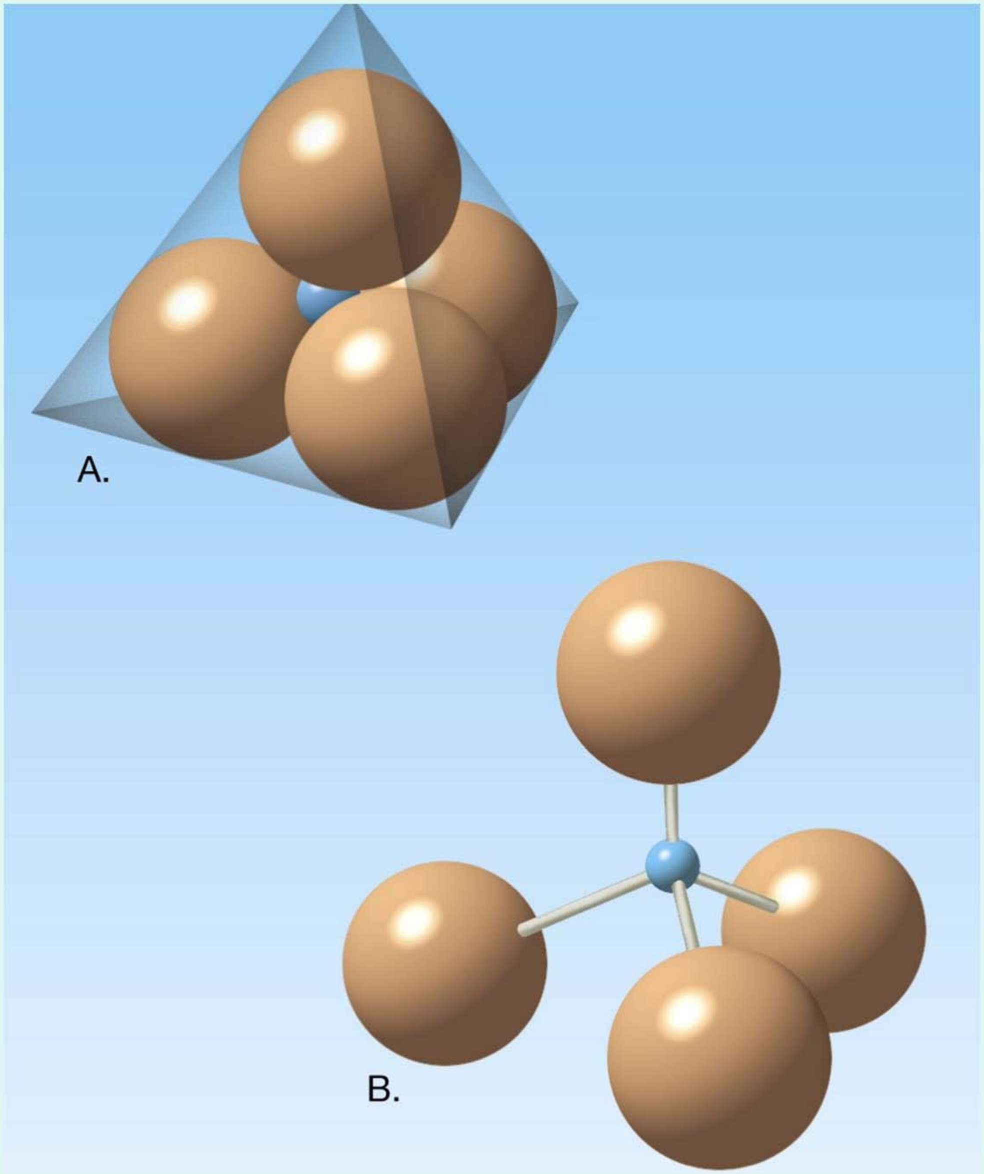
Physical Properties of Minerals

1. Crystal form
2. Luster
3. Color
4. Cleavage
5. Streak
6. Hardness
7. Smell
8. Taste
9. Magnetism
10. Specific Gravity
11. Fracture
12. Refraction

Mineral Groups

Silicates

- **Most important mineral group**
  - **Comprise most rock-forming minerals**
  - **Very abundant due to large % of silicon and oxygen in Earth's crust**
- **Silicon-oxygen tetrahedron**
  - **Fundamental building block**
  - **Four oxygen ions surrounding a much smaller silicon ion**



Two Illustrations of the Si–O Tetrahedron

Mineral Groups

Nearly 4000 minerals have been named

Rock-forming minerals

- **Common minerals that make up most of the rocks of Earth's crust**
- **Only a few dozen members**
- **Composed mainly of the 8 elements that make up over 98% of the continental crust**

Mineral Groups

Silicates

- **Most important mineral group**
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  - **Very abundant due to large % of silicon and oxygen in Earth’s crust**
- **Silicon-oxygen tetrahedron**
  - **Fundamental building block**
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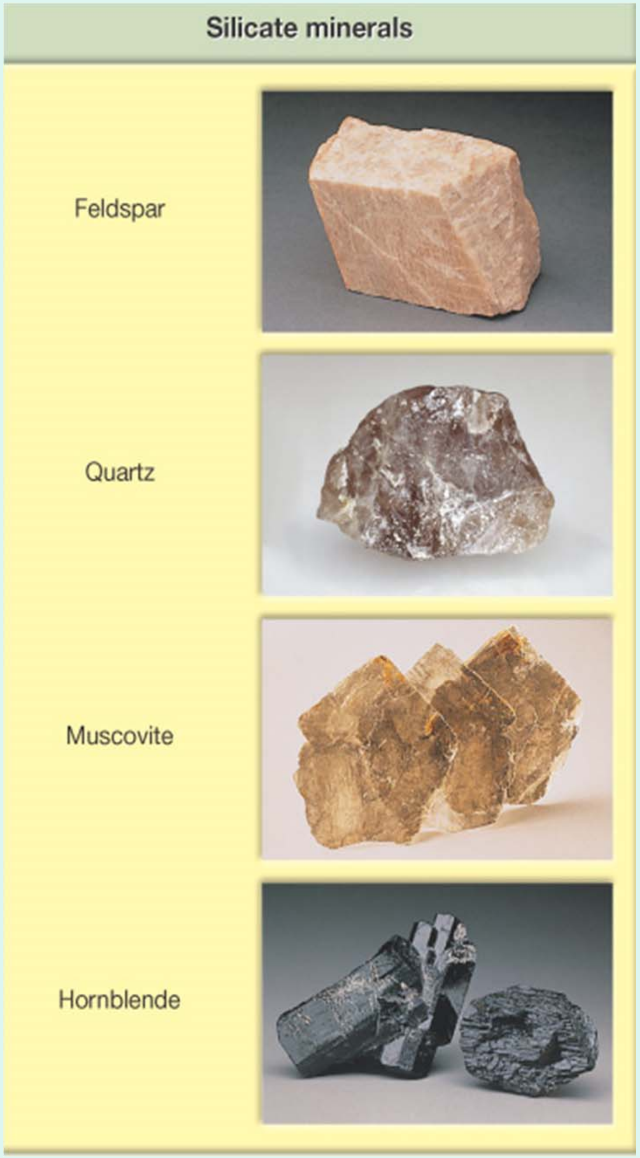
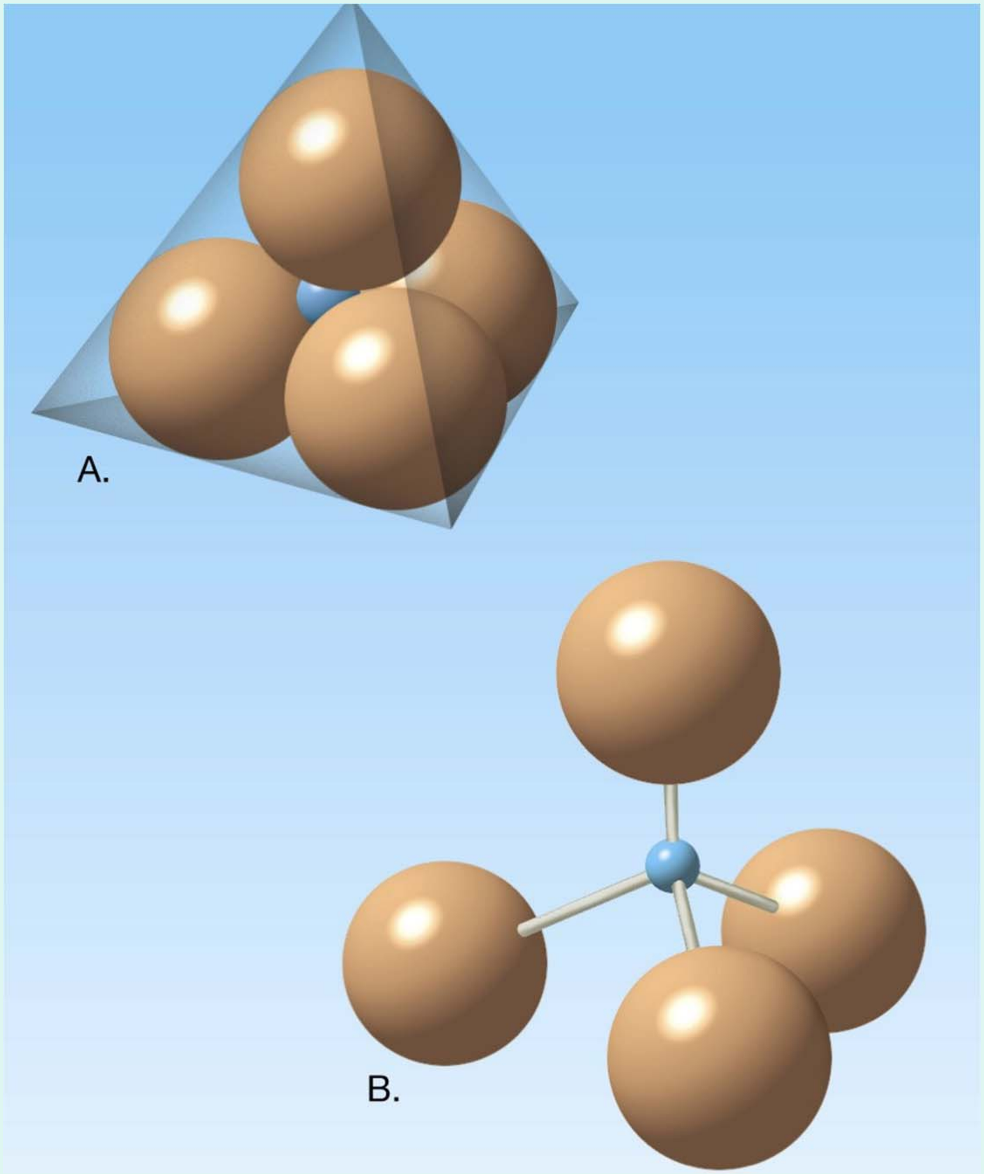
Mineral Groups

Common silicate minerals

- Feldspar group
  - Most common mineral group
- Quartz
  - Only common silicate composed entirely of oxygen and silicon

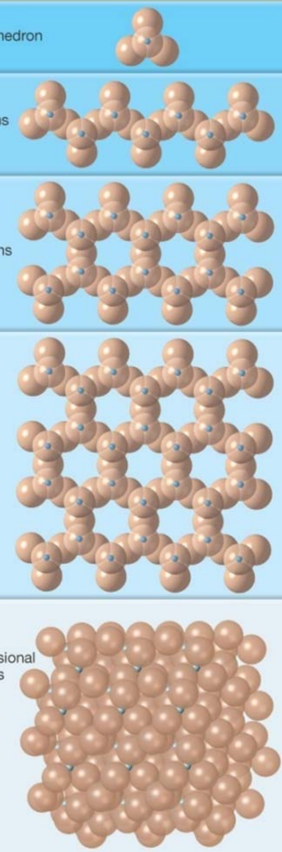




Two Illustrations of the Si–O Tetrahedron

Silicate Mineral Structures

Mineral		Idealized Formula	Cleavage	Silicate Structure
Olivine		$(Mg, Fe)_2SiO_4$	None	Single tetrahedron
Pyroxene group (Augite)		$(Mg,Fe)SiO_3$	Two planes at right angles	Single chains
Amphibole group (Hornblende)		$Ca_2(Fe,Mg)_5Si_8O_{22}(OH)_2$	Two planes at 60° and 120°	Double chains
Micas	Biotite	$K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$	One plane	Sheets
	Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$		
Feld-spars	Potassium feldspar (Orthoclase)	$KAlSi_3O_8$	Two planes at 90°	Three-dimensional networks
	Plagioclase	$(Ca,Na)AlSi_3O_8$		
Quartz		SiO_2	None	



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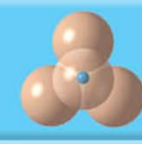
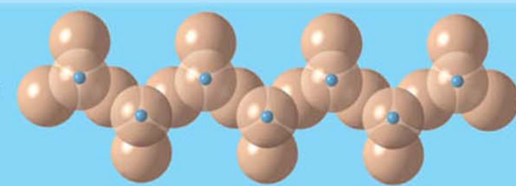
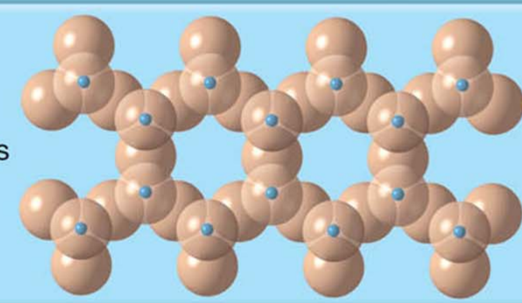
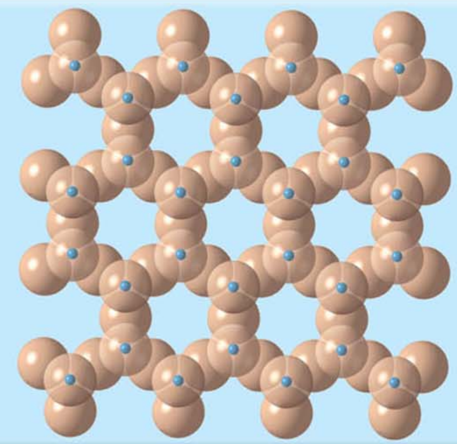
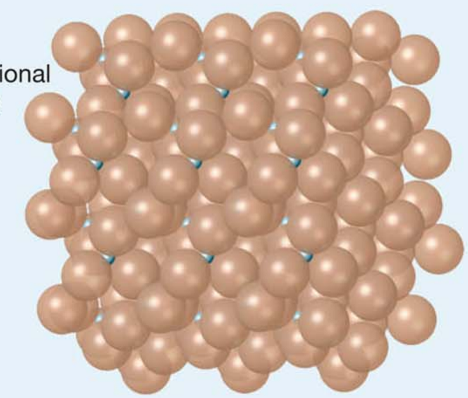
Olivine	$(Mg, Fe)_2SiO_4$	None	Single tetrahedron 
Pyroxene group (Augite)	$(Mg,Fe)SiO_3$	Two planes at right angles	Single chains 
Amphibole group (Hornblende)	$Ca_2(Fe,Mg)_5Si_8O_{22}(OH)_2$	Two planes at 60° and 120°	Double chains 

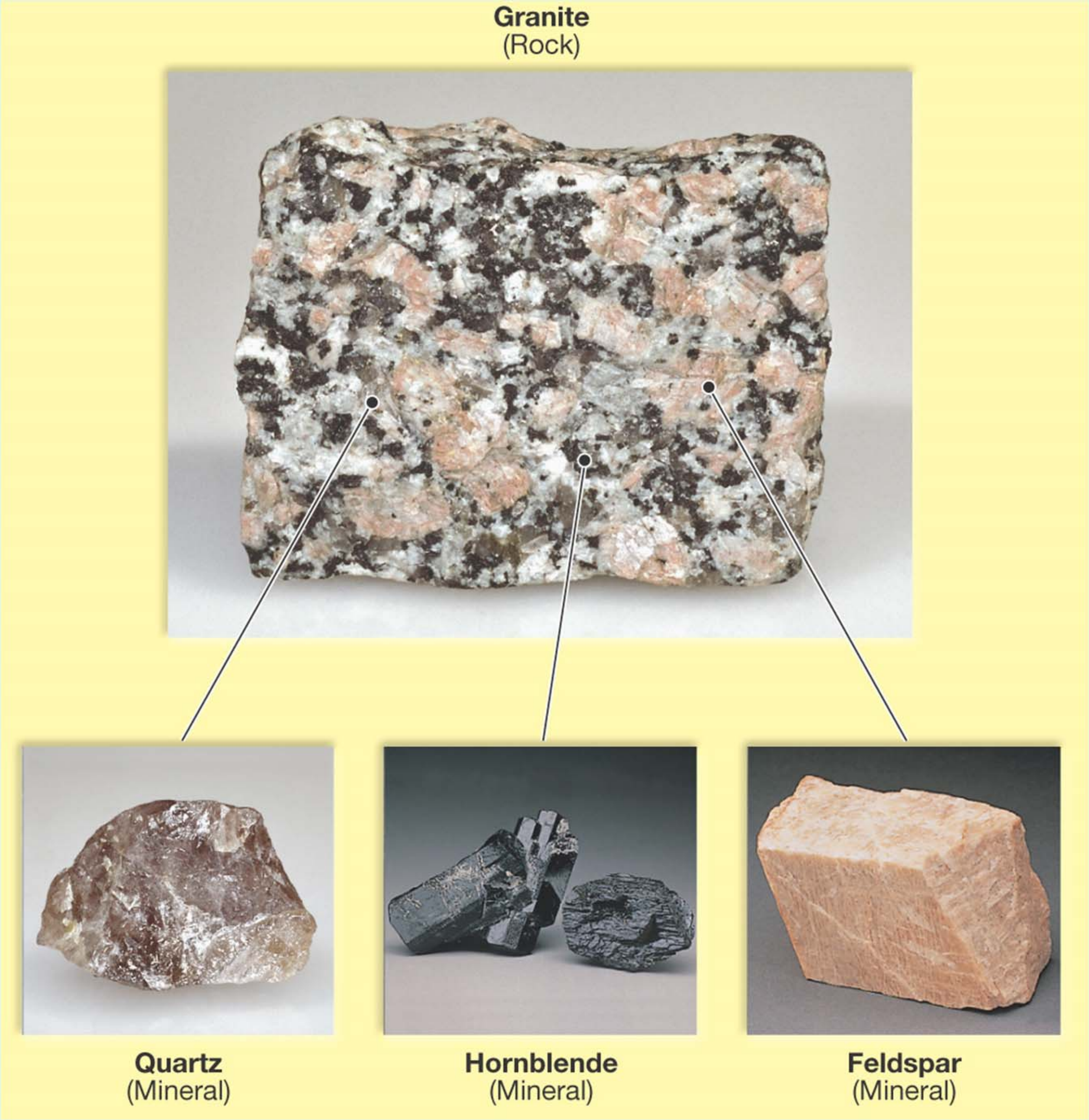
Silicate Mineral Structures

Micas	Biotite	$K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$	One plane	Sheets 
	Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$		
Feld-spars	Potassium feldspar (Orthoclase)	$KAlSi_3O_8$	Two planes at 90°	Three-dimensional networks 
	Plagioclase	$(Ca,Na)AlSi_3O_8$		
Quartz		SiO_2	None	

Mineral Resources and Reserves

- Resources are minerals that can be recovered for use
- Reserves include mineral deposits already identified that can be profitability extracted
- Resources include reserves, deposits that can not economically recovered, and minerals not yet discovered

Rocks are an aggregate of minerals

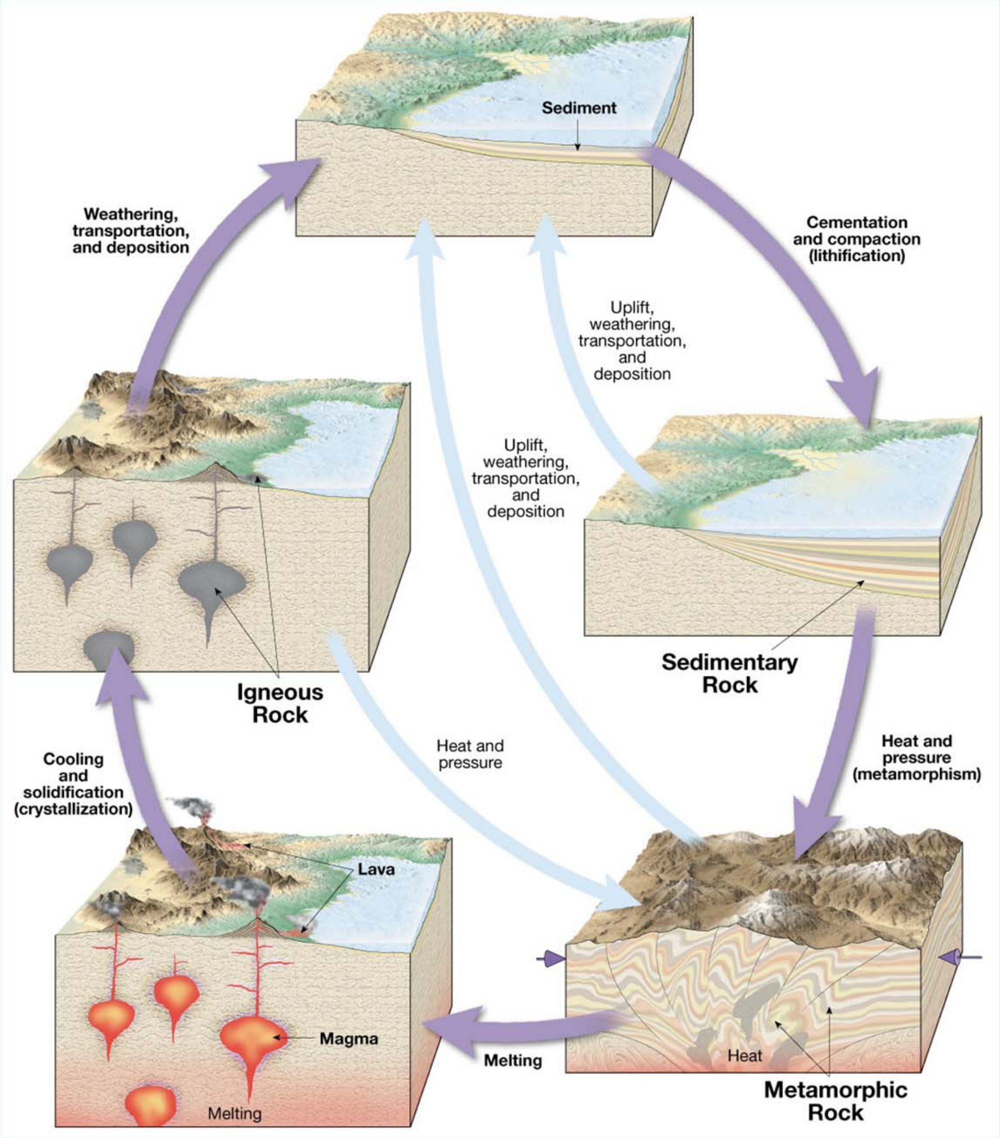


Chapter 2
Rocks: Materials of the Solid Earth

Rock Cycle

- **Shows the interrelationships among the three rock types**
- **Earth as a system: The *rock cycle***

The Rock Cycle



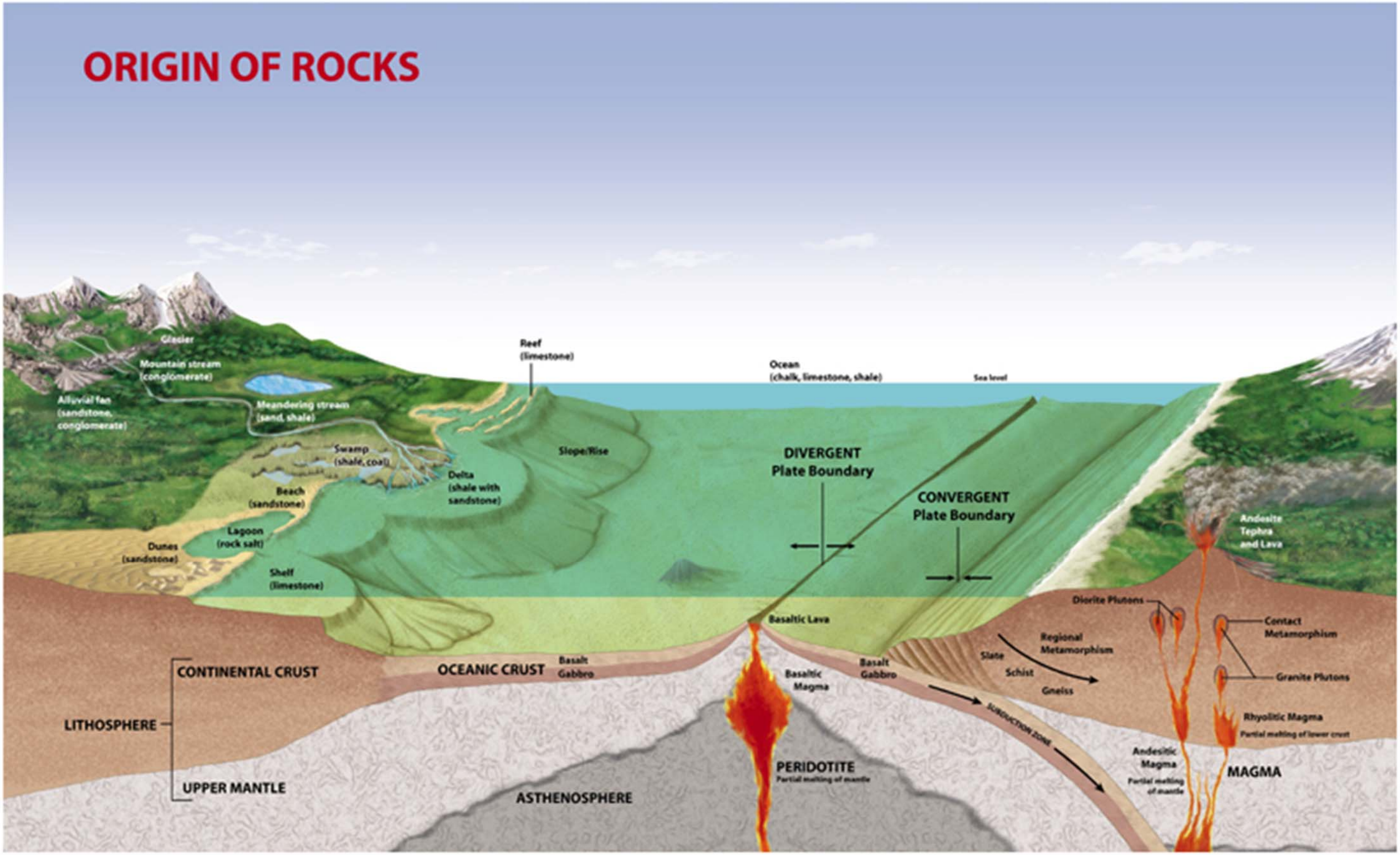
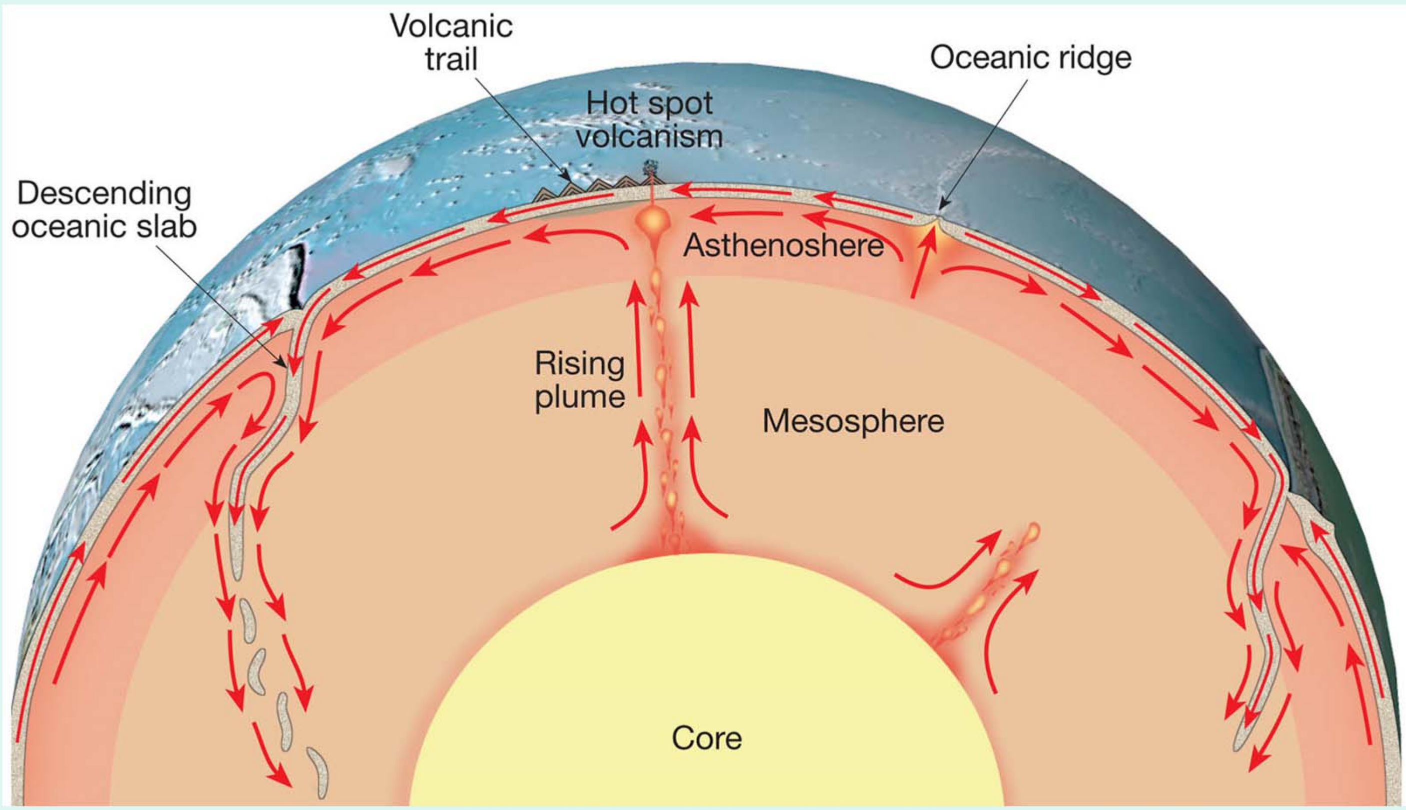
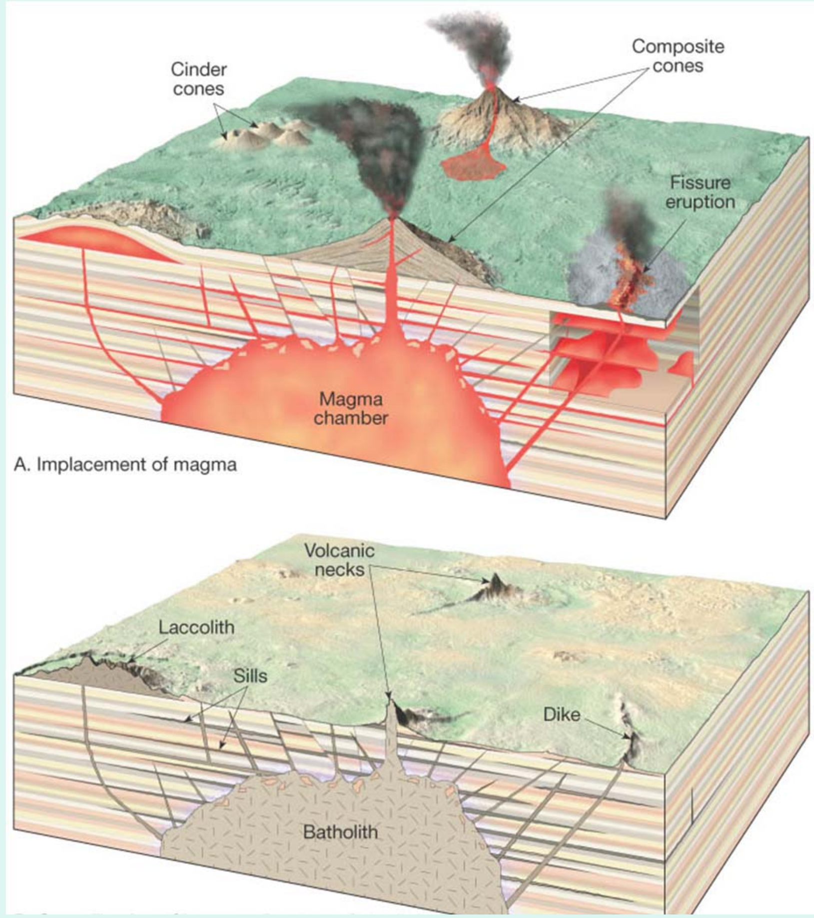

ORIGIN OF ROCKS
Glacier
Mountain stream (conglomerate)
Alluvial fan (sandstone, conglomerate)
Meandering stream (sand, shale)
Swamp (shale, coal)
Beach (sandstone)
Lagoon (rock salt)
Dunes (sandstone)
Shelf (limestone)
Delta (shale with sandstone)
Reef (limestone)
Slope/Rise
Ocean (chalk, limestone, shale)
Sea level
DIVERGENT Plate Boundary
CONVERGENT Plate Boundary
Andesite Tephra and Lava
Basaltic Lava
Diorite Plutons
Contact Metamorphism
Regional Metamorphism
Slate
Schist
Gneiss
Granite Plutons
CONTINENTAL CRUST
OCEANIC CRUST
Basalt Gabbro
Basaltic Magma
Basalt Gabbro
SUBDUCTION ZONE
Rhyolitic Magma
Partial melting of lower crust
LITHOSPHERE
UPPER MANTLE
ASTHENOSPHERE
PERIDOTITE
Partial melting of mantle
Andesitic Magma
Partial melting of mantle
MAGMA

Plate Tectonics



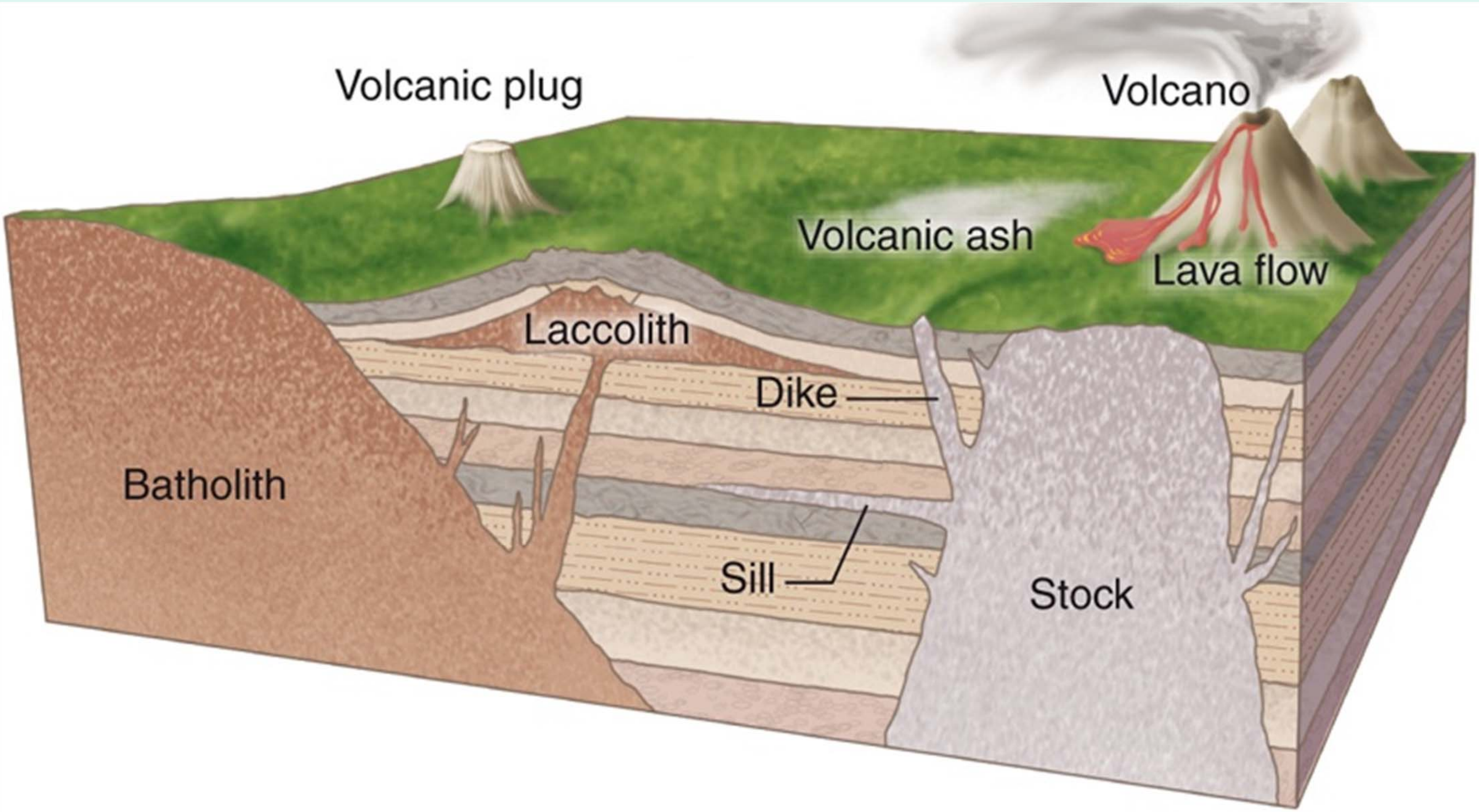
Igneous Rocks

Form as magma cools and crystallizes



Rocks formed inside Earth are called *plutonic* or *intrusive* rocks

Igneous Rocks

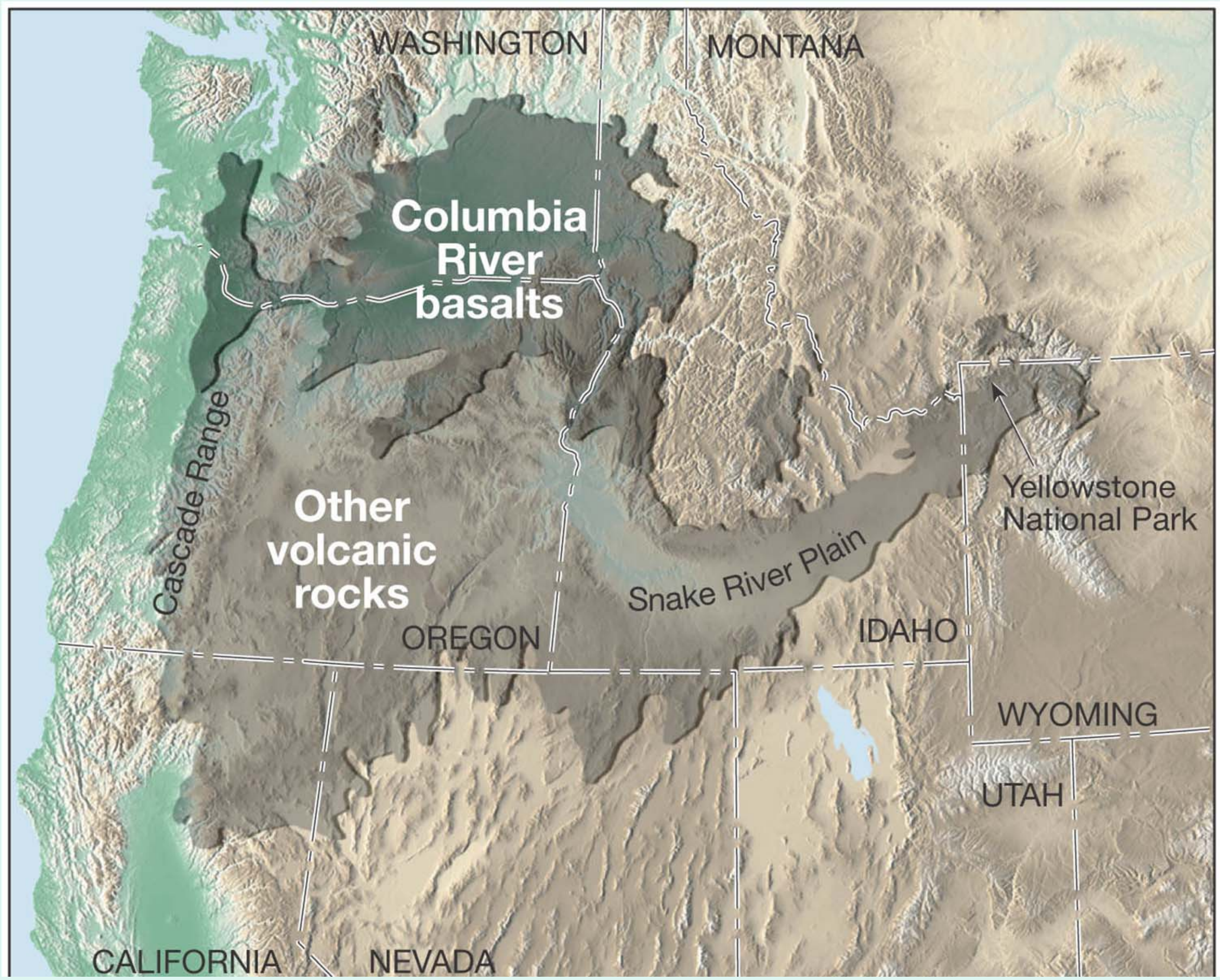


Plutonic rocks can be huge formations

Igneous Rocks

- **Rocks formed on the surface**
  - **Formed from *lava* (a material similar to magma, but without gas)**
  - **Called *volcanic* or *extrusive* rocks**

Extrusive rocks can also be huge formations



Igneous Rocks

- **Crystallization of magma**
  - **Ions are arranged into orderly patterns**
  - **Crystal size is determined by the rate of cooling**
    - **Slow rate forms large crystals**
    - **Fast rate forms microscopic crystals**
    - **Very fast rate forms glass**

Igneous Rocks

- **Classification is based on the rock's texture and mineral constituents**
  - **Texture**
    - **Size and arrangement of crystals**
    - **Types**
      - ***Fine-grained*—fast rate of cooling**
      - ***Coarse-grained*—slow rate of cooling**
      - ***Porphyritic* (two crystal sizes)— two rates of cooling**
      - ***Glassy*—very fast rate of cooling**

Fine-Grained Igneous Texture

Course-Grained Igneous Texture

Obsidian Exhibits a Glassy Texture

Porphyritic Igneous Texture

Igneous Compositions

- Composed mainly of silicate minerals
- Two major groups
  - Dark silicates = rich in iron and/or magnesium
  - Light silicates = greater amounts of potassium, sodium, and calcium

Igneous Compositions

- Granitic rocks
  - Composed almost entirely of light-colored silicates—quartz and feldspar
  - Also referred to as *felsic: fe*ldspar and *si*lica (quartz)
  - High silica content (about 70 percent)
  - Common rock is *granite*

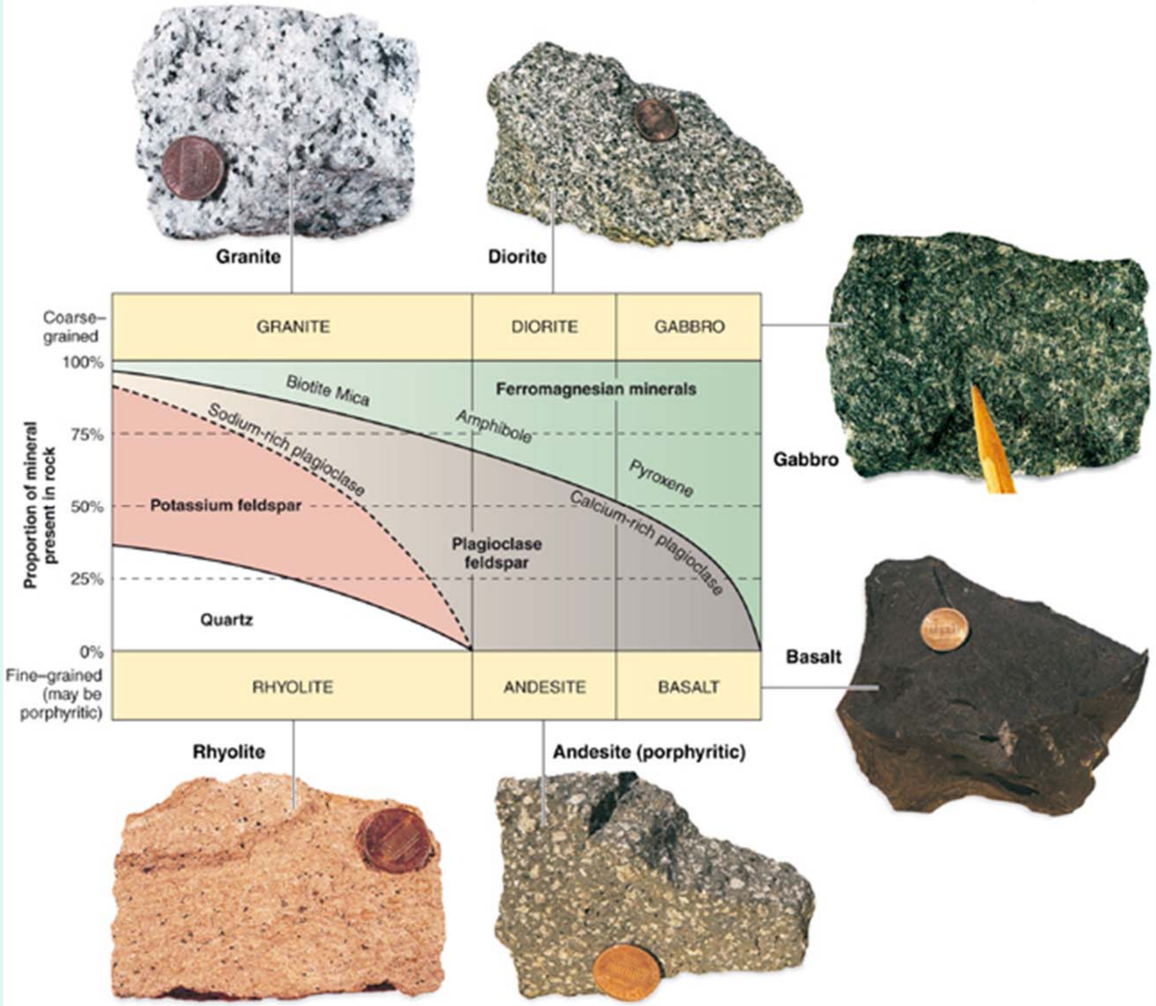
Igneous Compositions

- **Basaltic rocks**
  - **Contain substantial dark silicate minerals and calcium-rich plagioclase feldspar**
  - **Also referred to as *mafic: ma*gnesium and *fe*rrum (iron)**
  - **Common rock is *basalt***

Classification of Igneous Rocks

Chemical Composition		Granitic (Felsic)	Andesitic (Intermediate)	Basaltic (Mafic)	Ultramafic
Dominant Minerals		Quartz Potassium feldspar Sodium-rich plagioclase feldspar	Amphibole Sodium- and calcium-rich plagioclase feldspar	Pyroxene Calcium-rich plagioclase feldspar	Olivine Pyroxene
TEXTURE	Phaneritic (coarse-grained)	**Granite**	**Diorite**	**Gabbro**	**Peridotite**
TEXTURE	Aphanitic (fine-grained)	**Rhyolite**	**Andesite**	**Basalt**	**Komatiite** (rare)
TEXTURE	Porphyritic	"Porphyritic" precedes any of the above names whenever there are appreciable phenocrysts			Uncommon
TEXTURE	Glassy	**Obsidian** (compact glass) **Pumice** (frothy glass)			Uncommon
Rock Color (based on % of dark minerals)		0% to 25%	25% to 45%	45% to 85%	85% to 100%

Classification of Igneous Rocks

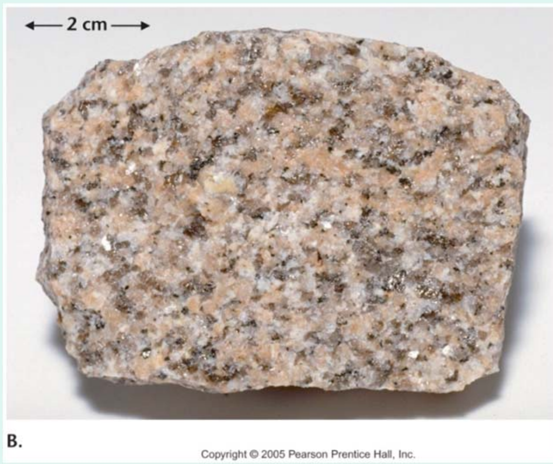


Texture and Composition

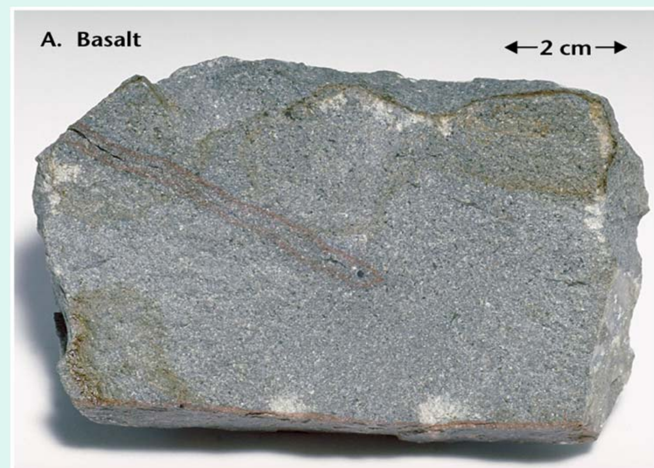
Felsic (quartz rich)

Mafic (quartz poor)

Coarse Grain



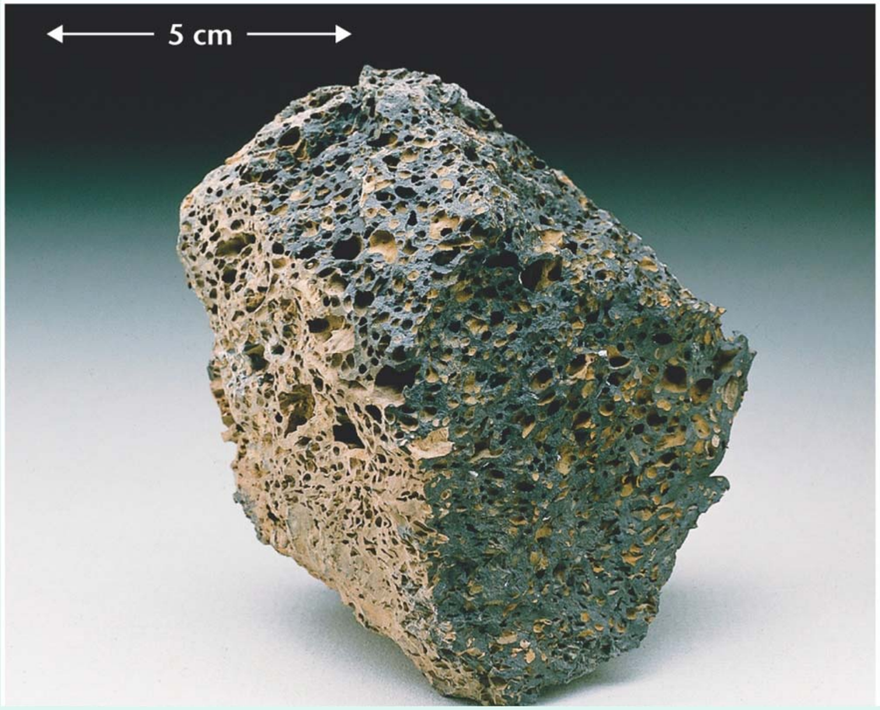
Fine Grain



Other Igneous Rocks

Felsic (quartz rich)

Mafic (quartz poor)



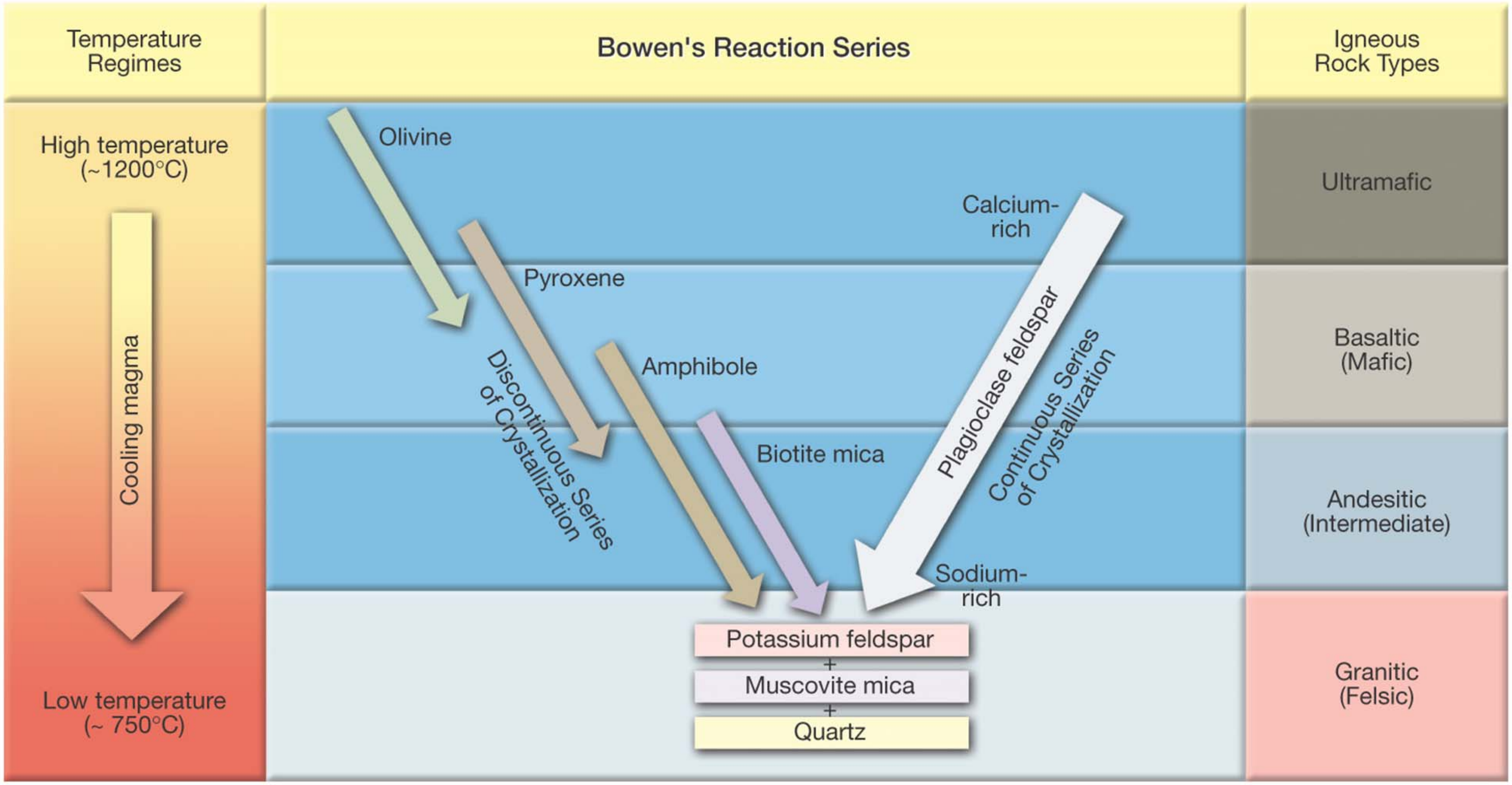
Pumice

Scoria

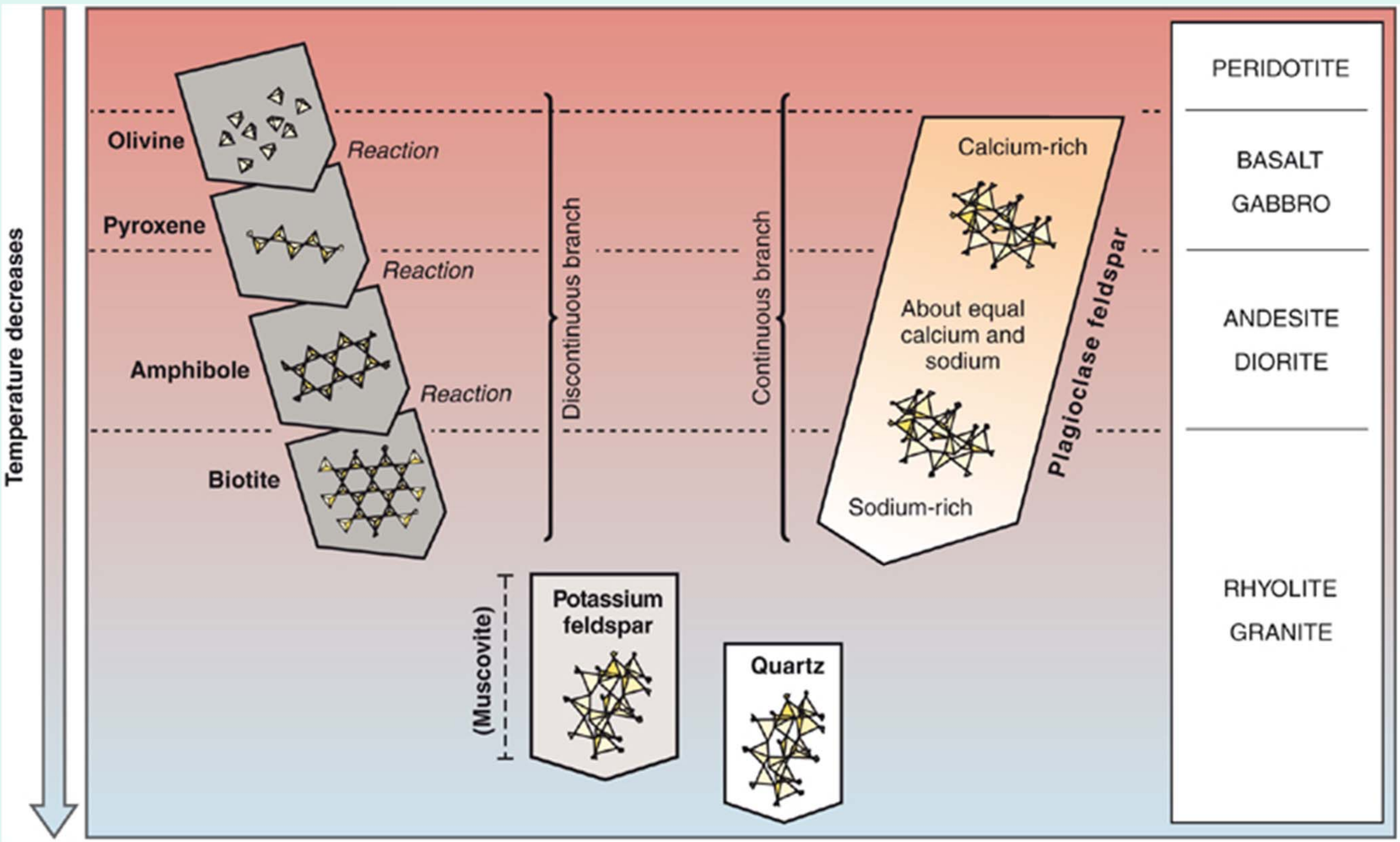
How Different Igneous Rocks Form

- Bowen's reaction series
  - Magma crystallizes over a temperature range of several hundred degrees
  - Therefore, minerals crystallize in a predictable order
  - Last minerals to crystallize are very different in composition from the earlier formed minerals

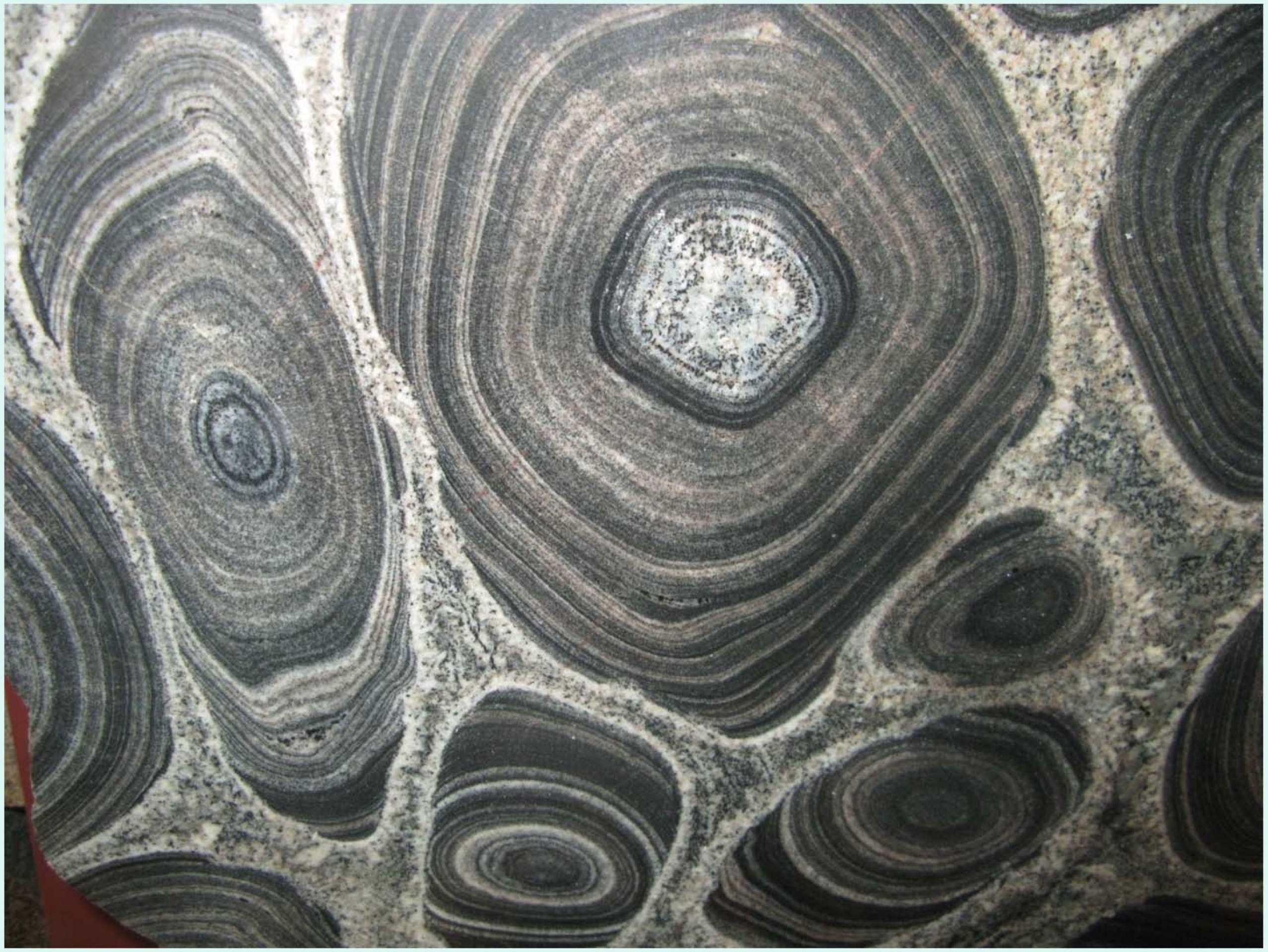
Bowen's Reaction Series



Bowen's Reaction Series



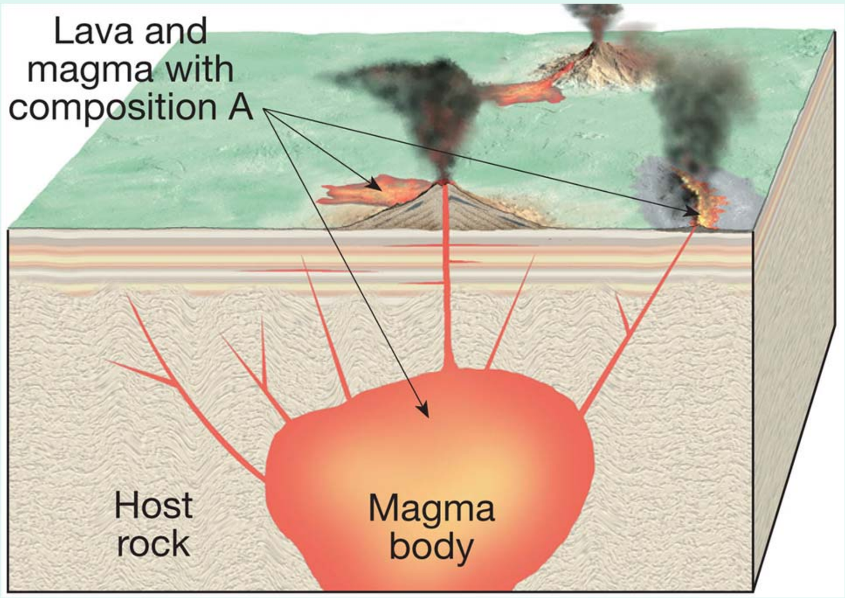
Bowen's Reaction Series – Continuous Reactions Series



How Different Igneous Rocks Form

Magmatic differentiation

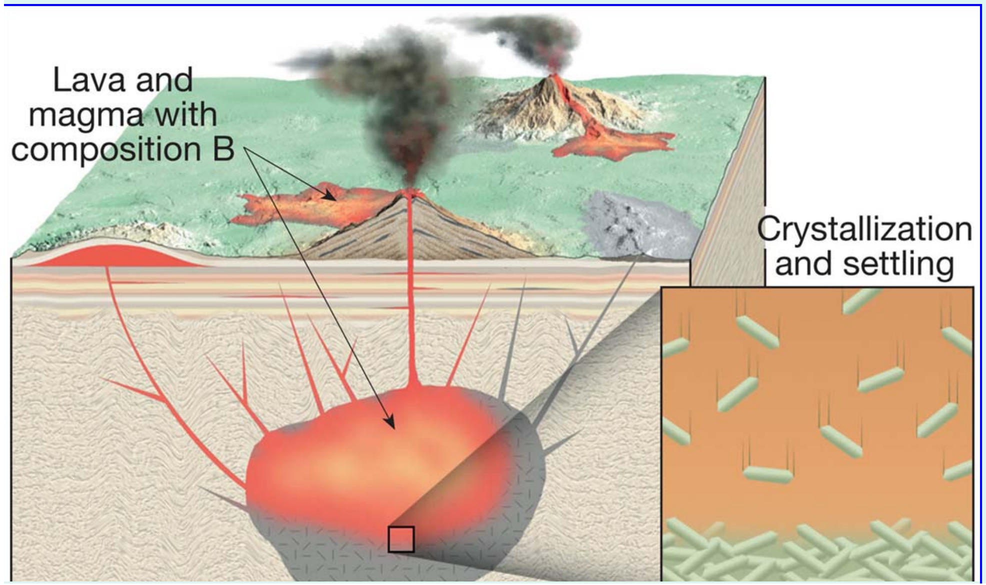
Differentiation refers to the formation of one or more secondary magmas from a single parent magma

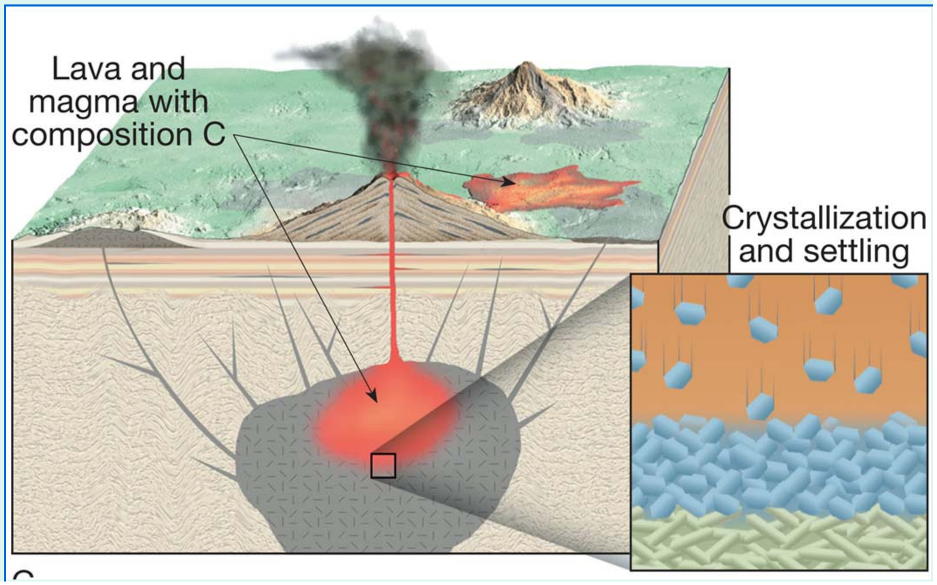


How Different Igneous Rocks Form

One example of this is *crystal settling*

Earlier-formed minerals are denser than the liquid portion and sink to the bottom of the magma chamber





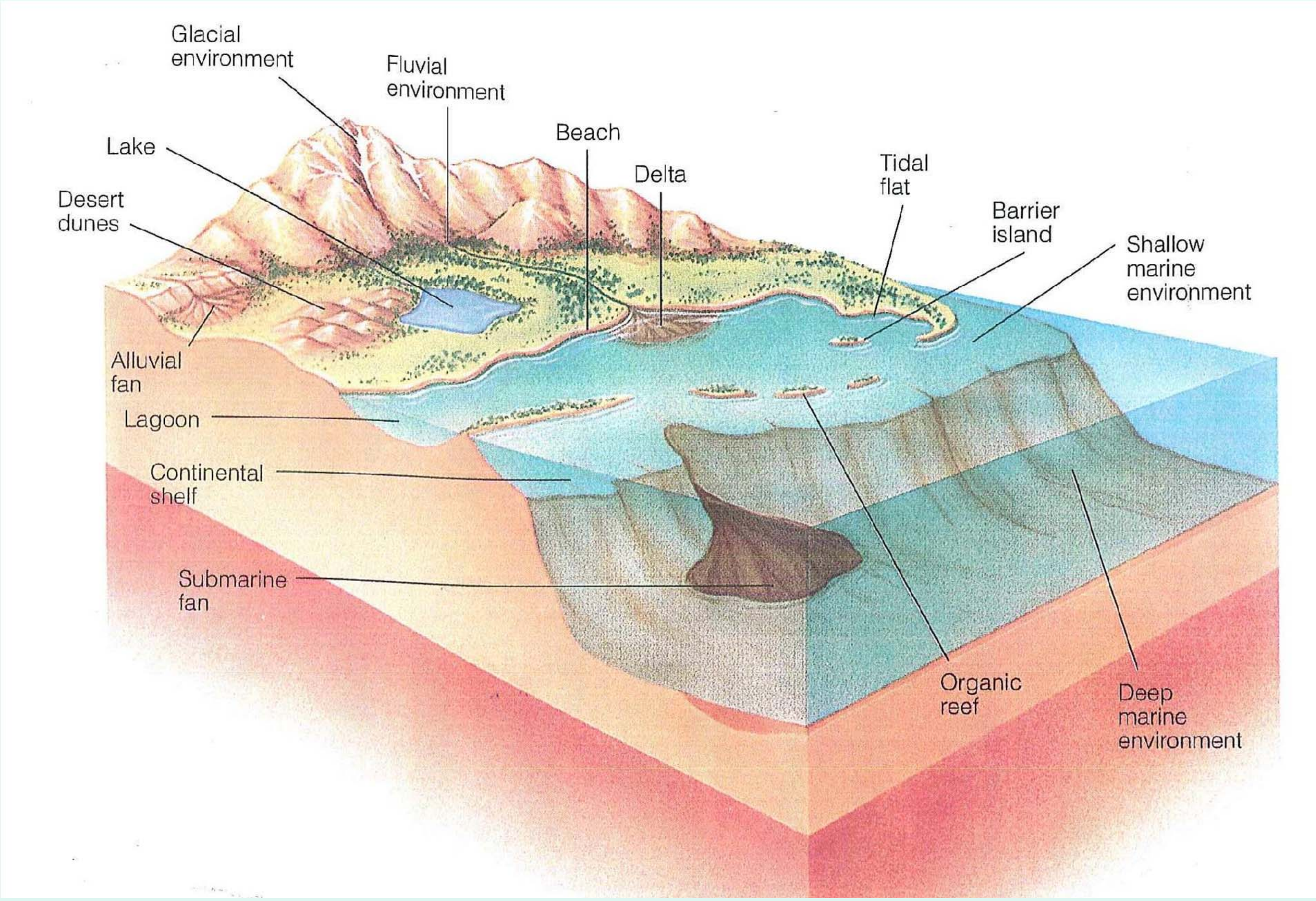
Bowen's Reaction Series – Settling

Bowen's Reaction Series – End of Reaction

Sedimentary Rocks

- **Form from *sediment* (weathered products)**
- **About 75% of all rock outcrops on the continents**
- **Used to reconstruct much of Earth's history**
  - **Clues to past environments (marine, margin marine, and continental)**
  - **Provide information about sediment transport**
  - **Rocks often contain fossils**

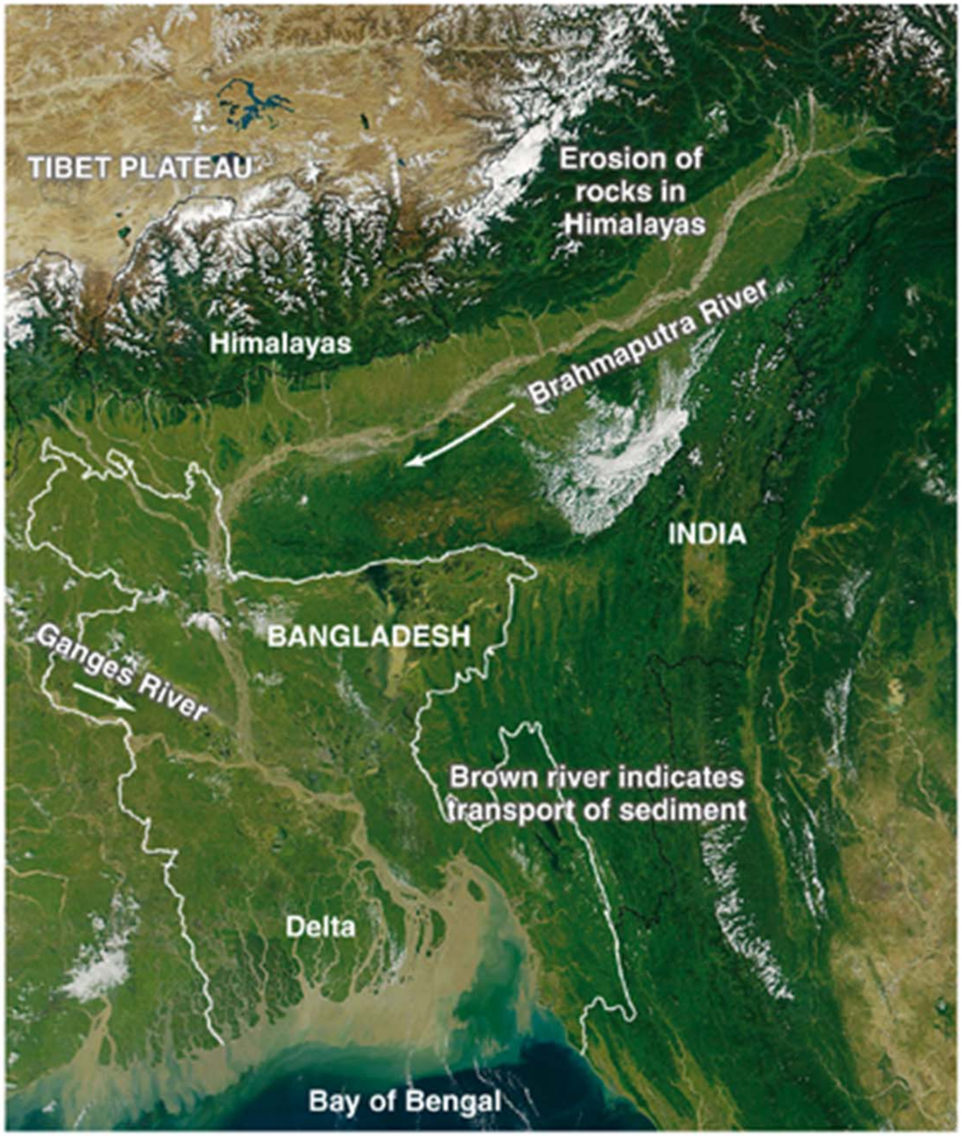
Sedimentary Rocks – Formation

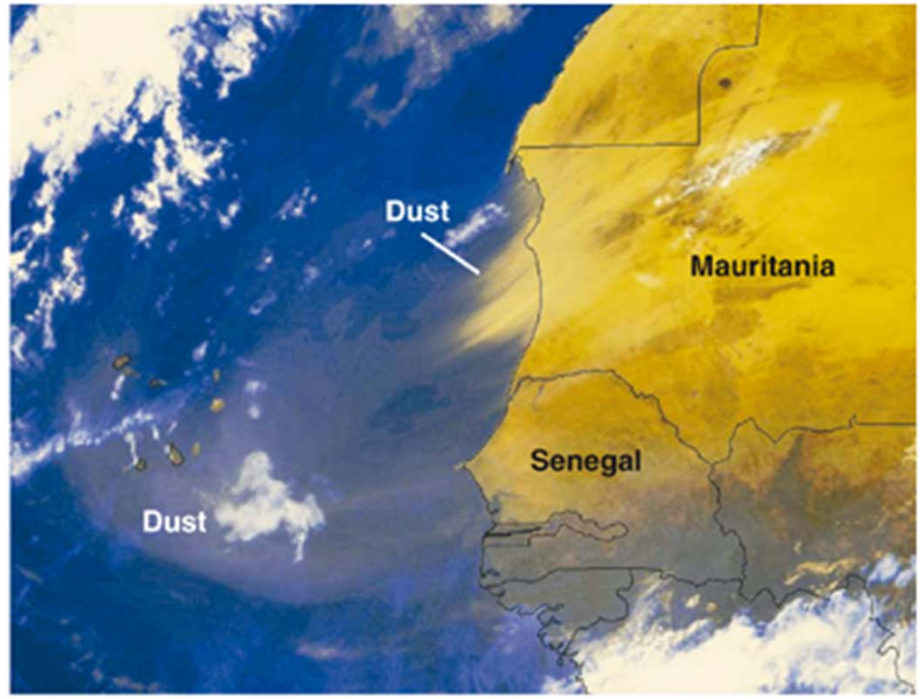


Sedimentary Rocks

- **Classifying sedimentary rocks**
  - **Two groups based on the source of the material : detrital and chemical**
    - ***Detrital rocks* are particles and chemical are most commonly precipitates**

Sedimentary Rocks – Formation





b.

Detrital = Sediments

Sedimentary Rocks – Chemical Formation

Sedimentary Rocks – Chemical Formation

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Classification of Sedimentary Rocks

Detrital Sedimentary Rocks			
Texture (grain size)		**Sediment Name**	**Rock Name**
Coarse (over 2 mm)		Gravel (Rounded fragments)	**Conglomerate**
		Gravel (Angular fragments)	**Breccia**
Medium (1/16 to 2 mm)		Sand (If abundant feldspar is present the rock is called **Arkose**)	**Sandstone**
Fine (1/16 to 1/256 mm)		Mud	**Siltstone**
Very fine (less than 1/256 mm)		Mud	**Shale**

Chemical Sedimentary Rocks			
Composition	**Texture** (grain size)	**Rock Name**	
Calcite, $CaCO_3$	Fine to coarse crystalline	**Crystalline Limestone**	
		Travertine	
	Visible shells and shell fragments loosely cemented	**Coquina**	**Biochemical Limestone**
	Various size shells and shell fragments cemented with calcite cement	**Fossiliferous Limestone**	
	Microscopic shells and clay	**Chalk**	
Quartz, SiO_2	Very fine crystalline	**Chert (light colored) Flint (dark colored)**	
Gypsum $CaSO_4 \cdot 2H_2O$	Fine to coarse crystalline	**Rock Gypsum**	
Halite, NaCl	Fine to coarse crystalline	**Rock Salt**	
Altered plant fragments	Fine-grained organic matter	**Bituminous Coal**	

Sedimentary Rocks

- **Classifying sedimentary rocks**
  - ***Detrital rocks***
    - **Material is solid particles**
    - **Classified by particle size**
    - **Common rocks include**
      - ***Shale* (most abundant)**
      - ***Sandstone***
      - ***Conglomerate***
      - ***Breccia***

Shale with Plant Fossils

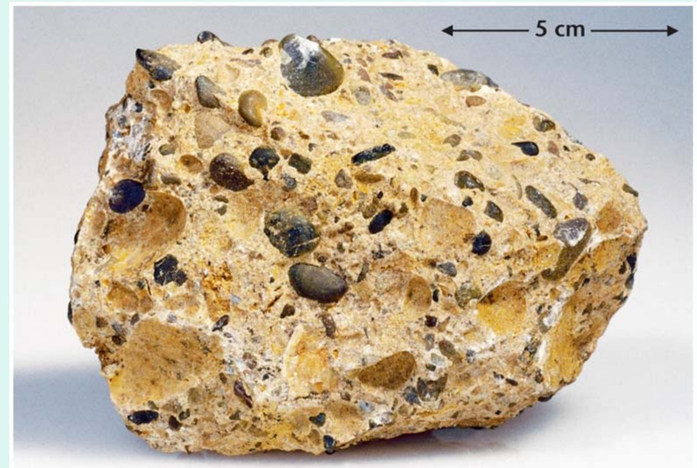
Sandstone

Conglomerate

Effects of Water Transport

Breccia

Conglomerate



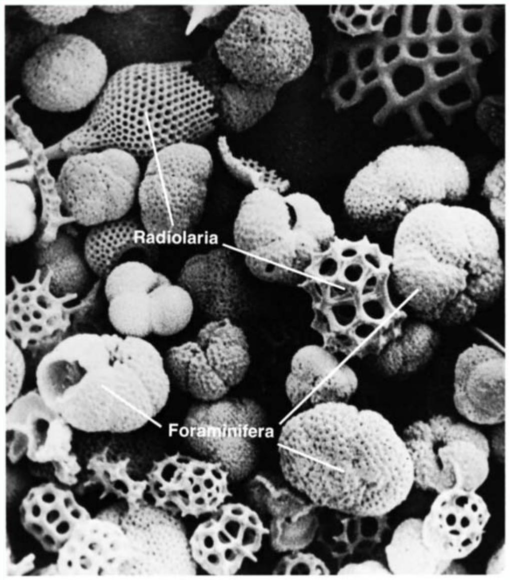
Sedimentary Rocks

- **Classifying sedimentary rocks**
  - **Chemical rocks**
    - **Derived from material that was once in solution, which precipitated to form sediment**
      - **Directly precipitated as the result of physical processes, or**
      - **Through life processes *(biochemical origin)***

Sedimentary Rocks

- **Classifying sedimentary rocks**
  - **Chemical rocks**
    - ***Limestone*—The most abundant chemical rock**
    - **Microcrystalline quartz (precipitated quartz) known as *chert, flint, jasper,* or *agate***
    - **Evaporites such as *rock salt* or *gypsum***
    - ***Coal?***

Limestones



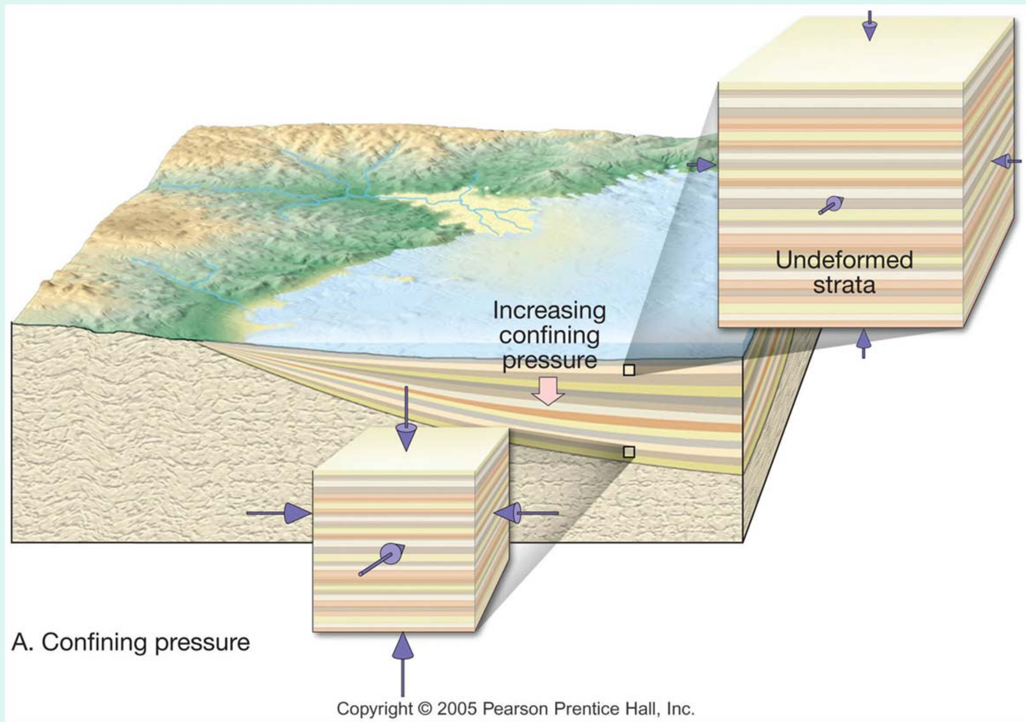
Limestones

Evaporites

Evaporites

Sedimentary Rocks

- Sedimentary rocks are produced through *lithification*
  - Loose sediments are transformed into solid rock
  - Lithification processes
    - *Compaction*
    - *Cementation* by
      - Calcite
      - Silica
      - Iron Oxide



Cement can vary in color

Sedimentary Rocks

Features of sedimentary rocks

Strata, or beds (most characteristic)

Sedimentary Rocks

- **Features of sedimentary rocks**
  - ***Bedding planes* separate strata**

Sedimentary Rocks

Features of sedimentary rocks

Fossils

- Traces or remains of prehistoric life
- Are the most important inclusions
- Help determine past environments
- Used as time indicators
- Used for matching rocks from different places

Metamorphic Rocks

- "Changed form" rocks
- Produced from preexisting
  - Igneous rocks
  - Sedimentary rocks
  - Other metamorphic rocks

Metamorphic Rocks

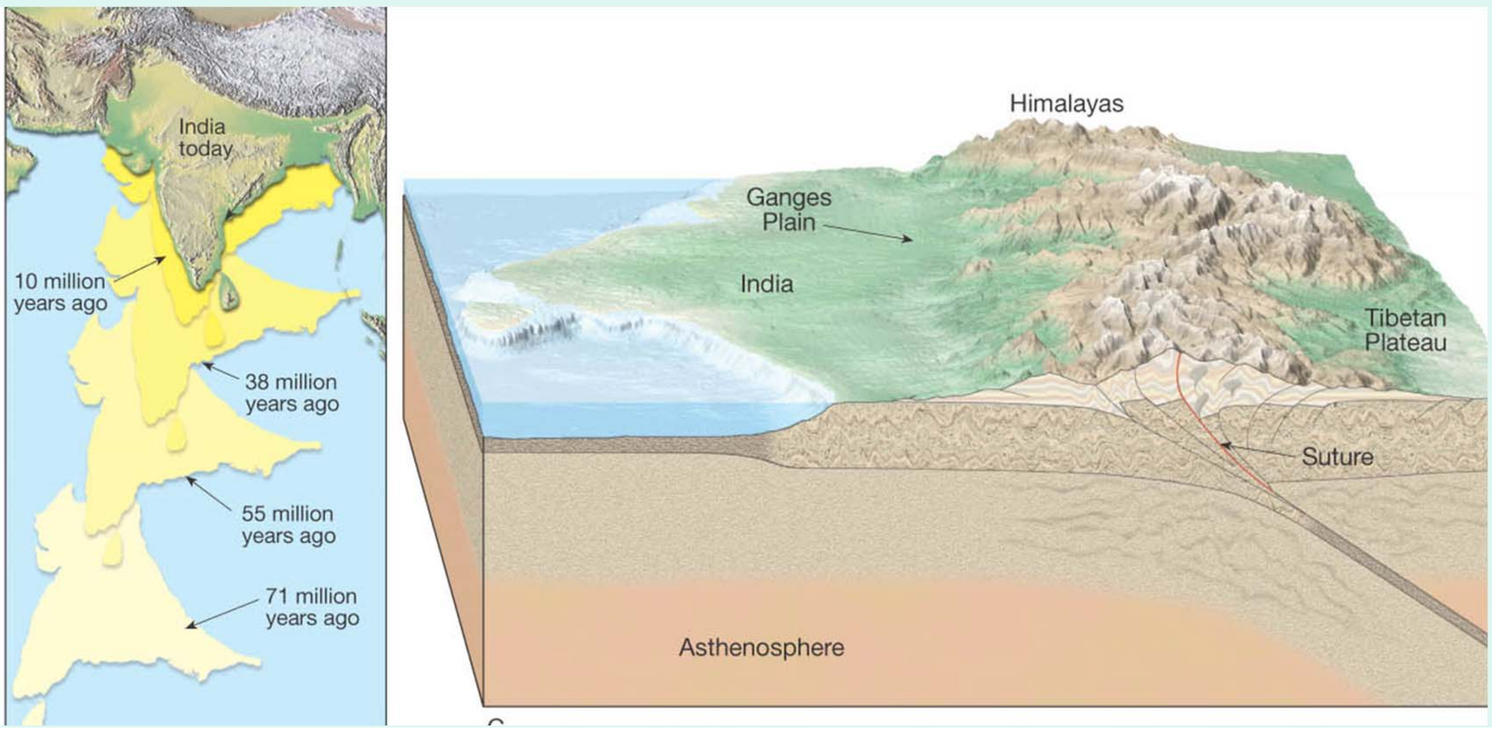
- Metamorphism
  - Takes place where preexisting rock is subjected to temperatures and pressures unlike those in which it formed
  - Degrees of metamorphism
    - Exhibited by rock texture and mineralogy
    - *Low-grade* (e.g., shale becomes slate)
    - *High-grade* (obliteration of original features)

Metamorphic Rocks

Metamorphic settings

Regional metamorphism

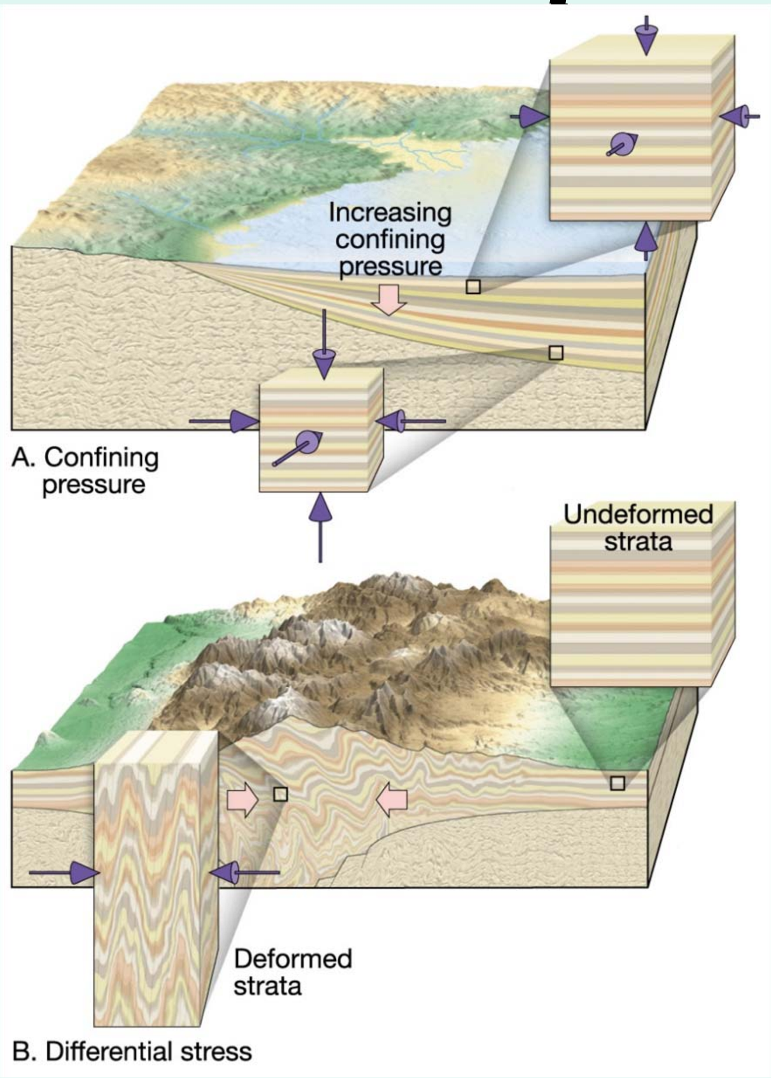
- Directed pressures and high temperatures during mountain building
- Produces the greatest volume of metamorphic rock



Metamorphic Rocks

- **Metamorphic agents**
  - **Heat**
  - **Pressure (stress)**
    - **From burial *(confining pressure)***
    - **From *differential stress* during mountain building**
  - **Chemically active fluids**
    - **Mainly water and other volatiles**
    - **Promote recrystallization by enhancing ion migration**

Origin of Pressure in Metamorphism

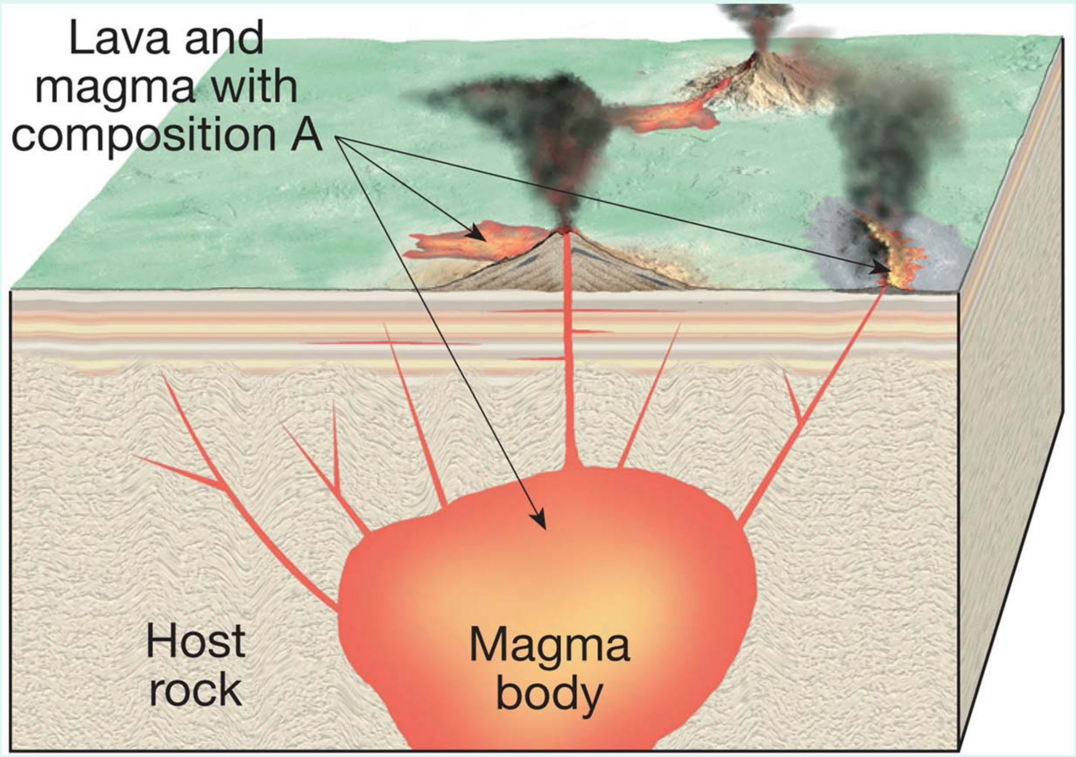


Metamorphic Rocks

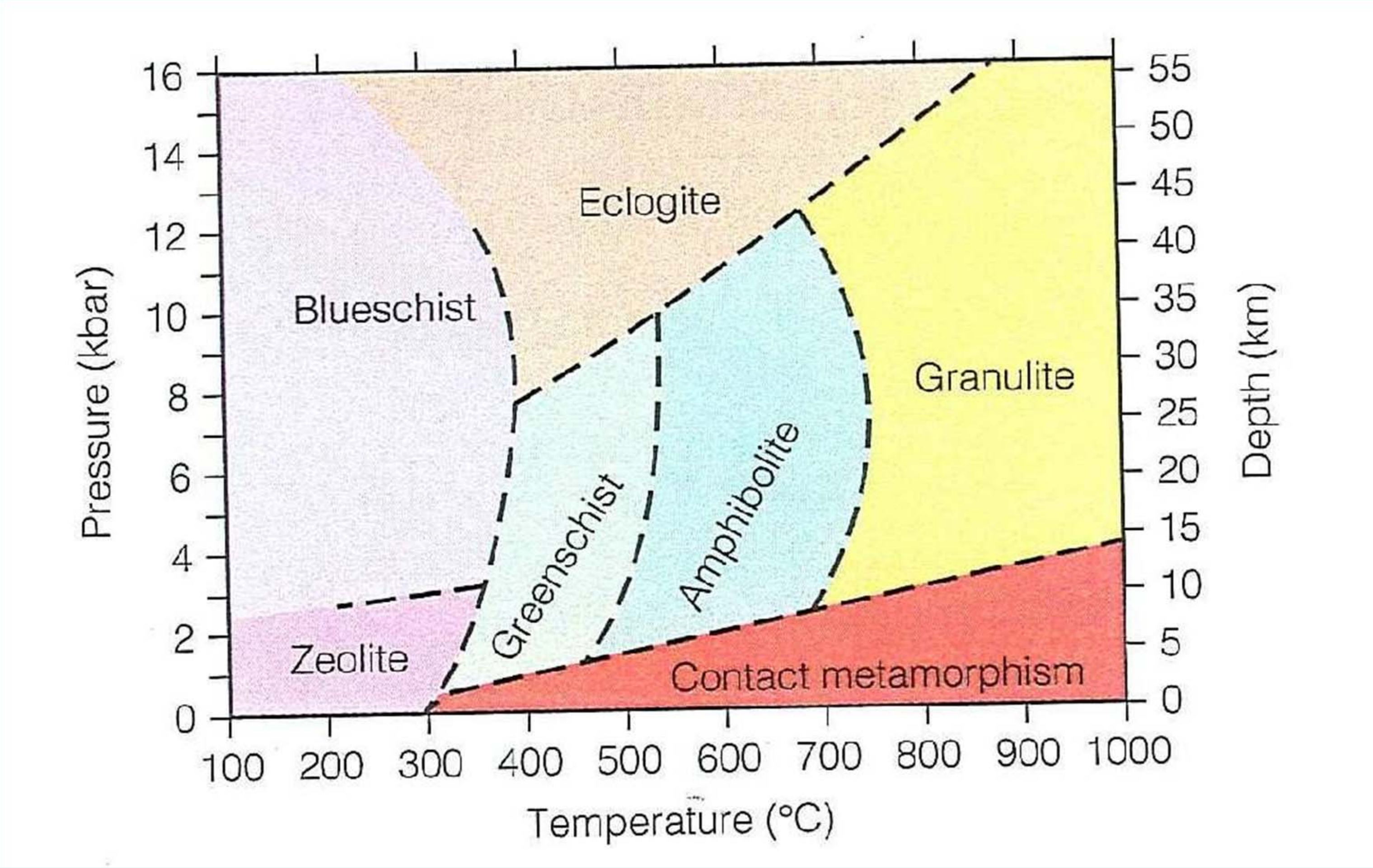
Metamorphic settings

Contact, or *thermal,* metamorphism

- Occurs near a body of magma
- Changes are driven by a rise in temperature



Metamorphic Rocks



Metamorphic Rocks - Textures

Foliated texture

- Minerals are in a parallel alignment
- Minerals are perpendicular to the compressional force

Nonfoliated texture

- Contain equidimensional crystals
- Resembles a coarse-grained igneous rock

Classification of Metamorphic Rocks

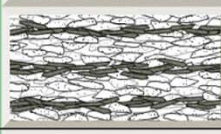
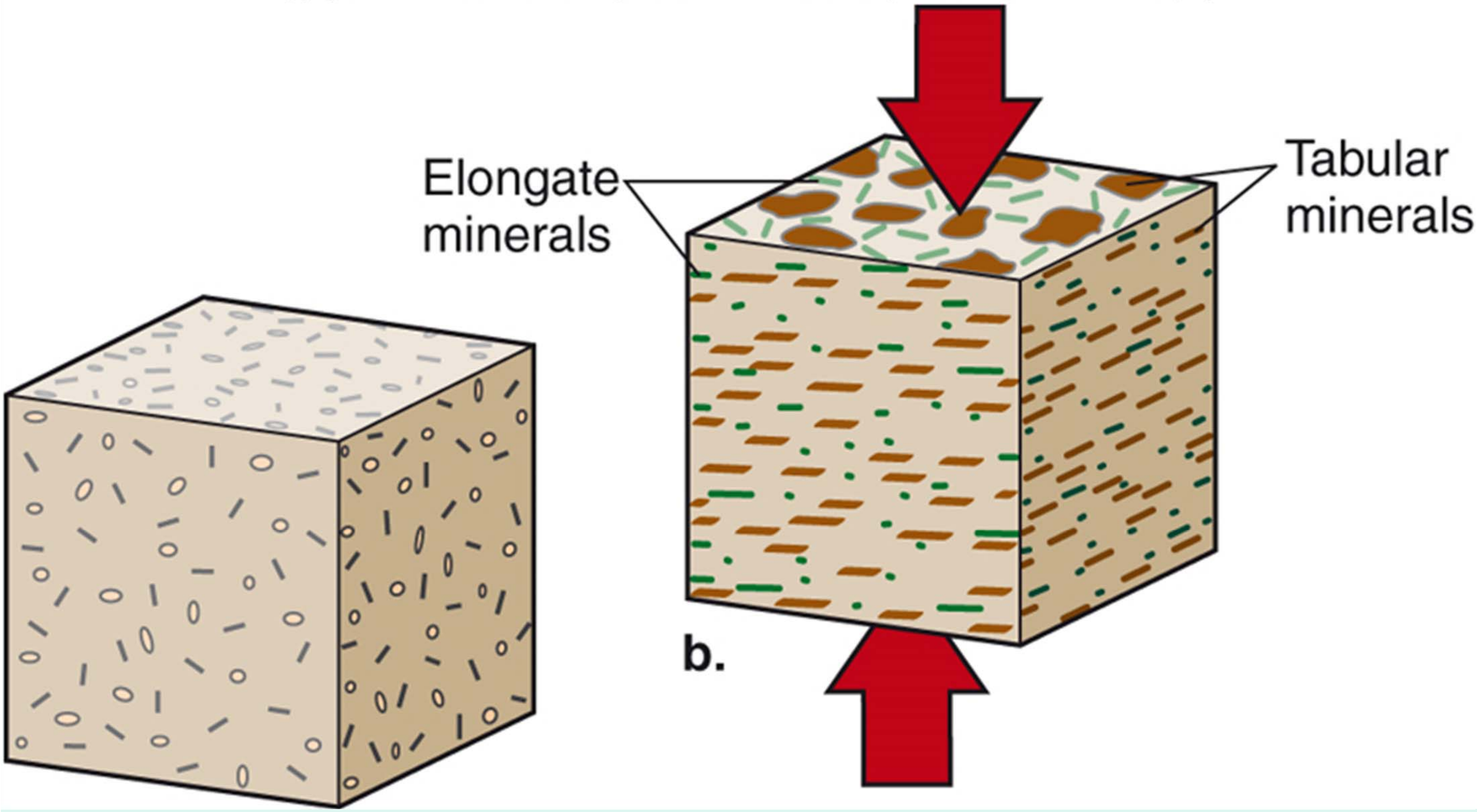
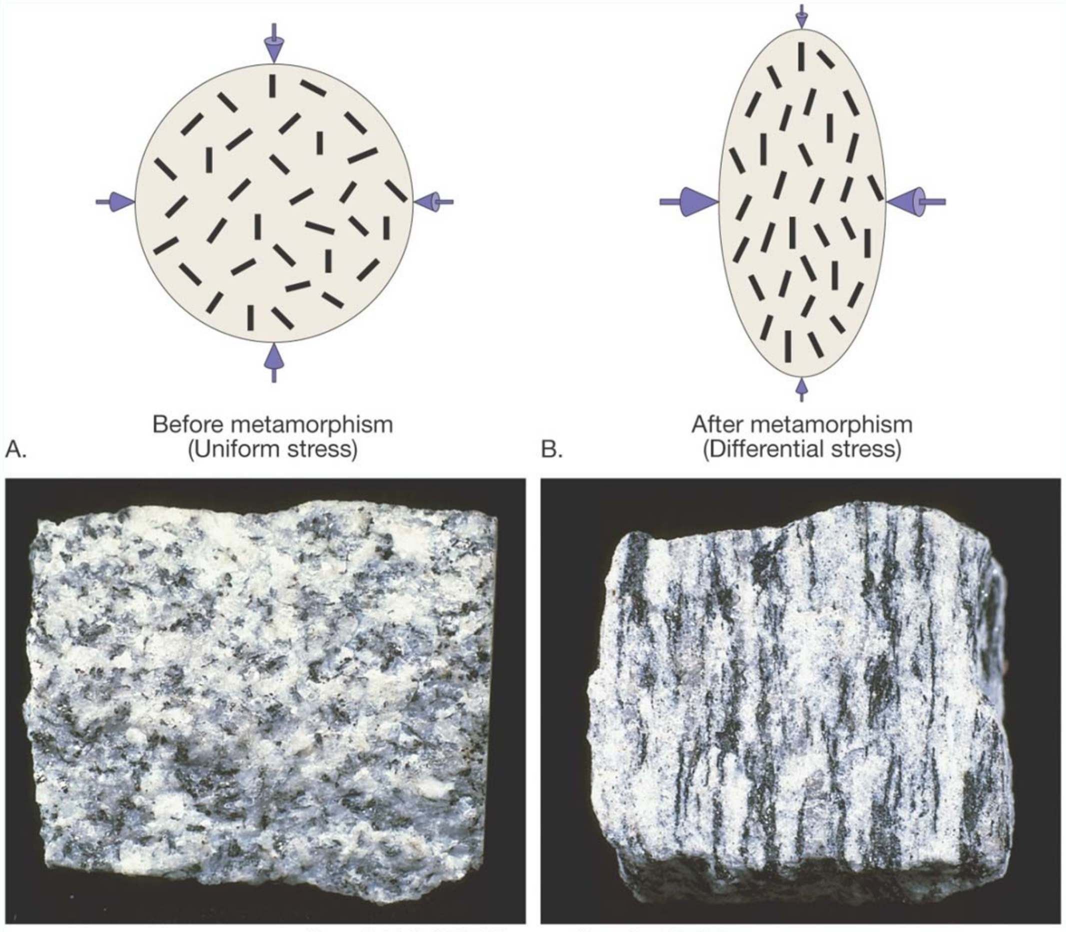
Rock Name		Texture		Grain Size	Comments	Parent Rock
Slate	Increasing Metamorphism	Foliated		Very fine	Excellent rock cleavage, smooth dull surfaces	Shale, mudstone, or siltstone
Phyllite				Fine	Breaks along wavey surfaces, glossy sheen	Slate
Schist				Medium to Coarse	Micaceous minerals dominate, scaly foliation	Phyllite
Gneiss				Medium to Coarse	Compositional banding due to segregation of minerals	Schist, granite, or volcanic rocks
Marble		Nonfoliated		Medium to coarse	Interlocking calcite or dolomite grains	Limestone, dolostone
Quartzite				Medium to coarse	Fused quartz grains, massive, very hard	Quartz sandstone
Anthracite				Fine	Shiny black organic rock that may exhibit conchoidal fracture	Bituminous coal

Figure 2.27

Development of Foliation



Development of Foliation



Metamorphic Rocks

- **Common metamorphic rocks**
  - **Foliated rocks**
    - ***Slate***
      - **Fine-grained**
      - **Splits easily**
    - ***Schist***
      - **Strongly foliated**
      - **"Platy"**
      - **Types based on composition (e.g., mica schist)**

Metamorphic Rocks

- **Common metamorphic rocks**
  - **Foliated rocks**
    - ***Gneiss***
      - **Strong segregation of silicate minerals**
      - **"Banded" texture**
  - **Nonfoliated rocks**
    - ***Marble***
      - **Parent rock is limestone**
      - **Large, interlocking calcite crystals**

Metamorphic Rocks

- Common metamorphic rocks
  - Nonfoliated rocks
    - *Marble*
      - Used as a building stone
      - Variety of colors
    - *Quartzite*
      - Parent rock—Quartz sandstone
      - Quartz grains are fused

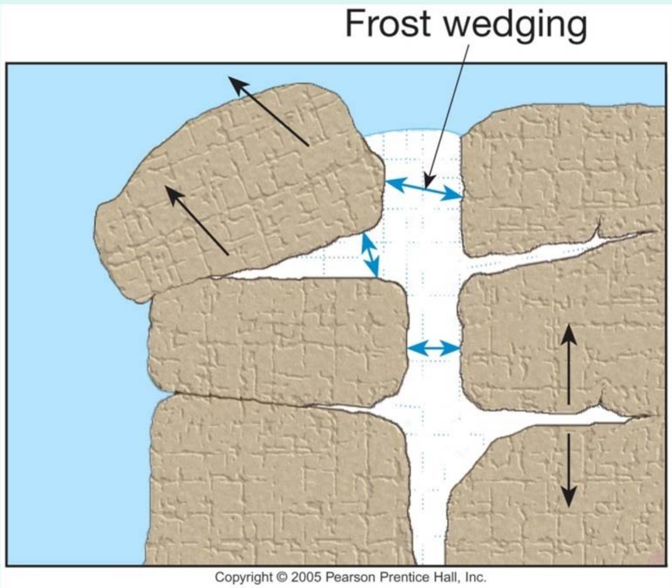
Marble—A Nonfoliated Metamorphic Rock

Weathering of Rocks

- ***Weathering of rocks can occur chemically and/or physically***

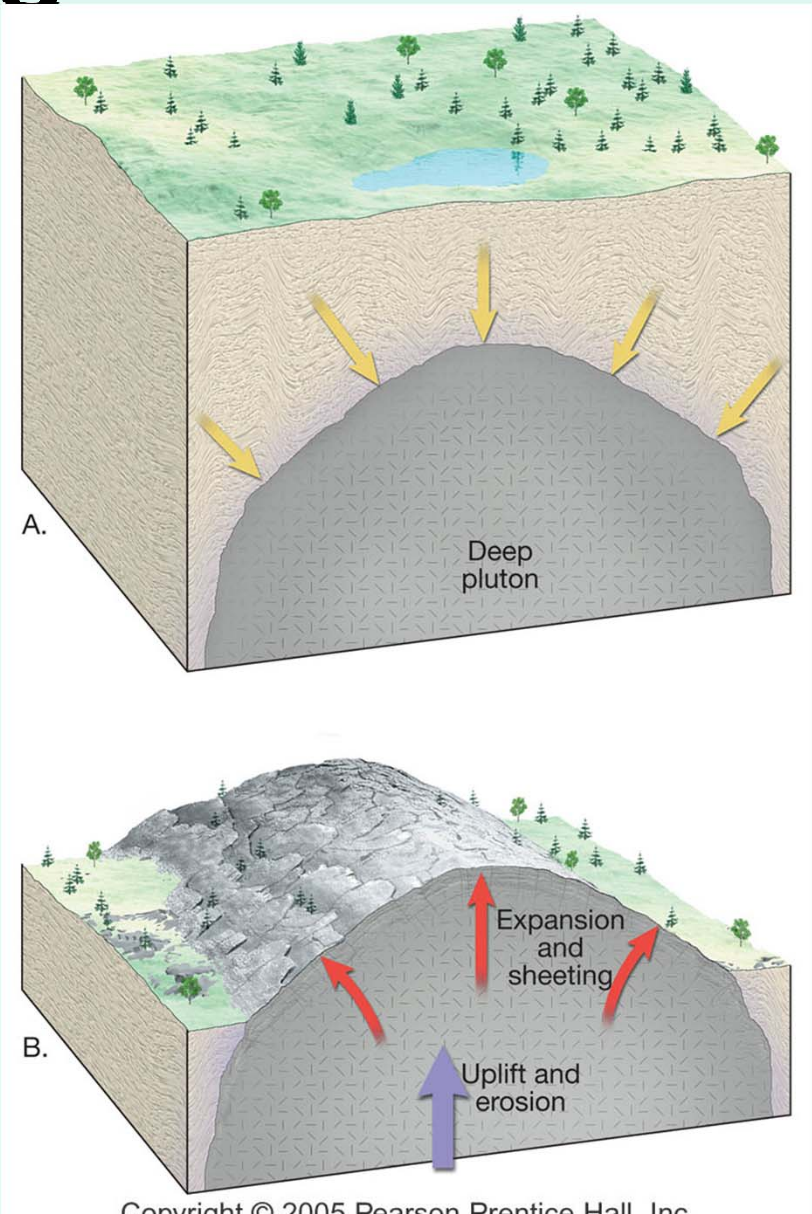
Weathering of Rocks

- *Mechanical weathering* is the physical breaking apart of Earth materials
  - *Frost wedging* = splitting of rocks due to alternate freezing and thawing of water in cracks or voids



Weathering of Rocks

- ***Mechanical weathering*** **is the physical breaking apart of Earth materials**
  - ***Unloading*** **= slabs of rock "peel" away due to a reduction in pressure when overlying rock is eroded away**



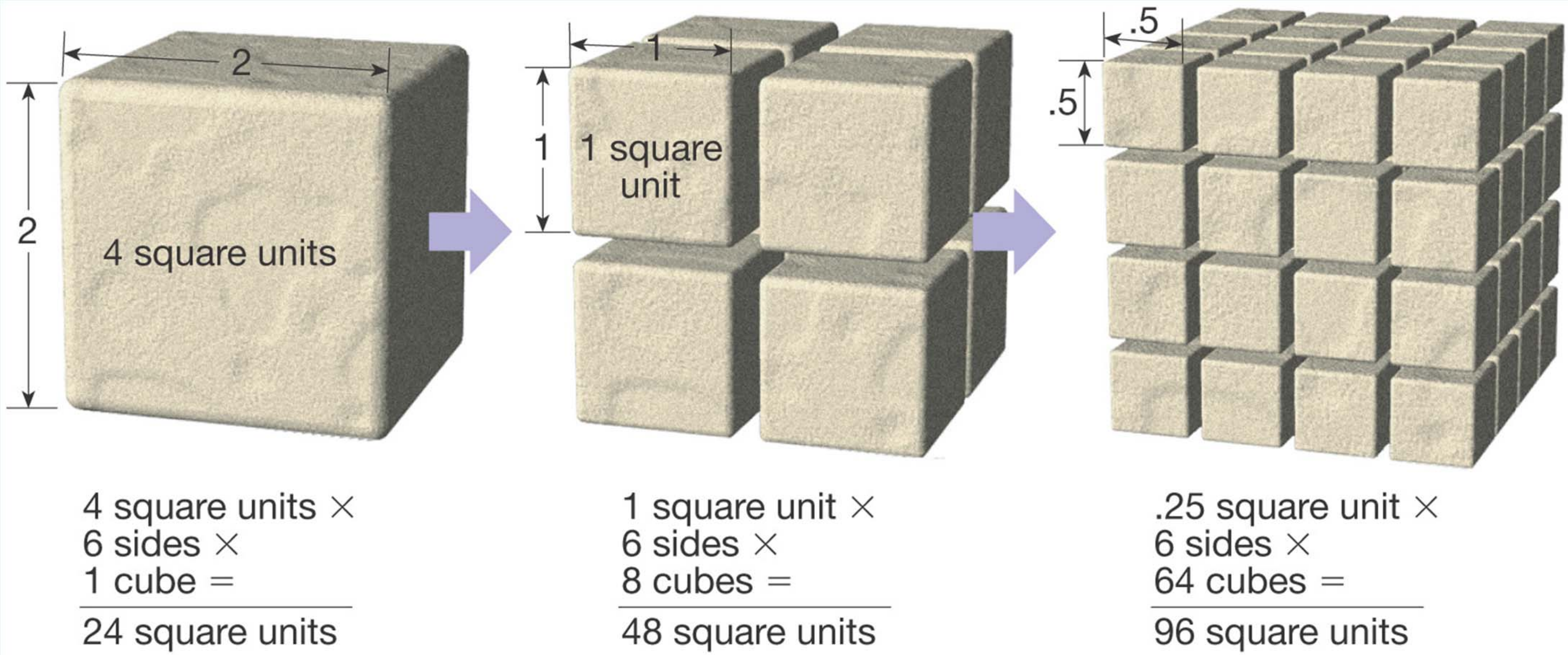
Weathering of Rocks- Unloading

Weathering of Rocks

Mechanical weathering

- Biological activity = activities of plants and burrowing animals

Weathering Increases Surface Area



Weathering of Rocks

- ***Chemical weathering*** **alters the internal structure of minerals by removing and/or adding elements**
  - **Water is the most important agent of chemical weathering**
  - **Reactions such as oxidation or dissolution by acids serve to decompose rocks**
  - **Clay minerals are the most abundant and stable product of chemical weathering**

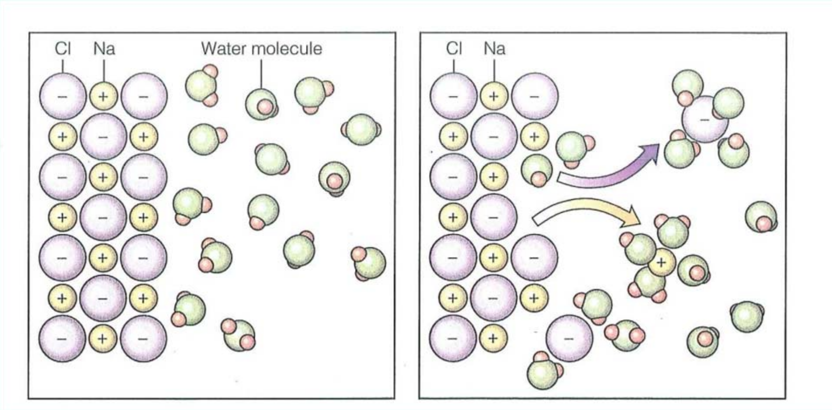


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Table 2.1 Products of weathering

Original Mineral	Weathers to Produce	Released into Solution
Quartz	Quartz grains	Silica (SiO_2)
Feldspar	Clay minerals	Silica (SiO_2)
		Ions of potassium, sodium, and calcium
Hornblende	Clay minerals	Silica (SiO_2)
	Iron minerals (limonite and hematite)	Ions of calcium and magnesium
Olivine	Iron minerals (limonite and hematite)	Silica (SiO_2)
		Ions of magnesium

End of Chapter 2