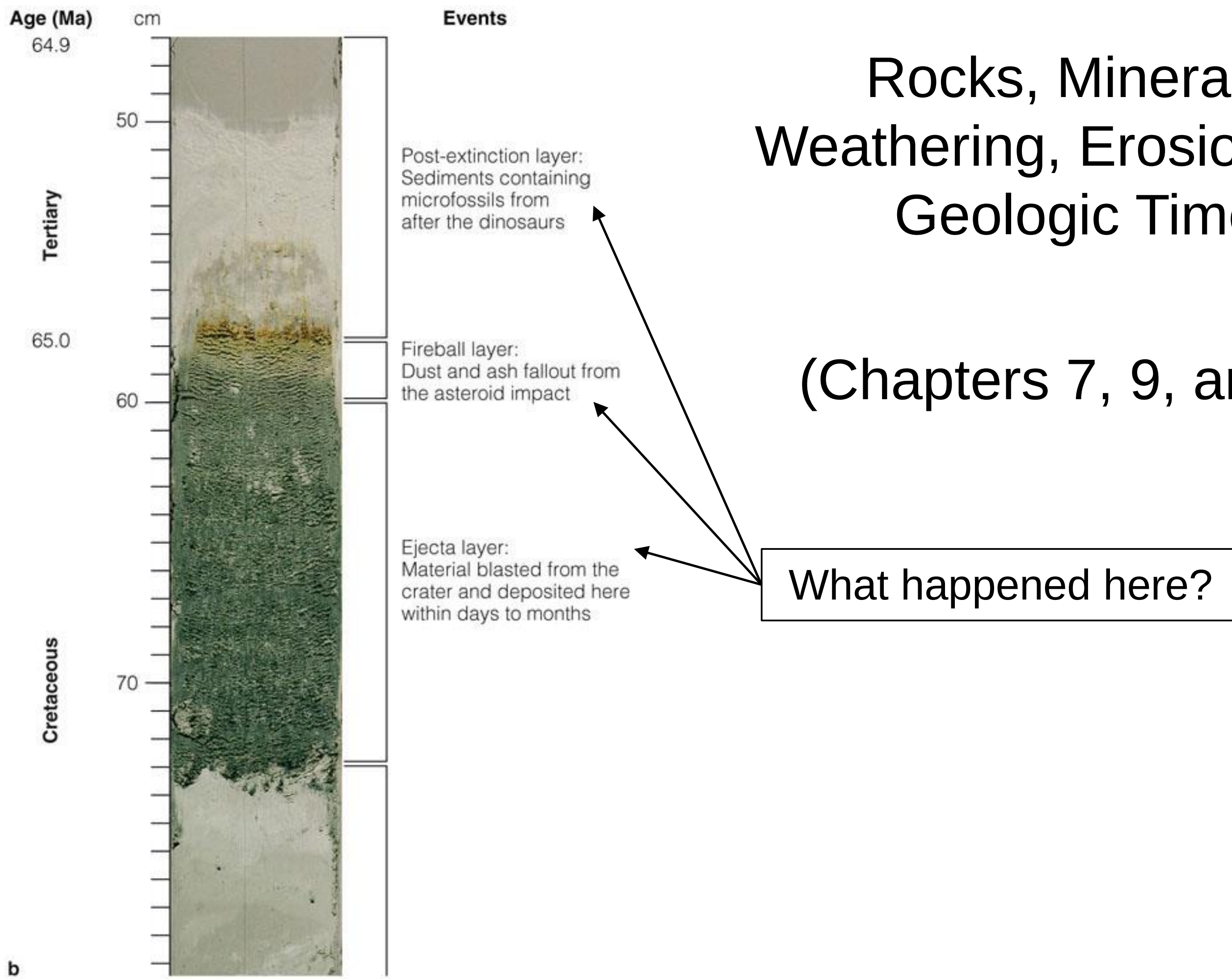
ESC1000 • Earth Science • Summer 2016



Rocks, Minerals, Weathering, Erosion, and Geologic Time

(Chapters 7, 9, and 8)

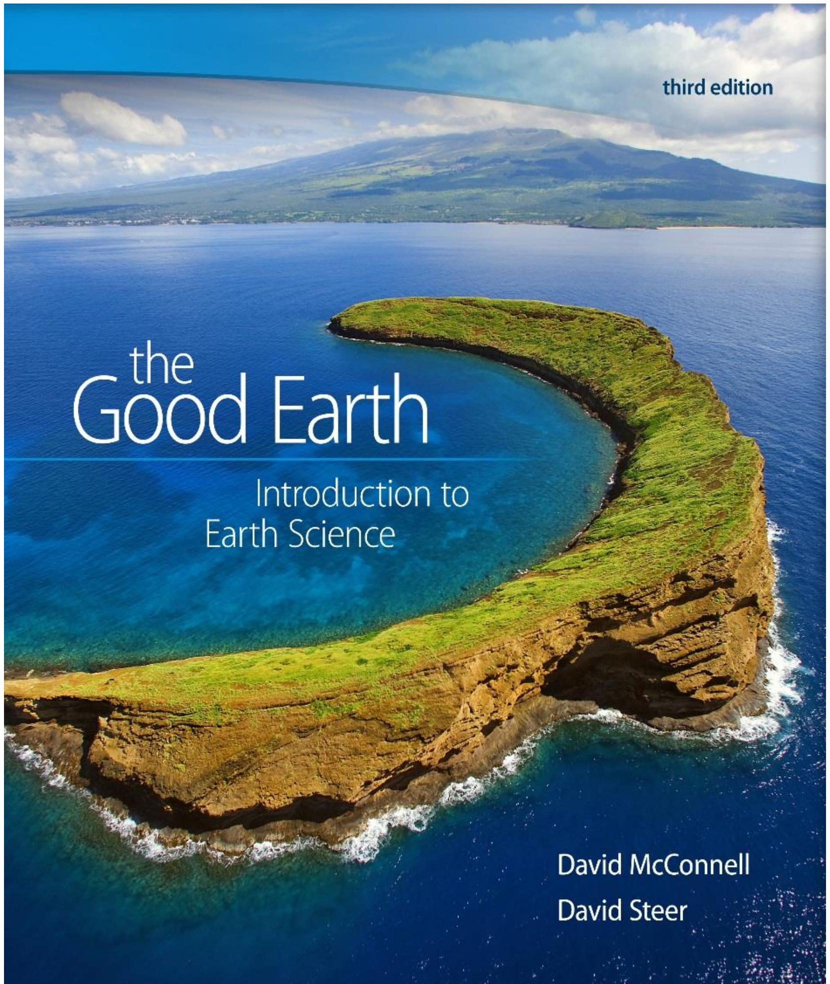
Announcements

- Grades
  - Exam 1 grade adjustments (if applicable) will be done today.
  - Current course grades will be given to you on Wednesday.
  - Last day to withdraw with a “W” is Thursday.

- Email
  - Please expect up to <u>two business days</u> for a response.
  - Please check your email regularly for urgent messages.

- Exam 2 Preparation
  - Work through the study guide first (some questions done in class).
  - I’ll answer questions on your work if you
    - (1) have done some work on your own already, and
    - (2) email me your work, on or before this Thursday.
  - In office hours this week, I will review more of the study guide. Look for email about scheduling a new time for this.

Chapter 7: Rocks and Minerals

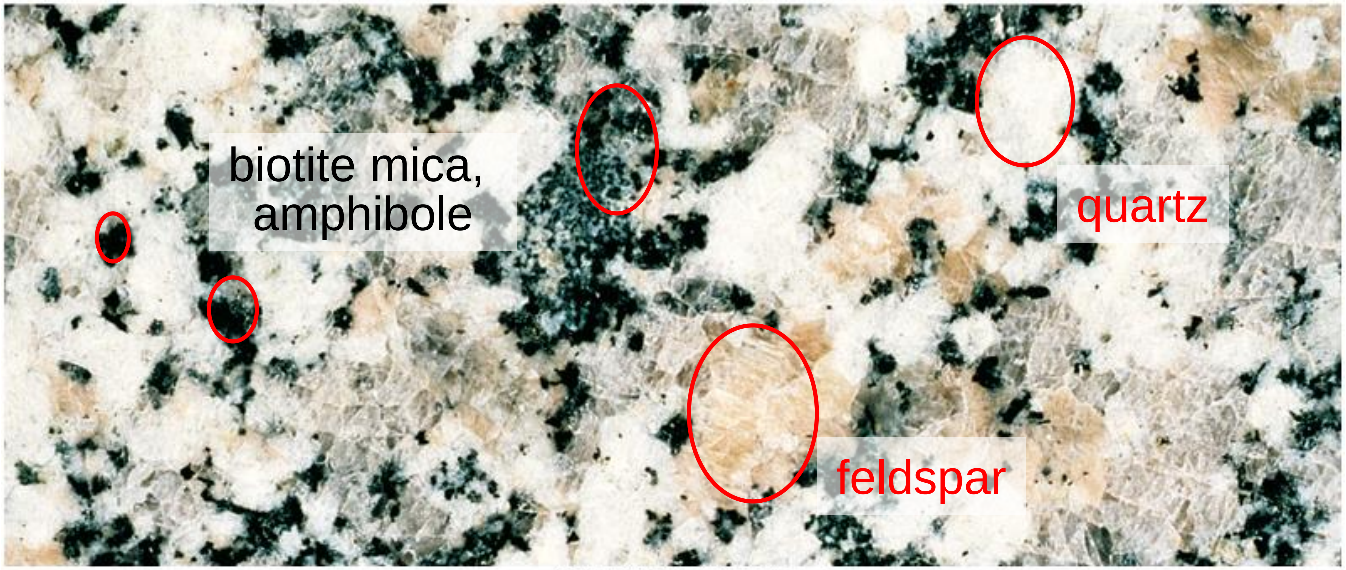


1. Earth Scientists: Nature Detectives
2. Elements and Atoms: Basic Building Blocks
3. Minerals
4. Igneous Rocks
5. Sedimentary Rocks
6. Metamorphic Rocks
7. The Rock Cycle and Mineral Resources

Introduction to Rocks

Rocks are made of minerals

- ~20 common minerals
- Example: The rock **granite** (below) is composed of 4 key minerals - ***feldspar, quartz, mica, amphibole*** - and minor amounts of others.



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Introduction to Soil and Sediments (Chapter 9)

Q: How many components of the Earth system are contained in soil?

A: All four:

- Geosphere
- Hydrosphere
- Atmosphere
- Biosphere

Soil (or dirt) is composed of:

- Regolith (rock and mineral fragments)
- Water
- Air
- Organic material

Rock formation is similar to making bricks…

b.

© David McConnell

- Brick making, like rock formation, involves:
  - Physical disintegration of raw materials
  - Chemical changes
  - Thermal effects

And brick making is influenced by the composition of the raw materials, just like the formation of rocks

Eight common elements compose 98% of continental crust.

Table 7.1 Most Common Elements in Continental Crust

Element	Ion	Percent by weight	Also found in
Oxygen (O)	O^{2-}	46.6	Air
Silicon (Si)	Si^{4+}	27.7	Window glass, computer chips
Aluminum (Al)	Al^{3+}	8.1	Cans, aircraft
Iron (Fe)	Fe^{2+}, Fe^{3+}	5.0	Meat, cornflakes, your car
Calcium (Ca)	Ca^{2+}	3.6	Milk, cheese, cement, antacids
Sodium (Na)	Na^{+}	2.8	Salt, bacon, cheese
Potassium (K)	K^{+}	2.6	Fish, fruit, nuts, fertilizer
Magnesium (Mg)	Mg^{2+}	2.1	Bread, nuts, salt
Other	–	1.5	–

Minerals are made of elements.

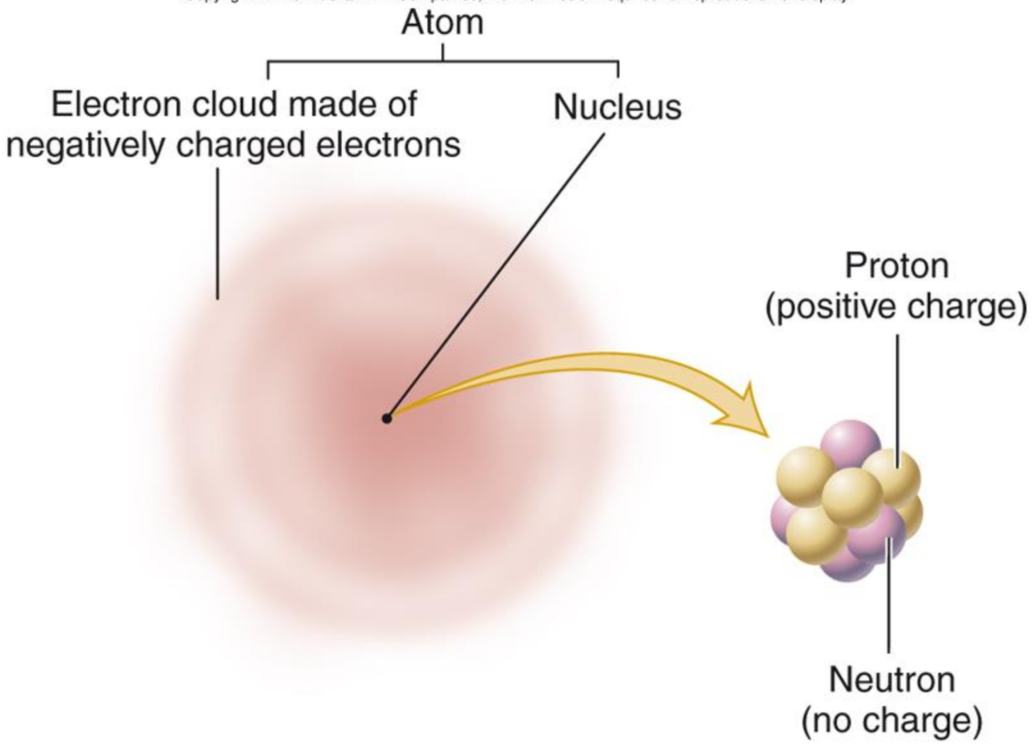
- Some minerals (e.g., quartz) are composed of just two elements
- Others (e.g., amphibole) are made up of several elements
- Some elements occur more frequently than others

Table 7.2 Most Common Elements in Granite Minerals

Mineral	Elements
Quartz	Oxygen, silicon
Feldspar	Oxygen, silicon, aluminum, calcium, sodium, potassium
Mica	Oxygen, silicon, aluminum, iron, potassium, magnesium
Amphibole	Oxygen, silicon, aluminum, iron, calcium, magnesium

Elements and Atoms: Basic Building Blocks

Atom – smallest particle that retains the characteristics of an element

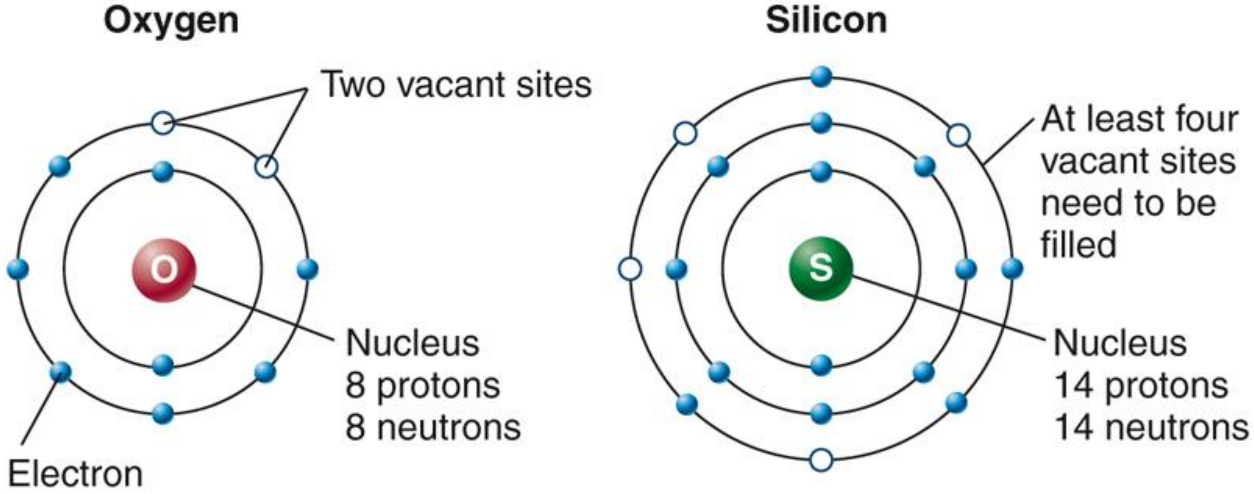


- Atoms are made up of **protons, neutrons,** and **electrons**
- Protons and neutrons in atomic nucleus
- Electrons in surrounding "cloud"

Elements and Atoms: Basic Building Blocks

Atoms may have negative or positive charge if they gain or lose electrons

- **Ions** – atoms with different numbers of protons (positive) and electrons (negative)

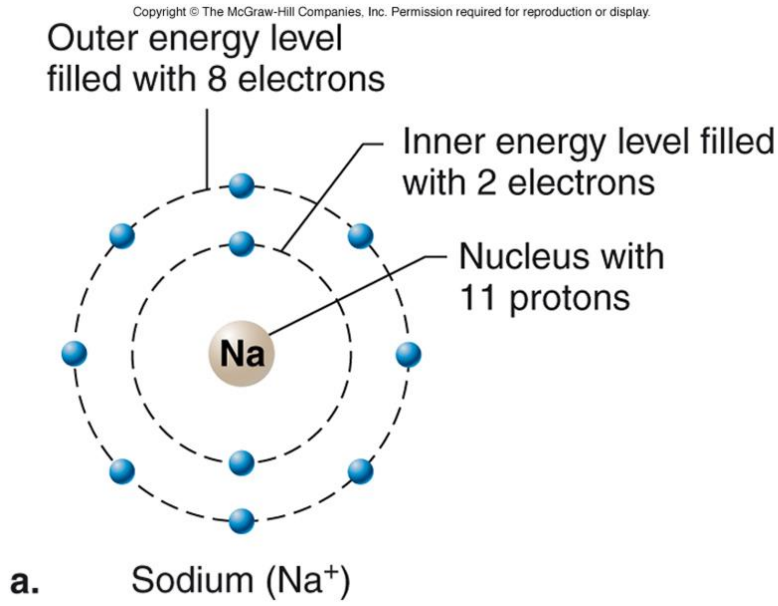


- Oxygen can gain two electrons to fill vacant sites
- 8 protons, 10 electrons → -2 (negative charge, O^{2-})
- Silicon may lose 4 electrons → +4 (positive charge, Si^{4+})

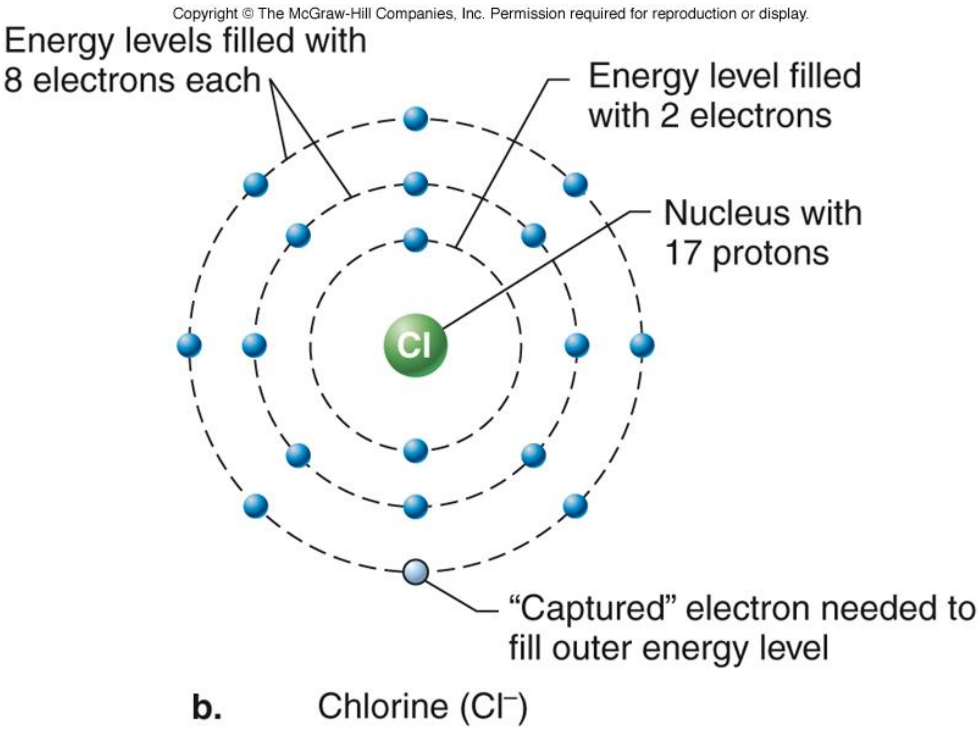
Elements and Atoms: Basic Building Blocks

- **Ionic bonds** – balance of negative and positive charges

Sodium atom loses extra electron to yield a positive charge (Na^+)

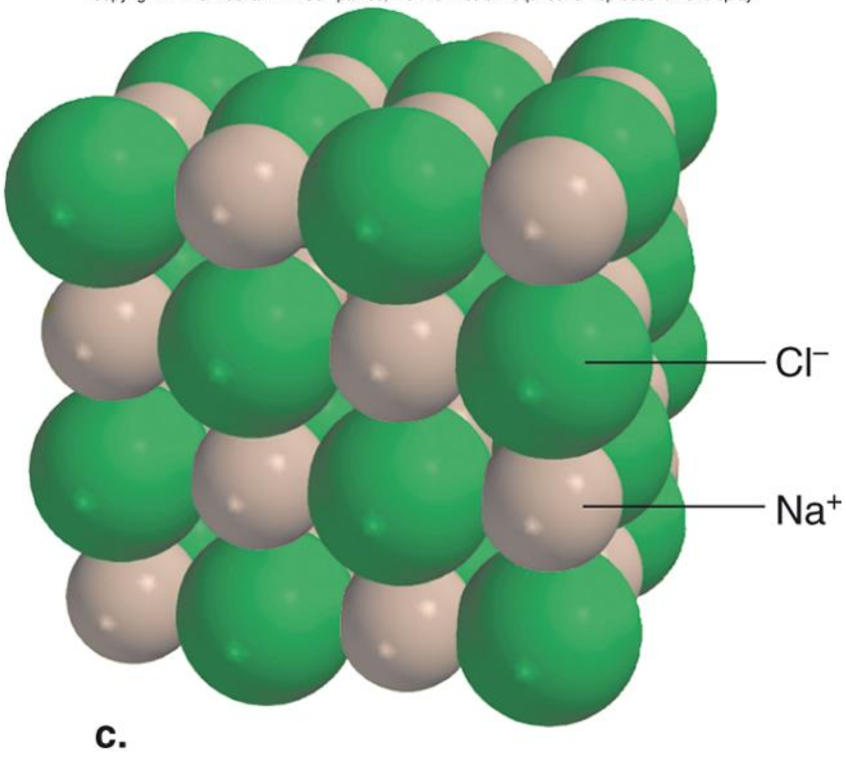


Chlorine ion gains extra electron to produce a negative charge (Cl^-)



Elements and Atoms: Basic Building Blocks

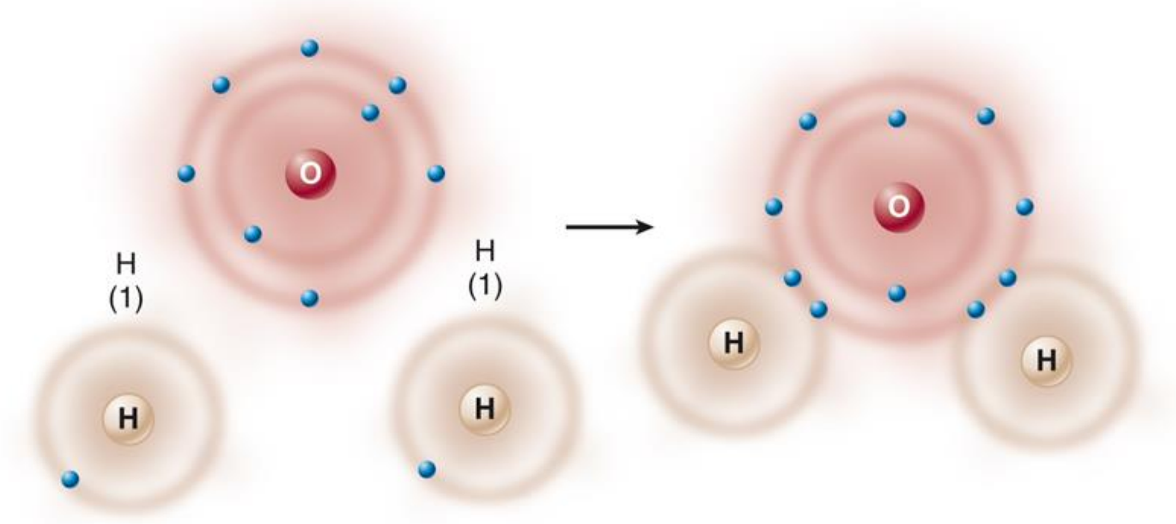
Ionic bonds – balance of negative and positive charges



- Sodium and chlorine bond together to form rock salt (halite)
  - **Ionic bond** – balance of positive sodium ions with negative chlorine ions (NaCl)

Elements and Atoms: Basic Building Blocks

Covalent bonds – sharing of electrons between elements



Oxygen is 2 electrons short of 8 electrons in its outer energy level.

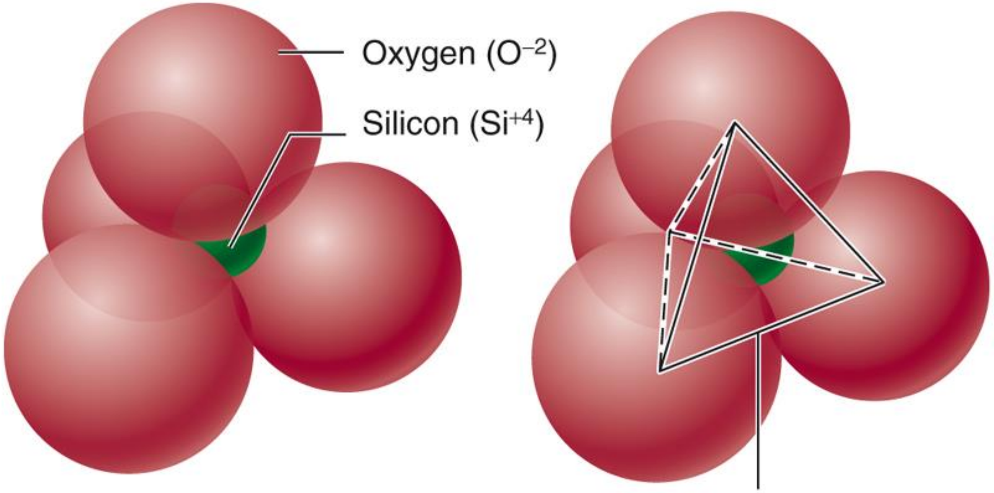
The hydrogen and oxygen atoms share electrons to give oxygen an outer energy level of 8, and the hydrogens each have 2.

- Hydrogen and oxygen bond together to form water (H_2O)
  - **Covalent bond** – sharing of electrons between atoms ions

Elements and Atoms: Basic Building Blocks

Multiple bonds – silicon and oxygen join together by a combination of ionic and covalent bonding

Silicate minerals – contain both silicon and oxygen



a. Arrangement of atoms in silica tetrahedron

b. Diagrammatic representation of a silica tetrahedron

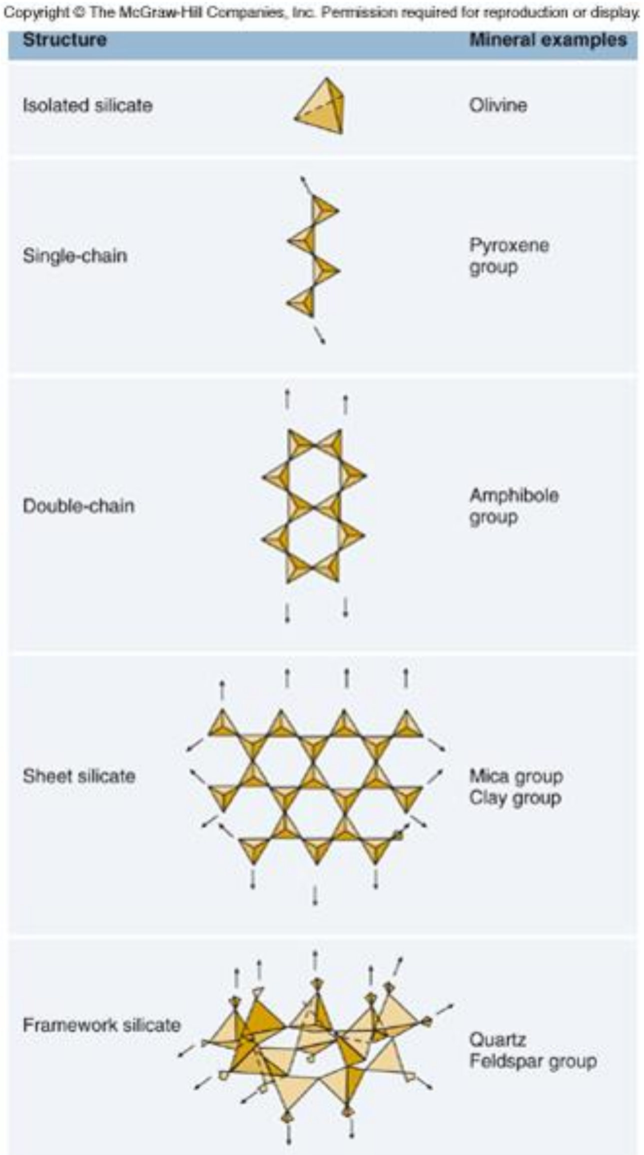
- Silicon and oxygen are most common elements in crust
- Silicates are the most common mineral group
  - Examples: quartz, feldspar, mica, amphibole

Elements and Atoms: Basic Building Blocks

Different types of bonds result in minerals of different strengths

- Type of bonds determine strength of minerals, rocks
  - **Ionic bonds** – Velcro analogy, weaker bonds
  - **Covalent bonds** – Rope analogy, stronger bonds
- Minerals formed with covalent bonds are stronger and more resistant to destructive forces at Earth's surface
  - Silicates form more resistant rocks than most other mineral groups

Elements and Atoms: Basic Building Blocks



Silica tetrahedra combine together in different patterns in different silicate minerals

- Minerals with low silica content have simple structures
  - Olivine, amphibole
- Minerals with high silica content have more complex structures
  - Quartz, feldspar

Rocks and Minerals Conceptest

Which of the following mineral formulae represents a silicate?

A. FeS_2

B. $KAlSi_3O_8$

C. Fe_2O_3

D. $CaSO_4 \cdot 2H_2O$

Instructions for Activity

Minerals

- **Minerals**: Naturally occurring, inorganic solids of one or more elements that have a definite chemical composition with an orderly internal arrangement of atoms

Minerals have different types of crystals.

***Crystal form* –** the arrangement of the faces of a crystal to form a particular shape

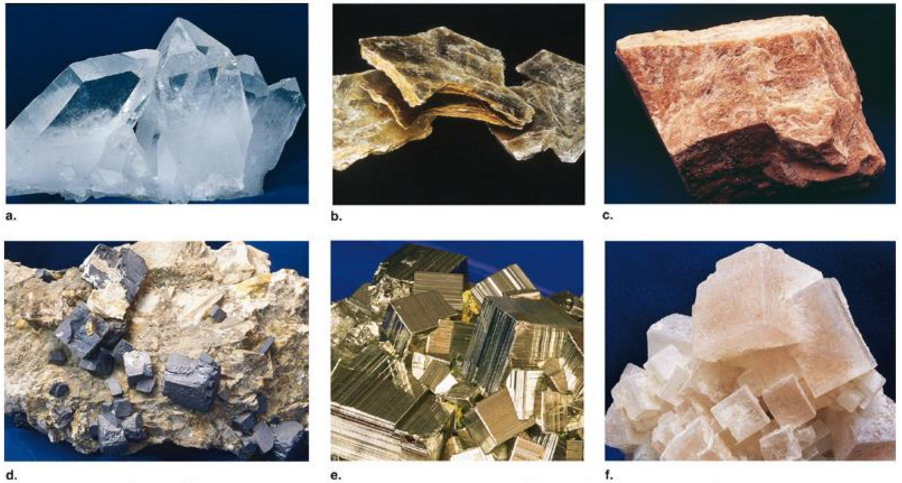
- Common shapes are
  - Prisms
  - Pyramids
  - Needles
  - Cubes
  - Sheets

Pyramids of calcite

Needles of tourmaline

Minerals have characteristic colors.

- Dark minerals (black, brown, dark green)
  - Olivine, amphibole, pyroxene, biotite mica
- Light minerals (white, gray, pink)
  - Quartz, feldspar, muscovite mica, calcite
- Careful, some minerals have many colors



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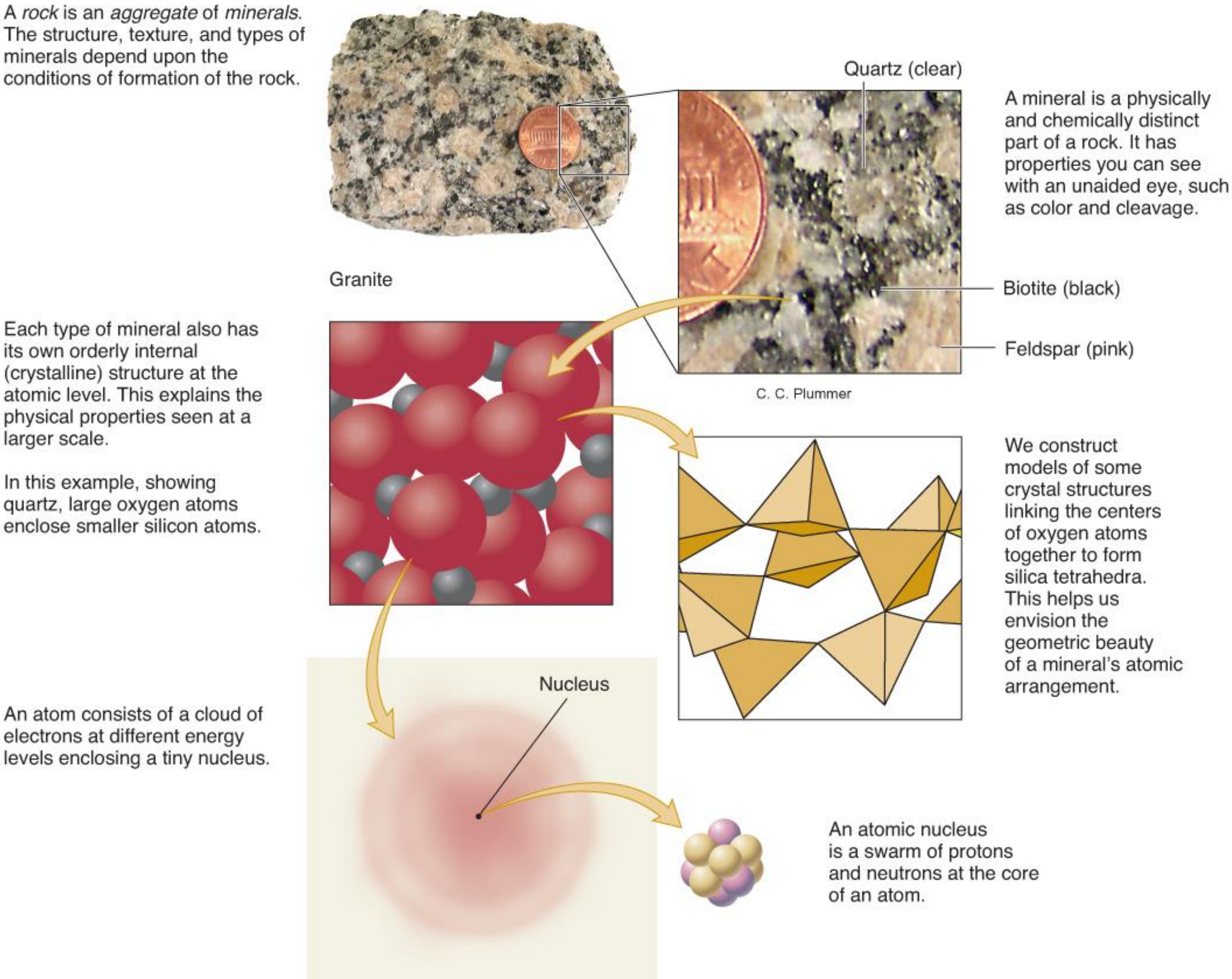
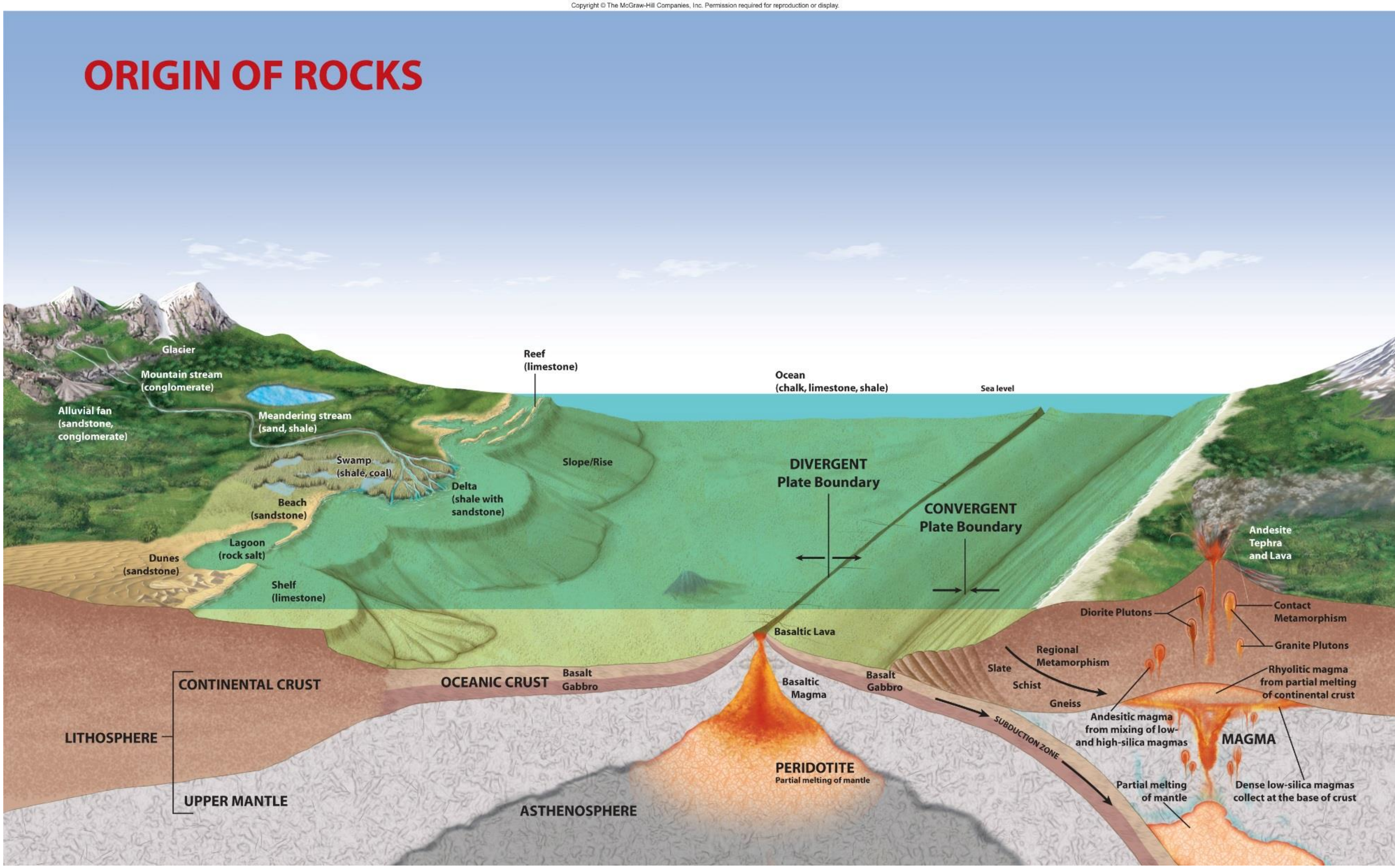
Atoms to rocks: How they fit together



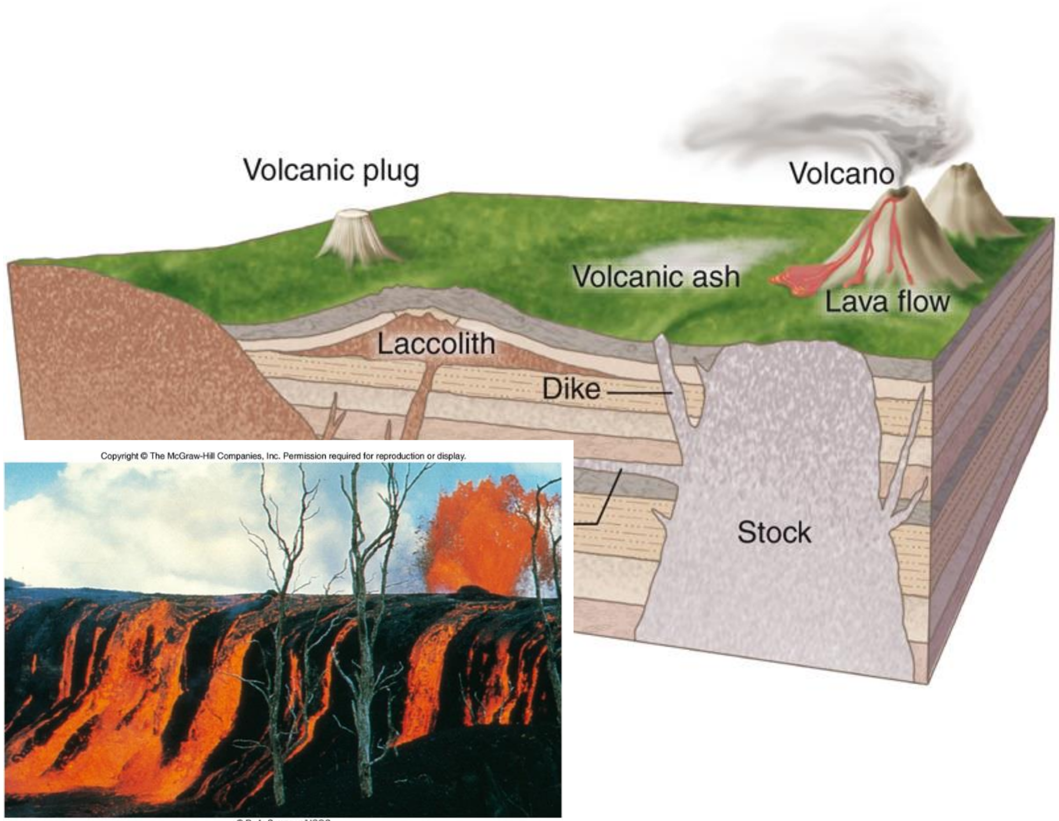
Igneous Rocks



Igneous Rocks

Two types of igneous rocks are classified based on texture and composition

The same magma can form both rock types



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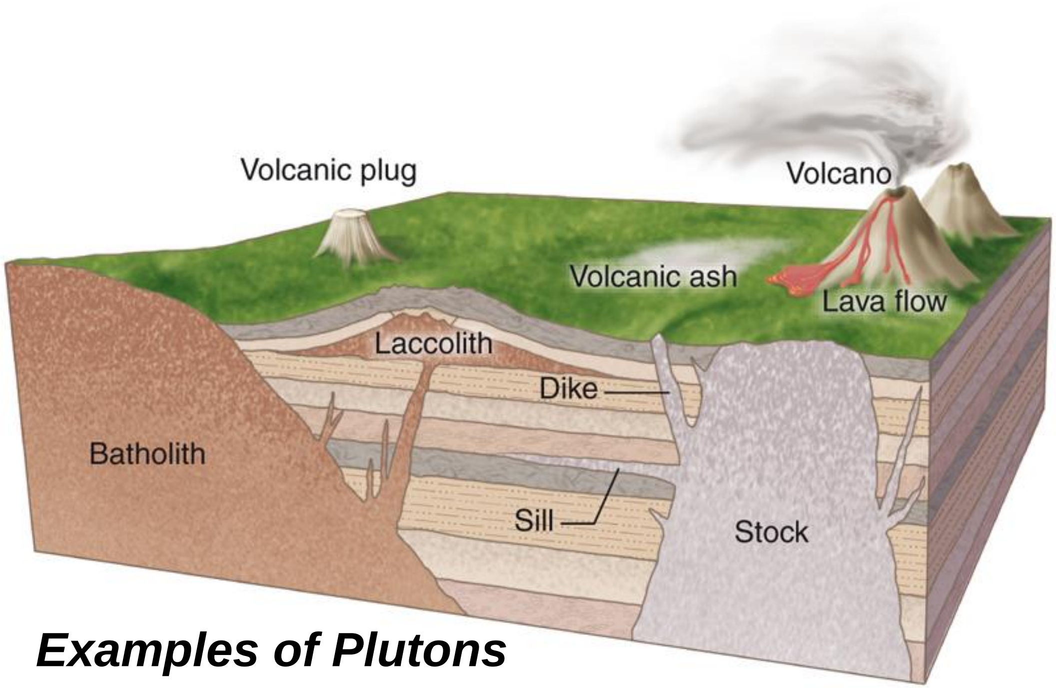
1. **Volcanic rocks** – form when magma rises to Earth's surface
    - Produces volcanoes, lava flows, tephra
    - Molten rock cools rapidly

Igneous Rocks

Two types of igneous rocks are classified based on texture and composition

The same magma can form both rock types

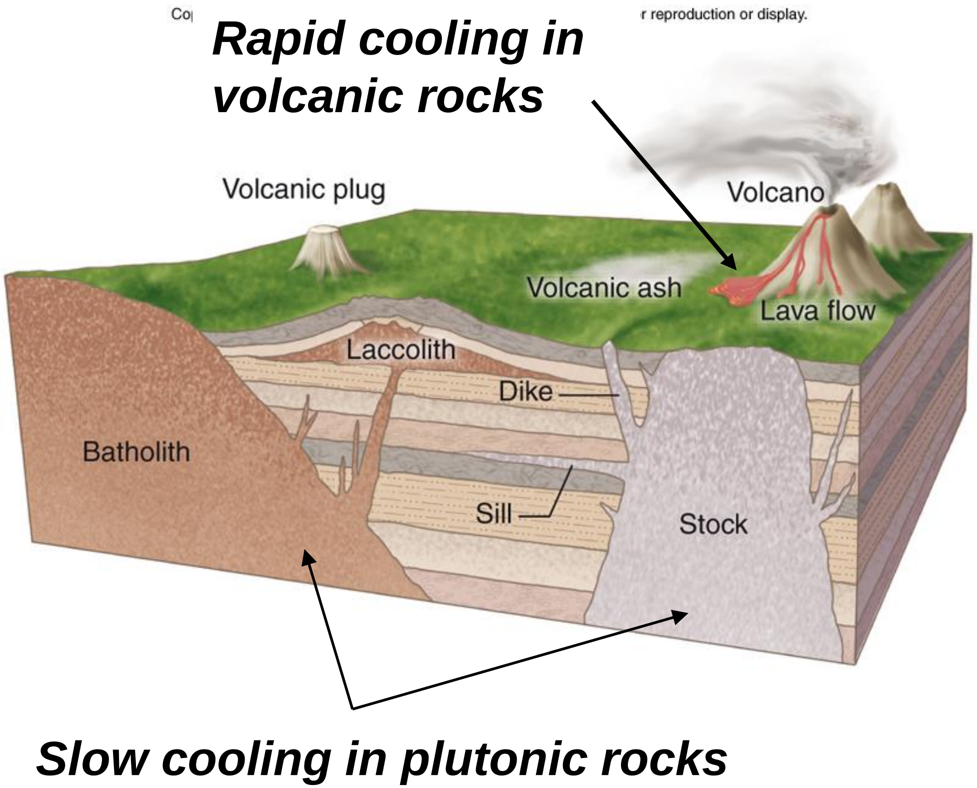


Examples of Plutons

Batholith, stock, sill, dike, laccolith

2. **Plutonic rocks** – form when magma solidifies below Earth's surface
   - Produces **plutons** that remain hidden until exposed by erosion
   - Molten rock cools slowly

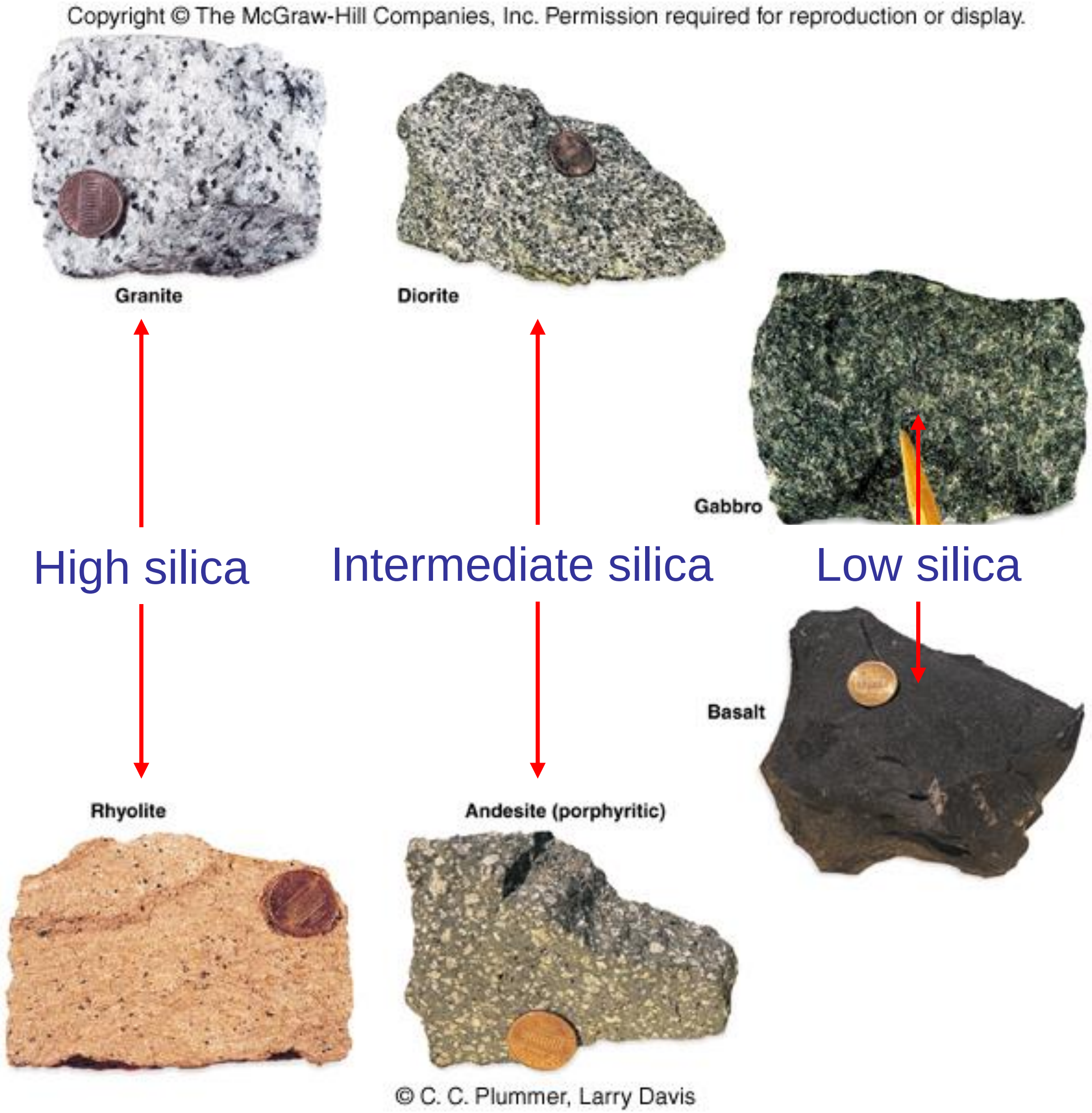
Igneous Rocks



Texture

- Size of crystals of minerals in igneous rocks depends on rate of cooling of magma
  - Rapid cooling produces microscopic crystals
  - Slow cooling produces large, visible crystals
- Crystal size interpreted to learn where rocks formed

Igneous Rocks



Color

- Color varies with silica content (composition)
  - Silica-rich minerals such as quartz and feldspar are light-colored
  - Silica-poor minerals such as amphibole, biotite mica are dark-colored

Igneous Rocks


Granite


Diorite


Gabbro

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Table 7.4 Silica Content of Igneous Rocks

Silica content	Volcanic rocks	Plutonic rocks	Common minerals
High	Rhyolite	Granite	Quartz, feldspar
Intermediate	Andesite	Diorite	Feldspar, amphibole, pyroxene
Low	Basalt	Gabbro	Pyroxene, feldspar, olivine

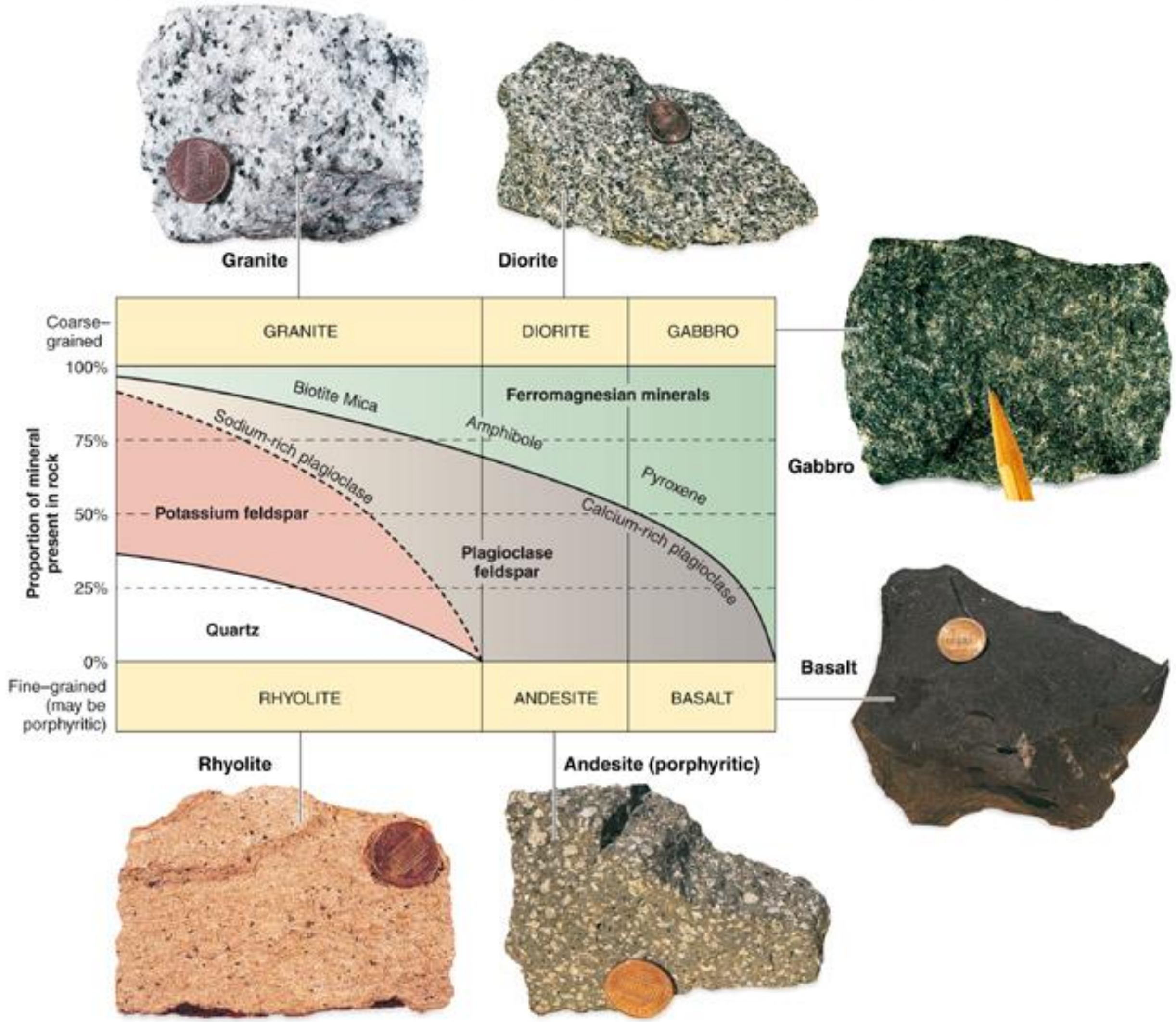

Basalt

Rhyolite


Andesite (porphyritic)


Igneous Rocks

Silica-rich rocks are composed mainly of minerals quartz and feldspar



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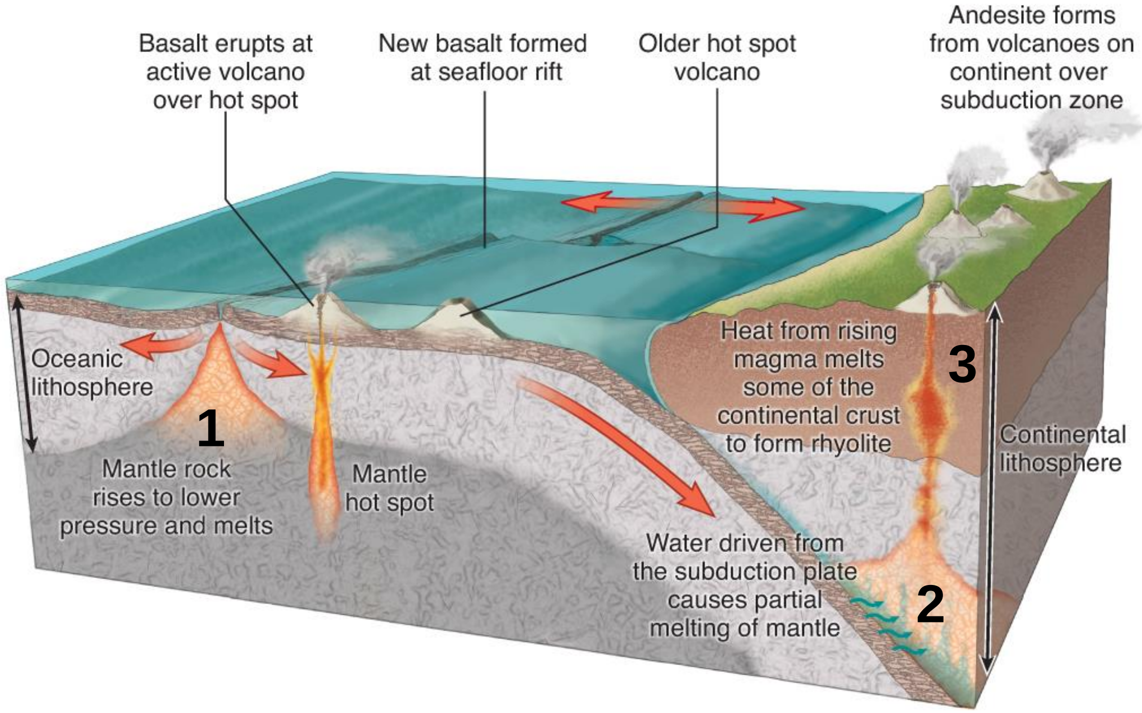
Silica-poor rocks are composed mainly of feldspar with iron and magnesium rich minerals (e.g. amphibole, pyroxene, olivine)

Igneous Rocks

Rock Types and Magma Types



Each magma type may produce two rocks – one volcanic, one plutonic

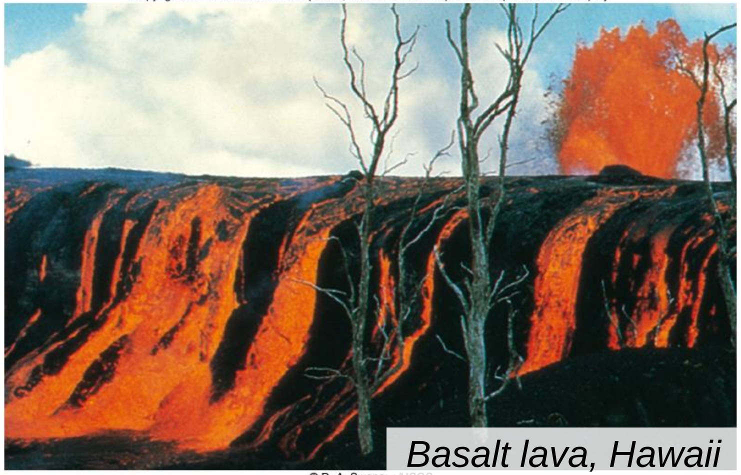
3 Magma Types

- **Basaltic magma** – partial melting parts of asthenosphere
- **Andesitic magma** – partial melting of mantle rocks (with water)
- **Rhyolitic magma** - melting of parts of continental crust

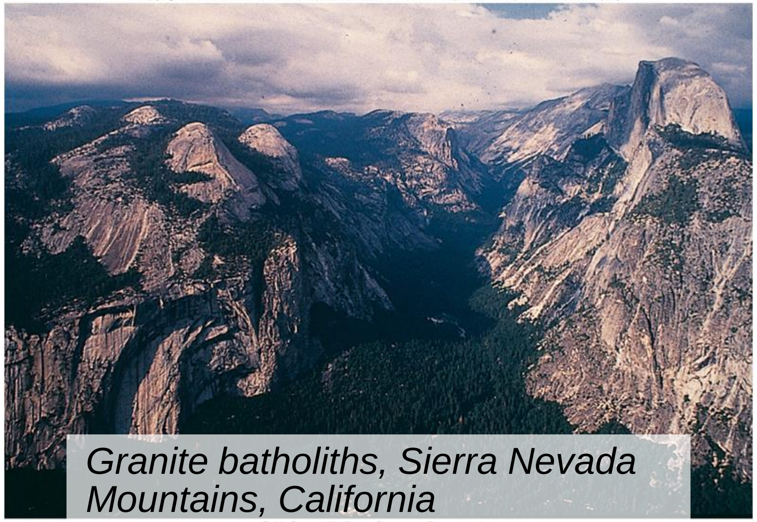
Igneous Rocks

Rock Types and Magma Types

- **Less viscous, low silica magma** likely to reach surface to form volcanic igneous rocks (e.g., basalt)



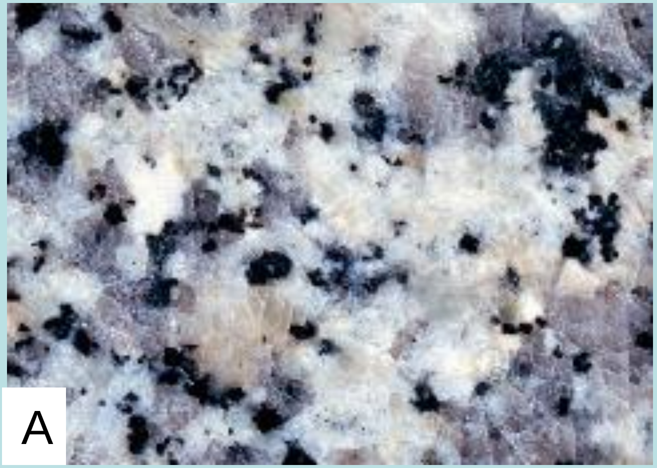
Basalt lava, Hawaii



Granite batholiths, Sierra Nevada Mountains, California

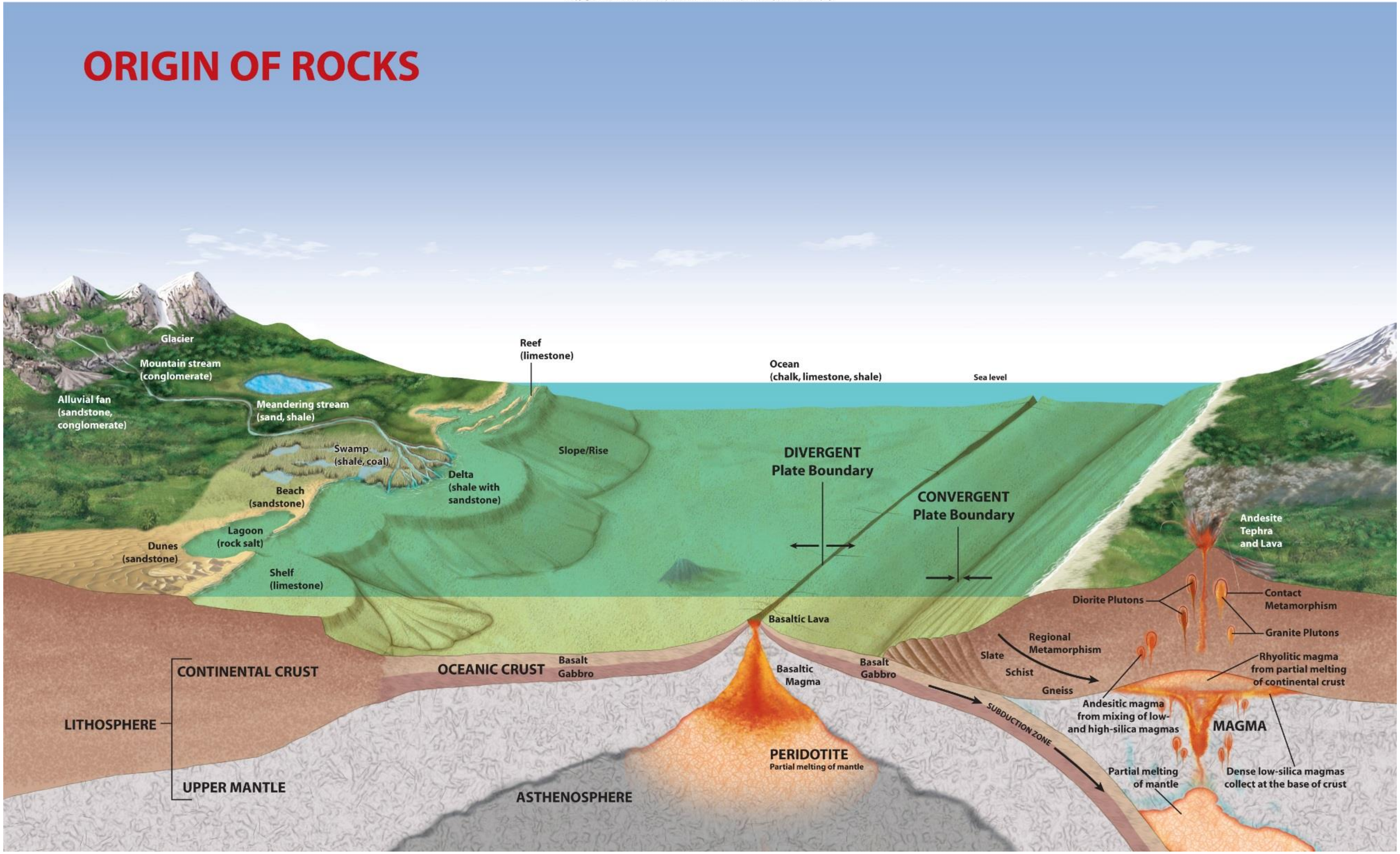
- **More viscous, high silica magma** likely to cool below surface to form plutonic igneous rocks (e.g., granite)

Rocks and Minerals Checkpoint 7.10



Name these igneous rocks and explain the reasons for your choices.

Sedimentary Rocks



Sedimentary Rocks

Sedimentary rocks form as horizontal layers (beds)

- identified based on composition, thickness
- oldest beds at bottom, youngest at top

a.

USGS

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b.

USGS

Sedimentary Rocks

Three types of sedimentary rocks

- Clastic, Chemical, Biochemical
  - Identified by materials that make up the rock and/or the process by which they formed

c.

USGS

d.

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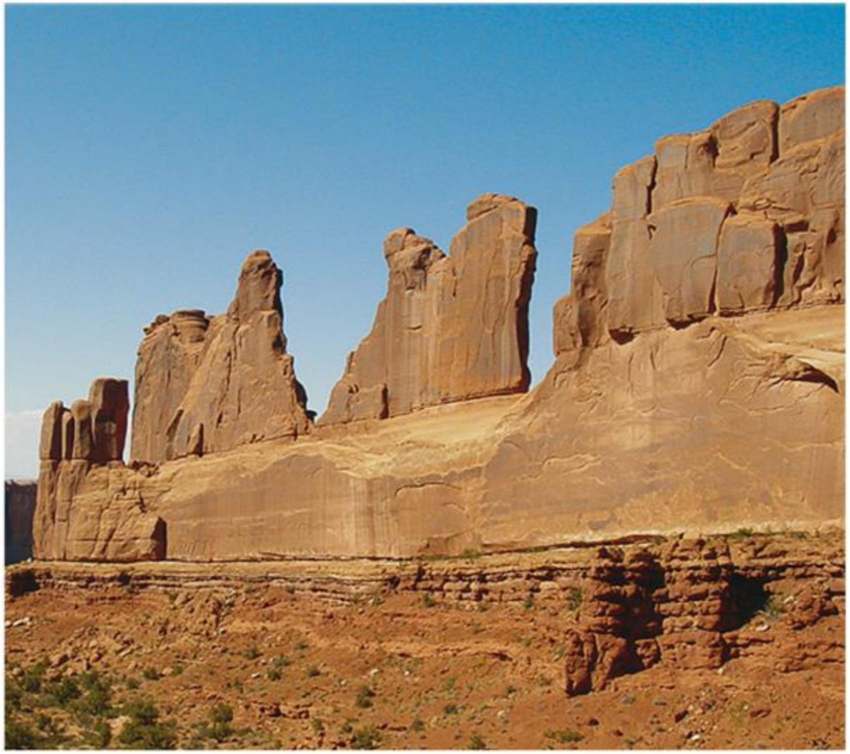
Sedimentary Rocks



b.

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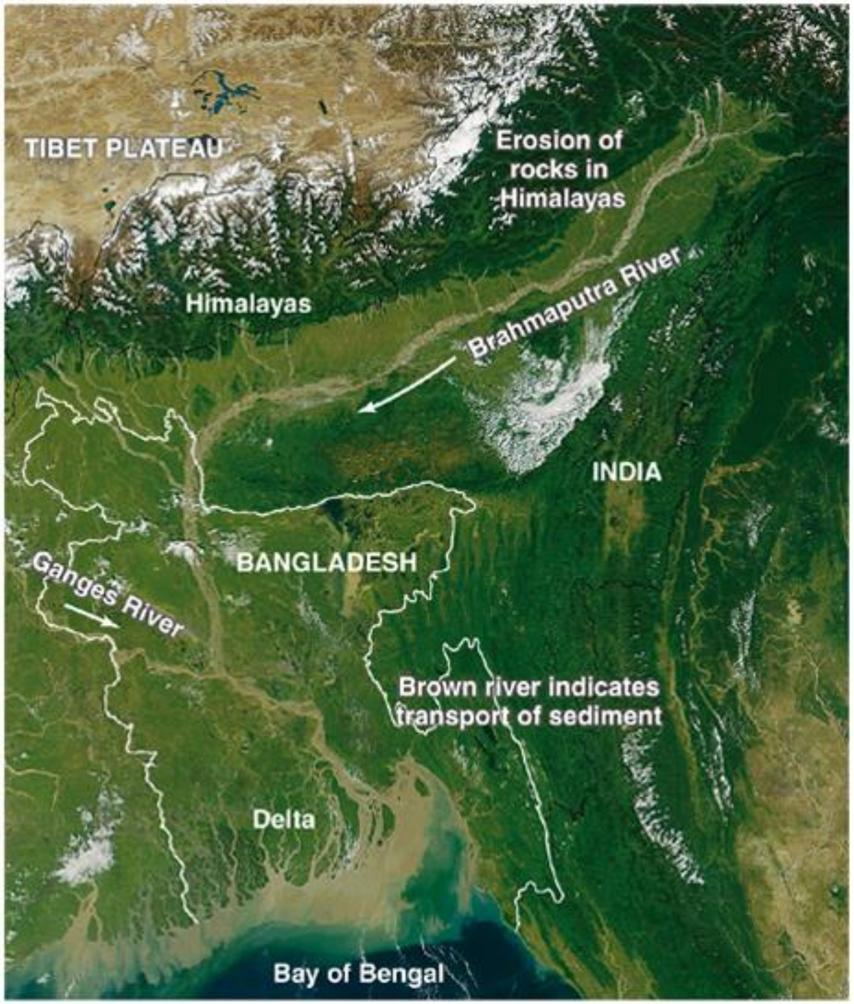
Clastic Sedimentary Rocks

- Composed of rock and mineral fragments
  - Most common type of sedimentary rock
- 3 stages of formation
  - Generation
  - Transportation
  - Lithification

Sedimentary Rocks



a.

Sediment generated by weathering of Himalayas and transported in rivers

Clastic Sedimentary Rocks

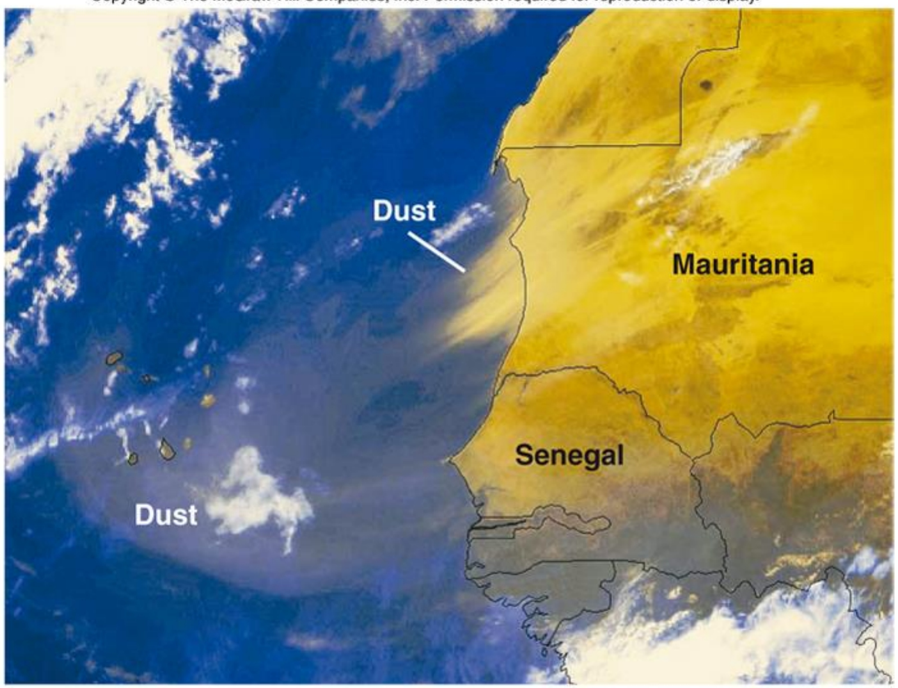
See Chapter 9: Weathering and Soils

1. Generation
   - **Physical and chemical breakdown of any rock at Earth's surface (weathering) to form sediment**
   - Sediment = rock and mineral fragments
   - Sediment classified by grain size
     - Clay
     - Silt
     - Sand
     - Gravel

↓ *Increasing grain size*

Sedimentary Rocks

Clastic Sedimentary Rocks

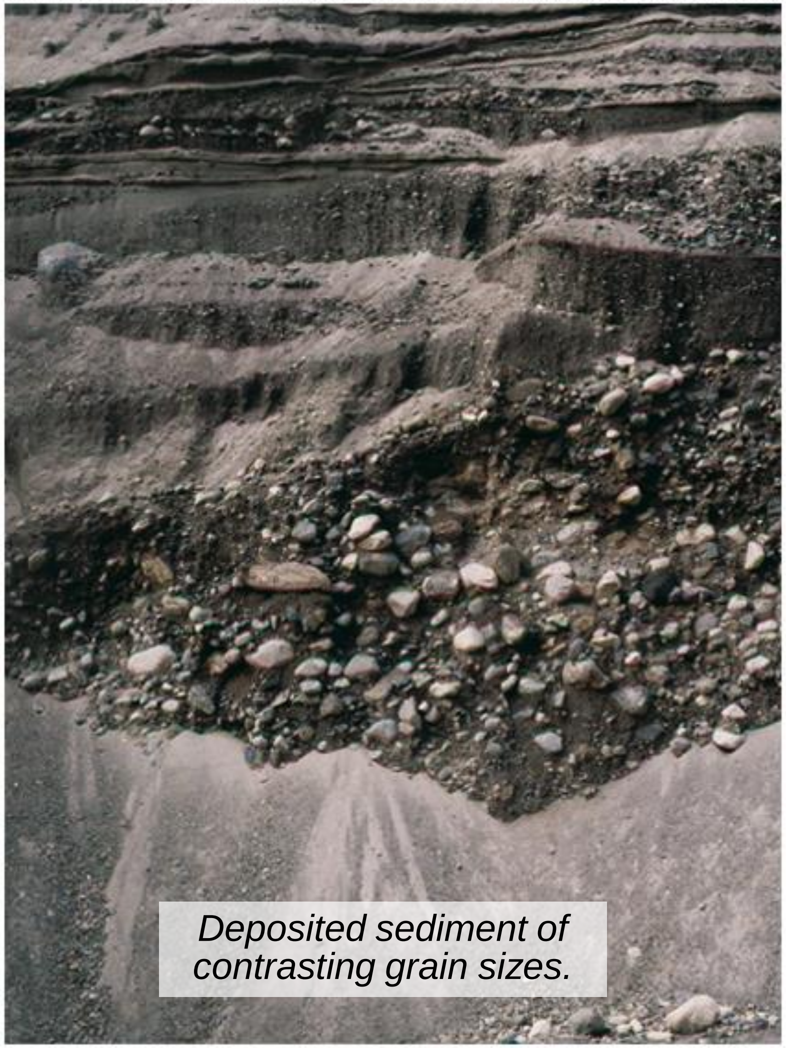


b.

Sediment (dust) transported by prevailing winds from Africa toward the Atlantic Ocean

2. Transportation
   - Erosion → Sediment moved from place of origin by streams, wind, glaciers
   - Size of transported grains depends on velocity of transport medium
   - Erosion produces characteristic landscapes

Sedimentary Rocks



Deposited sediment of contrasting grain sizes.

Clastic Sedimentary Rocks

3. Lithification
   - Sediment deposited when velocity of transport medium decreases
   - Larger grain sizes deposited first, finest grains remain in suspension and are deposited last
   - Over time, sediment is slowly compacted and grains are cemented together to form a new rock (lithification)

Sedimentary Rocks

Clastic Sediment and Clastic Sedimentary Rocks

- Rock names reflect grain size
  - **Mudstone, Shale** made of clay, silt-sized grains
  - **Sandstone** composed of sand-sized particles
  - **Conglomerate** made of gravel and larger fragments

a. © Scientifica/Visuals Unlimited

b. © Dr. John D. Cunningham/Visuals Unlimited

Sandstone composed of quartz grains of similar sizes.

Conglomerate composed of gravel-sized rock fragments

Sedimentary Rocks

Clastic Sediment and Clastic Sedimentary Rocks

- Rock names reflect grain size (see Table 7.5)
- Transportation process sorts grains so deposits may have characteristic grain size (e.g., sand on a beach)

Table 7.5 Clastic Sediments and Sedimentary Rocks

Sediment	Grain size (diameter)	Rock	Grain size comparisons
Clay	Less than 0.0039 mm (less than 0.00015 in)	Shale, mudstone	Smaller than granulated sugar
Silt	0.0039 to 0.0625 mm (0.00015 to 0.0025 in)	Siltstone	
Sand	0.0625 to 2 mm (0.0025 to 0.079 in)	Sandstone	Ranges from sugar to coarse salt
Gravel	More than 2 mm (more than 0.079 in)	Conglomerate	Ranges from rice grains to oranges

Sedimentary Rocks

Clastic Sediment and Clastic Sedimentary Rocks

- Transportation process sorts grains so deposits may have characteristic grain size (e.g., sand on a beach)
- Sedimentary rocks hold clues to the environment where they were formed:
  - Example: river channels
    - High velocity flow in floods - gravels (conglomerate)
    - Moderate speed flow – sand (sandstone)
    - Slow flow - muds (shale)

Sedimentary Rocks

Chemical Sedimentary Rocks

© Dennis Flaherty/ Photo Researchers, Inc.

Salt deposited on floor of ancient Lake Bonneville, Utah

- Form when minerals precipitate (crystallize) from a solution as a result of changing physical conditions
  - Solutions = fresh water in lakes, groundwater or seawater
  - Changing conditions commonly = increased temperatures (evaporation)

Sedimentary Rocks

Chemical Sedimentary Rocks

Salt deposited on floor of ancient Lake Bonneville, Utah

- Can be readily dissolved in water and transported to oceans
- Rocks are typically indicative of shallow, coastal marine conditions in geologic past
  - Termed **evaporites** as most form by precipitation due to evaporation

Sedimentary Rocks

Biochemical Sedimentary Rocks

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a.

© Gerald & Buff Corsi/Visuals Unlimited

- Link the biosphere and geosphere
- Form due to actions of living organisms that cause minerals to be extracted from solution

OR

- From the remains of dead organisms

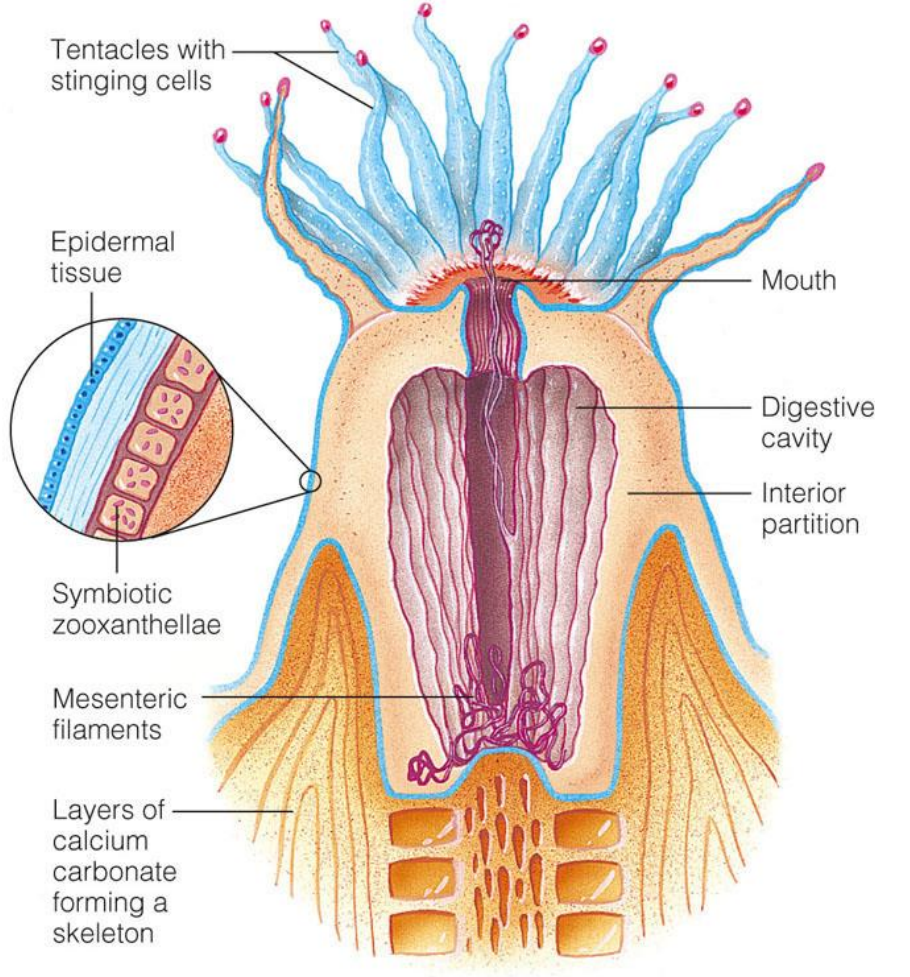
Sedimentary Rocks

Biochemical Sedimentary Rocks

Coral reef formed in shallow, tropical sea

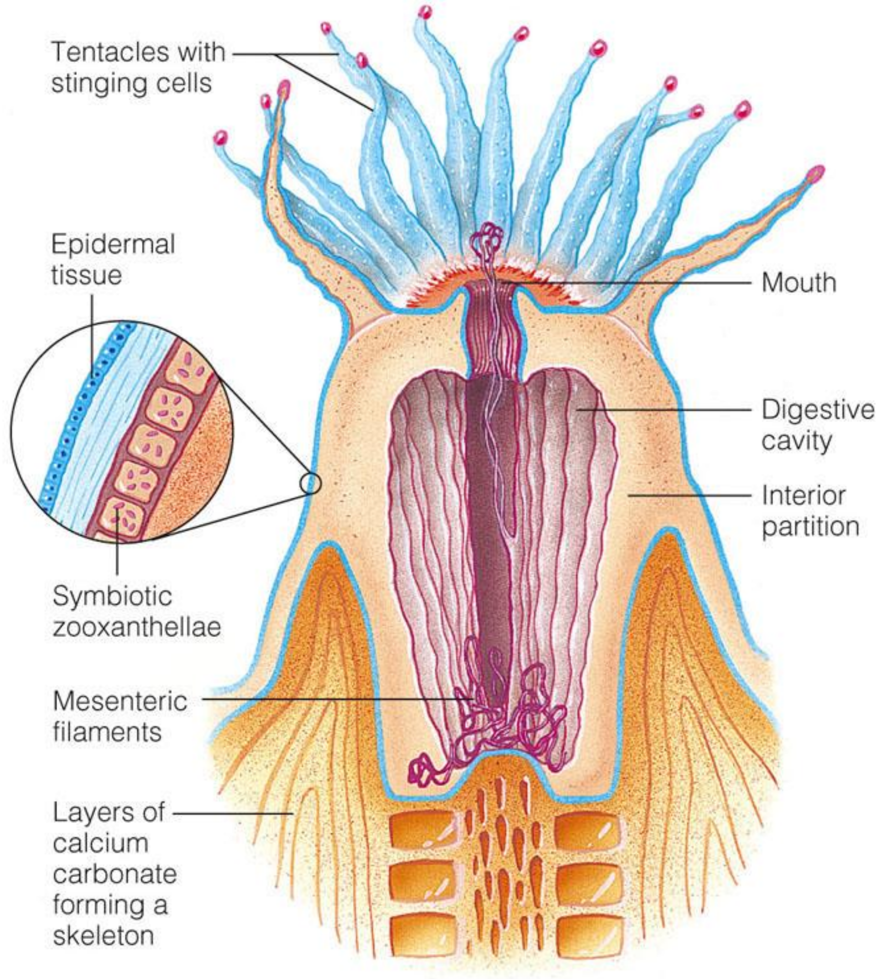
- Form due to actions of living organisms that cause minerals to be extracted from solution
  - The mineral calcite is present in the rock limestone formed by coral organisms that build tropical reefs

Coral Biology



Corals have symbiotic relationship with zooxanthellae, which are a type of phytoplankton (plant-like microorganisms). Corals provide safe environment, source of CO_2 & nutrients.

a



Zooxanthellae provide corals with oxygen, carbohydrates and alkaline pH to enhance $CaCO_3$ deposits.

Florida is built on limestone.

Animation of Florida's Tectonic History:

https://www.youtube.com/watch?v=qQT12lzlwNM

The Florida Peninsula is a **limestone plateau** formed many millions of years ago when the area was a warm, shallow sea.

http://www.dep.state.fl.us/geology/geologictopics/geohist-2.htm

Florida eventually found itself wedged between Gondwanaland and North America when they combined to form the super continent Pangea. When Pangea began to break up, Florida remained behind with North America.

Florida slipped slowly beneath the waves to become part of North America's continental shelf. The landmass that is now Florida remained shallowly submerged beneath the ocean. Coral, shellfish, and fish skeletons piled up. This created a layer of limestone hundreds (in some places thousands) of feet thick.

As the Appalachian Mountains eroded, sand and clay were deposited over Florida's limestone layer. Much of the quartz sand covering the state today came from the rocks of that mountain chain.

http://fcit.usf.edu/florida/lessons/land/land.htm

Sedimentary Rocks

Biochemical Sedimentary Rocks

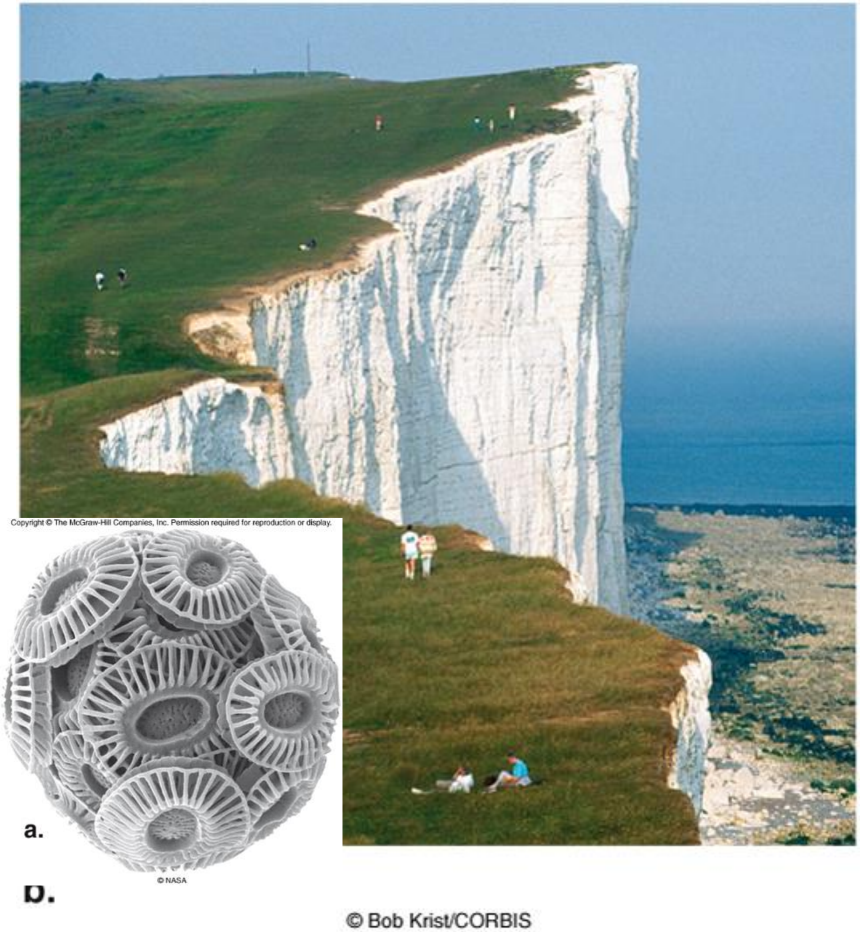
a.

b.

- May form from the remains of dead organisms
  - **Coquina → limestone formed from broken shell fragments**
  - Coal → carbon-rich rock formed from compacted plant remains

Sedimentary Rocks

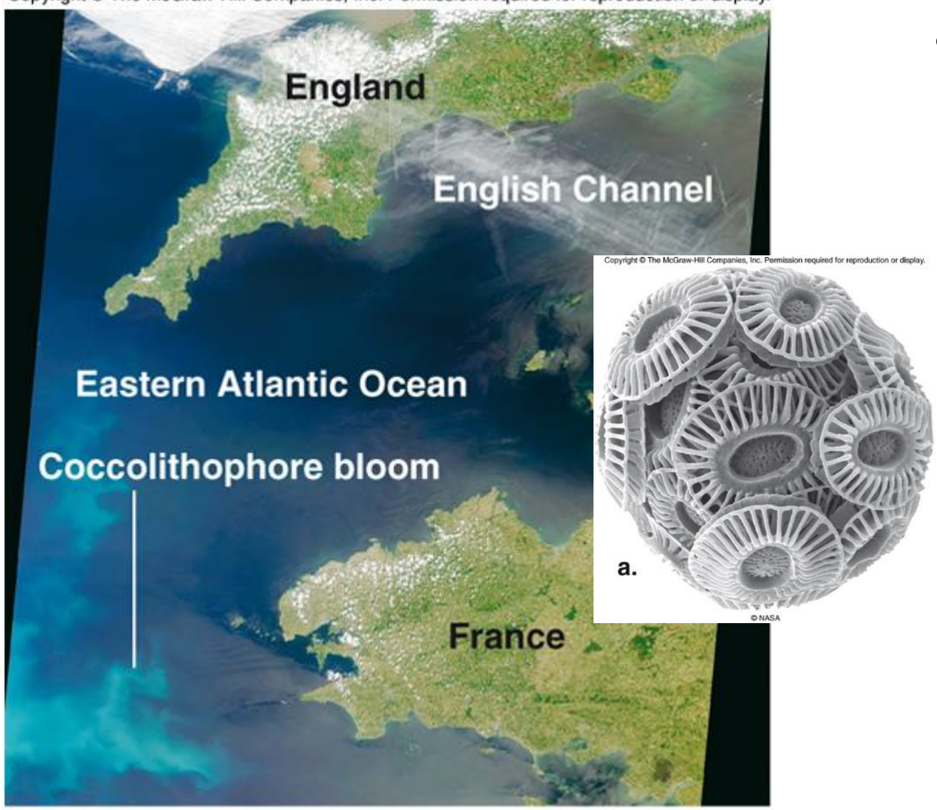
Biochemical Sedimentary Rocks



- May form from the remains of dead organisms
  - Chalk formed from billions of coccoliths, round plates of calcite from microscopic (clay-sized) coccolithophore organisms
  - Chalk is a type of limestone

Sedimentary Rocks

Biochemical Sedimentary Rocks



c.

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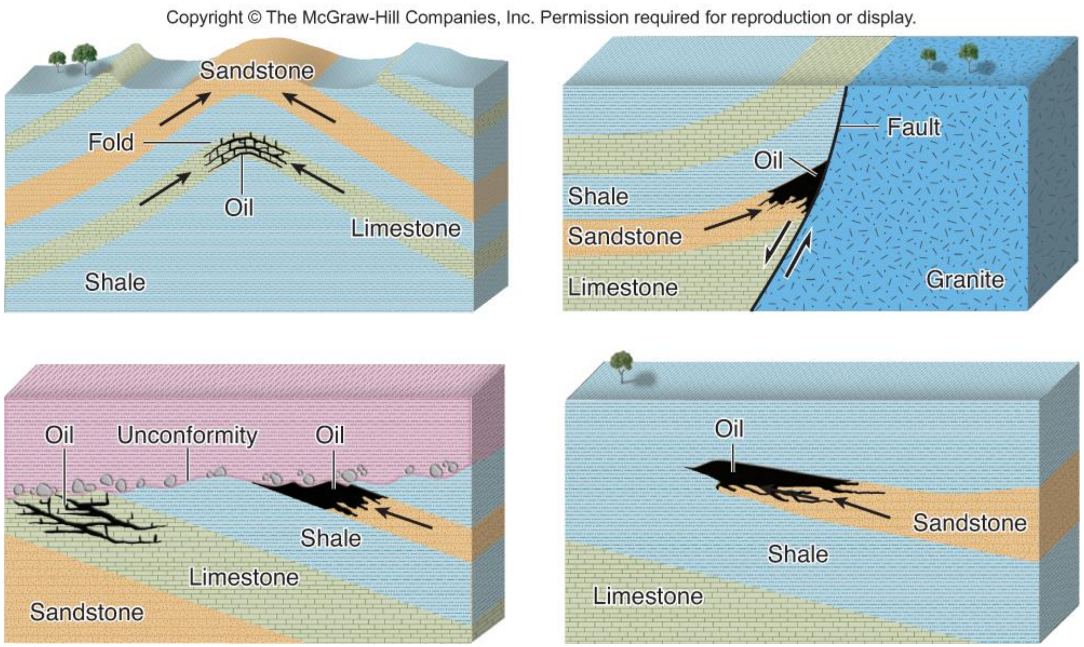
- May form from the remains of dead organisms
  - Coccolithophores live in cold oceans
  - Reflect sunlight to change water color
  - Chalk indicates specific marine conditions in geologic past

Sedimentary Rocks and Fossil Fuels

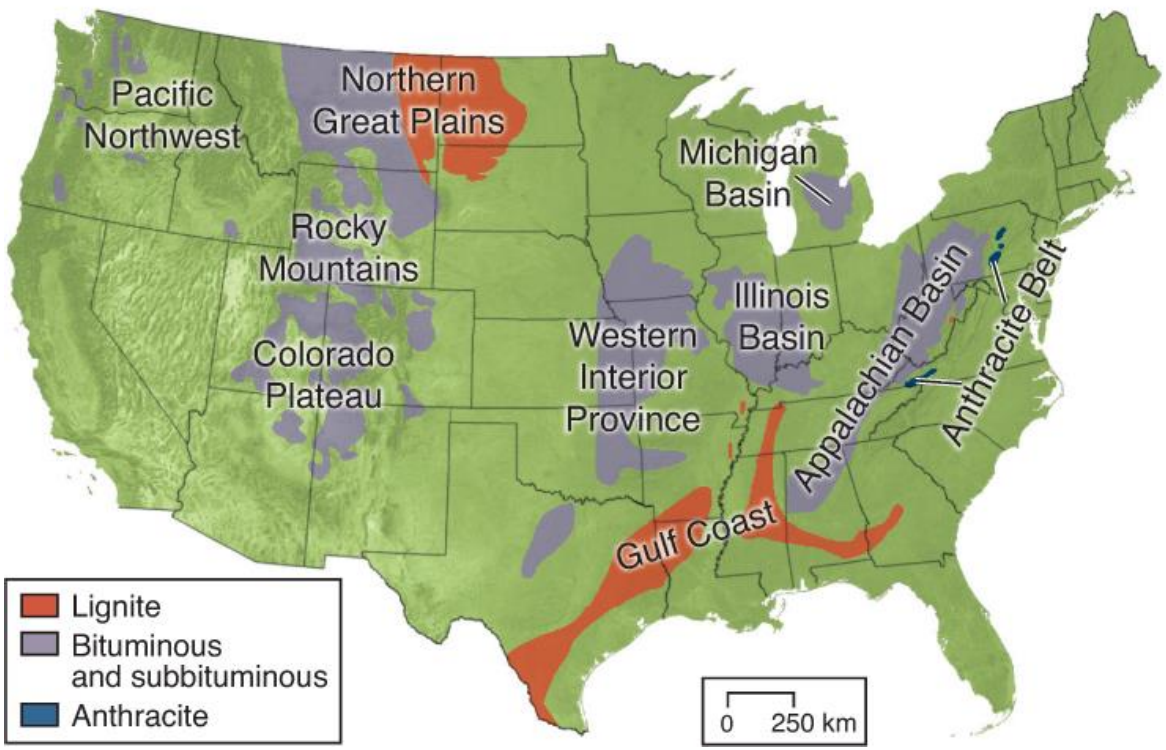
The world is heavily dependent on oil and natural gas



- Form from buried organic-rich sediments.
- Chemical reactions convert organics with increased pressures and temperatures of 50-100 ºC.
- Over time (millions of years), oil and gas can form.
- Oil and gas may be trapped to form hydrocarbon reservoirs.

Sedimentary Rocks and Coal

US has some of the largest coal reserves in the world.



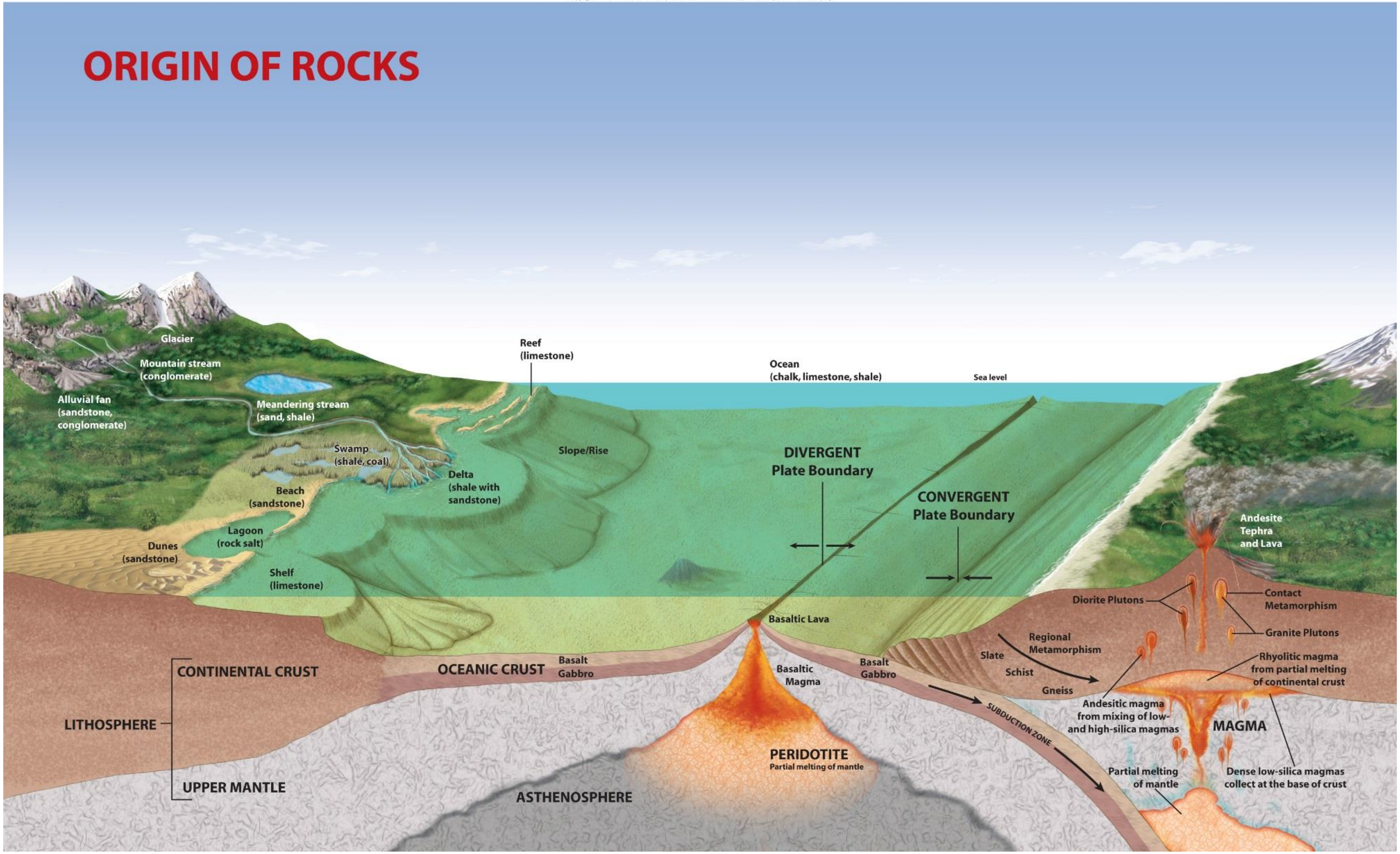
Form from buried plants.

Over time (Myrs), coal can form.

Coal type (rank) depends on organic content of parent material, burial depth and heat.

Lignite (low grade); bituminous (medium); anthracite (high).

Metamorphic Rocks

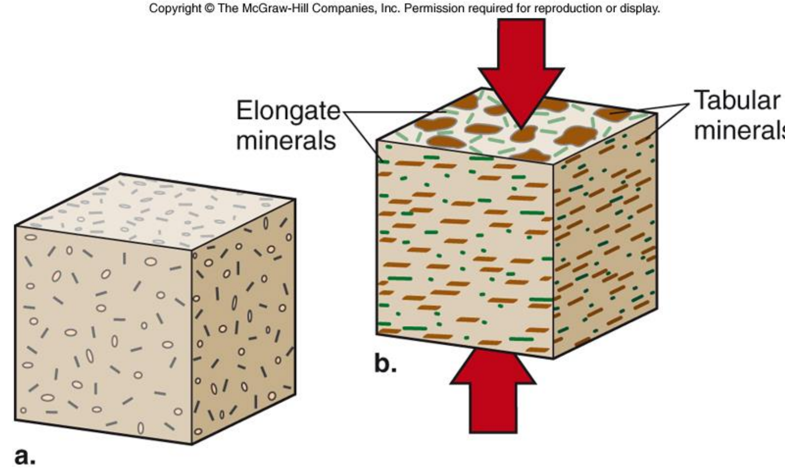


Metamorphic Rocks

Metamorphism

- Changes in mineral composition and texture that can occur in any solid rock
- Changes due to increasing **temperature** and/or **pressure** and/or the **presence of fluids.**
  - Temperatures high enough to promote chemical reactions but not high enough to cause melting
    - Approximately 200°C → 1100°C, depending on rock type and conditions
    - Similar temperatures found deep in crust or near magma chambers

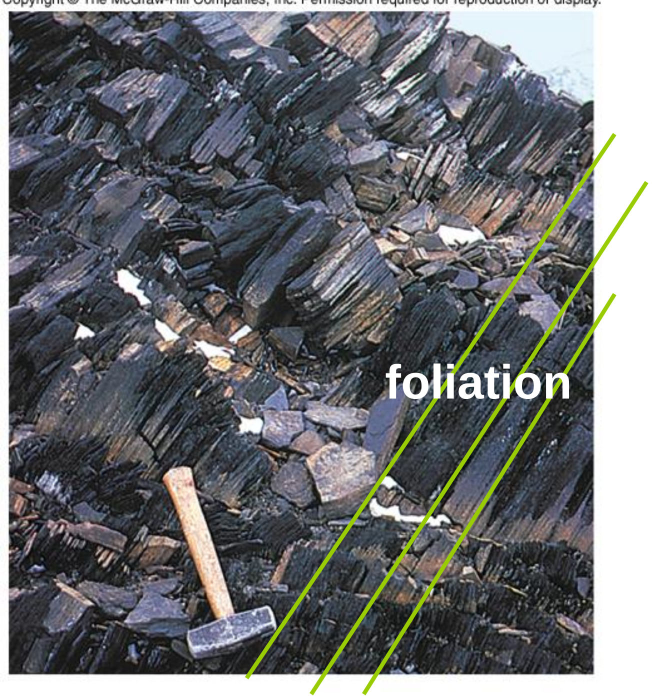
−Example: limestone around a magma chamber is baked by heat to form marble



Foliation is produced when tabular minerals grow perpendicular to the direction of pressure.

Metamorphic Rocks

Increased pressures and temperatures cause tabular minerals to take on a preferred orientation, known as **foliation**, perpendicular to direction of pressure



a.

© P.D. Rowley, USGS Photo Library,Denver. CO

Unmetamorphosed, non-foliated original rock (granite) with random distribution of minerals

Metamorphic rock (gneiss) with foliation illustrates parallel alignment of minerals

c.

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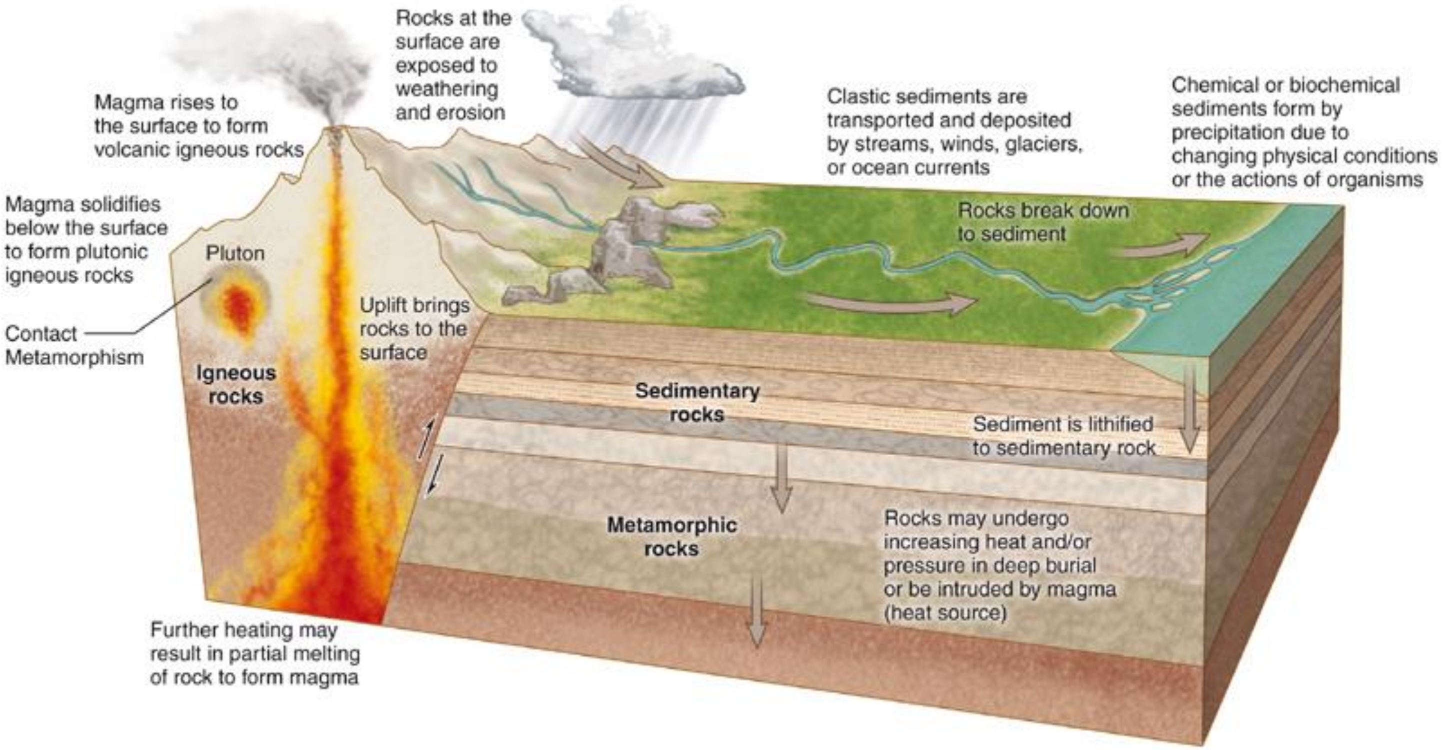
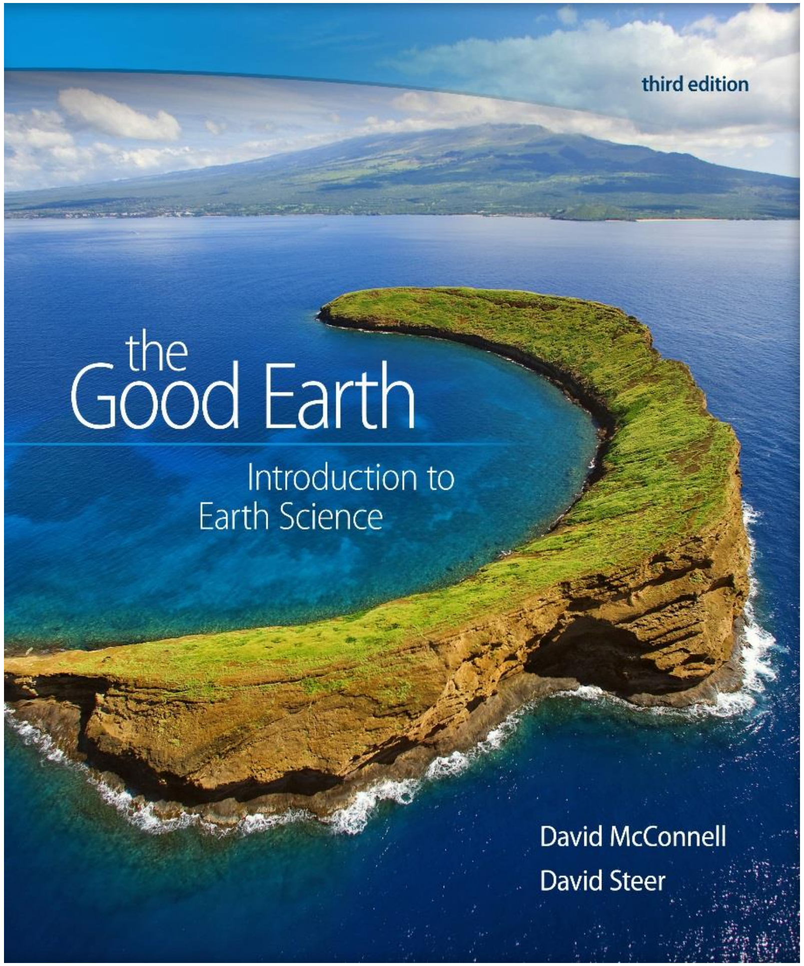
The Rock Cycle and Mineral Resources

- Rock cycle links igneous, sedimentary, and metamorphic rocks together.
  - Any rock can become any other rock under the appropriate conditions.



Chapter 9: Weathering and Soils



1. The Dirt on Weathering
2. Physical Weathering
3. Chemical Weathering
4. Biological Weathering and Decay
5. Weathering Rates
6. Soils: An Introduction
7. Soil Erosion and Conservation

Weathering Checkpoints- from Study Guide

Imagine that you have been appointed to a team of researchers charged with determining which of the five World Heritage sites in Figure 9.1 is at greatest risk from ***physical, chemical, and biological*** **weathering**. For each type of weathering, identify at least three general questions you will ask as you begin to gather data for your study.

Weathering Rates

What controls how quickly a rock weathers?

Rock composition

Rock properties

Climate

© USGS

In these low porosity rocks, weathering is restricted to the outer rind.

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a.

© USGS

Weathering concentrated along fractures. The degree of weathering decreases downward. **Why?**

The Dirt on Weathering

Weathering is the **physical, chemical, and biological** breakdown of rocks and minerals.

a.

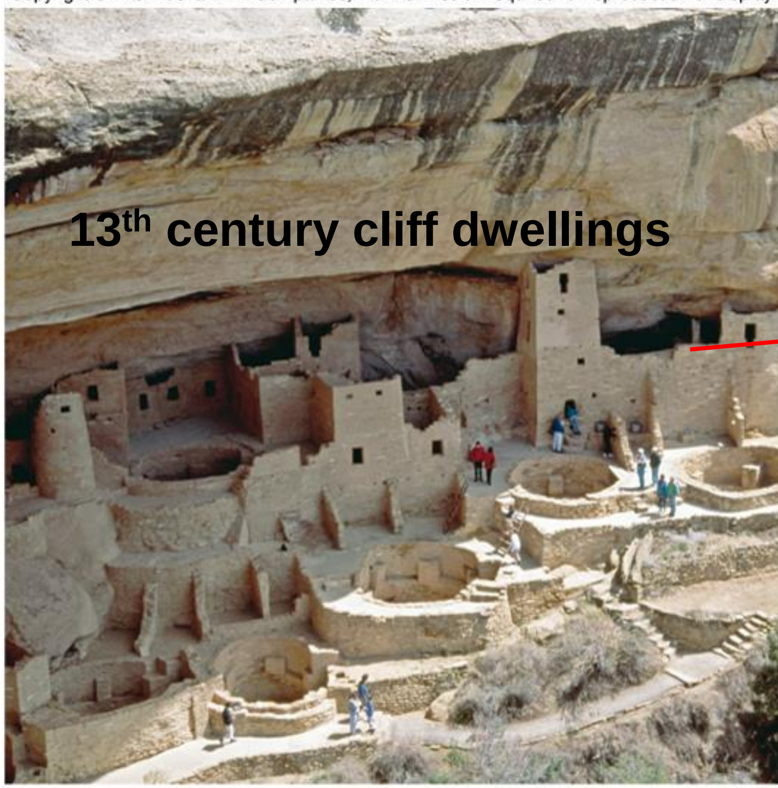
© Atlantide Phototravel/Corbis

Five World Heritage Sites

Very few ancient structures are preserved in higher latitudes with colder climates. Why might that be?

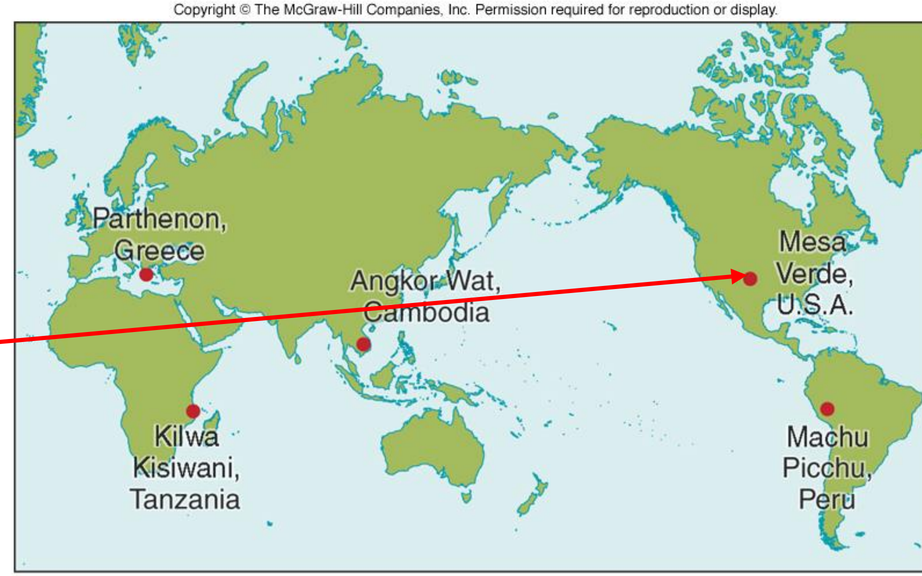
The Dirt on Weathering

Rocks exposed at Earth's surface were originally formed under different temperature/pressure conditions, and **weathering** converts their minerals into new minerals that are stable at Earth's surface.



b.

© Franz-Marc Frei/CORBIS



The World Heritage sites are those deemed to be "of outstanding value to humanity."

The Dirt on Weathering

Weathering is the **physical, chemical, and biological** breakdown of rocks and minerals.

a.

© Atlantide Phototravel/Corbis

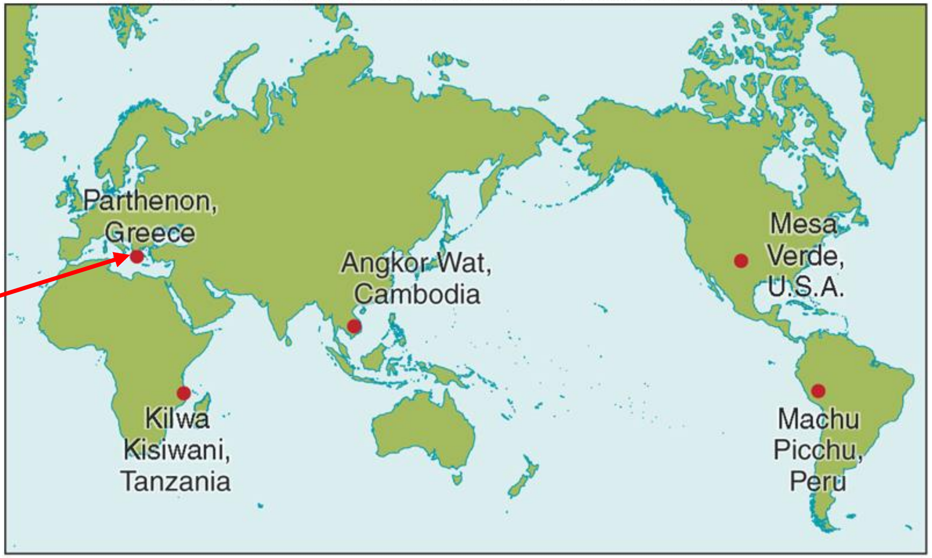
Five World Heritage Sites

Very few ancient structures are preserved in higher latitudes with colder climates. Why might that be?

The Dirt on Weathering

Weathering modifies the geological and cultural landscape around us.

c.



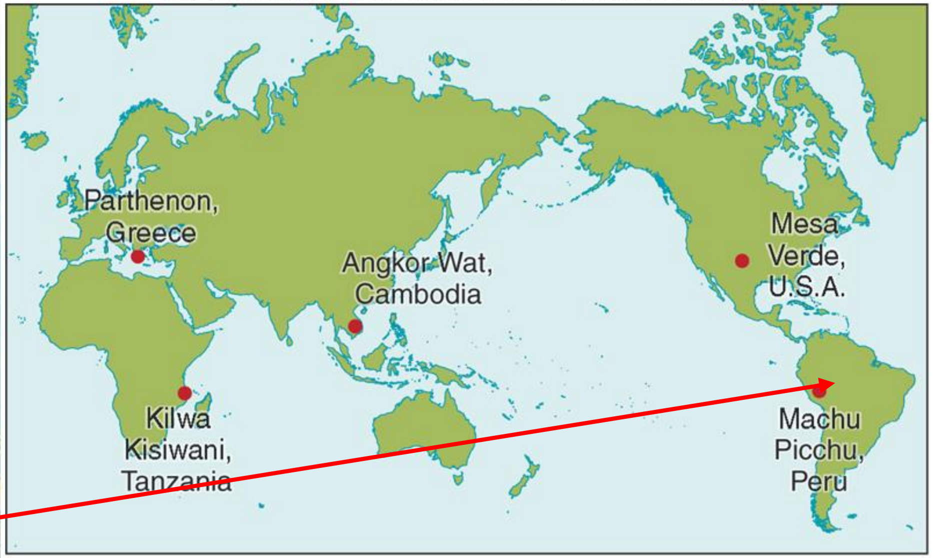
The weathering of the Parthenon adds character to the structure, but is accelerated by air pollution.

The Dirt on Weathering

Why do some rocks show more deterioration than others?

d.

© Adalberto Rios Szalay/Sexto Sol/Getty Images

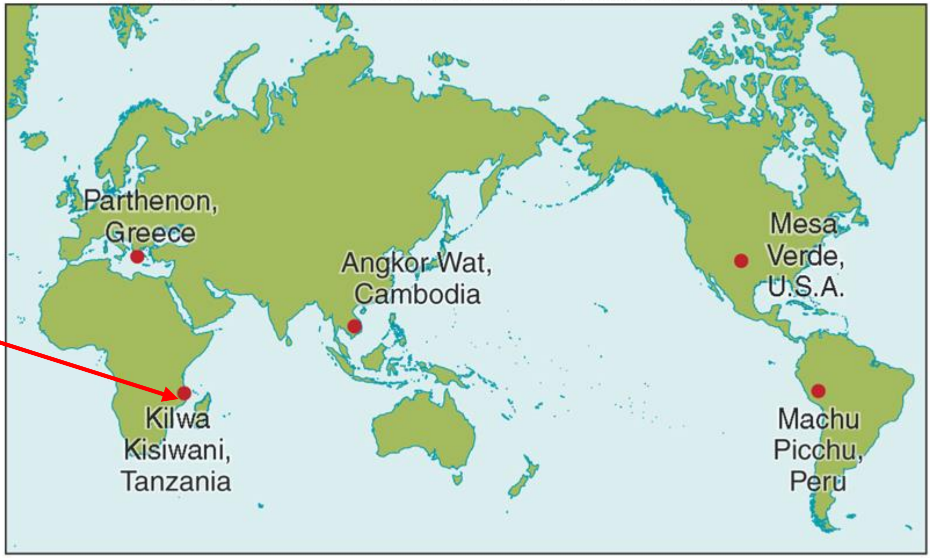


Machu Picchu sits high in the Andes Mountains. Is it particularly susceptible to weathering? Why?

The Dirt on Weathering

Why is weathering faster in some places than others?

e.



What can be done to stop or slow down the natural processes that cause weathering of important structures?

Weathering Rates of World Heritage Sites

Table 9.1 Characteristics of the Featured World Heritage Sites

Location	Rainfall, cm/year (inches/year)	Average temperature range	Rock type	Elevation	Age of structure (approximate)	Vegetation
Angkor Wat, Cambodia	140 (55)	21–35°C (70–95°F)	Sandstone	20 meters (66 feet)	900–1,000 years	Abundant
Kilwa Kisiwani, Tanzania	120 (47)	18–35°C (65–95°F)	Limestone	10 meters (33 feet)	600–750 years	Sparse
Machu Picchu, Peru	80 (31)	-1–24°C (30–75°F)	Granite	2,400 meters (7,870 feet)	550 years	Moderate
Mesa Verde, U.S.	45 (18)	-7–29°C (20–85°F)	Sandstone	2,400 meters (7,870 feet)	800–900 years	Sparse
Parthenon, Greece	40 (16)	4–32°C 40–90°F)	Marble	250 meters (820 feet)	2,440 years	Sparse

Evaluate how these different factors make structures more, or less, resistant to weathering.

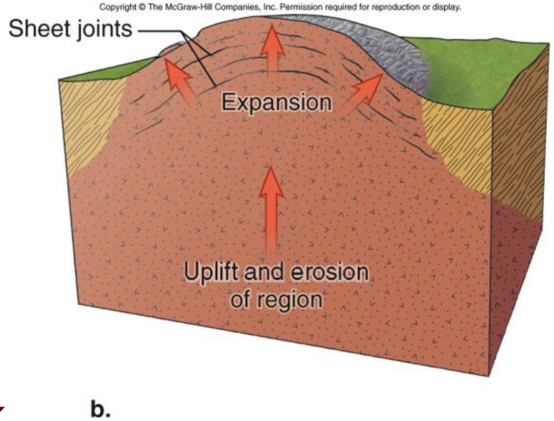
For example, rock type:

Granite = most resistant
Sandstone = less resistant
Limestone = weak rock

Physical Weathering

Disintegration of rocks and minerals into smaller pieces

- Unloading
  - Erosion strips away overlying material
  - Decrease in overlying pressure (load) causes underlying rock to expand upward
  - Leads to pressure release cracks in the exposed rock



- Wedging
  - Water enters cracks in surface materials (rocks, roads)
  - Temperature drop causes water to freeze, expand, and force the cracks to expand.
  - Process repeats when ice melts, water finds new cracks, freezes again and expands the cracks
  - Example: potholes

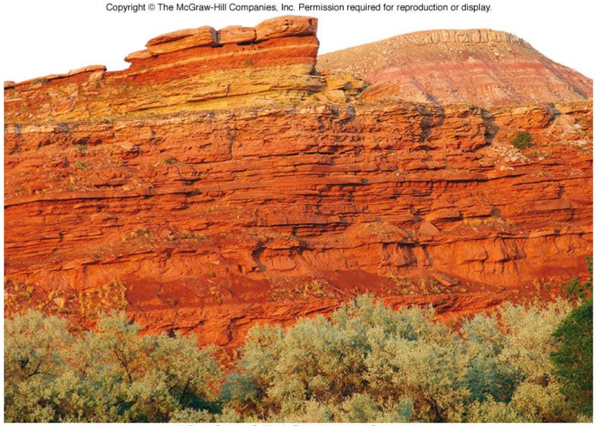
Chemical Weathering

The decomposition of rock due to the chemical breakdown of minerals is called *chemical* weathering

- Dissolution
  - Minerals in a rock are dissolved by water
  - Example – acid rain removes detail of a statue
- Hydrolysis
  - Hydrogen ions (H^+) in water replace other ions in silicate minerals
  - Example – Feldspar reacts with water and H ions to form clay which is used in manufacturing glossy magazine paper
- Oxidation
  - Oxygen reacts with iron and other metals to form new mineral compounds
  - Example – the rust on your car

b.

© David McGeary



© Diane Carlson, California State University at Sacramento

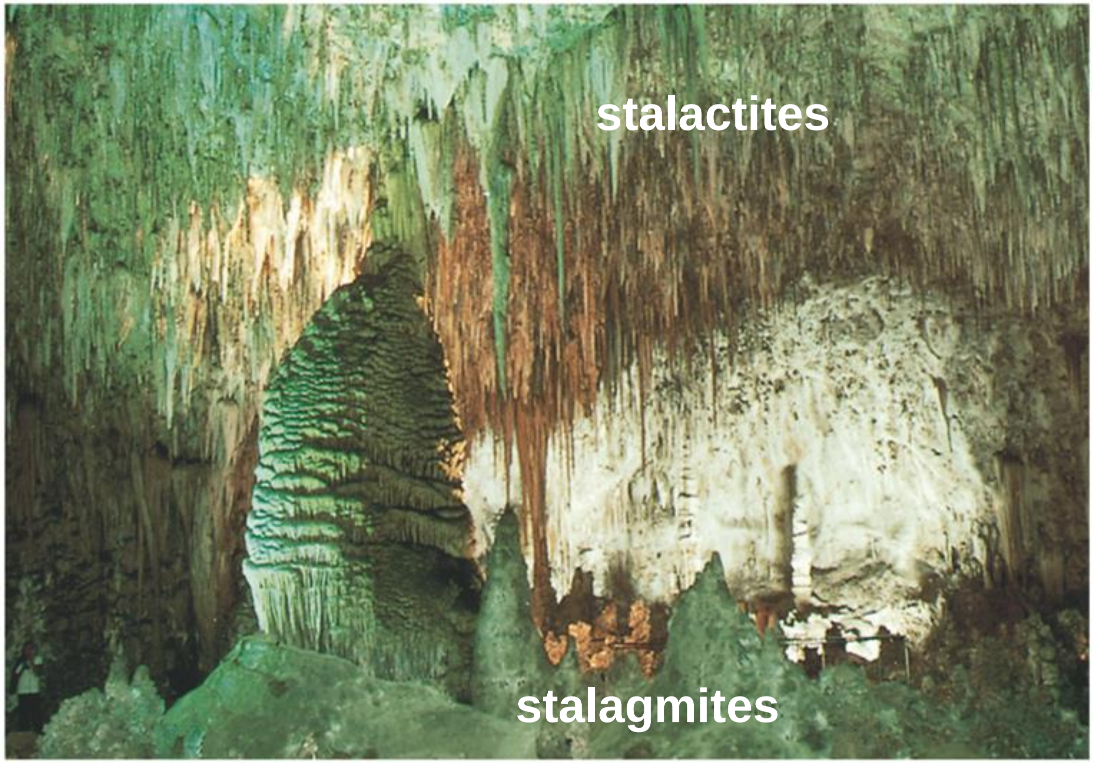
Chemical Weathering

- A sugar cube disappearing in a cup of coffee is an example of dissolution
- Carbon dioxide is a small portion of the air we breathe, but when combined with rainwater it creates a weak acid called carbonic acid (H_2CO_3)

H_2O	+	CO_2	→	H_2CO_3
rain		from air or bacterial decomposition		carbonic acid

- Carbonic acid can dissolve limestone and marble
- Limestone is common on Earth's surface – dissolution of limestone creates *karst* landforms (sinkholes, caves)

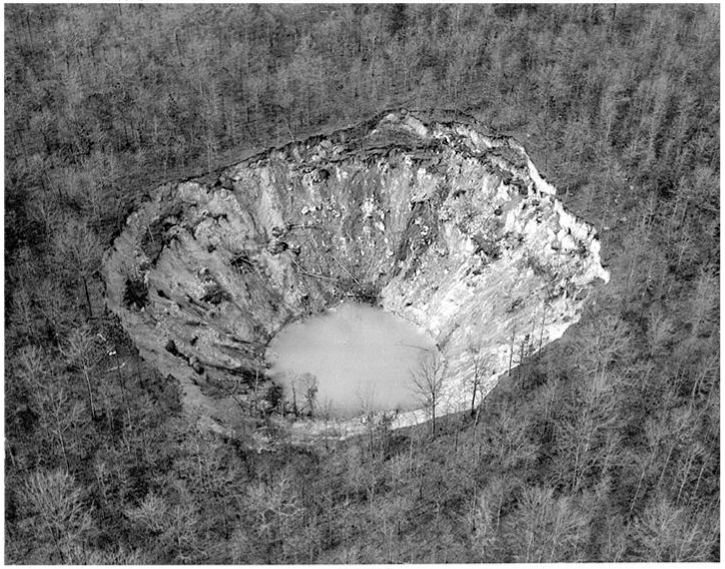
Chemical Weathering



a.

© National Park Service

All rocks contain some cracks. Water carrying dissolved limestone is transported through caves and may precipitate the limestone out of solution as stalactites and stalagmites.



© USGS

Sinkholes are large depressions on the surface where limestone bedrock has been dissolved resulting in collapse on the overlying surface (above: Alabama's "December Giant")

Chemical Weathering

- When hydrogen ions replace other ions in silicates (hydrolysis), the silicates become weaker and more likely to break down.
- Where do the hydrogen ions come from?

$$H_2CO_3 \rightarrow H^+ + HCO_3^-$$

(break down of carbonic acid)

Hydrolysis and dissolution can occur together to chemically weather a rock more quickly

More hydrogen ions = more rapid chemical weathering

Chemical Weathering

All rain water is mildly acidic.

Pollutants (sulfur dioxide, nitrogen oxides) significantly decrease the pH of rain water (increase acidity).

pH scale is logarithmic – each increment represents a 10 times increase/decrease in hydrogen concentration per volume of solution.

Chemical Weathering

- Natural acids and microbial activity cause reactions with iron and other metals in rocks that can pollute streams. Such acid mine drainage is common in coal mining regions.

Pennsylvania Department of Environmental Protection

Biological Weathering and Decay

- Living organisms can remove and/or break down rocks and minerals.
  - Macroscopic (by organisms we can see)
    - Includes the actions of: plant roots, animal burrows, termites, and other boring organisms
  - Microscopic (by organisms we cannot see with the naked eye)
    - Primarily caused by decomposition of material that converts solid material to gases with or without water
    - Works mostly on organic material such as dead plant or animal matter

Sugars in organic material + oxygen → carbon dioxide + water

Sugars in organic material → carbon dioxide + methane gas

Biological Weathering and Decay

a.

Q: Is this an example of micro or macroscopic biological weathering?

Biological Weathering and Decay

a.

© Diane Carlson, California State University at Sacramento

Q: Is this an example of micro or macroscopic biological weathering?

A: **Macroscopic** – tree roots are forcing apart the rock

Biological Weathering and Decay

b.

© Diane R. Nelson

c.

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- Other examples of macroscopic biological weathering:
  - Chitons (a type of mollusk) wear away at limestone
  - Sea urchins excavate holes in bedrock beneath shallow water

Weathering Rates

What controls how quickly a rock weathers?

Rock composition

Rock properties

Climate

© USGS

In these low porosity rocks, weathering is restricted to the outer rind.

a.

© USGS

Weathering concentrated along fractures. The degree of weathering decreases downward. **Why?**

Rates of Weathering Concept Survey

Say whether each of the following statements relates to the influence on weathering by *rock composition*, *rock properties*, or *climate*.

1. Exposed rock in the mountains of Alaska
2. A lack of fractures in an outcrop
3. Quartz is rarely affected by dissolution, hydrolysis, or oxidation
4. High porosity (a large amount of space between grains in a rock)
5. Rocks on the coast of a tropical island
6. Minerals that dissolve in the presence of water

Weathering Rates

Composition as a variable

1. Weathering is faster in rocks composed of weaker material or material that is easily converted to weaker material (such as feldspars)
2. Weathering is faster in rocks made up of minerals that dissolve in water (salt, gypsum)
3. Weathering is slower in rocks made of resistant materials (quartz)

Rock property as a variable

1. Weathering is faster in rocks that allow air and water in (porous, fractured)
2. Fractures are natural weathering surfaces
3. Igneous and metamorphic rocks generally have low porosity – do you think they are particularly susceptible to weathering?

Weathering Rates

Climate as a variable

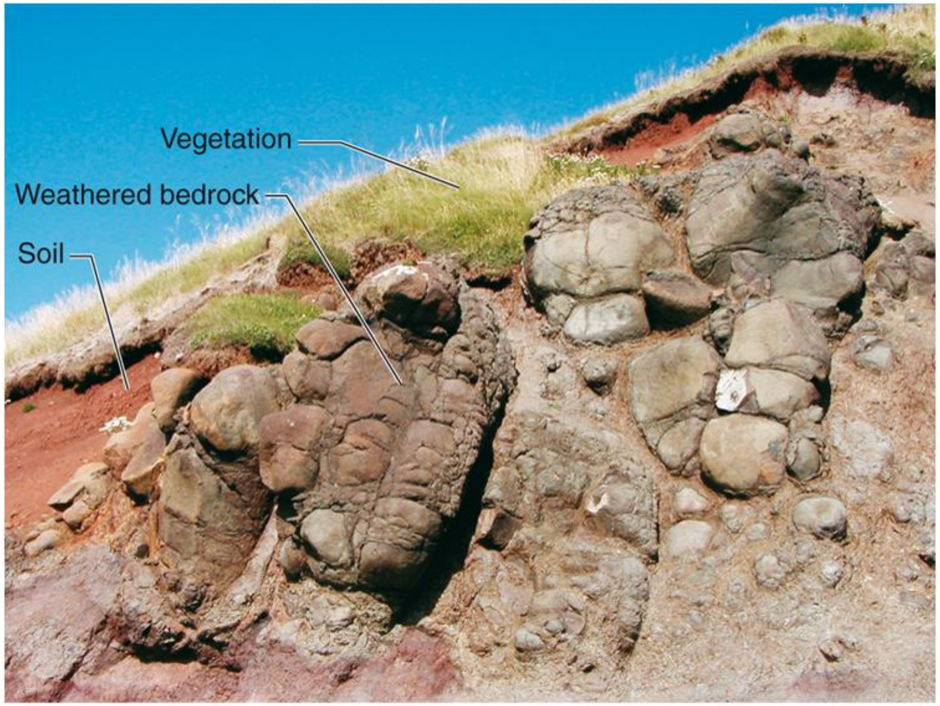
(*Climate = a region's average annual temperature, precipitation, and vegetation*)

1. Chemical weathering is faster in warmer climates
2. More water (rain, humidity) = more dissolution and hydrolysis reactions
3. More shade provided by vegetation can impede evaporation and allow more water to find its way into cracks thereby increasing rates of weathering
4. Carbon dioxide released from plants can combine with water to make carbonic acid
5. Higher elevations may have more freeze/thaw cycles, increasing rates of physical weathering
6. Extremely cold regions don't have much thawing, therefore not much wedging occurs

The Dirt on Weathering

Soil forms slowly by weathering, and is often eroded faster than it is replaced.

- loss of soil is a threat to agriculture
- Influenced by human activity and natural factors



© David McConnell

A thin soil layer over bedrock, Giant's Causeway, N. Ireland. On average, soil is 45% mineral fragments, 25% water, 25% air, and 5% organic material.

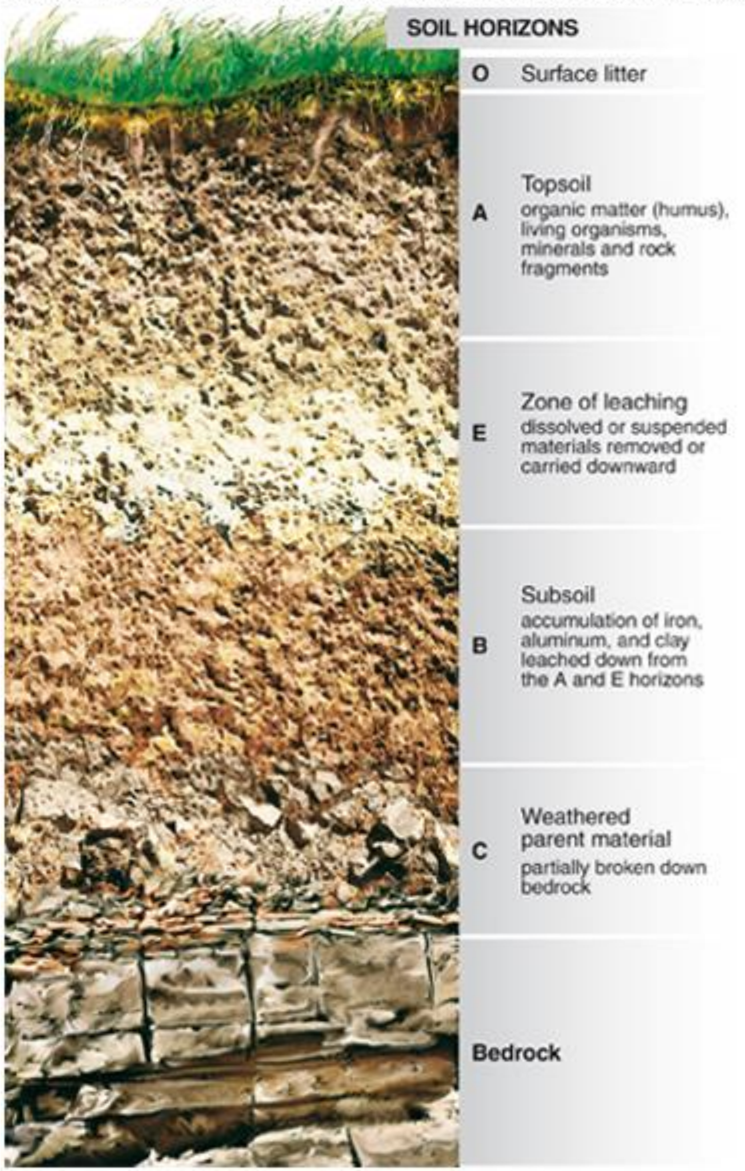
Soils: An Introduction

Soils from different areas of the U.S.

Soils: An Introduction

- Soil = a stratified mixture of regolith that includes enough organic material, water, and air to support plant life
  - Organic material is supplied by decaying plants and animals
  - Organics get mixed with soil by burrowing animals, worms, and insects
  - Water moves through the soil and leaches it (dissolves iron)
  - Water can transport fine clay particles to lower layers

Soils: An Introduction



Characteristic soil profile:

O – Organic debris, dead leaves, plant and animal remains make up 30% of this layer. Usually at top. Why?

A – Topsoil, dark organics mixed with mineral grains by organic activity. Lacking in fine particles and soluble ions.

E – Subsurface layers that have lost most of their minerals. Can be embedded in A horizon or replace A horizon.

B – Ions leached from A are precipitated here. Includes clay particles that were carried down from A. Little organic material is present. Red color due to oxidation (rainy areas), or accumulation of calcium carbonate (arid areas) forming a white layer.

C – Lowest layer, consists of soil parent material, either weathered bedrock (regolith) or unconsolidated sediments

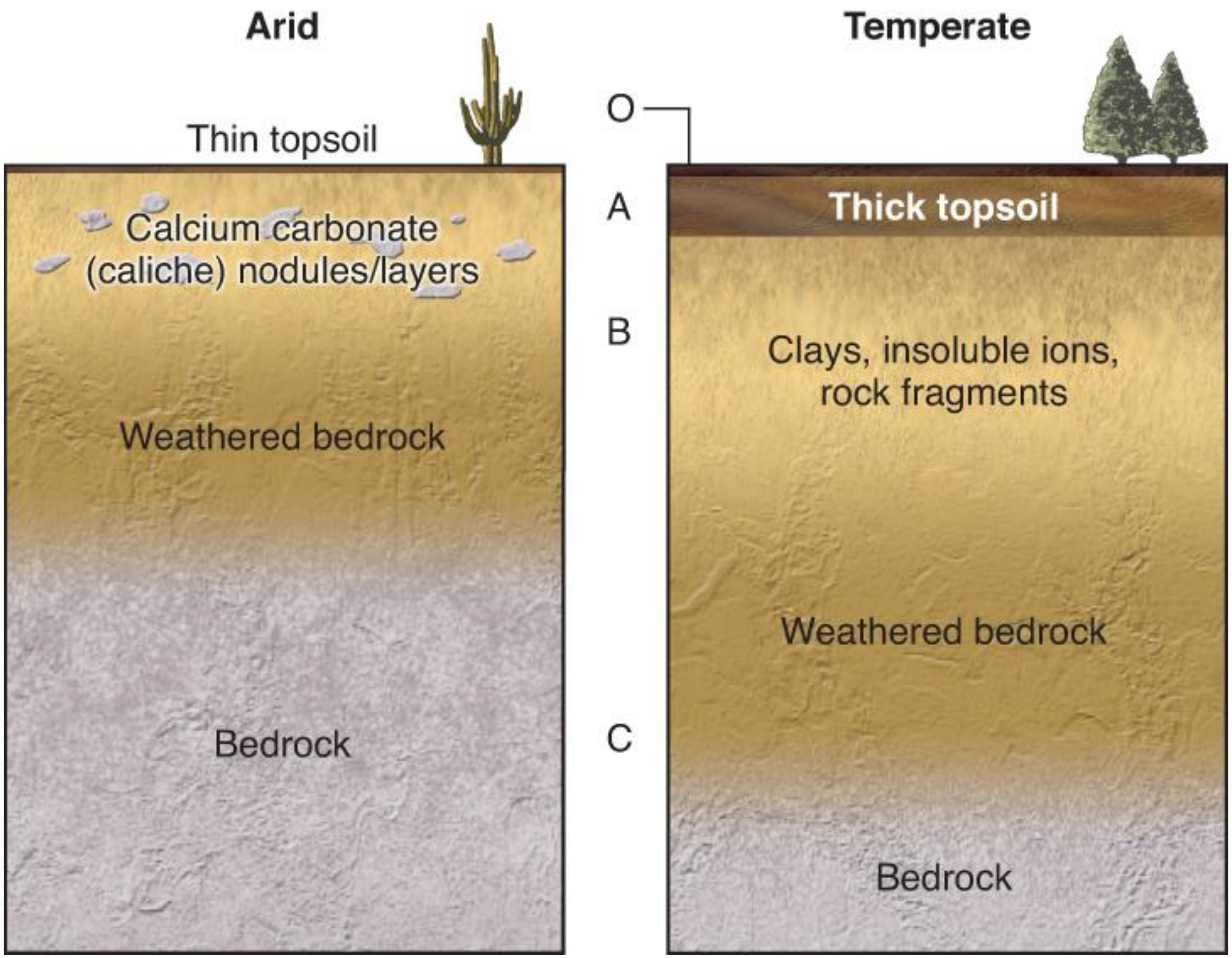
Soils: An Introduction

- Soil formation is controlled by
  - The rock in the source area
  - Temperature and amount of rain in a region (climate factors)
  - Biological activity occurring in an area

Q: How might soil formation differ on bare rock surfaces exposed in cold climates (e.g. Alaska) vs. warm, wet climates?

A: In cold climates soil may take thousands of years to develop due to slow rates of chemical weathering. In warm, wet climates soils may develop in a few hundred years owing to rapid chemical weathering. The thickest soils exist in tropical regions that have year-round warm temperatures and rainfall.

Affect of climate on soil profiles



Soil Erosion and Conservation

- Soil forms very slowly and is often depleted faster than it can be formed
  - Soil erosion rates are affected by climate factors (water and wind) and land use practices
- Erosion of soil by wind and water occurs when soil particles are detached from soil column and transported away. This is controlled by:
  - the amount and frequency of rainfall
  - wind velocity
  - character of the soil
  - vegetation cover
  - slope of the land surface

Soil Erosion and Conservation

Examples of soil erosion features:

a. b. c. d.

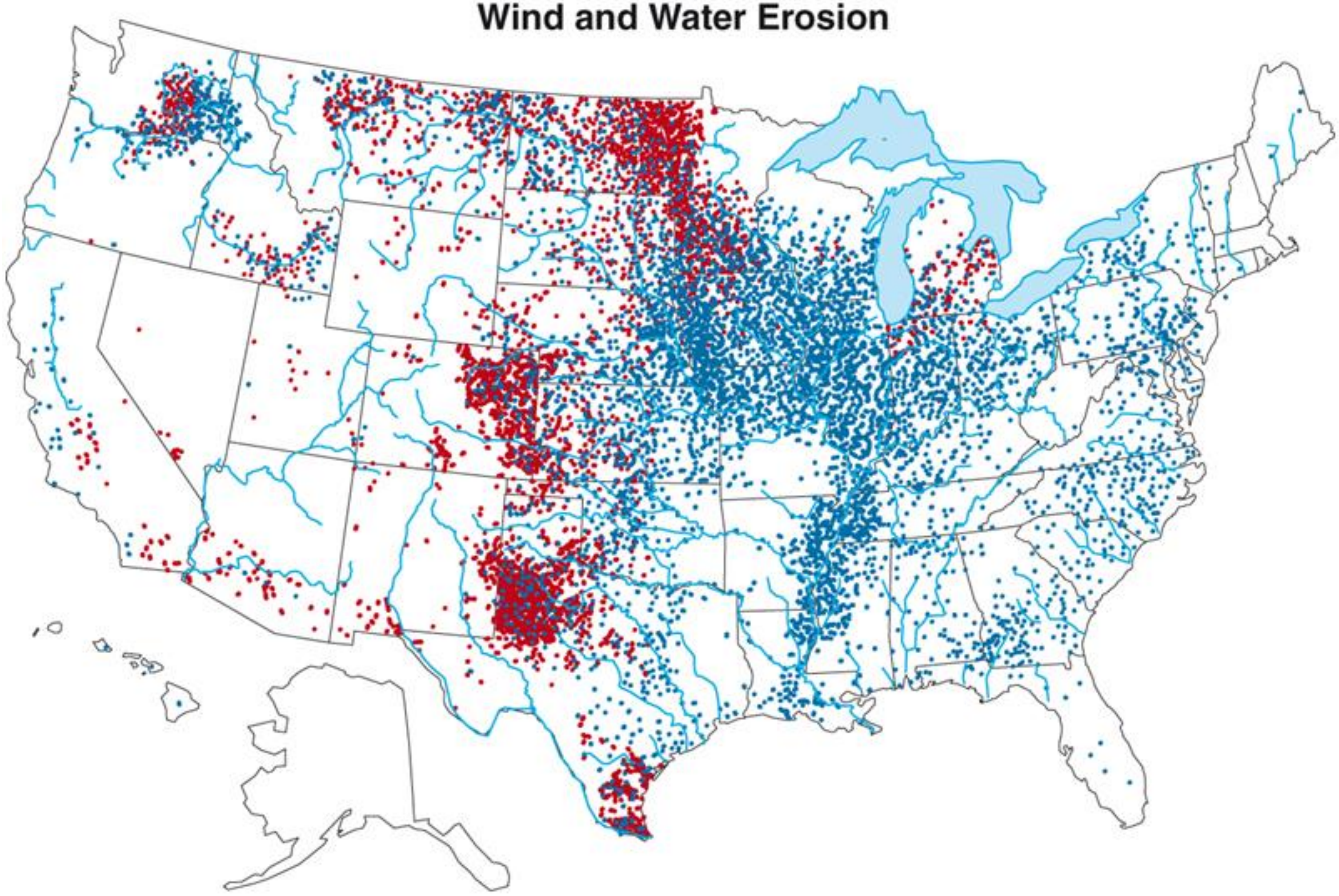
a. Rain can dislodge soil particles.

b. Water carves channels (rills) in a plowed field. Visible rills indicate an erosion rate of at least 12 tons per acre.

c. Wind erosion – dust rises above a cultivated field.

d. A massive dust storm approaches a Great Plains town.

Why do you think these patterns exist?

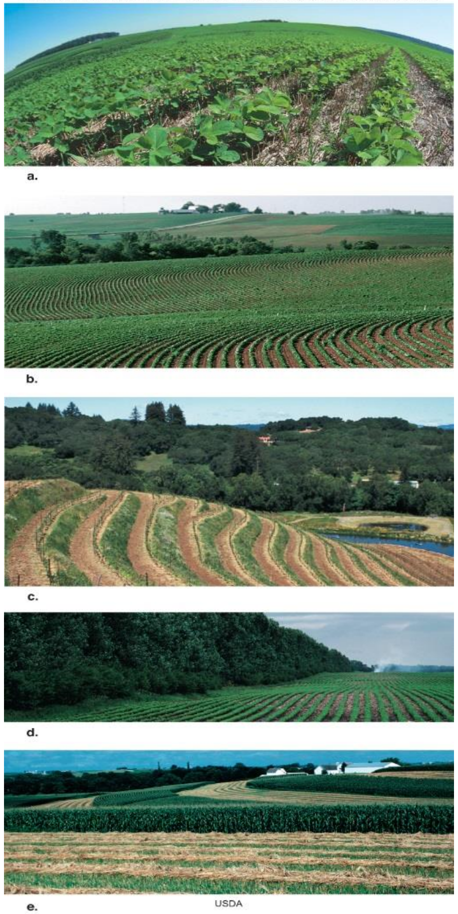


Each dot represents erosion of 200,000 tons of soil due to:

water (blue) and wind (red)

Soil Erosion and Conservation

Humans are now more important as agents in moving soils and sediments than all other natural processes operating on Earth combined.



Agriculture can accelerate soil loss:

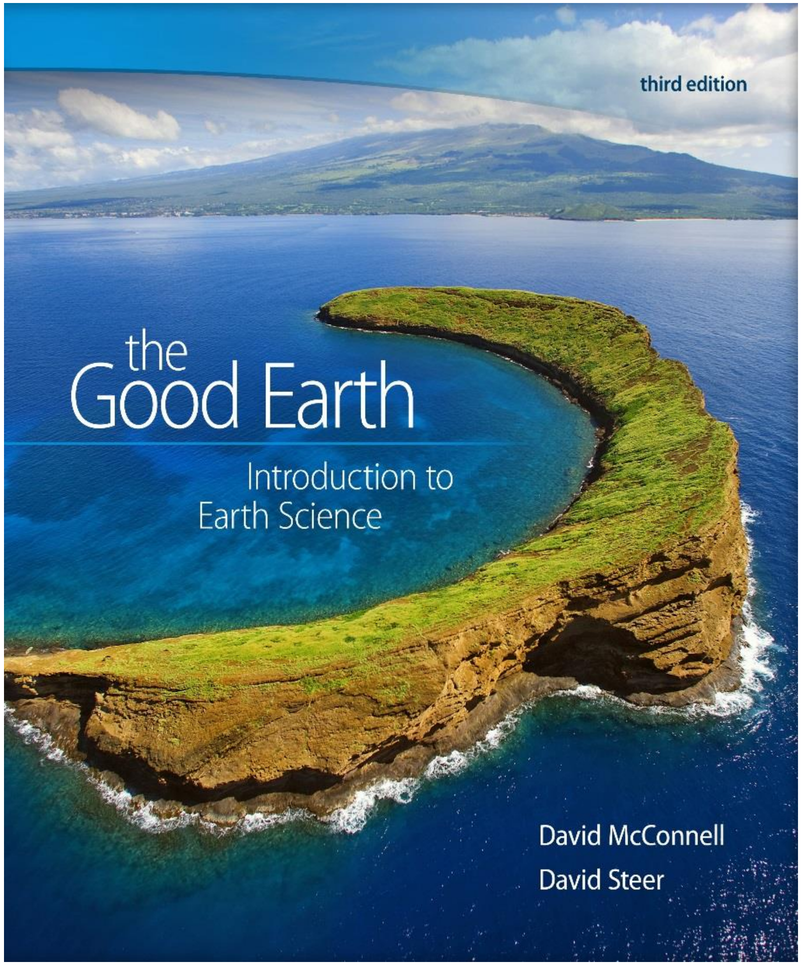
-Poor soil management causes widespread soil erosion

-Highest erosion rates are in parts of Africa, South America, and Asia where farming practices aren't well regulated and rainfall is abundant

-Lowest erosion rates are generally in Europe and N. America where governments encourage preservation of soils by good agricultural practices

The economic cost of soil erosion in U.S. alone is estimated to be tens of billions of dollars a year!

Chapter 8: Geologic Time



The following slides are from my Oceanography course.

See the study guide for the relevant questions from your textbook.

As Earth continued to cool, volcanic activity caused “outgassing” of many substances, especially water vapor.

Outgassed water vapor eventually condensed to liquid.

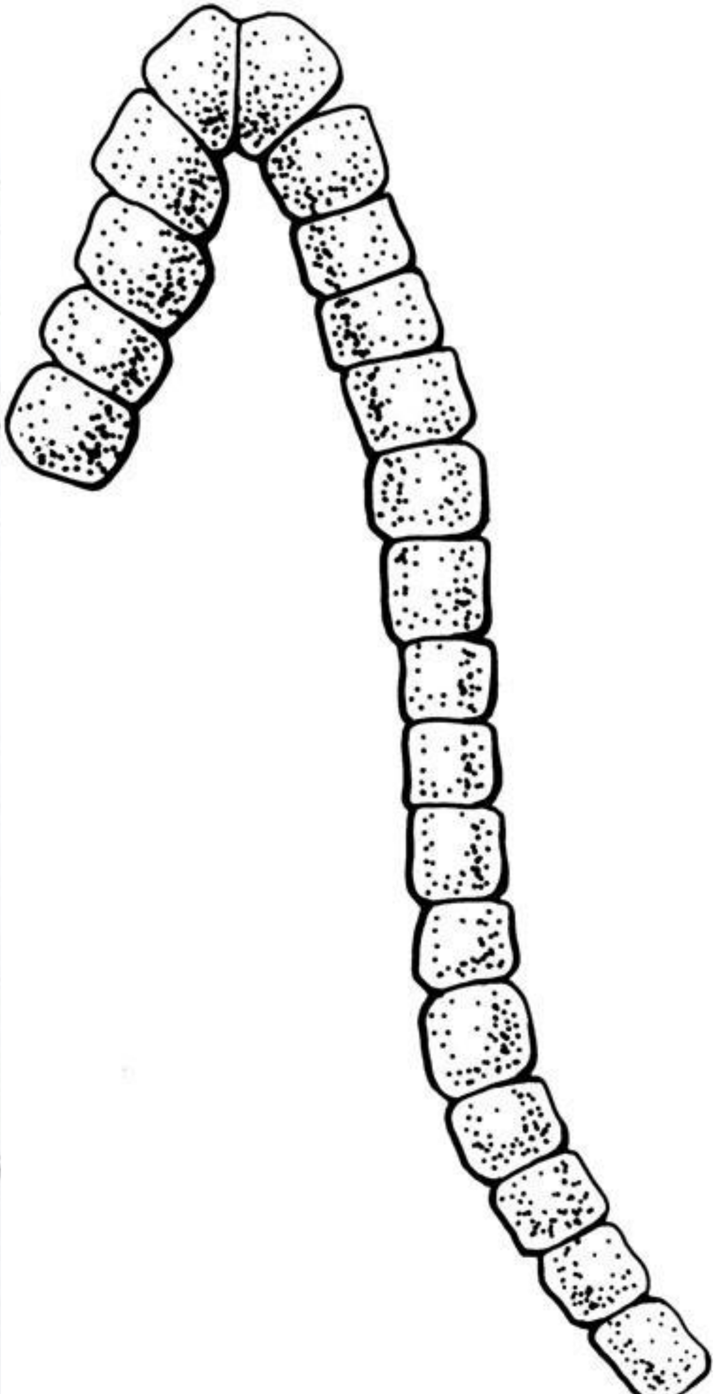
The first oceans were born … about 4.5 billion years ago.

Comet impacts may have also added water and organic compounds to ocean.

The Scale of the Universe

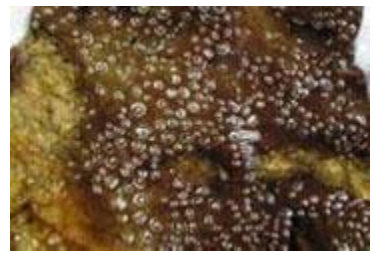
http://htwins.net/scale2/?bordercolor=white

How/where did life begin?

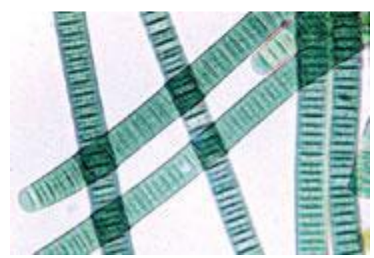


Life on Earth originated about 3.5 billion years ago.

The first life forms were likely anaerobic – they survived without oxygen (and perhaps in the dark).

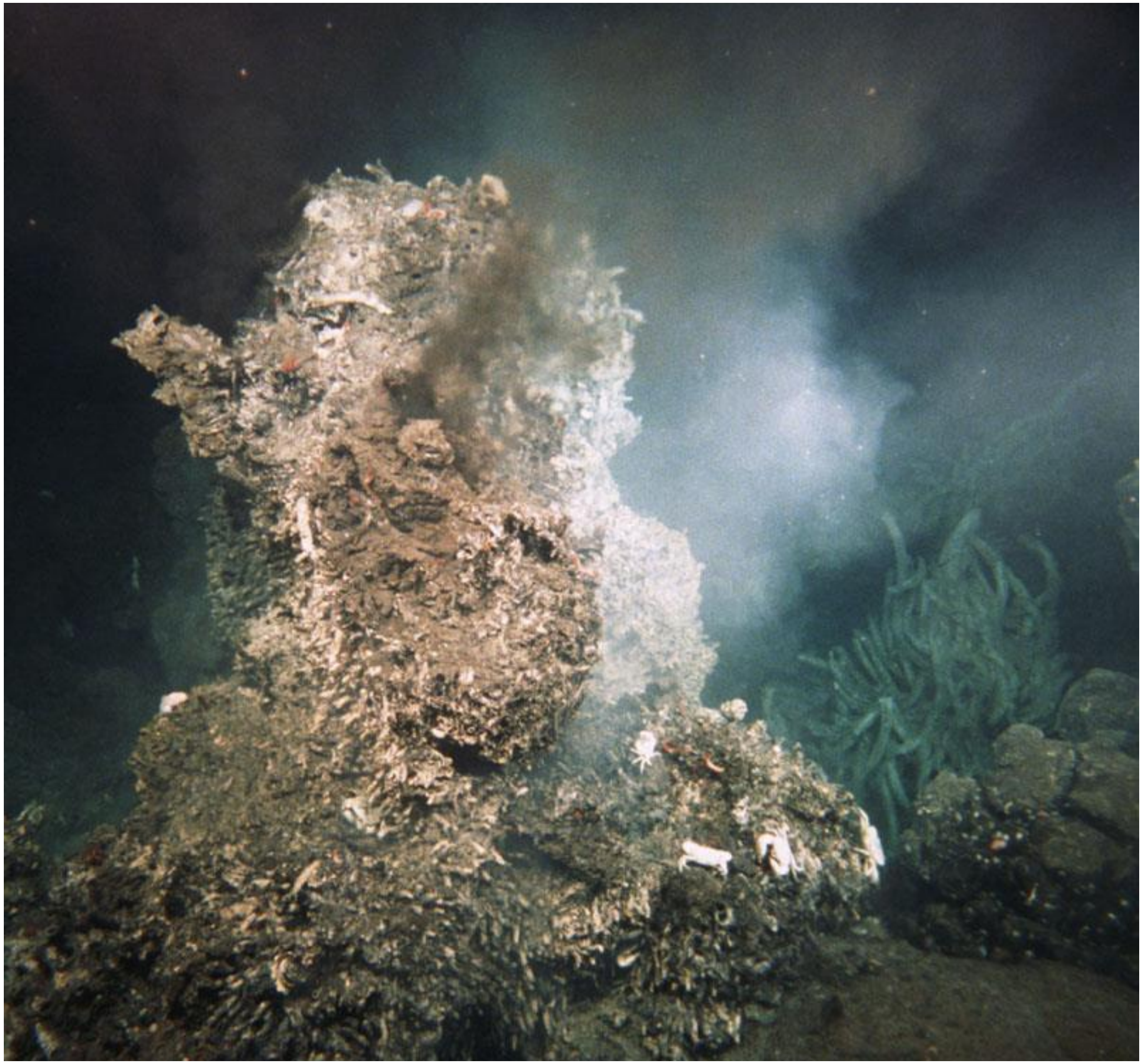


Microbial mats
(living)
formed
stromatolites
(fossils)



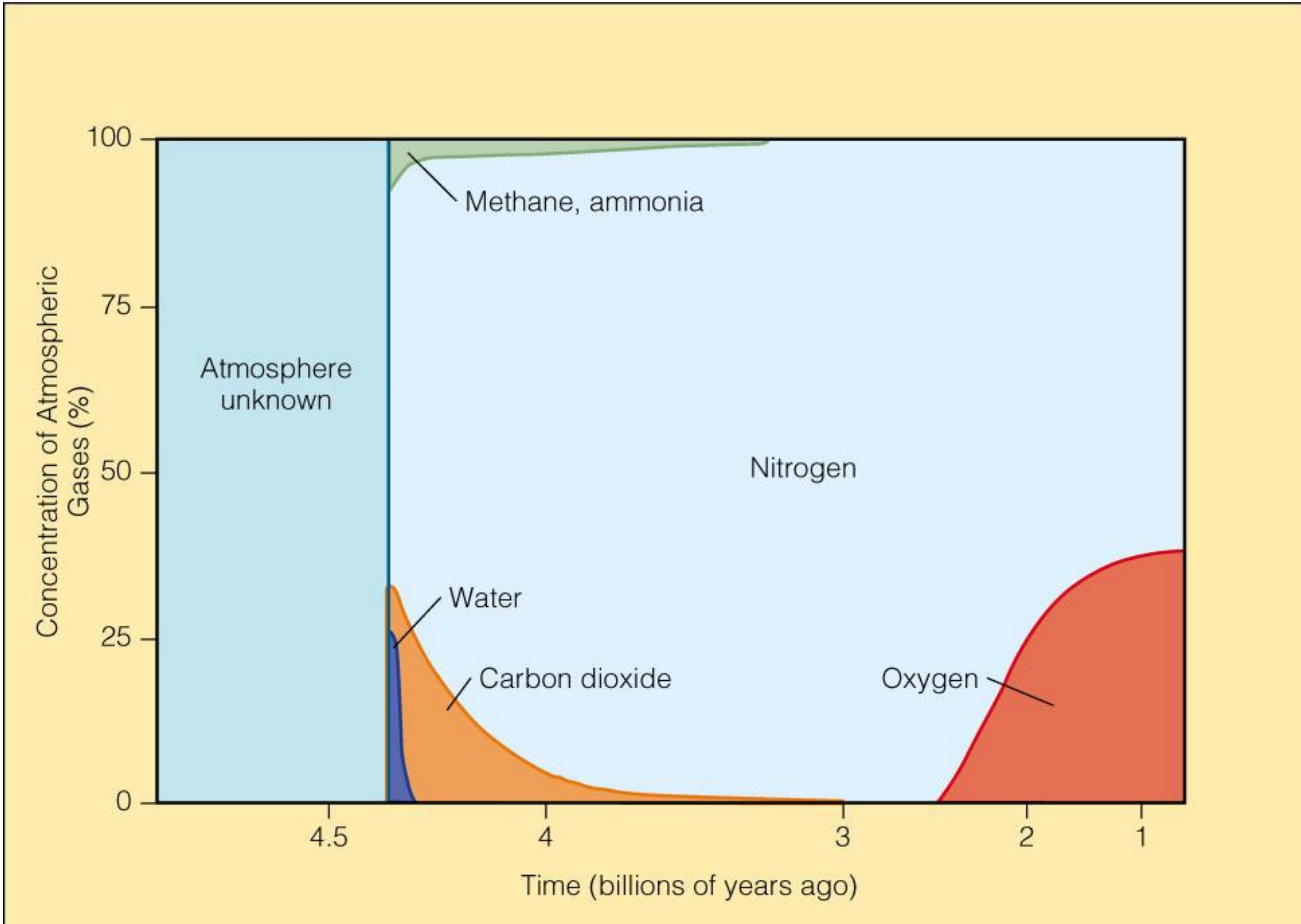
<u>Cyanobacteria</u>:
Early life forms
(Later) produced oxygen
- **aerobic**
Now dominate the ocean

We believe that life began in the oceans.



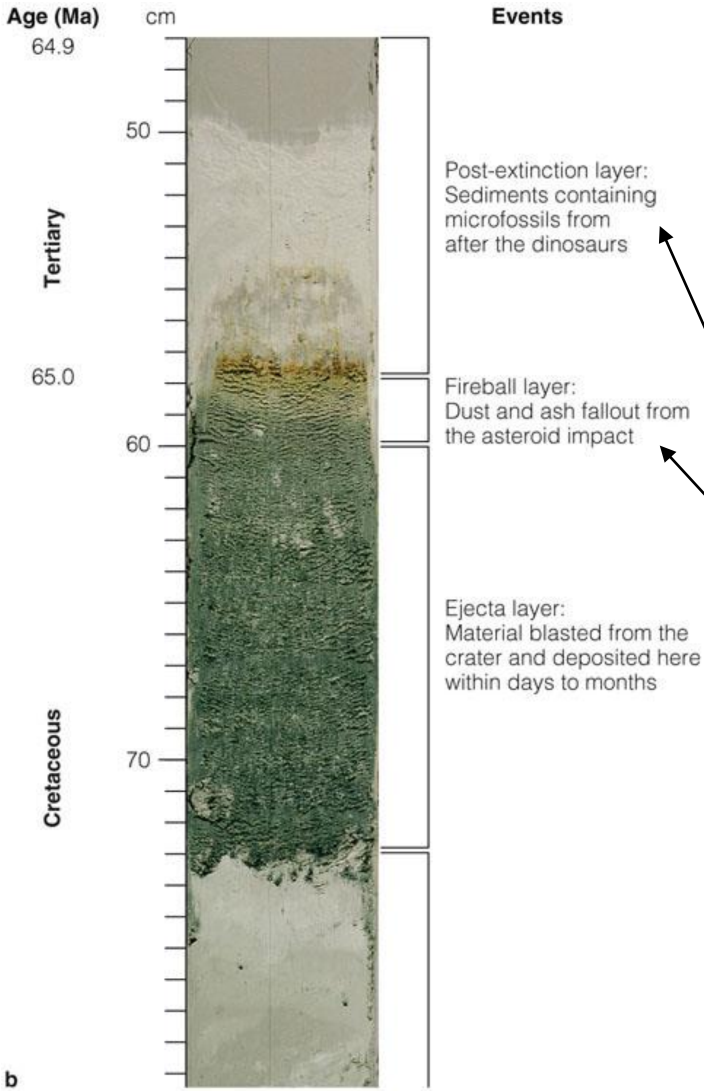
- All life depends on salty water within its cells to dissolve and transport chemicals.
- Water holds heat.
- Water moderates temperatures.
- Water suspends nutrients and wastes.

Did life originate at hydrothermal vents?



Earth’s atmosphere responded to this life.

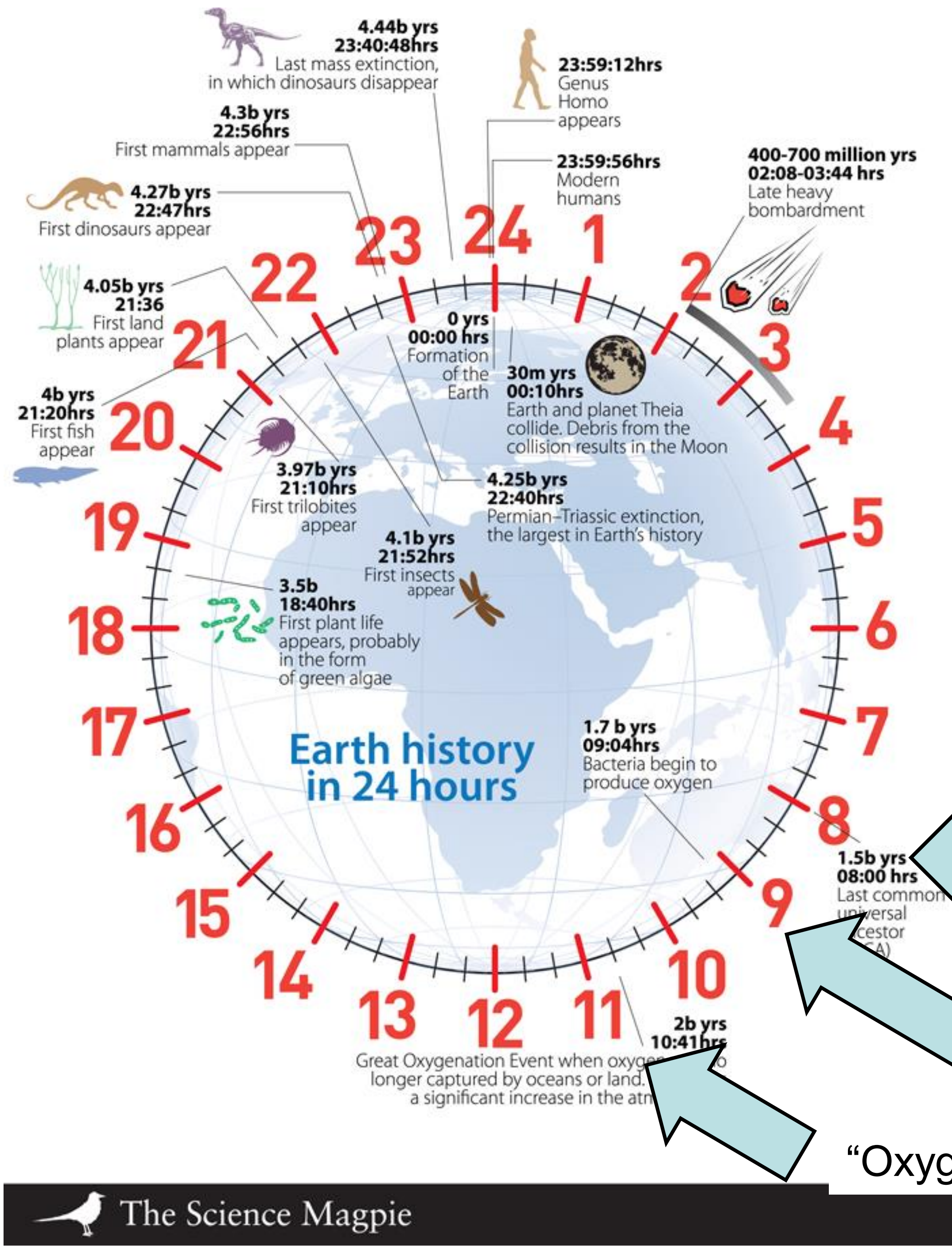
Exam question on geologic time



See study guide for more information…

What happened here?

Geological Time



First life form

Bacteria began to produce oxygen

“Oxygen revolution”