ROCKS

Reading Assignment

- Chapter 3
- Write down answers to Concept Check questions.

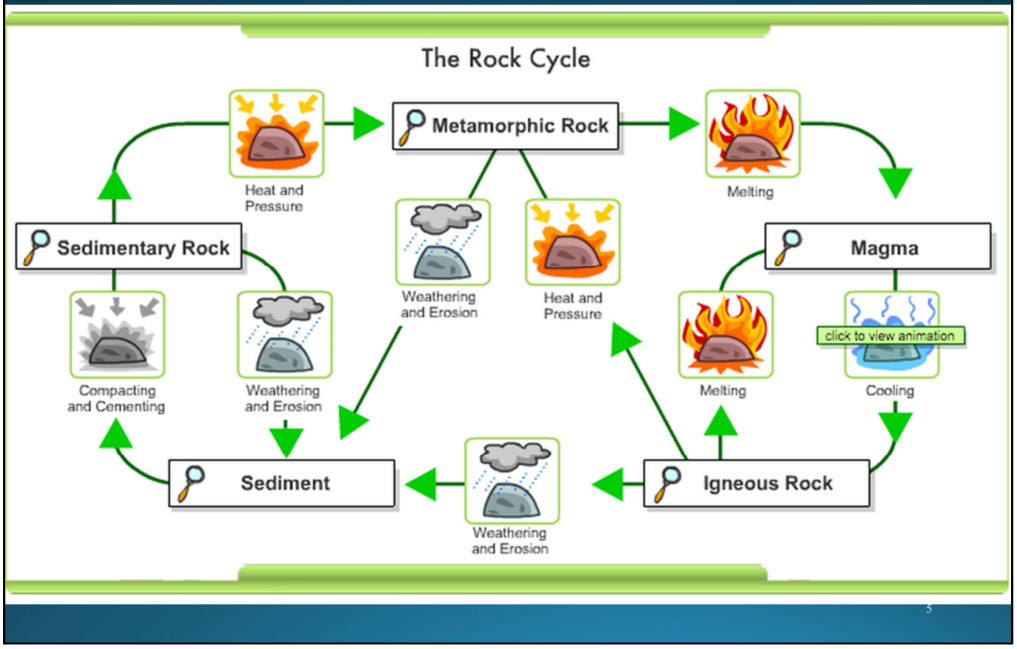
- Click links, read, watch video

Rock cycle

- Shows the interrelationships among the three rock types

Rock Cycle

(spend some time on this slide)



Rock cycle

- Full cycle does not always take place due to "shortcuts" or interruptions
  - e.g., Sedimentary rock melts
  - e.g., Igneous rock is metamorphosed
  - e.g., Sedimentary rock is weathered
  - e.g., Metamorphic rock weathers

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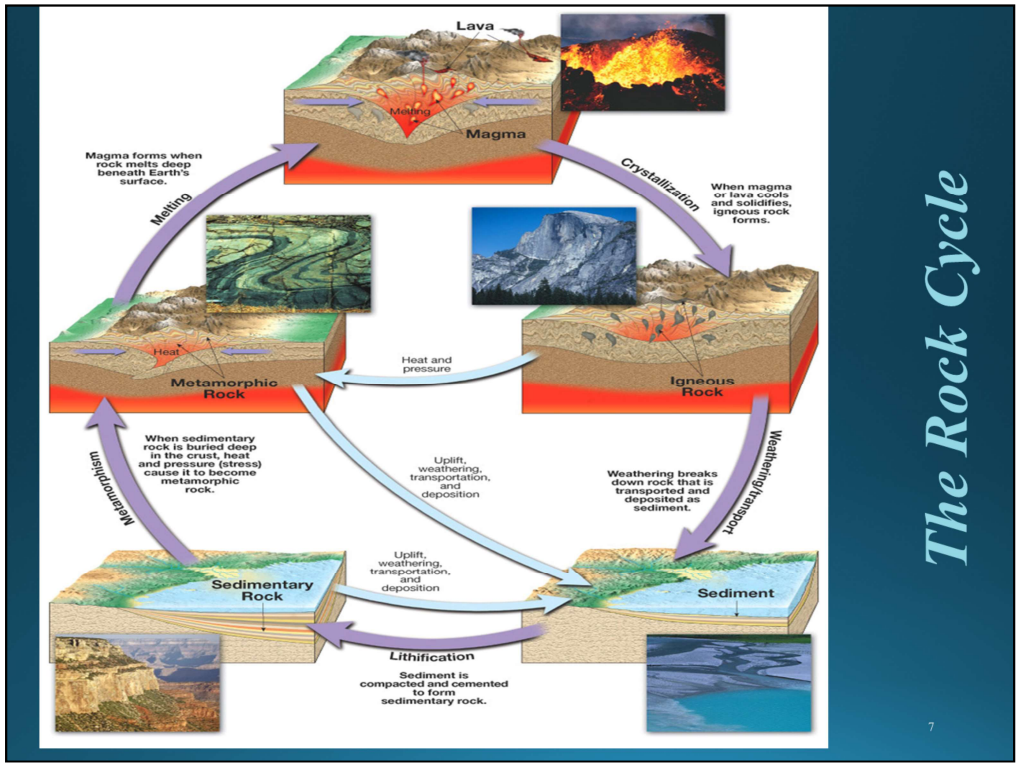
The Rock Cycle
Lava
Melting
Magma
Magma forms when rock melts deep beneath Earth's surface.
Melting
Crystallization
When magma or lava cools and solidifies, igneous rock forms.
Heat
Metamorphic Rock
Heat and pressure
Igneous Rock
When sedimentary rock is buried deep in the crust, heat and pressure (stress) cause it to become metamorphic rock.
Metamorphism
Uplift, weathering, transportation, and deposition
Weathering breaks down rock that is transported and deposited as sediment.
Weathering/transport
Uplift, weathering, transportation, and deposition
Sedimentary Rock
Sediment
Lithification
Sediment is compacted and cemented to form sedimentary rock.
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Igneous rocks

- Form as magma cools and crystallizes
  - Rocks formed inside Earth are called plutonic or intrusive rocks

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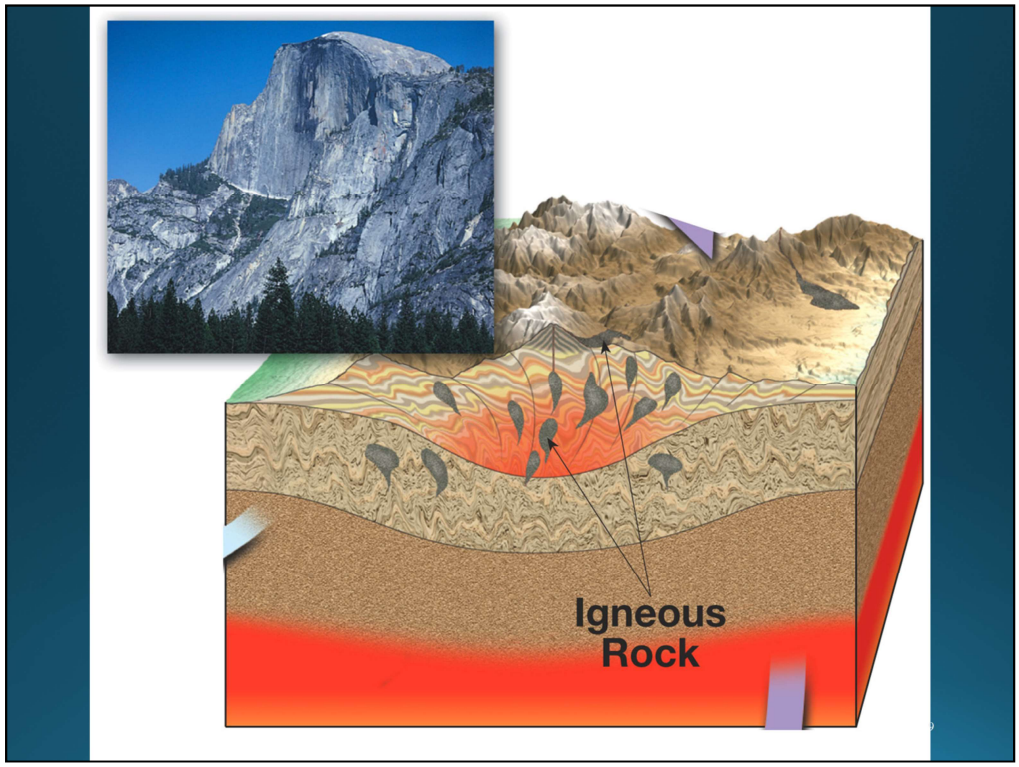

Half Dome, Yosemite Valley California

El Capitan

Yosemite Valley

Devil’s Tower Wyoming

Igneous rocks

- Form as magma cools and crystallizes
- Magma that cools on the surface is called lava.
- Extrusive igneous rocks.

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Chain of Craters Road, Big Island of Hawaii

Mauna Loa

Igneous rocks

- As the liquid magma cools (either slowly or quickly), crystals are formed.
  - 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
- Classification is based on the rock's texture and mineral constituents

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Igneous rocks

- Types of igneous textures
  - 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
  - Vesicular – contains hole left by gas bubbles
  - Pyroclastic – fragmented; produced by consolidation of volcanic fragments

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Caption:

A. Igneous rocks that form at or near Earth's surface cool quickly and often exhibit a fine-grained texture. B. Coarse-grained igneous rocks form when magma slowly crystallizes at depth. C. During a volcanic eruption in which silica-rich lava is ejected into the atmosphere, a frothy glass called pumice may form. D. A porphyritic texture results when magma that already contains some large crystals migrates to a new location where the rate of cooling increases. The resulting rock consists of larger crystals embedded within a matrix of smaller crystals. (Photos courtesy of E. J. Tarbuck)

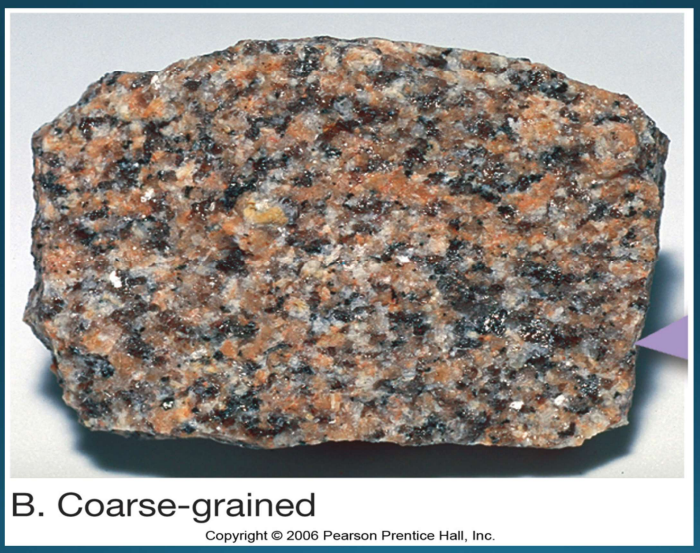
Mt. St. Helen's

Fine-grained igneous texture

A. Fine-grained

Figure 3.4 A

Course-grained igneous texture



B. Coarse-grained

Figure 3.4 B

Porphyritic igneous texture

D. Porphyritic

Figure 3.4 D

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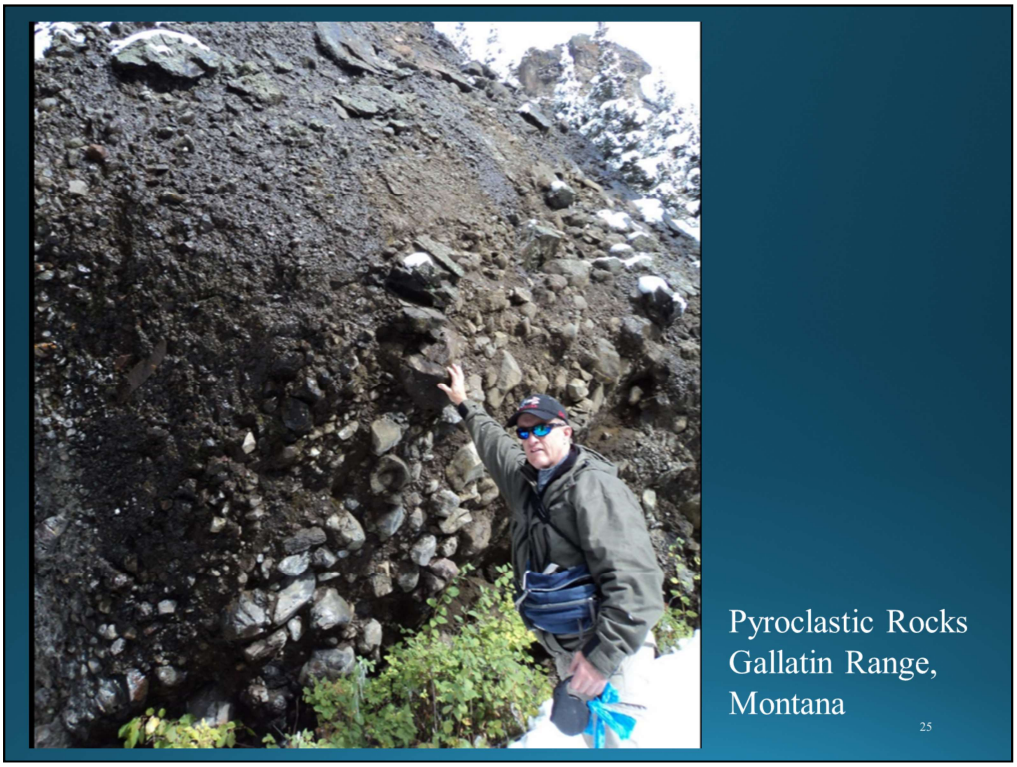
Obsidian exhibits a glassy texture

Figure 3.6


Spatter Cone, Sunset Crater, AZ



Pyroclastic Rocks
Gallatin Range,
Montana

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Igneous rocks

- Classification is based on the rock's texture and mineral constituents
  - Mineral composition
    - Explained by Bowen's reaction series which shows the order of mineral crystallization
    - Influenced by crystal settling in the magma

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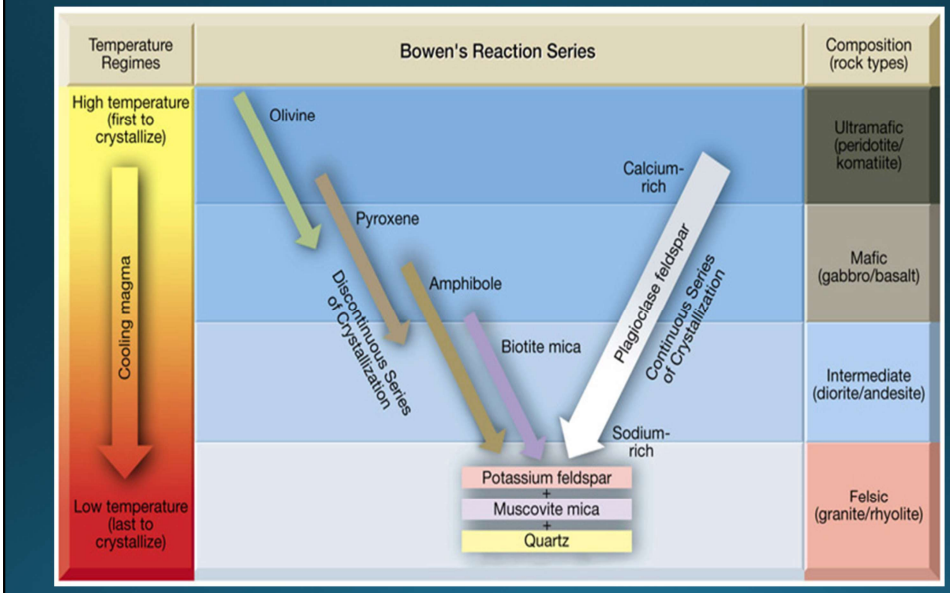
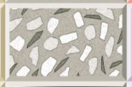

Temperature Regimes
Bowen's Reaction Series
Composition (rock types)
High temperature (first to crystallize)
Cooling magma
Low temperature (last to crystallize)
Olivine
Pyroxene
Amphibole
Biotite mica
Potassium feldspar
+
Muscovite mica
+
Quartz
Discontinuous Series of Crystallization
Calcium-rich
Plagioclase feldspar
Continuous Series of Crystallization
Sodium-rich
Ultramafic (peridotite/ komatiite)
Mafic (gabbro/basalt)
Intermediate (diorite/andesite)
Felsic (granite/rhyolite)

Classification of igneous rocks

			Granitic (Felsic)	Andesitic (Intermediate)	Basaltic (Mafic)	Ultramafic
Chemical Composition						
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**
	Aphanitic (fine-grained)		**Rhyolite**	**Andesite**	**Basalt**	**Komatiite** (rare)
	Porphyritic		"Porphyritic" precedes any of the above names whenever there are appreciable phenocrysts			Uncommon
	Glassy		**Obsidian** (compact glass) **Pumice** (frothy glass)			
Rock Color (based on % of dark minerals)			0% to 25%	25% to 45%	45% to 85%	85% to 100%

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Classification of igneous rocks

Igneous rocks

- Naming igneous rocks
  - 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

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Granite

B.

Igneous rocks

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

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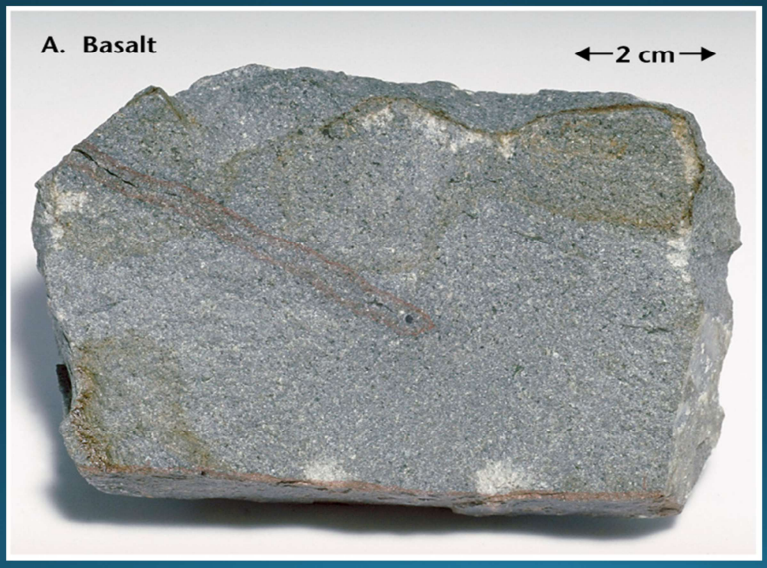
Basalt



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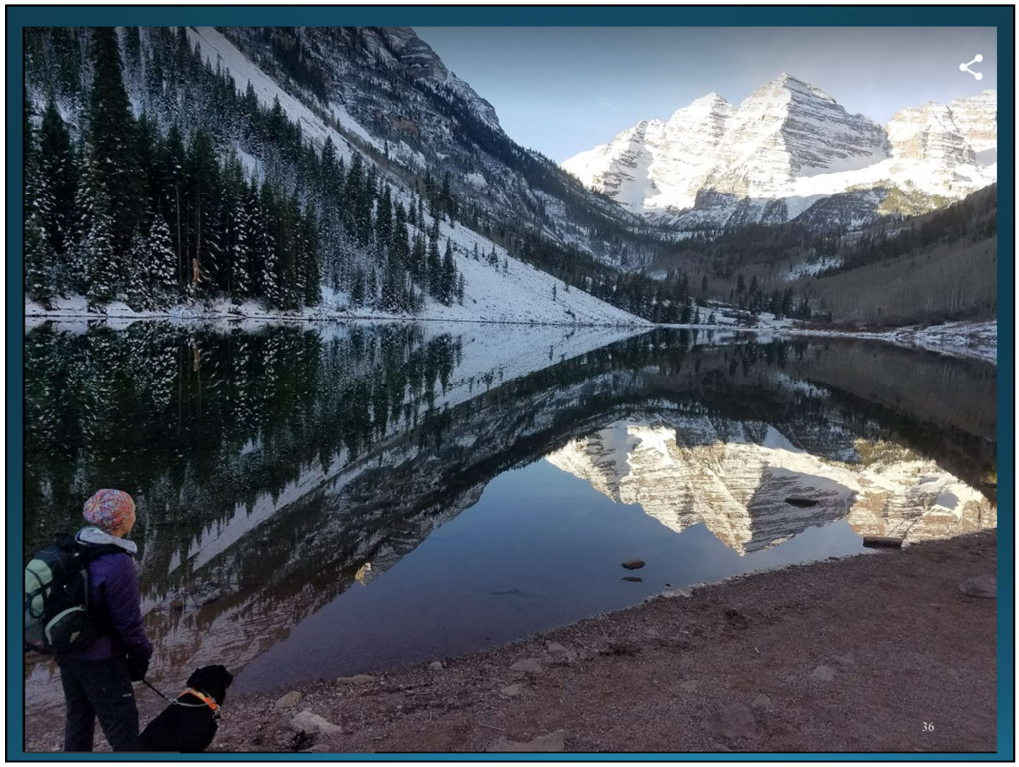
Igneous rocks

- Naming igneous rocks
  - Other compositional groups
    - Andesitic (or intermediate)
    - Ultramafic

Slides Removed



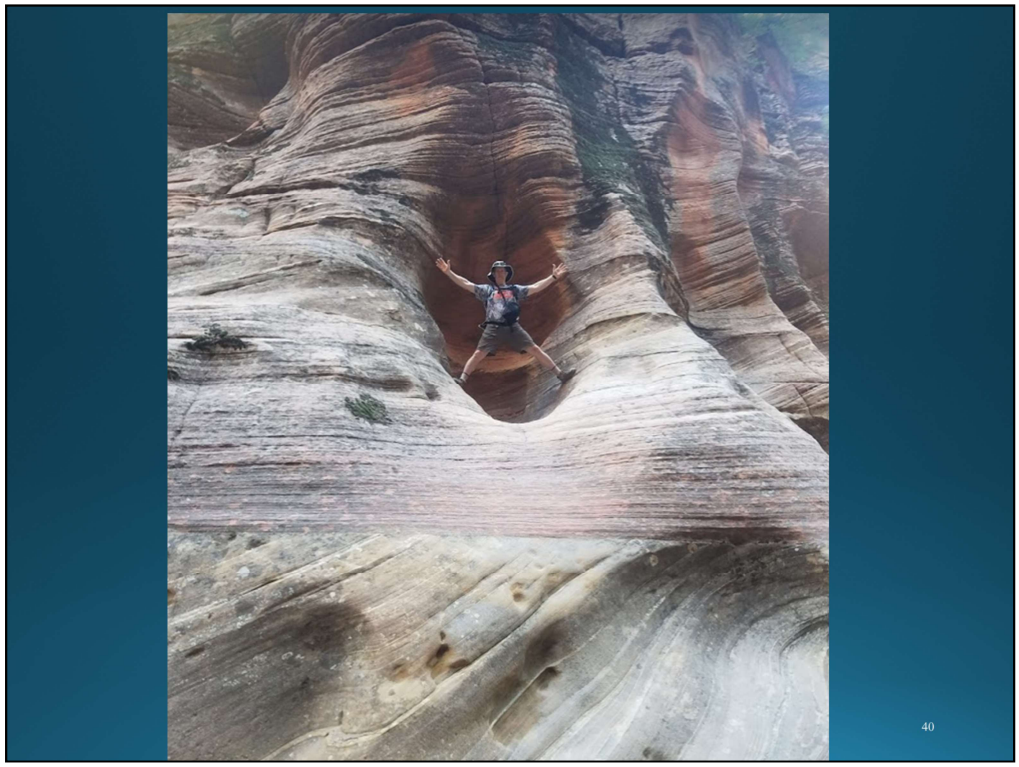
Maroon Bells outside Aspen, Colorado.

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
  - Provide information about sediment transport
  - Rocks often contain fossils

Grand Canyon.

The Fire Wave. Valley of Fire State Park, Nevada.



Petrified Sand Dunes. Zion National Park, Utah.

Sedimentary rocks

- Economic importance
  - Coal
  - Petroleum and natural gas
  - Sources of iron and aluminum

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Sedimentary rocks

- Classifying sedimentary rocks
  - Two groups based on the source of the material
    - Detrital
    - Chemical

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Detritral Sedimentary Rocks

Detrital Sedimentary Rocks

Clastic Texture (particle size)	Sediment Name	Rock Name
Coarse (over 2 mm)	Gravel (Rounded particles)	**Conglomerate** 
	Gravel (Angular particles)	**Breccia** 
Medium (1/16 to 2 mm)	Sand	**Sandstone** 
		Arkose* 
Fine (1/16 to 1/256 mm)	Silt	**Siltstone** 
Very fine (less than 1/256 mm)	Clay	**Shale or Mudstone** 

*If abundant feldspar is present the rock is called arkose.

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Conglomerate

A

Giant Conglomerate in the Blue Hills

Sandstone

C

Red Sandstone. Outside Moab, UT

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Sandstone. Canyonlands NP, Utah

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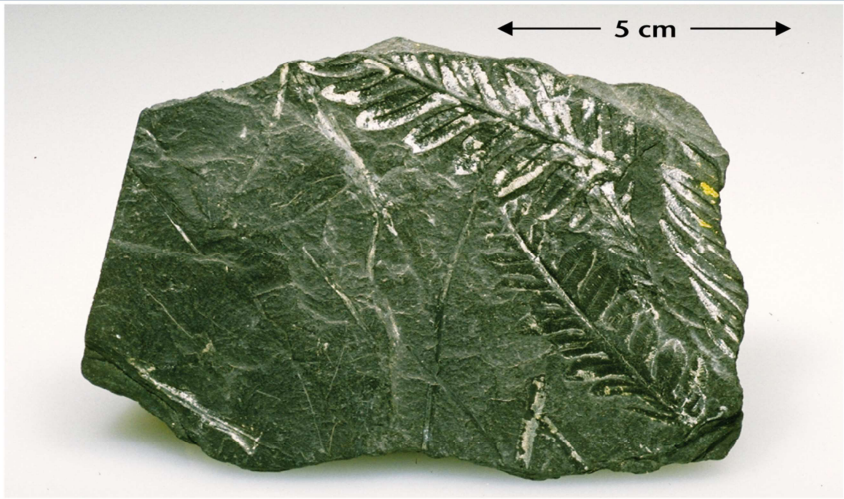
Shale with plant fossils



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Check Question

- Why do you think most fossils are found in Sedimentary Rocks (as opposed to igneous or metamorphic)?

Sedimentary rocks

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

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Sedimentary rocks

- Common sedimentary 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

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Sedimentary rocks

Chemical, Biochemical, and Organic Sedimentary Rocks

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

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Fossiliferous limestone

Rock salt

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Travertine Terraces. Mammoth Hot Springs, Yellowstone N.P. 56

Sedimentary rocks

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

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Sedimentary rocks

- Features of sedimentary rocks
  - Strata, or beds (most characteristic)
  - Bedding planes separate strata
  - 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

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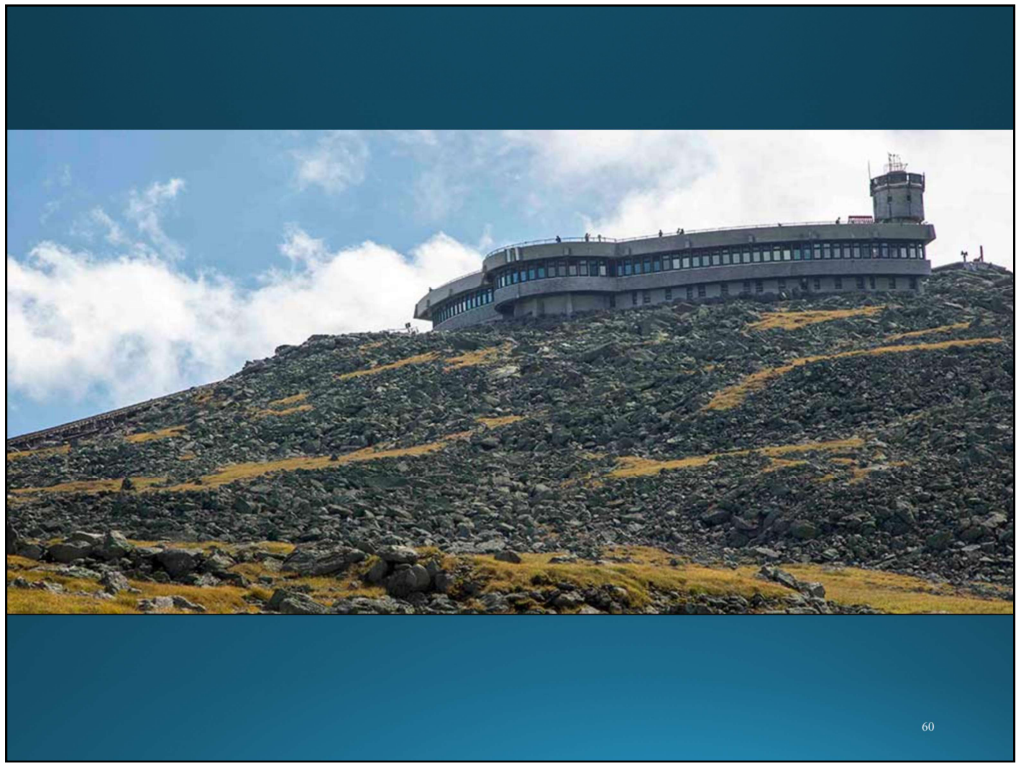

Mt. Washington, New Hampshire. Affectionately referred to as "The Rock Pile".

Metamorphic rocks

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

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Vishnu Schist. Grand Canyon.

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)

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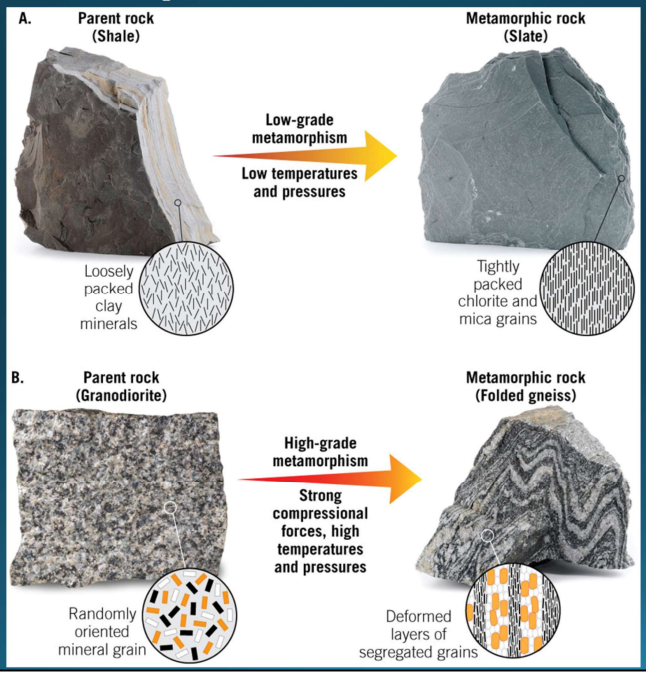
Metamorphic rocks



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Metamorphic rocks

- Metamorphic settings
  - Contact, or thermal, metamorphism
    - Occurs near a body of magma
    - Changes are driven by a rise in temperature
  - Regional metamorphism
    - Directed pressures and high temperatures during mountain building
    - Produces the greatest volume of metamorphic rock

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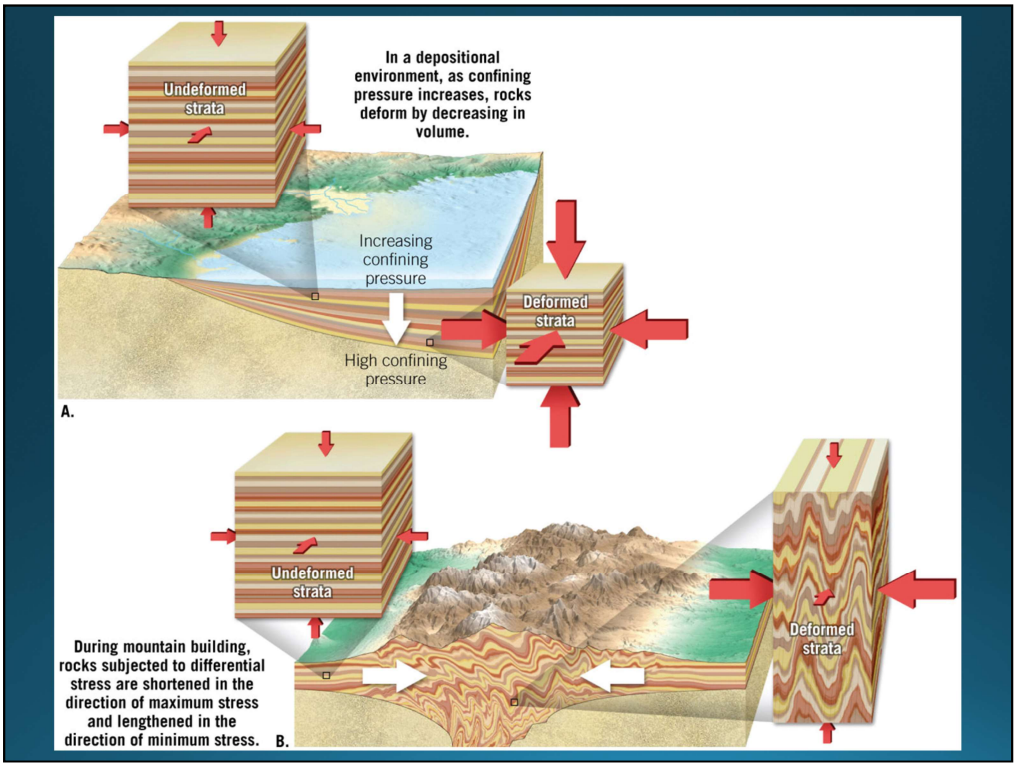
Metamorphic rocks

- 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


In a depositional environment, as confining pressure increases, rocks deform by decreasing in volume.
Undeformed strata
Increasing confining pressure
Deformed strata
High confining pressure
A.
Undeformed strata
Deformed strata
During mountain building, rocks subjected to differential stress are shortened in the direction of maximum stress and lengthened in the direction of minimum stress.
B.

Metamorphic rocks

- Metamorphic 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

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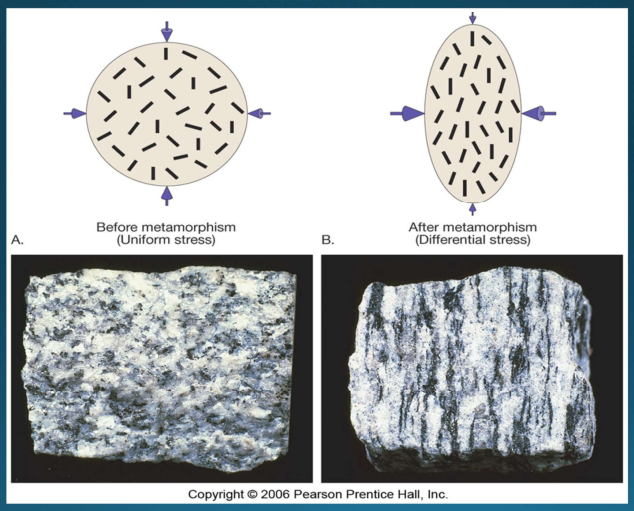
Development of foliation due to directed pressure



Common Foliated Metamorphic Rocks

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

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Comma

COMMON METAMORPHIC ROCKS

Metamorphic Rock	Texture	Comments	Parent Rock
Slate	Foliated	Composed of tiny chlorite and mica flakes, breaks in flat slabs called slaty cleavage, smooth dull surfaces	Shale, mudstone, or siltstone
Phyllite	Foliated	Fine-grained, glossy sheen, breaks along wavy surfaces	Shale, mudstone, or siltstone
Schist	Foliated	Medium- to coarse-grained, scaly foliation, micas dominate	Shale, mudstone, or siltstone
Gneiss	Foliated	Coarse-grained, compositional banding due to segregation of light and dark colored minerals	Shale, granite, or volcanic rocks
Marble	Nonfoliated	Medium- to coarse-grained, relatively soft (3 on the Mohs scale), interlocking calcite or dolomite grains	Limestone, dolostone
Quartzite	Nonfoliated	Medium- to coarse-grained, very hard, massive, fused quartz grains	Quartz sandstone

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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
    - Quartzite
      - Parent rock – quartz sandstone
      - Quartz grains are fused

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Gneiss typically displays a banded appearance

Figure 3.24

Marble – a nonfoliated metamorphic rock

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Phyllite

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Schist

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Slides removed.

Resources from Rocks and Minerals

- Metallic mineral resources
  - Gold, silver, copper, mercury, lead, etc.
  - Concentrations of desirable materials are produced by
    - Igneous processes
    - Metamorphic processes

Resources from Rocks and Minerals

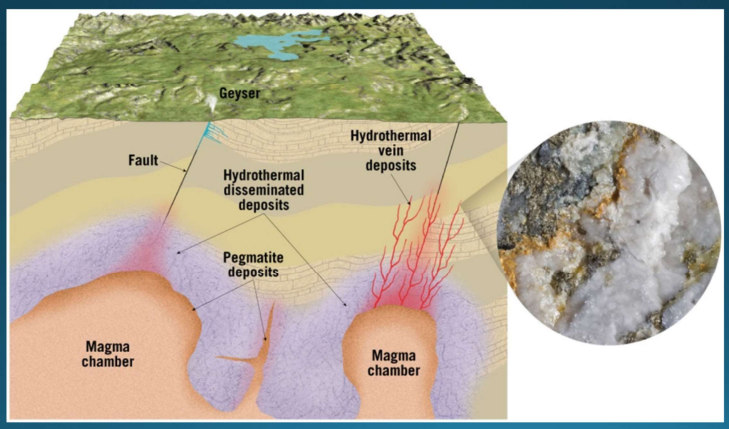
- Metallic mineral resources
  - Most important ore deposits are generated from hydrothermal (hot-water) solutions
    - Hot
    - Contain metal-rich fluids
    - Associated with cooling magma bodies

Resources from Rocks and Minerals

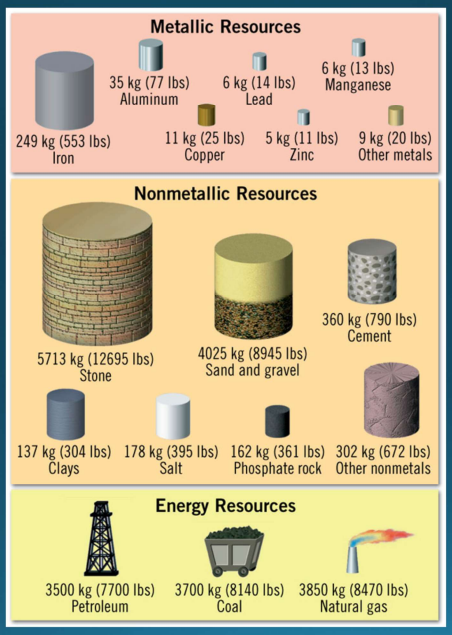
- Pegmatites
  - Result from crystallization in fluid-rich environment
  - Unusually large crystals

Resources from Rocks and Minerals

- Types of deposits include
  - Vein deposits in fractures or bedding planes, and
  - Disseminated deposits which are distributed throughout the rock



Metallic Resources

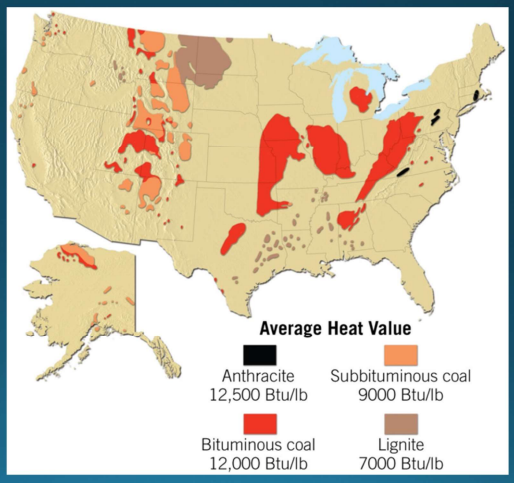


Resources from Rocks and Minerals

- Nonmetallic mineral resources
  - Make use of the material's
    - Nonmetallic elements
    - Physical or chemical properties
  - Two broad groups
    - Building materials (e.g., limestone, gypsum)
    - Industrial minerals (e.g., fluorite, corundum, sylvite)

Energy Resources: Fossil Fuels

- Coal
  - Burns energy stored by plants millions of years ago
  - Air pollution
  - Surface scarring



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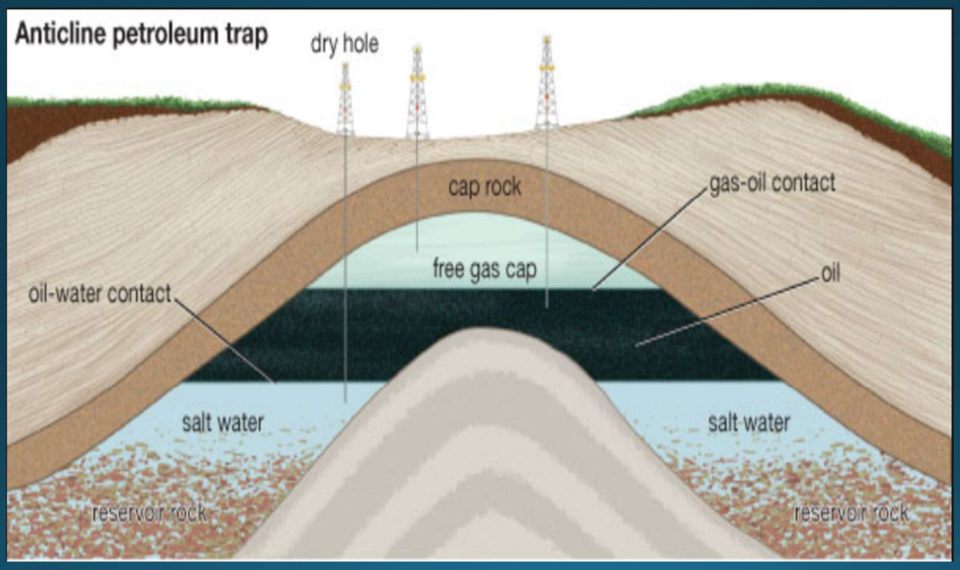
Energy Resources: Fossil Fuels

- Oil and Natural Gas
  - More than 60% of U.S.-consumed energy
  - Remains of marine plants and animals
  - Source rock – where oil and natural gas originate
  - Oil trap – geologic environment allowing oil and gas to accumulate

Energy Resources: Fossil Fuels

- Oil trap – two basic features
  - Reservoir rock
    - Porous and permeable
    - Yields oil and gas in significant quantities
  - Cap rock
    - Impermeable
    - Keeps oil and gas from surface escape


Anticline petroleum trap
dry hole
cap rock
gas-oil contact
free gas cap
oil
oil-water contact
salt water
salt water
reservoir rock
reservoir rock

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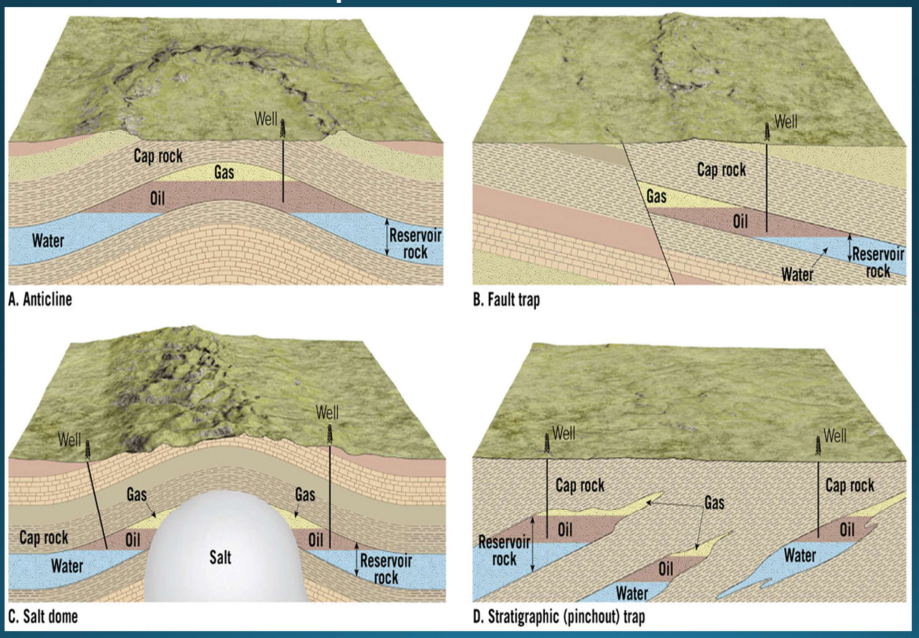
Energy Resources: Fossil Fuels

- Common oil and natural gas traps
  - Anticline – up-arched sedimentary strata
  - Fault trap – displaced strata
  - Salt dome – includes layers of rock salt
  - Stratigraphic (pinchout) trap – original sedimentation pattern

Common Oil Traps



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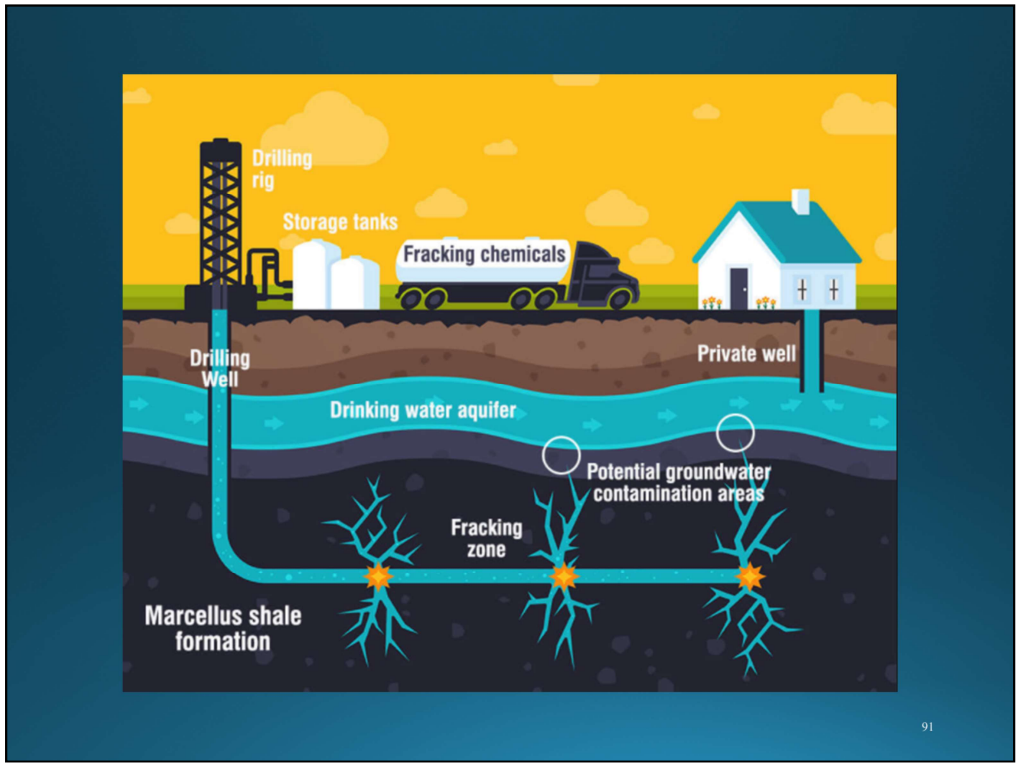
Energy Resources: Fossil Fuels

- Hydraulic Fracturing
  - "Fracking"
  - Shatters shale with significant gas and petroleum reserves
  - Pumping liquids into rock at very high pressure
  - Can include toxic chemicals


Drilling rig
Storage tanks
Fracking chemicals
Drilling Well
Private well
Drinking water aquifer
Potential groundwater contamination areas
Fracking zone
Marcellus shale formation
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