Chapter One
Introduction to Geology

Geology literally means "study of the Earth."

Physical geology examines the materials and processes of the Earth.

Historical geology examines the origin and evolution of our planet through time.

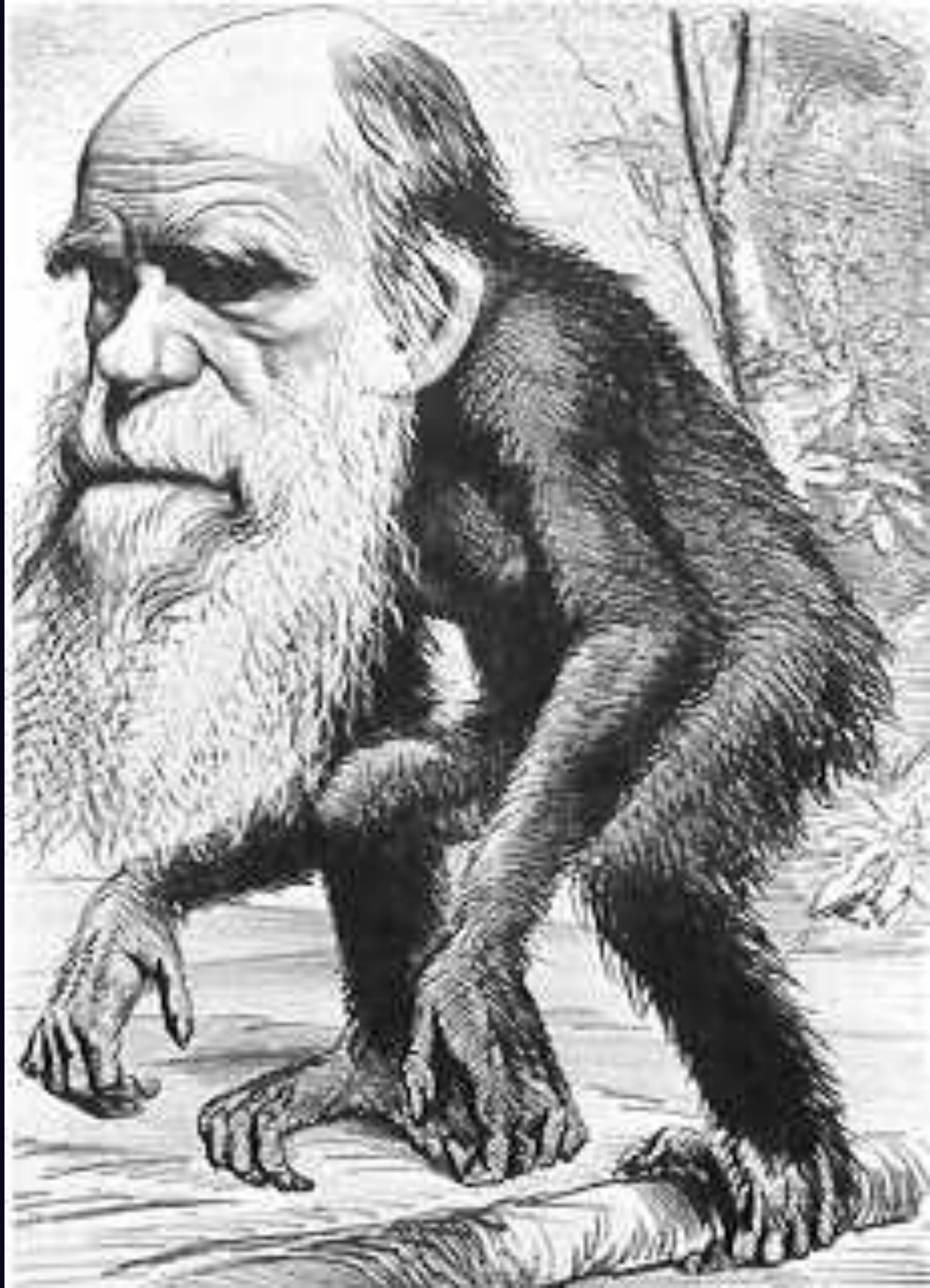
• Geology is an evolving science - the theory of plate tectonics was just accepted in the 1960's.

• Plate tectonics is *the* unifying *theory* in geology.

• Although geologists treat it as a law - plate tectonics is still and will likely remain a theory…

Geology is an extremely controversial science - the theory of evolution (paleontology) is *central* to geology.

Geology seeks to understand the origin of our planet and our place in the Universe - answers to these questions are also posed outside of the realm of science.

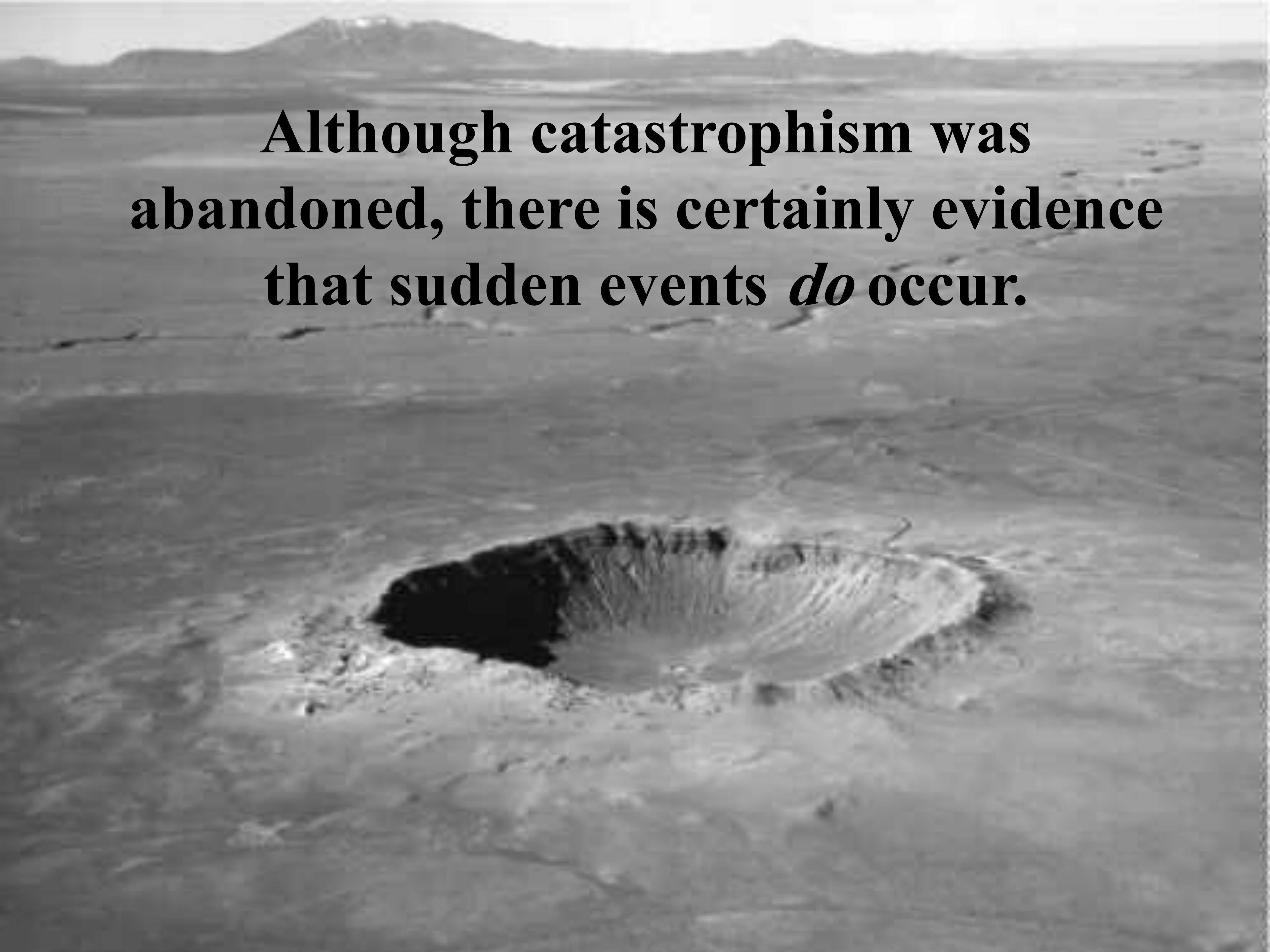


History of Early Geology

Catastrophism (James Ussher, mid 1600s) - He interpreted the Bible to determine that the Earth was created at 4004 B.C. This was generally accepted by both the scientific and religious communities. Subsequent workers then developed the notion of *catastrophism*, which held that the the Earth's landforms were formed over very short periods of time.

Uniformitarianism (James Hutton, late 1700s) - He proposed that the same processes that are at work today were at work in the past. Summarized by *"The present is the key to the past."* Hutton, not constrained by the notion of a very young planet, recognized that *time* is the critical element to the formation of common geologic structures. *Uniformitarianism* is a basic foundation of modern geology.


BLAMMO!


Although catastrophism was abandoned, there is certainly evidence that sudden events *do* occur.

Geologic Time

Relative Dating: Putting geologic events into proper order (oldest to youngest), but without absolute ages. We use a number of principles and laws to do this:

Law of Original Horzontality - Sedimentary units and lava flows are deposited horizontally.

Law of Superposition - the layer below is older than the layer above.

Principle of fossil succession - life forms succeed one another in a definite and determinable order and therefor a time period can be determined by its fossils.

Law of Cross-cutting Relationships - A rock is younger than any rock across which it cuts.

Geologic Time

Absolute (Radiometric) Dating: Using radioactive decay of elements to determine the absolute age of rocks. This is done using igneous and metamorphic rocks.

Parent	Decay Product	Half-Life (billion years)
Aluminum-26	Magnesium-26	0.00072 (720,000 years)
Uranium-235	Lead-207	0.71
Potassium-40	Argon-40	1.3
Uranium-238	Lead-206	4.5
Thorium-232	Lead-208	14
Rubidium-87	Strontium-87	47
Samarium-147	Neodymium-147	106

Geologic Time

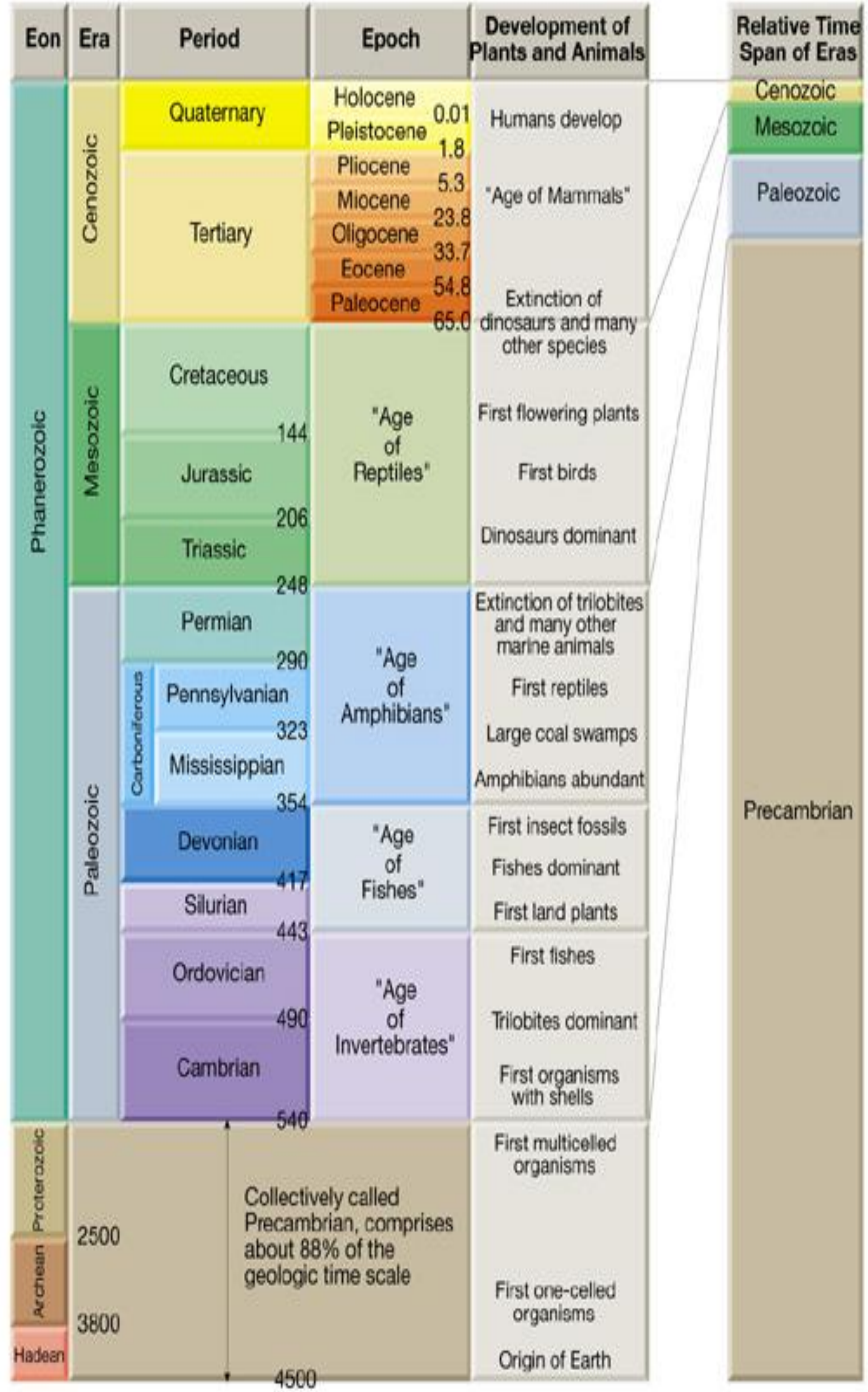
- The concept of geologic time is new (staggering) to many nongeologists.

- The current estimate is that the Earth is ~4,600,000,000 (4.6 billion) years old.

- As humans we have a hard time understanding the amount of time required for geologic events.

- We have a good idea of how long a century is. One thousand centuries is only 100,000 years. That huge amount of time is only 0.002% of the age of the Earth!

- An appreciation for the magnitude of geologic time is important because many processes are very gradual.



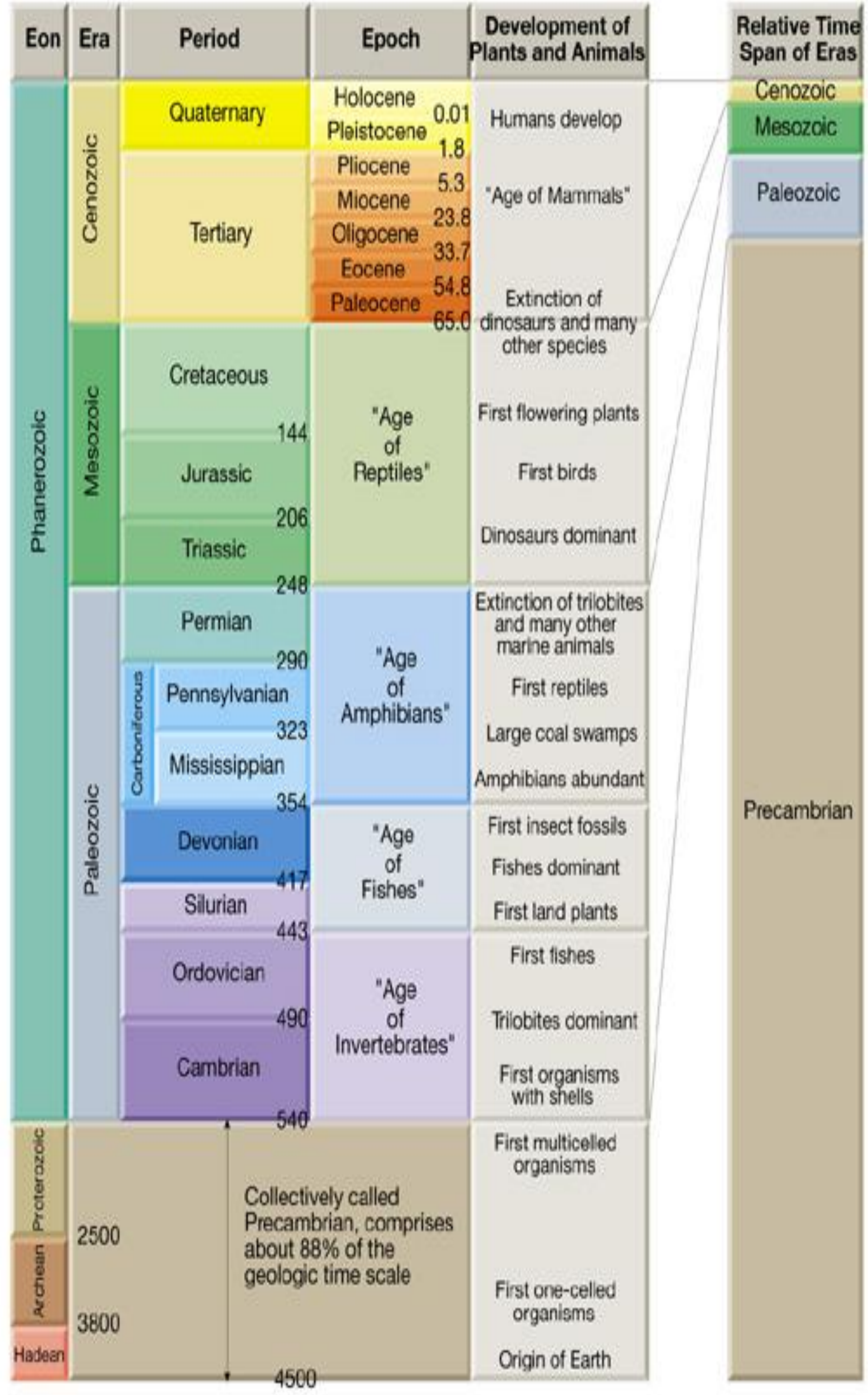
• Geologic time is divided into different types of units.

• Note that each Eon, Era or Period represents a different amount of time. For example, the Cambrian period encompasses ~65 million years whereas the Silurian period is only ~30 million years old.

• The change in periods is related to the changing character of life on Earth and other changes in environment.

• The beginning of the Phanerozoic represents the explosion of life.

• The time before the Phanerozoic is commonly referred to as the PreCambrian and represents over 4 billion years of time. The Phanerozoic eon (abundant life) represents only the last 13% of Earth time.



Our generation is unique in its perspective of our planet. From space, Earth looks small, finite and fragile.

What's the first thing that you notice about our planet when you see this image?

The Earth is composed of several integrated parts (spheres) that interact with one another:

- atmosphere
- hydrosphere
- solid earth (lithosphere)
- biosphere
- (cryosphere)

The Earth System

Hydrosphere: the global ocean is the most prominent feature of our (blue) planet. The oceans cover ~71% of our planet and represent 97% of all the water on our planet.

Atmosphere: the swirling clouds of the atmosphere represent the very thin blanket of air that covers our planet. It is not only the air we breathe, but protects us from harmful radiation from the sun.

The Earth System

Biosphere: includes all life on Earth - concentrated at the surface. Plants and animals don't only respond the their environment but also exercise a very strong control over the other parts of the planet.

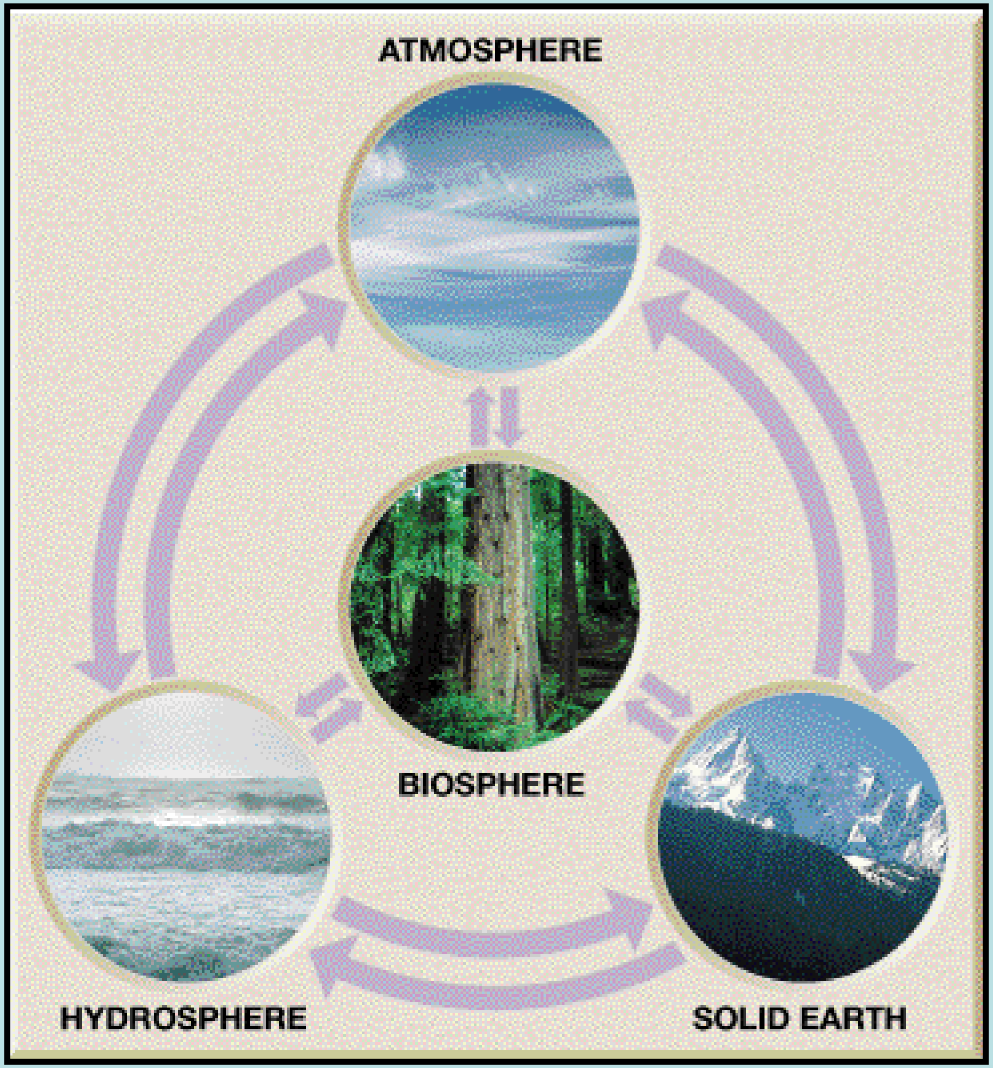
Solid Earth: represents the majority of the Earth system. Most of the Earth lies at inaccessible depths. However, the solid Earth exerts a strong influence on all other parts (ex. magnetic field).

The Earth System

This figure shows the dynamic interaction between the major spheres.

As humans, we desire to divide the natural world into artificial portions to make it easier. It should be stressed that these divisions are artificial.

What are some of the interactions between these spheres?



The Rock Cycle

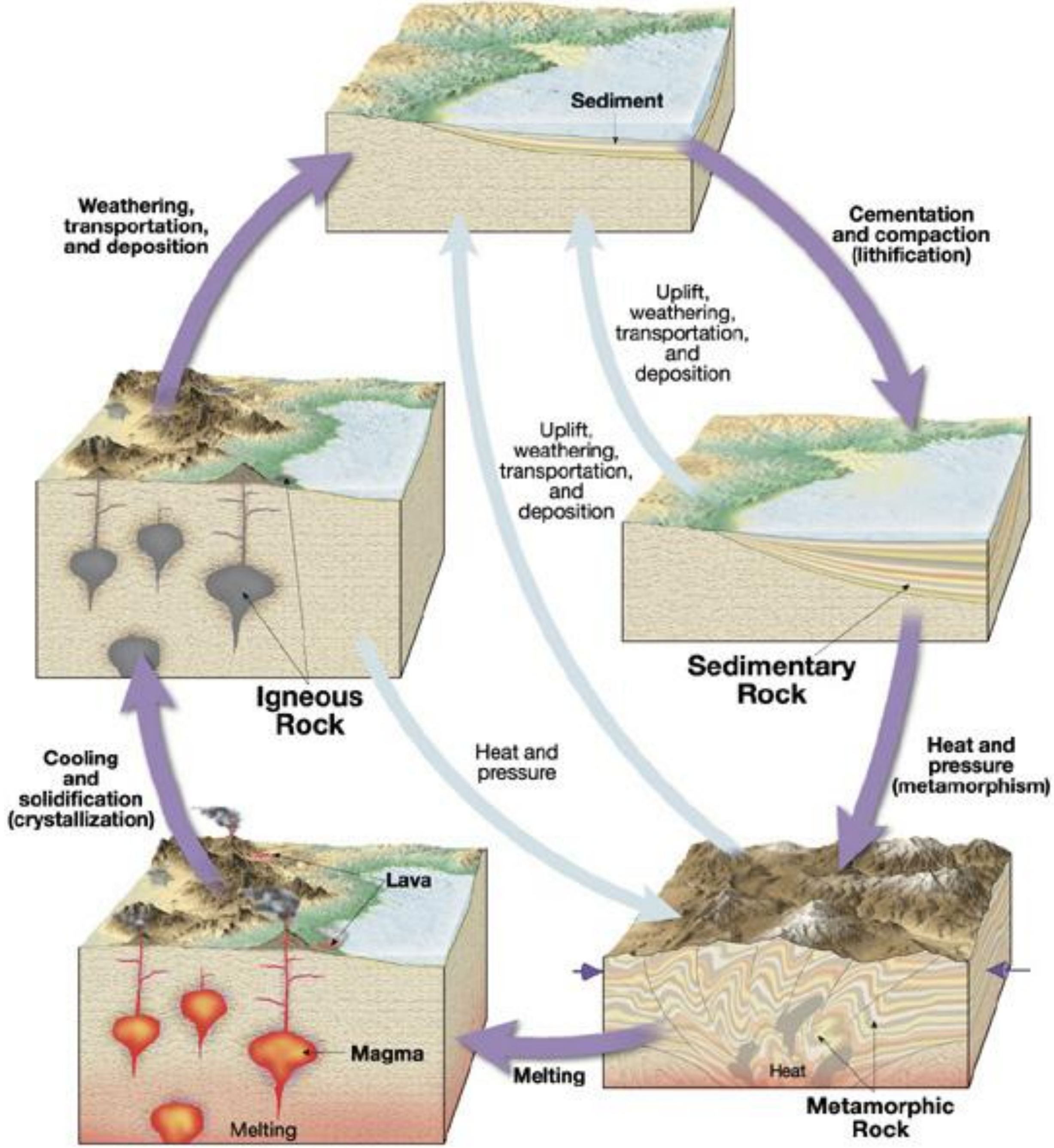
Three basic rock types:

igneous - form from magma/lava

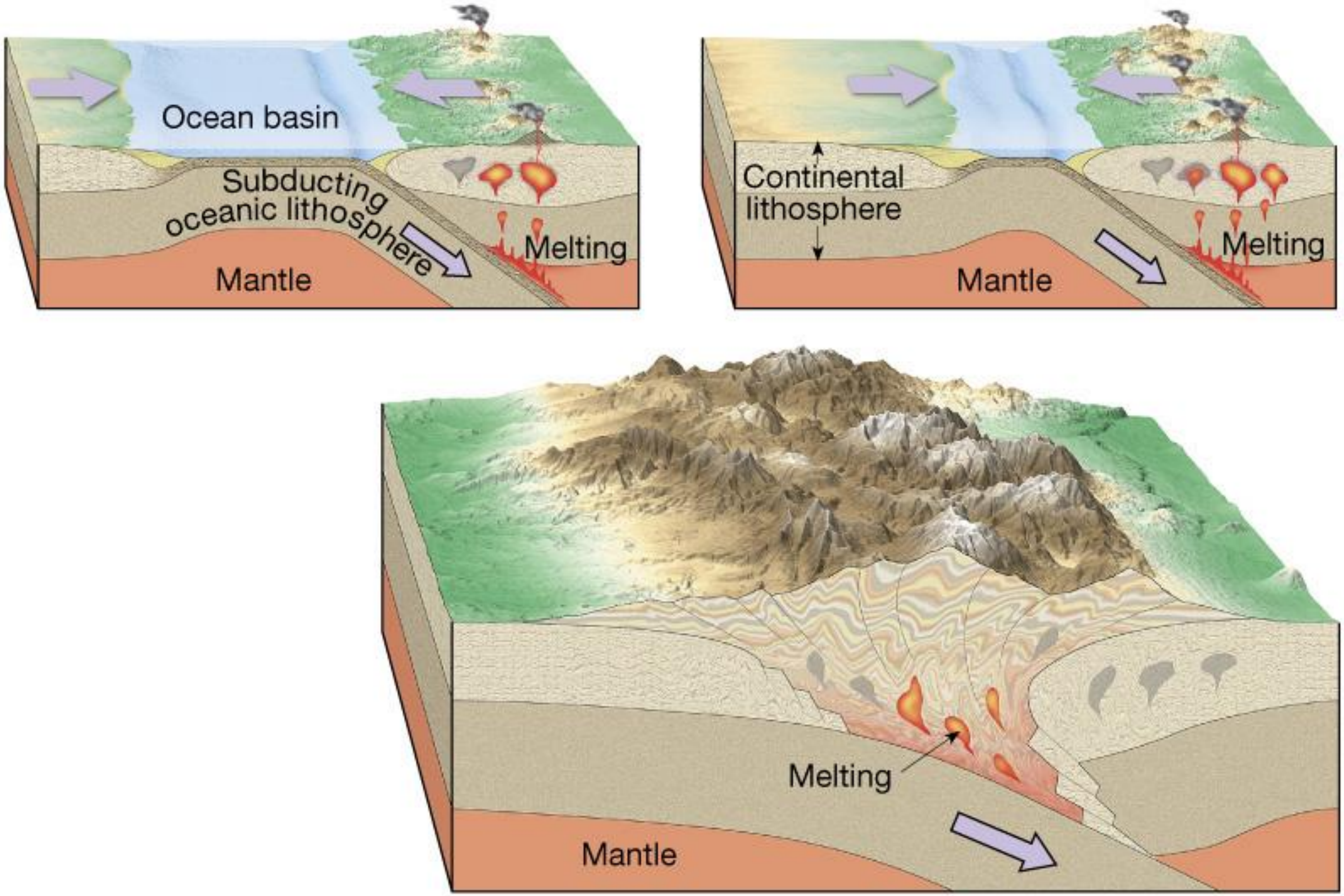
sedimentary - form from sediment and chemical precipitation from seawater

metamorphic - form from other rocks that recrystallize under higher pressures and/or temperatures.

A number of geological processes can transform one rock type into another.



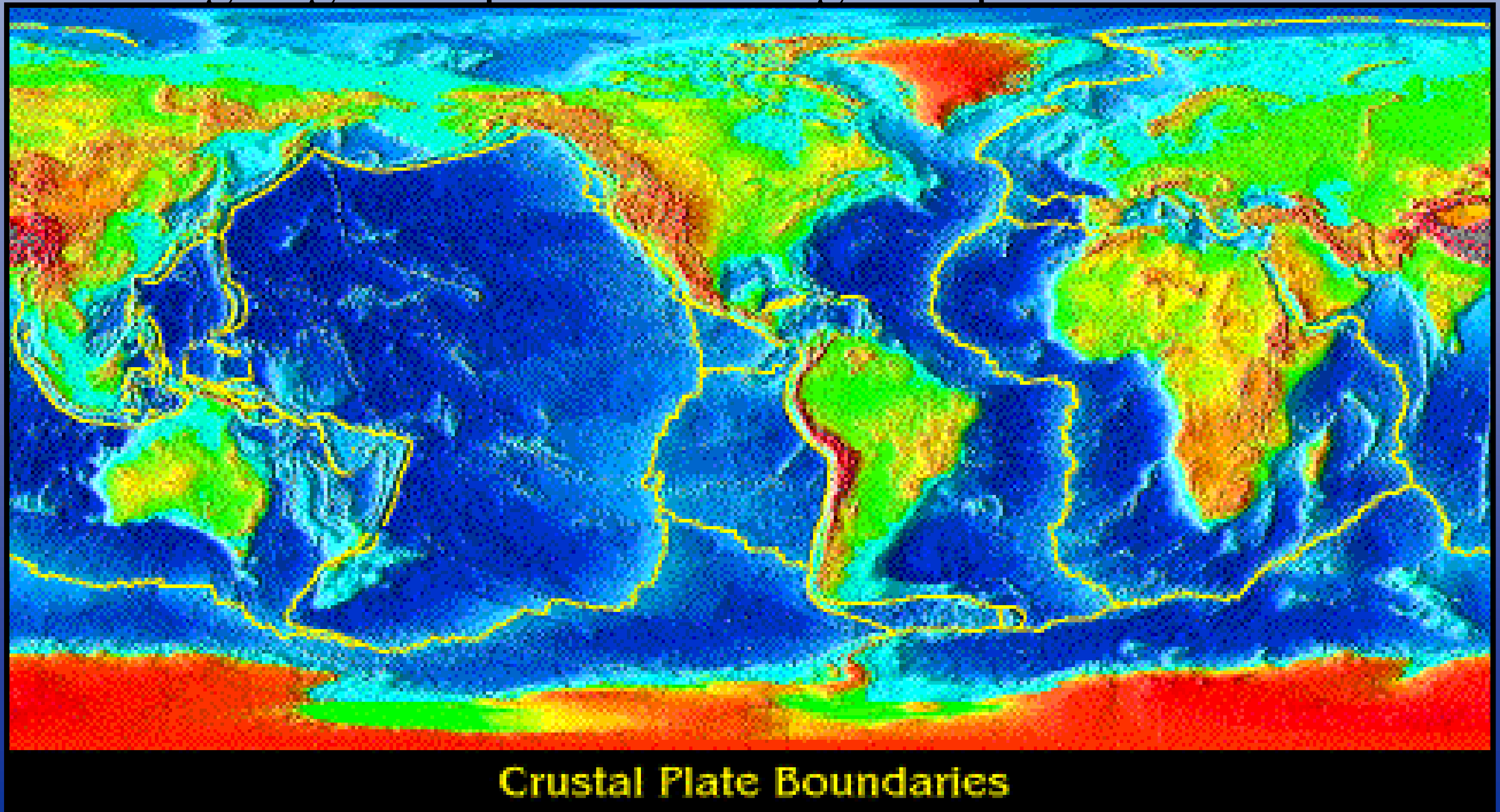
The Rock Cycle

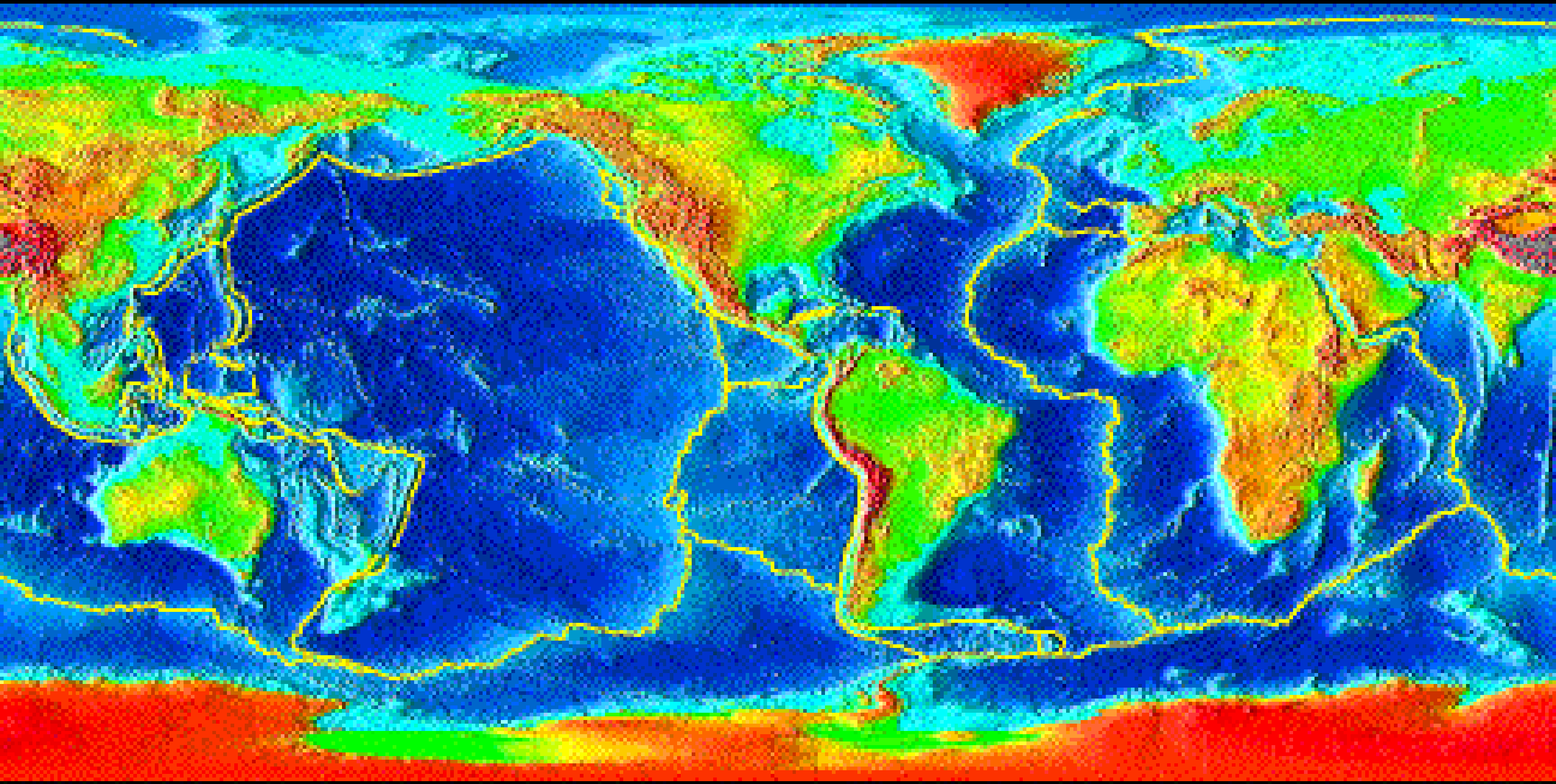


The Face of the Earth

• The continents sit just above sea level, except for the mountain belts, and include continental areas which are slightly covered by the oceans (<100m depth).

• The oceans are about 5km deep in the basins, but run to 10km in the trenches and as shallow as 2km on the mid-ocean ridges. Something systematic is going on to produce these global patterns.





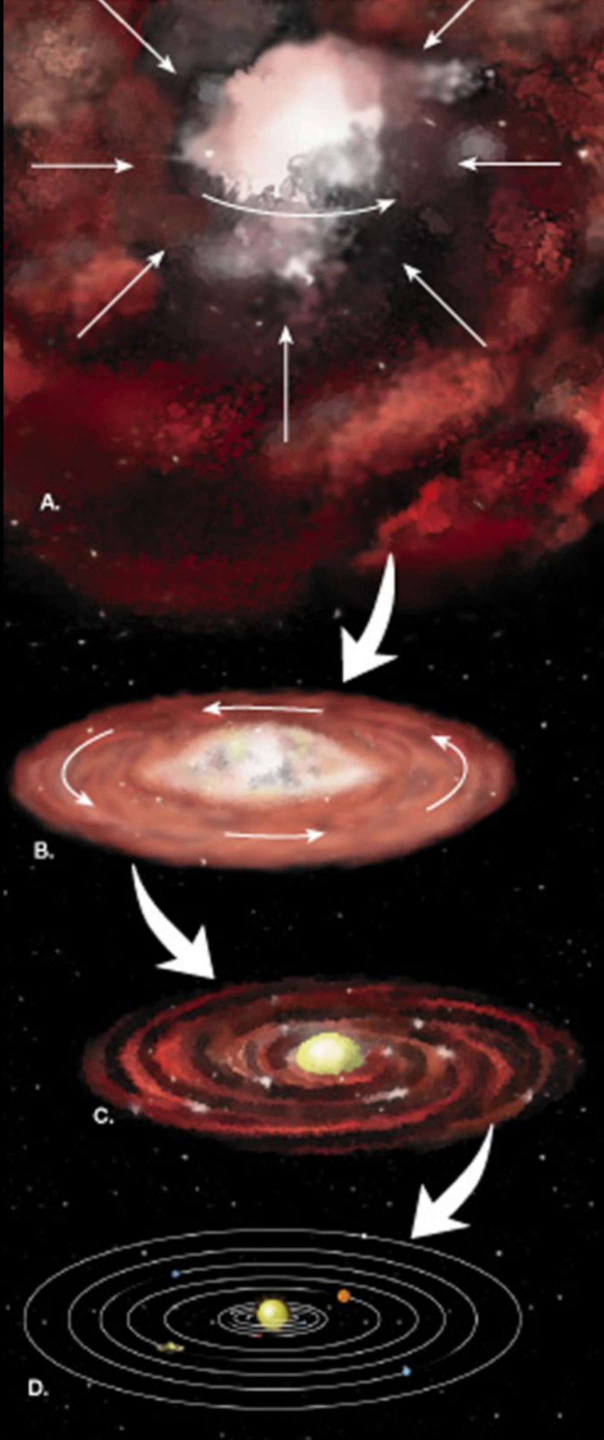
Crustal Plate Boundaries

The Origin of the Earth

The Earth and the other 8 planets and the Sun accreted at about the same time from a vast cloud of dust and gas (nebula).

About 5 billion years ago, the nebula began to gravitationally contract, began to rotate and flattened. Eventually, the Sun ignited (fusion) and the newly formed planets began to differentiate - heavier elements and chemical components sank to the center and rocky material formed the crust. The newly formed planets and moons released gas forming early atmospheres.

We will spend more time talking about the Earth's place in our solar system later in this course.



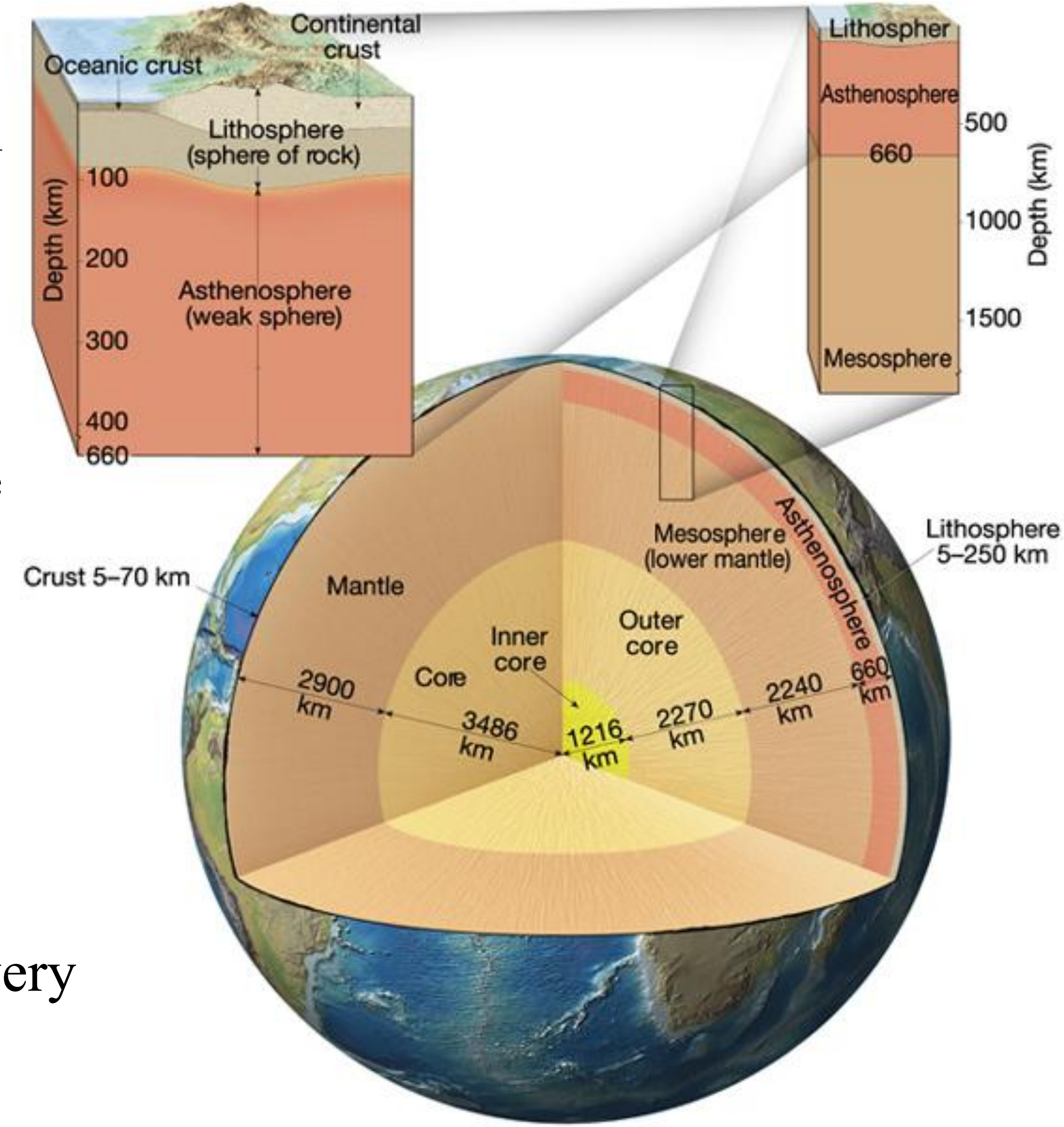
Earth's Internal Structure

The Earth's interior is characterized by a gradual increase in temperature, pressure and density with depth.

At only 100 km depth, the temp is ~1300°C.

At the Earth's center, the temperature is >6700°C.

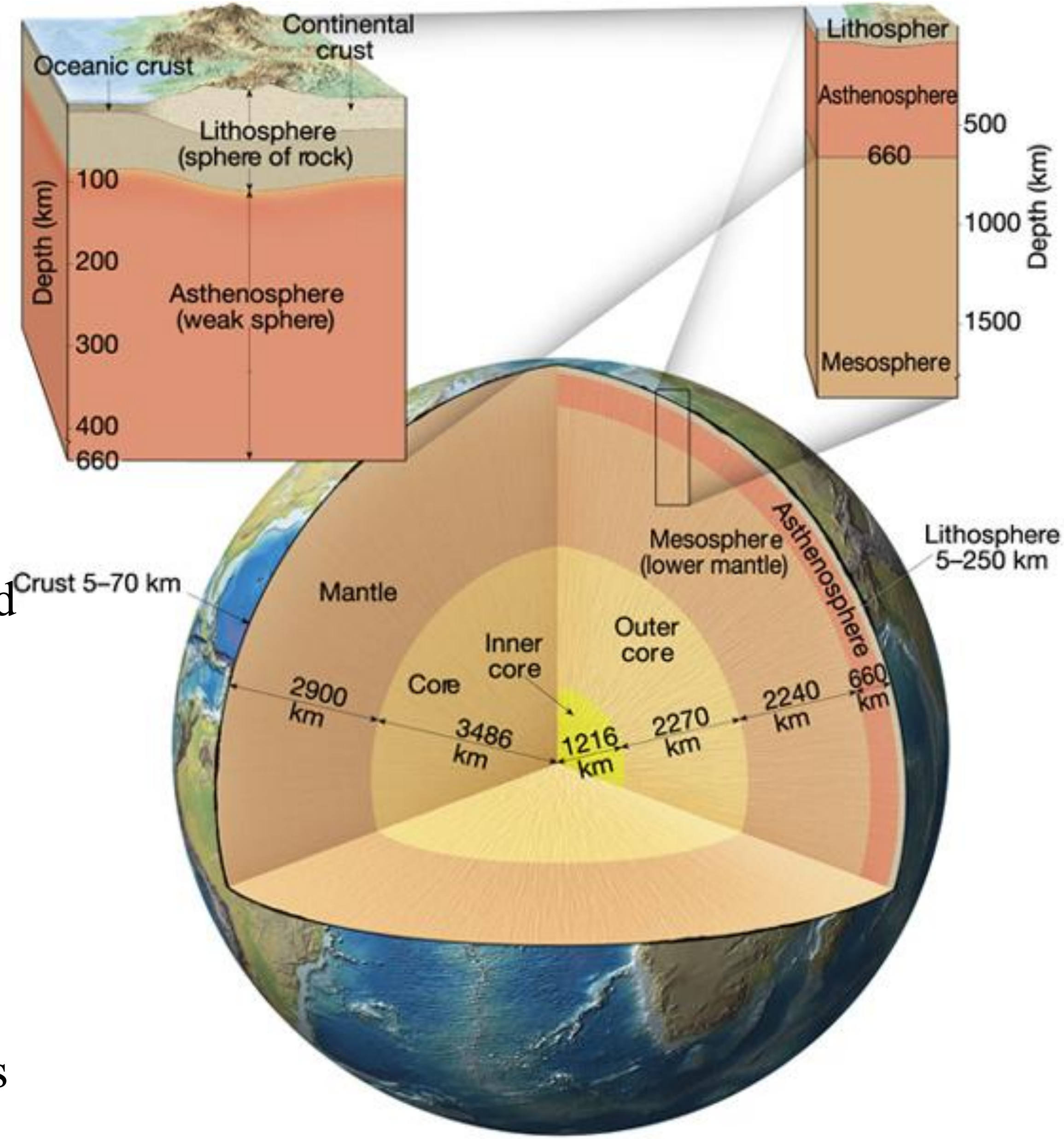
The pressure in the crust increases ~280 bars for every kilometer depth.



Earth's Internal Structure

The Earth consists of 3 major regions marked by differences in chemical composition.

Crust: rigid outermost layer of the Earth. Consists of two types:



1. **oceanic** - 3-15 km thick and is composed of *basalt* (igneous). Young (<180 million years old).

2. **continental** - up to 70 km thick and composed of a wide variety of rock types (ave. *granodiorite*). Ranges from young to old (>3.8 billion years old).

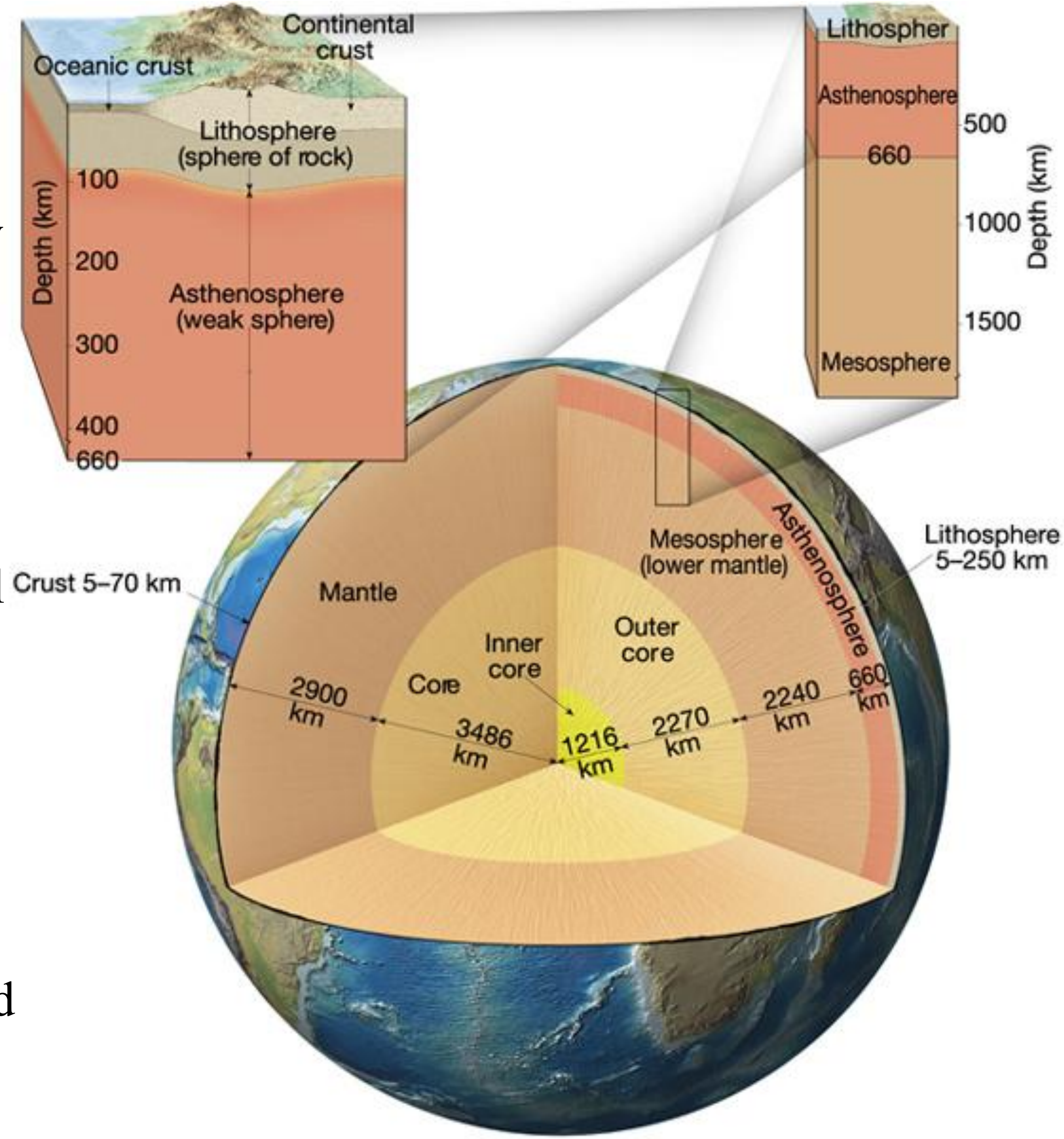
Earth's Internal Structure

Mantle: comprises ~82% of the Earth by volume and is ~2900 km thick.

- The mantle is characterized by a change in composition from the crust.
- The mantle is able to flow (plastically) at very slow rates.

Core: composed of iron, nickel and other minor elements.

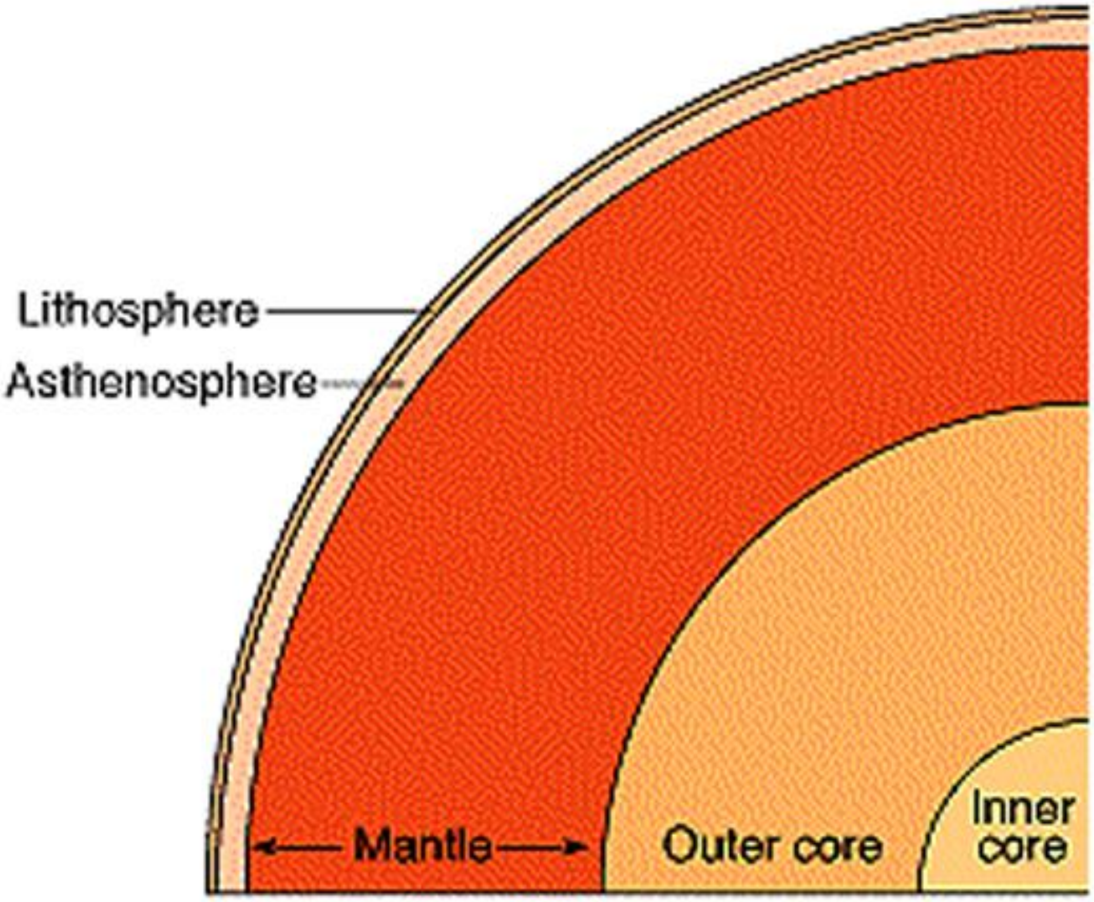
- The outer core is liquid — capable of flow and source of the Earth's magnetic field.
- The inner core is solid Fe-Ni. There is no major chemical difference between the outer and inner core.



***Lithosphere** (0 to ~100 km)*

It's very stiff, and fractures if you push too hard

The outer 75 km (with big variations between 10 and 300km) of the earth is a region which does not get heated up to near-melting because it is losing heat rapidly to the surface - it is stuck at a temperature close to 0°C. This relatively cool shell is called the *lithosphere*. The lithosphere is fractured into a few large plates - just enough so that the movement of the plates can deliver interior heat to the surface particularly near the spreading boundaries, where two plates are moving apart, and new material wells up from depth.



Asthenosphere (~100 to 660 km)

It's hot and flows like molasses

• Radioactive dacay causes the Earth to heat up on time scales of millions of years. In the course of tens/hundreds of millions of years, this heat production is enough to warm the interior by hundreds of °C.

• This heat is carried away by the convective circulation of the earth's interior. The convection delivers heat to the surface, so it can eventually be lost into space.

• Most of the earth's interior is heated to a temperature (> 300°C) which makes it ductile, so that it is soft, and can flow like a viscous liquid. You have seen this behavior as glass is heated to near its melting point. The soft region (just below the lithospheric plates) is called the asthenosphere

Mesosphere / Lower Mantle (660 to 2900 km)

• Rock in the lower mantle gradually strengthens with depth, but it is still capable of flow.

Outer (2900 to 5170 km) and Inner Core (5170 to 6386 km)

• Outer core is liquid and composed of an iron-nickel alloy. Convective flow of this fluid generates much of the Earth's magnetic field.
• Inner core is solid iron-nickel alloy. It is hotter than the outer core, but the intense pressure keeps it solid.

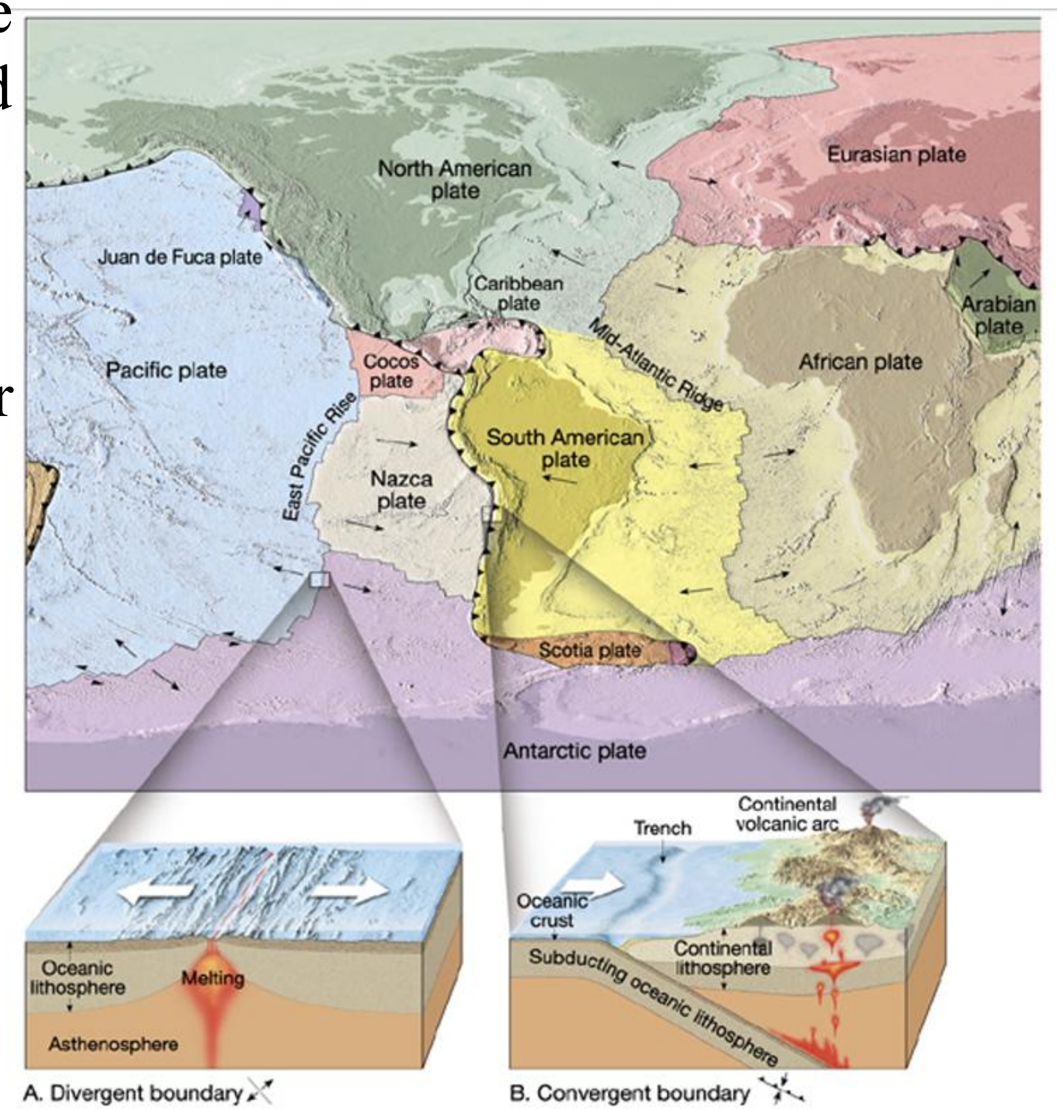
Plate Tectonics

A relatively recent theory that the Earth's crust is composed of rigid plates that move relative to one another.

Plate movements are on the order of a few centimeters/year - about the same rate as your fingernails grow!

There are 3 types of plate boundaries:

1. divergent
2. convergent
3. transform



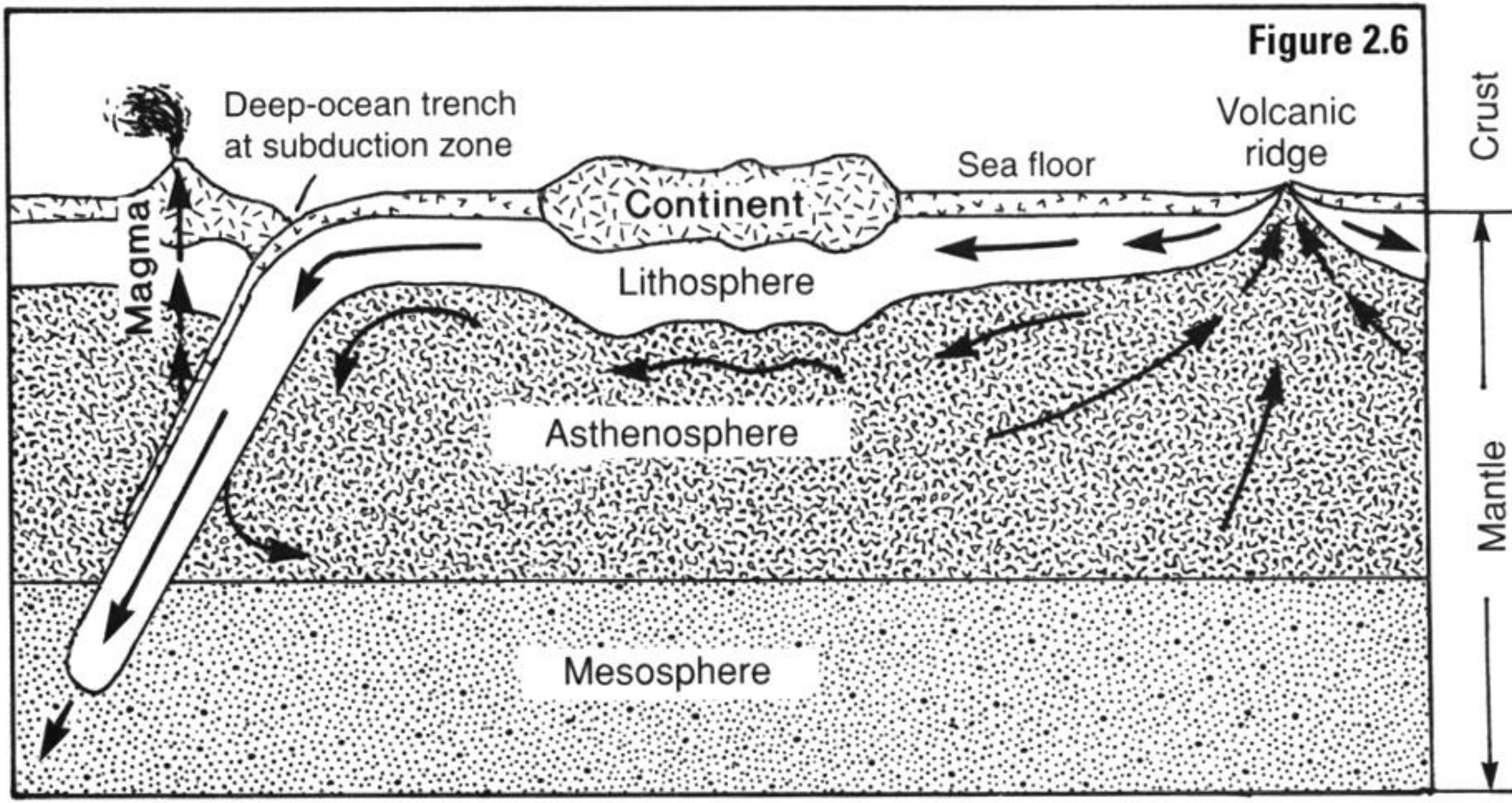
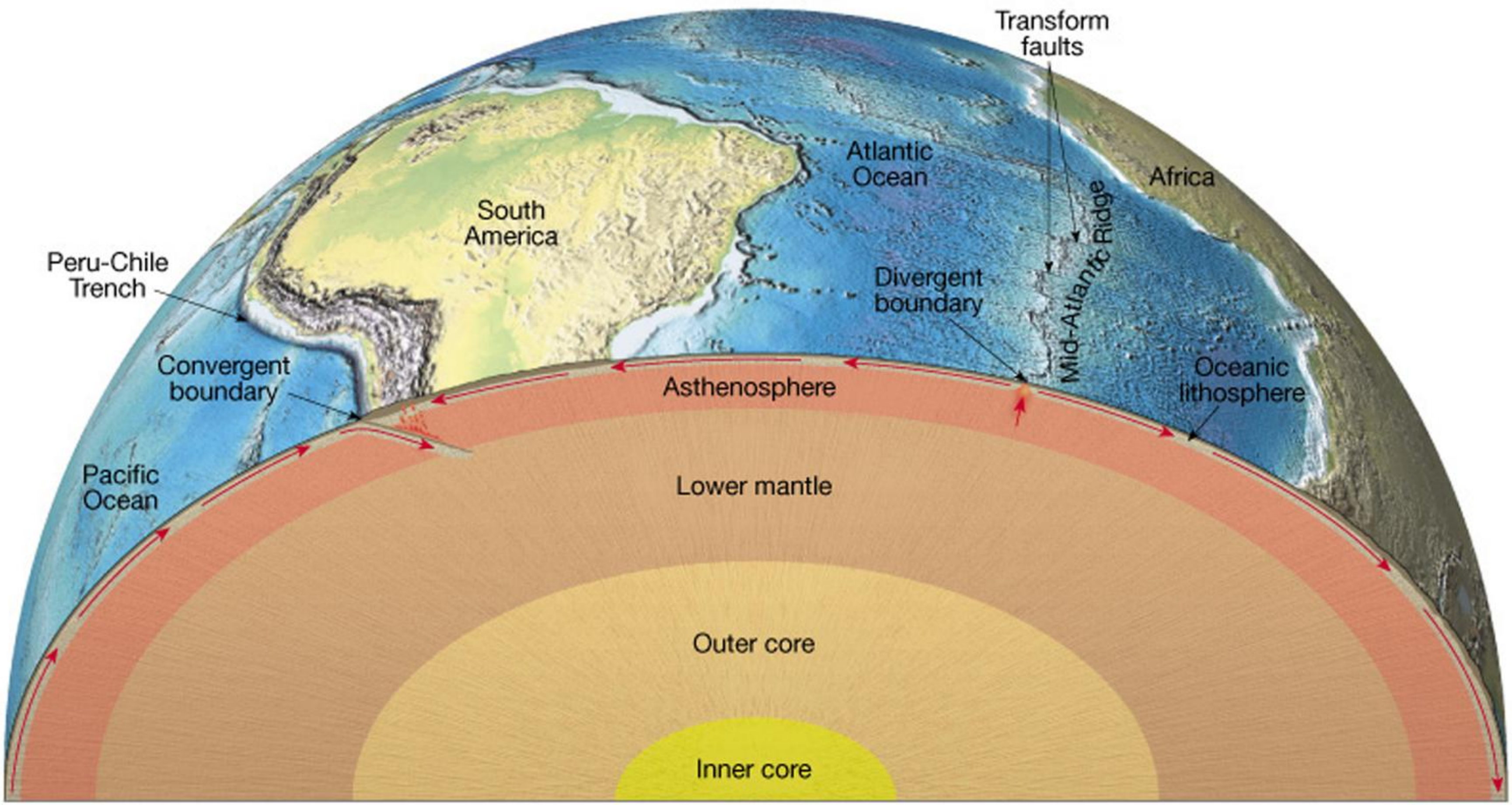

Deep-ocean trench
at subduction zone
Magma
Continent
Sea floor
Volcanic
ridge
Crust
Lithosphere
Asthenosphere
Mantle
Mesosphere

Figure 2.6

Plate Tectonics

- ***Convergent boundaries*** - plates move together forming a subduction zone and mountain chains.
- ***Divergent boundaries*** - plates move apart forming the mid-ocean ridge and seafloor spreading.
- ***Transform boundaries*** - plates grind past one another. These boundaries subdivide the mid-ocean ridge and also form the San Andreas fault system.



A simplifed model of tectonic plates and the location and nature of earthquakes.

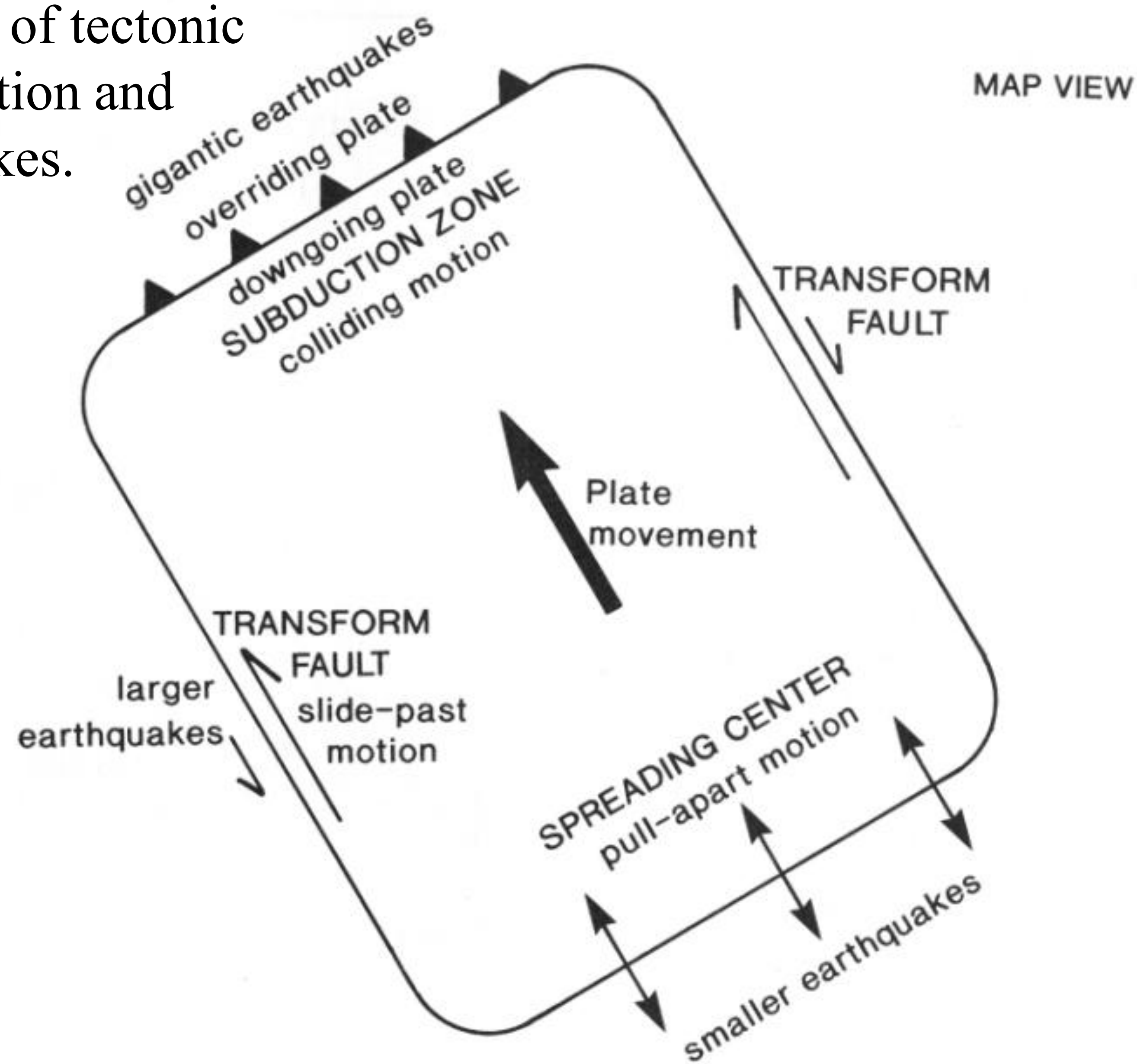


Plate Boundaries: *where the real action occurs.*

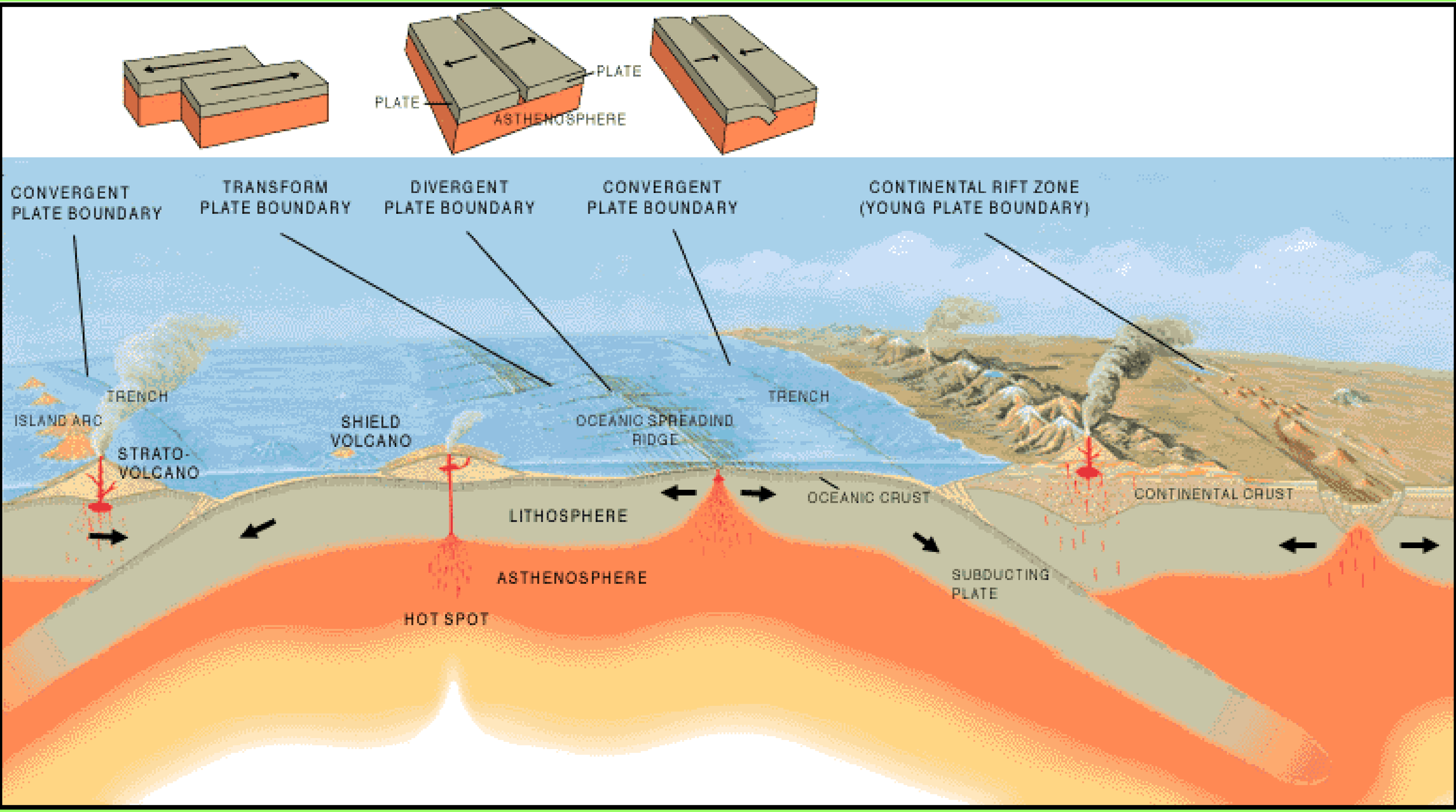
The plates are all moving relative to each other. At the boundary between two plates, there must be some motion of one relative to the other. You get three possibilities:

Spreading center: Divergent boundary
At the top of a rising convection limb. Heat is being brought up. Volcanism. Usually under-ocean. Often associated with a rift valley.

Collision zone: Convergent boundary
Cold lithosphere bends downward and begins sinking into the mantle (subduction). Mountains are squeezed up here by the collision. Most earthquakes occur here.

Parallel plate motion: Transform / Transcurrent / Strike Slip faulting
The San Andreas Fault is the most famous transform fault system.

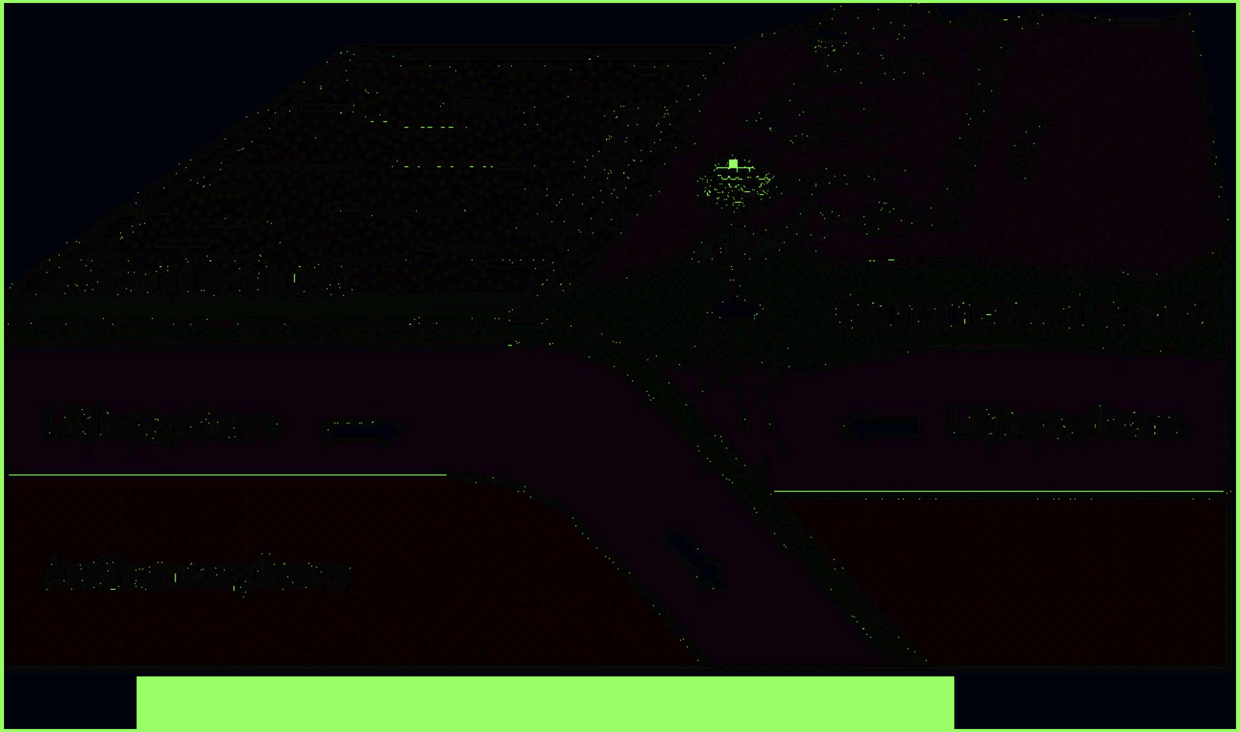
Plate Margins



Oceanic - Oceanic Convergence - Example: Japan

At an ocean-ocean collision, one plate subducts beneath the other, leaving a trace of the process in volcanoes and earthquakes. At the fast collisions (Fiji-Tonga) the subducting plate gets as deep as 700 km while still cool: it is here that you get the deepest (deep focus) earthquakes.

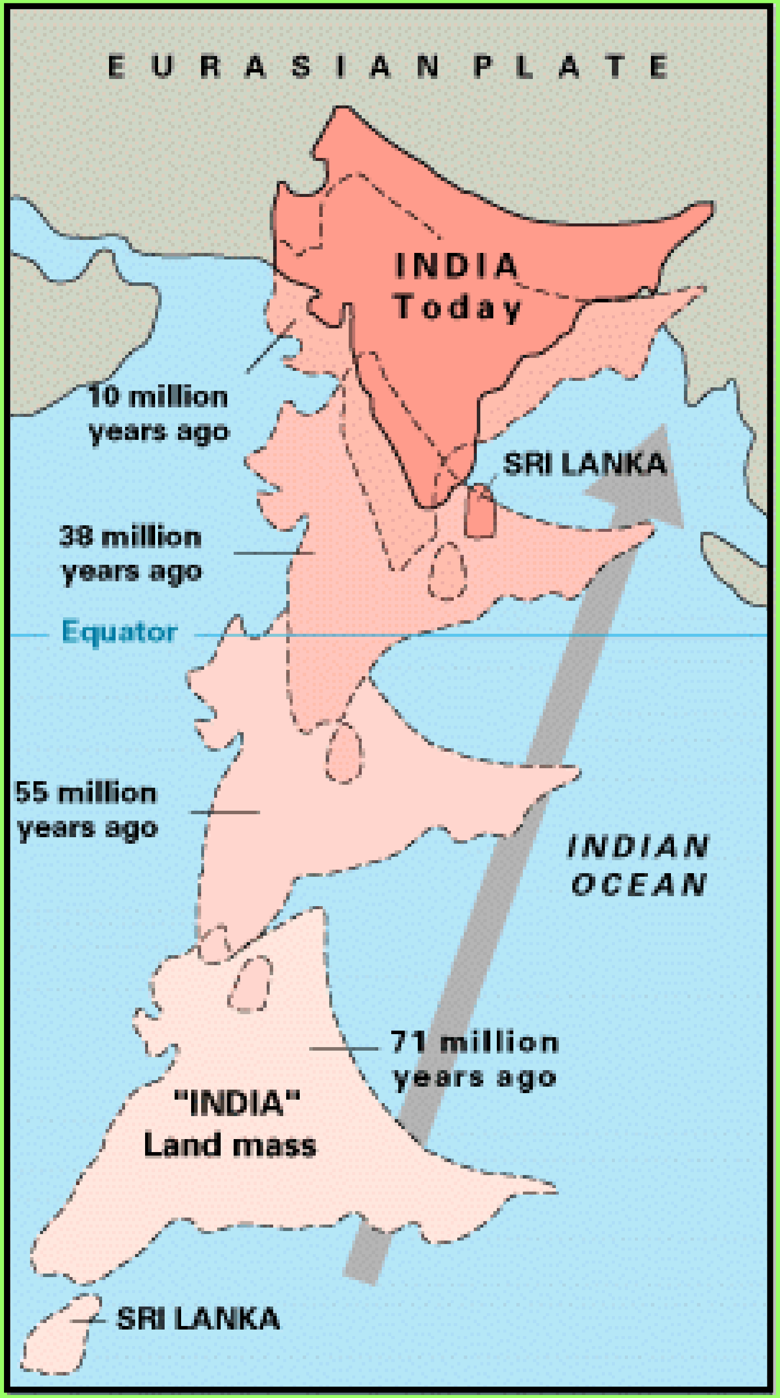
Oceanic - Continent Convergence - Example: Andes, Cascades

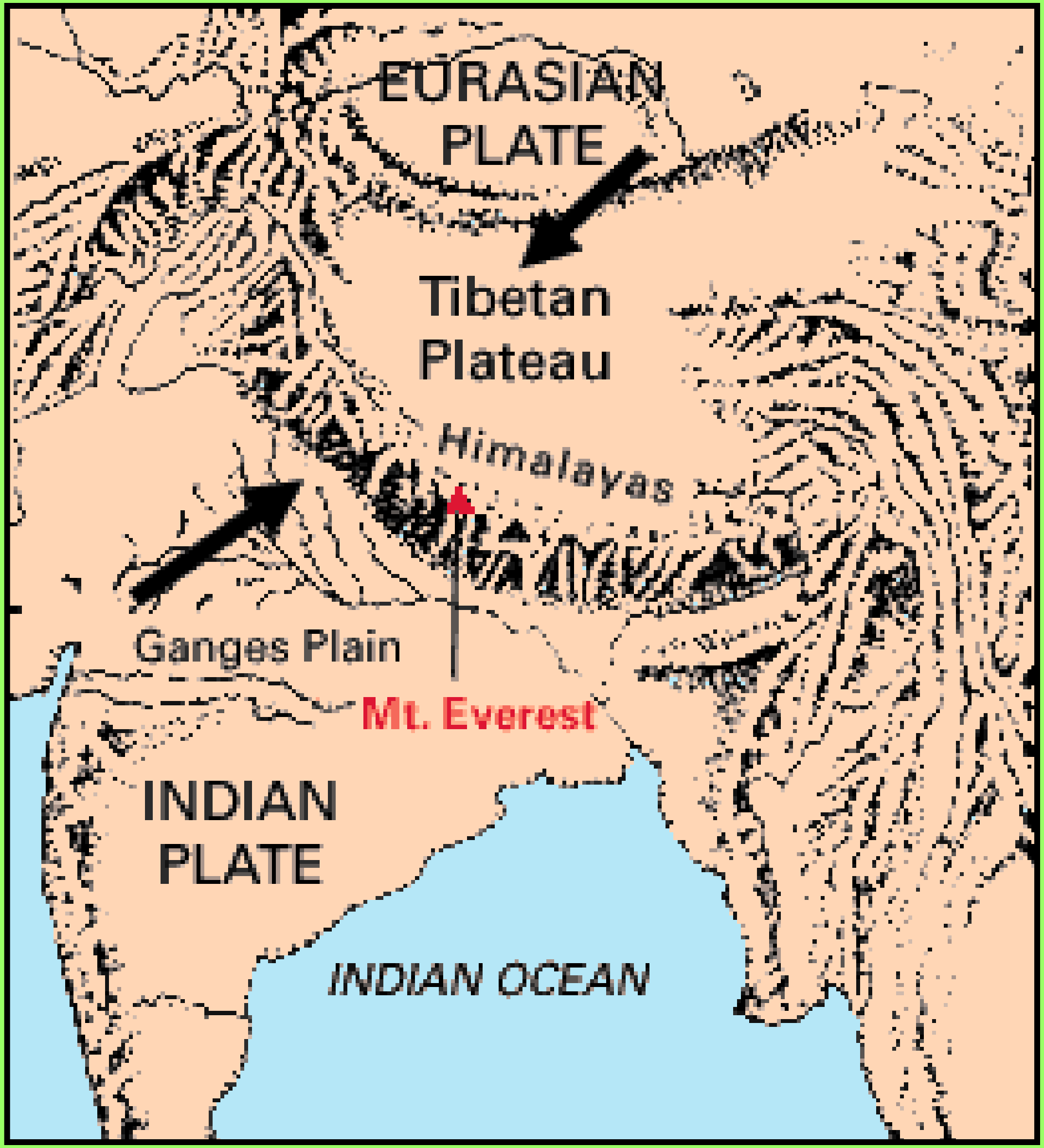


At an ocean-continent collision, the ocean subducts, and the continent rides high. Volcanoes are built on the continental side due to melt which comes off the subducting plate. Nazca-South America is an excellent example.

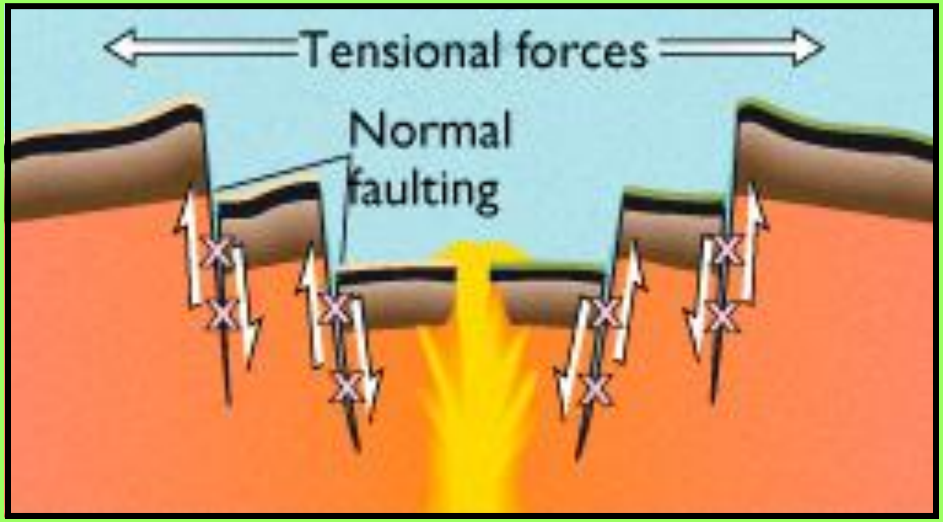
Continent - Continent Convergence - Example: Himalayas

A continent-continent collision is like a train wreck - both sides end up taking severe damage. Neither side wants to subduct. The entire Alpine-Himalayan mountain system from Spain to Thailand is behaving this way. Mountain belts are stacked range upon range across the landscape for 1000's of km. These mountains are permeated with thrust faults, which carry slices of crust many dozens or 100's of km over other slices.

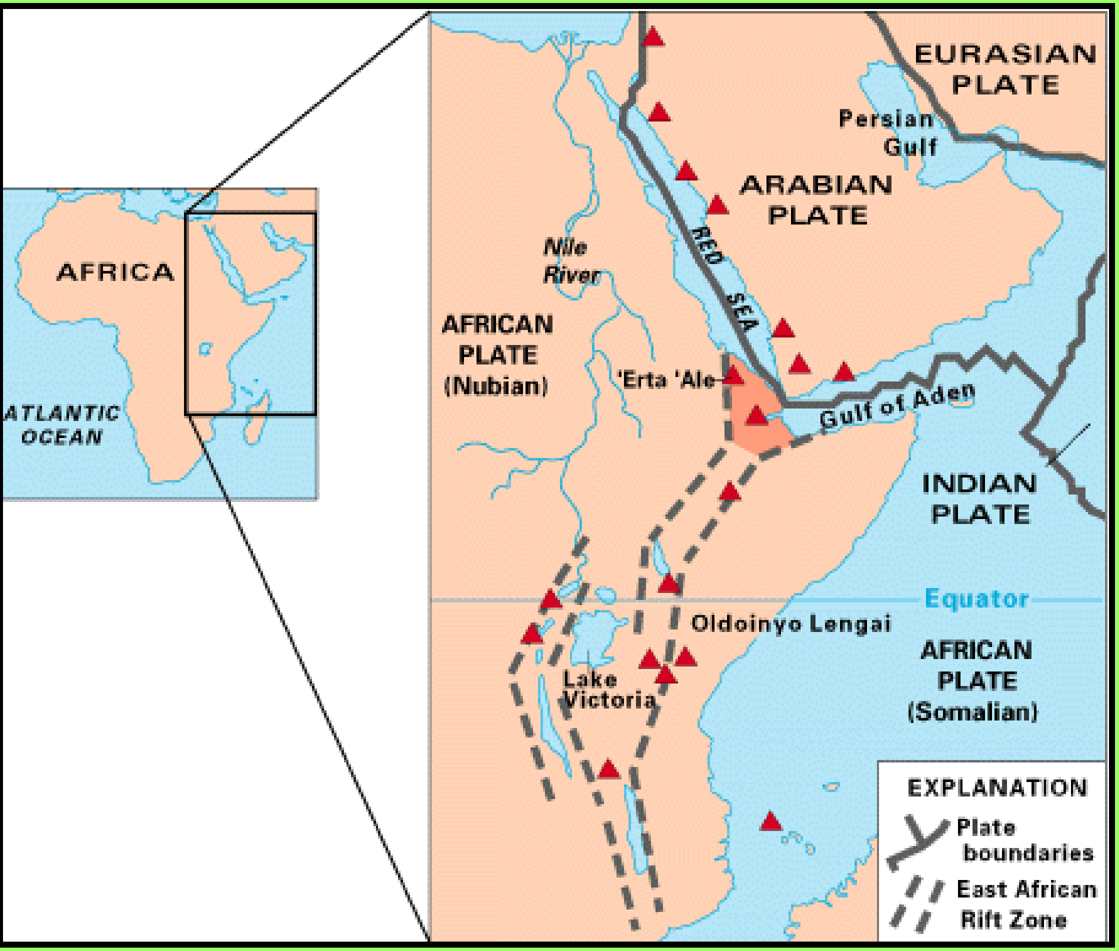

EURASIAN PLATE
INDIA
Today
10 million
years ago
SRI LANKA
38 million
years ago
Equator
55 million
years ago
INDIAN
OCEAN
71 million
years ago
"INDIA"
Land mass
SRI LANKA

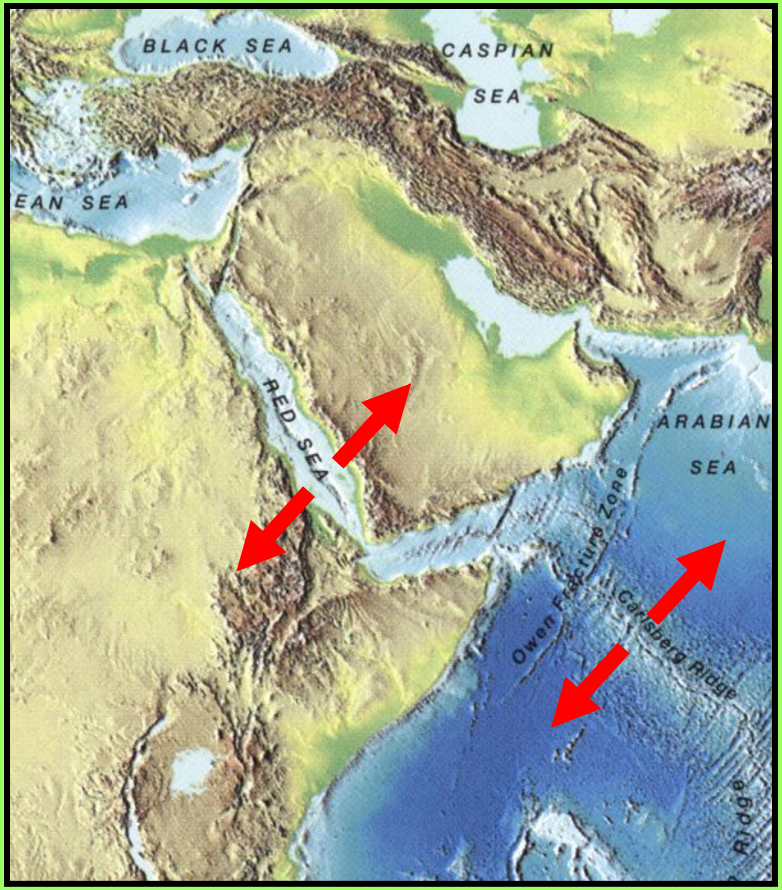

EURASIAN
PLATE
Tibetan
Plateau
Himalayas
Ganges Plain
Mt. Everest
INDIAN
PLATE
INDIAN OCEAN

Oceanic Divergent Boundary Example: Mid-Atlantic Ridge



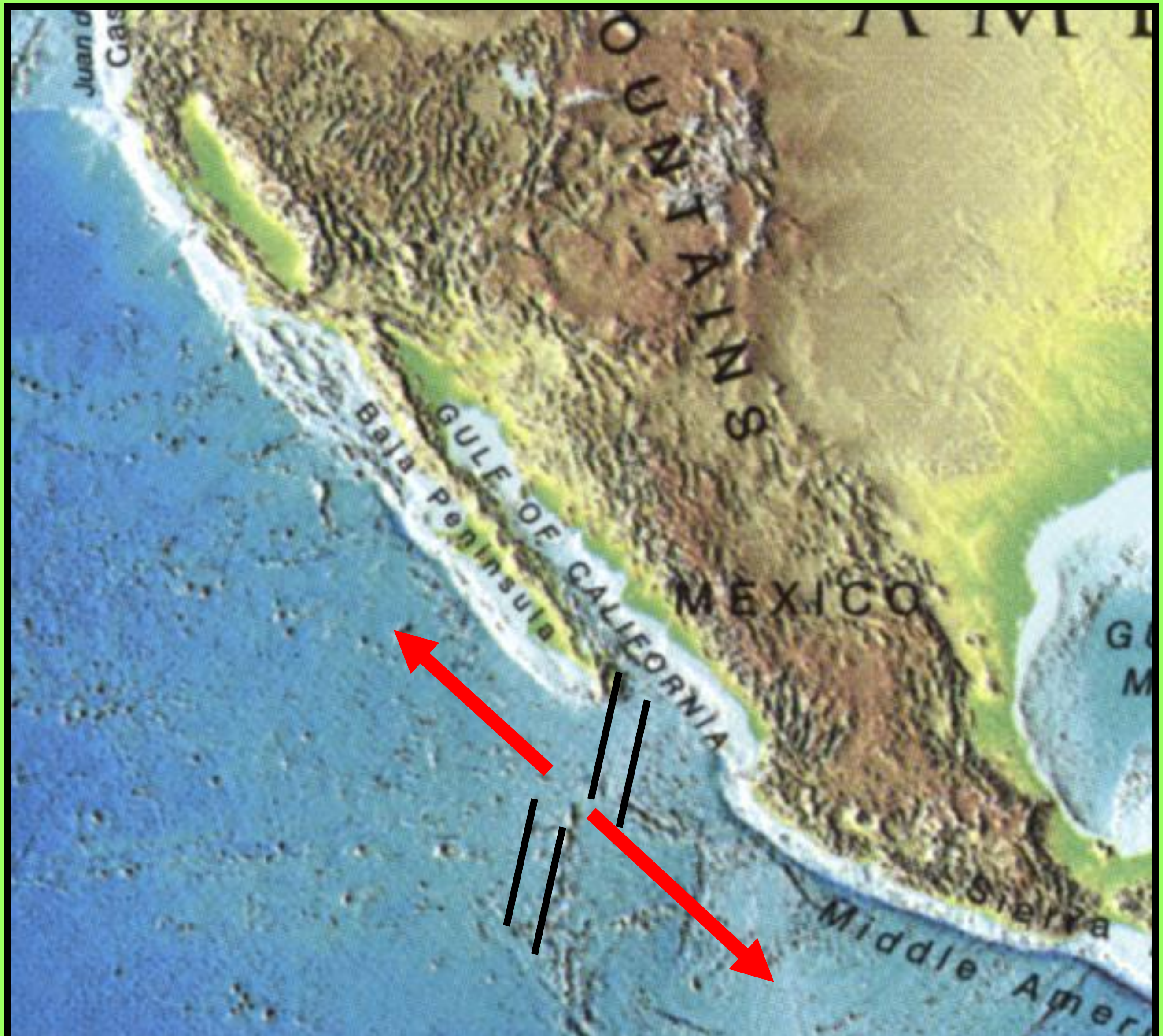
Continental Divergent Boundary
Example: Red Sea / E. African Rift



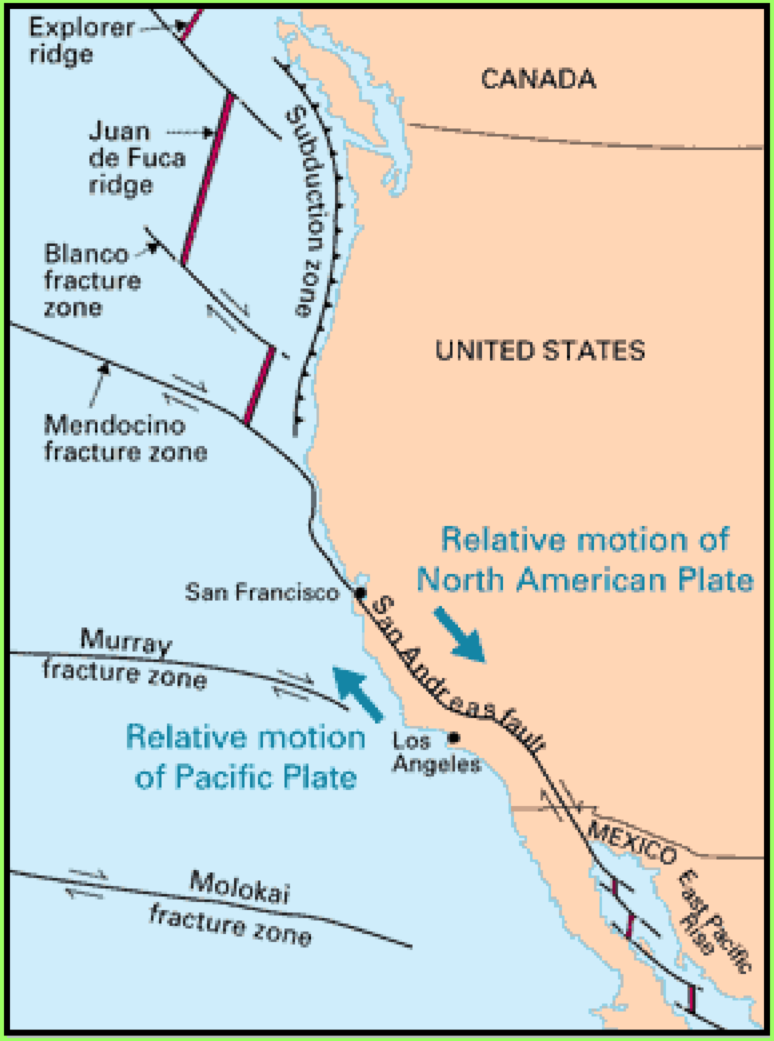


This image of the Sinai peninsula shows where the Red Sea spreading center forks into two branches which can be seen as forming a brand-new oceanic rift in the land.

Continental Divergent Boundary
Example: Baja California



Continental Transform Boundary - Example: San Andreas



Weathering

By Lisa Bolin

Weathering and Erosion

This is a monument called Cleopatra's Needle. It was carved in Egypt around 1450B.C. The sides are carved with hieroglyphs, the writing of ancient Egypt. It stood in the dry, hot Egyptian desert for over 3000 years. During that time, the hieroglyphs remained distinct.

Weathering

- In 1800, the monument was moved to New York City. Almost immediately, the hieroglyphs began to fade. In only a few years in the wet and variable climate of New York, the Egyptian writing became indistinct!

- Cleopatra’s Needle was carved from granite, a hard tough, crystalline rock.
- Although it is tough, granite is changed by the atmosphere.
- Some of the minerals that make up granite change to clay.
- Chips and flakes of minerals break away from the granite surface.

Weathering

- Weathering is simply the chemical and/or physical breakdown of a rock material-- weathering involves specific processes acting on rock materials at or near the surfac

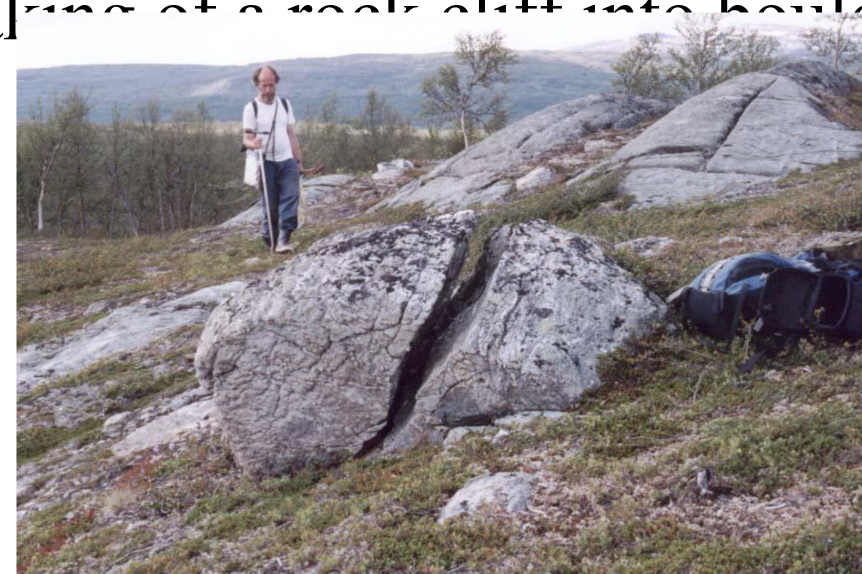
Weathering

- In other rocks, minerals may slowly dissolve.
- Eventually the surface of ALL rocks crumble

Types of Weathering

- Physical Weathering(mechanical)
  - Takes place when rock is split or broken into smaller pieces of the same material without changing its composition.

Example: Breaking of a rock cliff into boulders and pebbles



Weathering
Physical

- Common weath  rocesses:
  - Frost action
  - Wett  nd  g
  - Action of plants and animals 
  - Loss of overlying  d soil

Types of Weathering

- Chemical (decomposition)
  - takes place when the rock's minerals are changed into different substances.
  - Water and water vapor are important agents of chemical weathering.

Example: Formation of clay minerals from feldspar

Types of Weathering

- The two processes of weathering, mechanical and chemical seldom occur alone!
- Since water vapor is present in the air everywhere means that chemical weathering occurs everywhere.

Types of Mechanical Weathering

- Frost action or **Ice Wedging**:
  - Water takes up about 10% more space when it freezes.
  - This expansion puts great pressure on the walls of a container.
  - Water held in the cracks of rocks wedges the rock apart when it freezes.
  - Often occurs in places where temperatures vary from below the freezing point of water to above the freezing point.

Types of Mechanical Weathering

- Frost action or **Ice Wedging** con't
- Occurs mostly in porous rocks and rocks with cracks in them
  - Bare mountaintops are especially subject to ice wedging.

Types of Mechanical Weathering

- Frost action or **Ice Wedging** causes:
  - Vast fields of large, sharp-cornered boulders
  - Potholes on streets and highways

Types of Mechanical Weathering

- Repeated wetted and drying
- Especially effective at breaking up rocks that contain clay.
- Clays swell up when wet and shrink when dry.
- Causes rocks that contain clay, such as shale, to fall apart.

Types of Mechanical Weathering

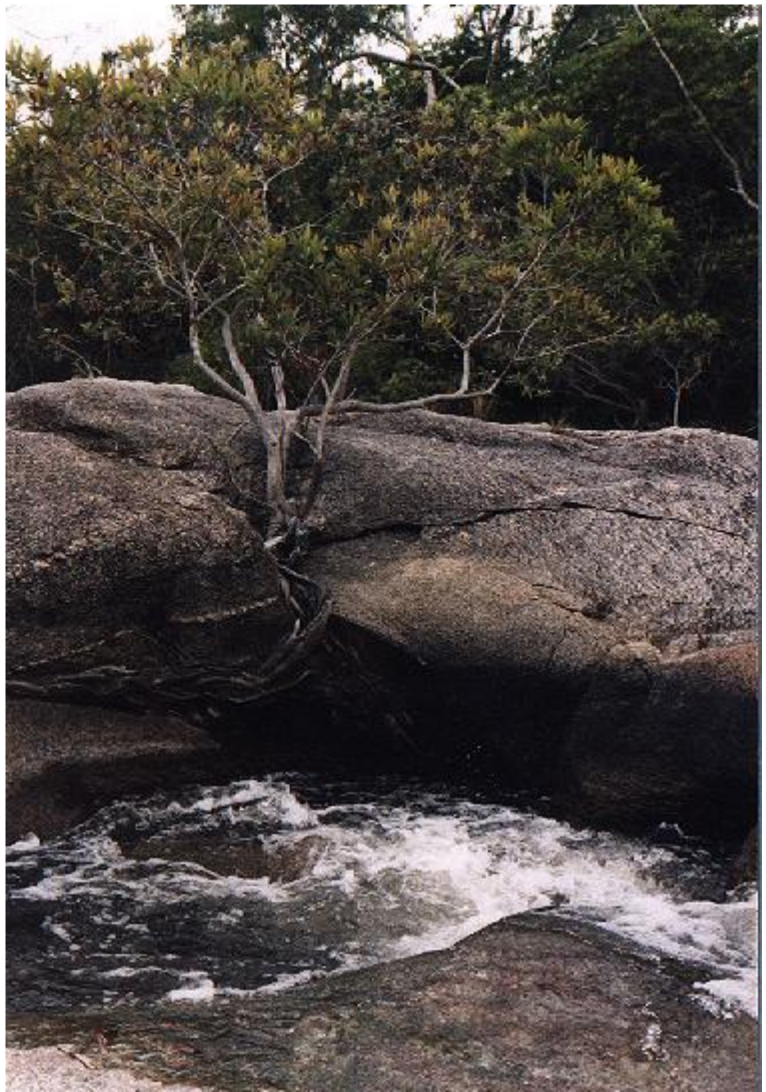
- *Action of plants and animals:*
  - *Lichens and mosses grow on rocks*
    - *They wedge their tiny roots into spores and crevices.*
    - *When the roots grow, the rock splits.*

- Action of plants and animals:
  - Lichens and mosses grow on rocks
    - They wedge their tiny roots into spores and crevices.
    - When the roots grow, the rock splits.

Types of Mechanical Weathering

- Action of plants and animals:
  - Larger trees and shrubs may grow in the cracks of boulders.
  - Ants, earthworms, rabbits, woodchucks, and other animals dig holes in the soil.
    - These holes allow air and water to reach the bedrock and weather it.

Types of Mechanical Weathering



Types of Mechanical Weathering

Types of Mechanical Weathering

- Loss of Overlying Rock and Soil
  - Sheet jointing on a granite outcrop produces cracks in the rock, thereby exposing more of the rock surface to weathering.

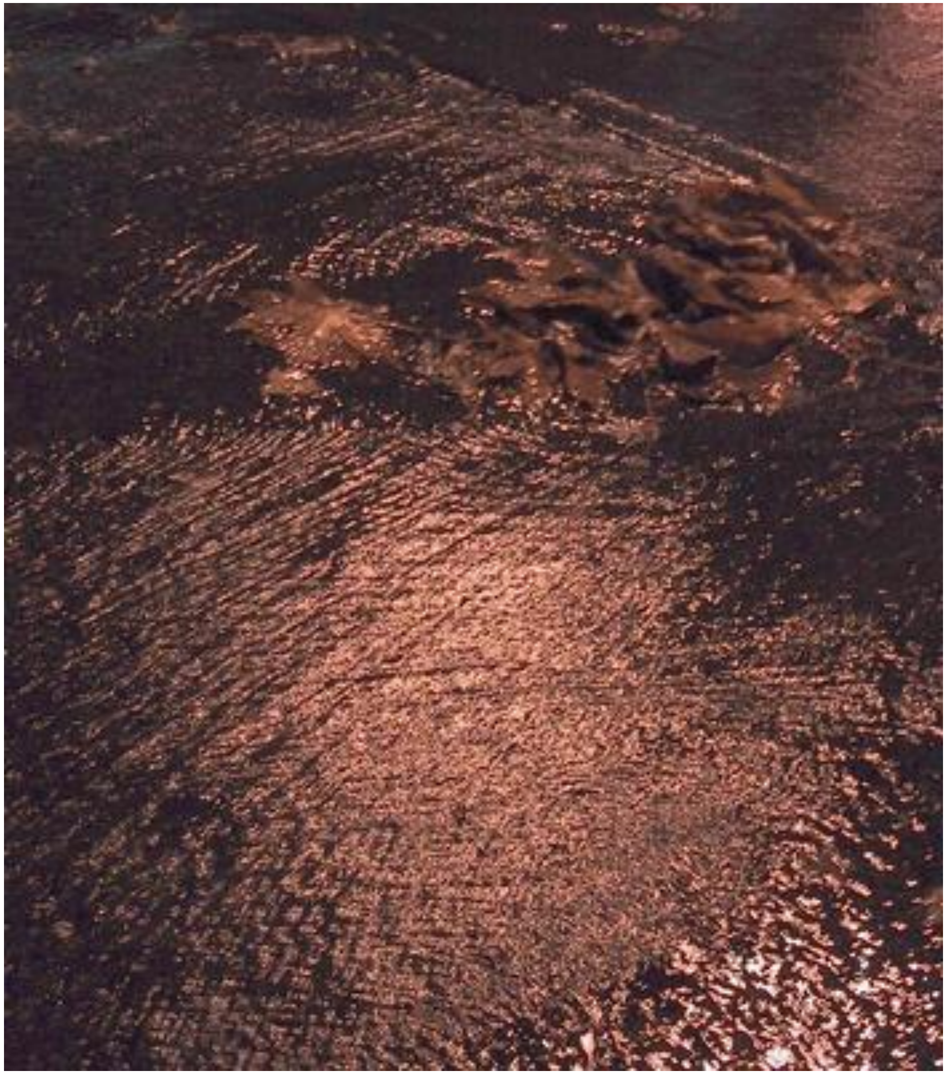
Types of Mechanical Weathering

Granite exfoliation

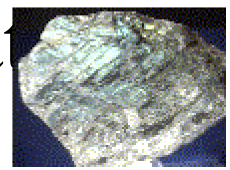
Types of Chemical Weathering

- Results mainly from the action of rainwater, oxygen, carbon dioxide, and acids of plant decay.

Agents of Chemical Weathering



Agents of Chemical Weathering

- The chemical reaction of water with other substances is called **hydrolysis**.
- Common mat  undergoing hydrolysis:
  - Feldspar
  -
  - Hornblende 
  - Augite 

Agents of Chemical Weathering

- The chemical reaction of oxygen with other substances is called **oxidation**.
  - Iron-bearing minerals are the ones most easily attacked by oxygen.
  - Examples:
    - Magnetite
    - Pyrite
    - Dark-colored ferromagnesian silicates

Agents of Chemical Weathering

- Oxidation of these minerals results in kinds of rust, or iron oxides.

Agents of Chemical Weathering

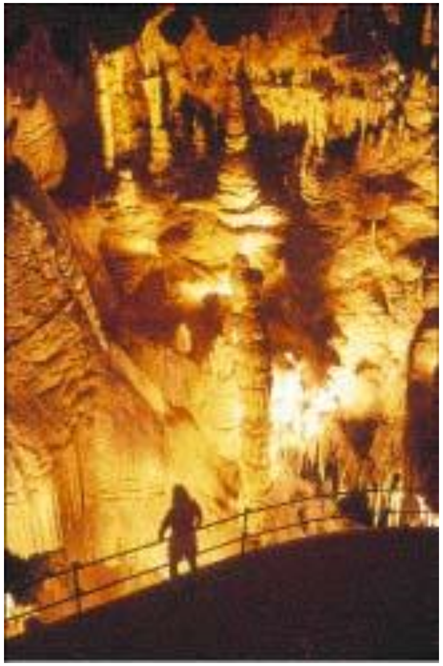
- Carbon dioxide dissolves easily in water.
  - It forms a weak acid called **carbonic acid**
  - This is the same compound that is in carbonated drinks.
  - Attacks many common minerals such as feldspar, hornblende, augite and biotite mica.
  - The original mineral is changed into a clay mineral.

Agents of Chemical Weathering

- Has the greatest effect on calcite than any other mineral.
- It dissolves it completely, with no clay left over.

Agents of Chemical Weathering

- Hollows out great caverns in limestone bedrock.



Agents of Chemical Weathering

- Acids are formed from the decay of plants and animals.
- These acids are dissolved by rainwater and carried through the ground to the bedrock.

Agents of Chemical Weathering

- Carbon dioxide and sulfur compounds released by industries unite with water in the atmosphere to form **acid rain**.
- Increasing amounts of acid rain in the environment increase the rate of chemical weathering.

Agents of Chemical Weathering

Chemical Weathering

- Occurs most quickly at the corners and edges of rock outcrops and boulders.
- These areas are more exposed to chemicals.
- This process rounds the rock and is called spheroidal weathering.
- Boulders rounded this way are called spheroidal boulders

Weathering

By Lisa Bolin

Weathering and Erosion

This is a monument called Cleopatra's Needle. It was carved in Egypt around 1450B.C. The sides are carved with hieroglyphs, the writing of ancient Egypt. It stood in the dry, hot Egyptian desert for over 3000 years. During that time, the hieroglyphs remained distinct.

Weathering

- In 1800, the monument was moved to New York City. Almost immediately, the hieroglyphs began to fade. In only a few years in the wet and variable climate of New York, the Egyptian writing became indistinct!

- Cleopatra’s Needle was carved from granite, a hard tough, crystalline rock.
- Although it is tough, granite is changed by the atmosphere.
- Some of the minerals that make up granite change to clay.
- Chips and flakes of minerals break away from the granite surface.

Weathering

- Weathering is simply the chemical and/or physical breakdown of a rock material-- weathering involves specific processes acting on rock materials at or near the surfac

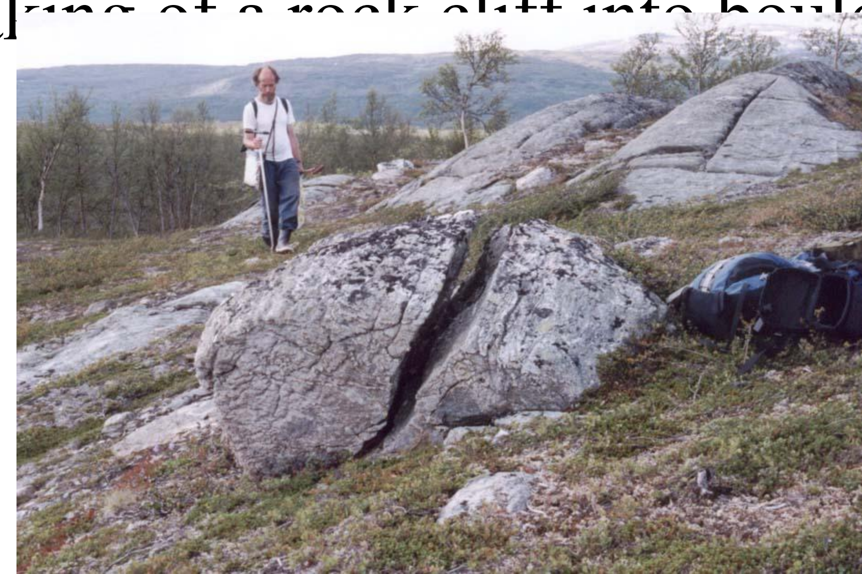
Weathering

- In other rocks, minerals may slowly dissolve.
- Eventually the surface of ALL rocks crumble

Types of Weathering

- Physical Weathering(mechanical)
  - Takes place when rock is split or broken into smaller pieces of the same material without changing its composition.

Example: Breaking of a rock cliff into boulders and pebbles



Weathering
Physical

- Common weathering processes:
  - Frost action 
  - Wett  nd  g
  - Action of plants and animals 
  - Loss of overlying rock and soil 

Types of Weathering

- Chemical (decomposition)
  - takes place when the rock's minerals are changed into different substances.
  - Water and water vapor are important agents of chemical weathering.

Example: Formation of clay minerals from feldspar

Types of Weathering

- The two processes of weathering, mechanical and chemical seldom occur alone!
- Since water vapor is present in the air everywhere means that chemical weathering occurs everywhere.

Types of Mechanical Weathering

- Frost action or **Ice Wedging**:
  - Water takes up about 10% more space when it freezes.
  - This expansion puts great pressure on the walls of a container.
  - Water held in the cracks of rocks wedges the rock apart when it freezes.
  - Often occurs in places where temperatures vary from below the freezing point of water to above the freezing point.

Types of Mechanical Weathering

- Frost action or **Ice Wedging** con't
- Occurs mostly in porous rocks and rocks with cracks in them
  - Bare mountaintops are especially subject to ice wedging.

Types of Mechanical Weathering

- Frost action or **Ice Wedging** causes:
  - Vast fields of large, sharp-cornered boulders
  - Potholes on streets and highways

Types of Mechanical Weathering

- Repeated wetted and drying
- Especially effective at breaking up rocks that contain clay.
- Clays swell up when wet and shrink when dry.
- Causes rocks that contain clay, such as shale, to fall apart.

Types of Mechanical Weathering

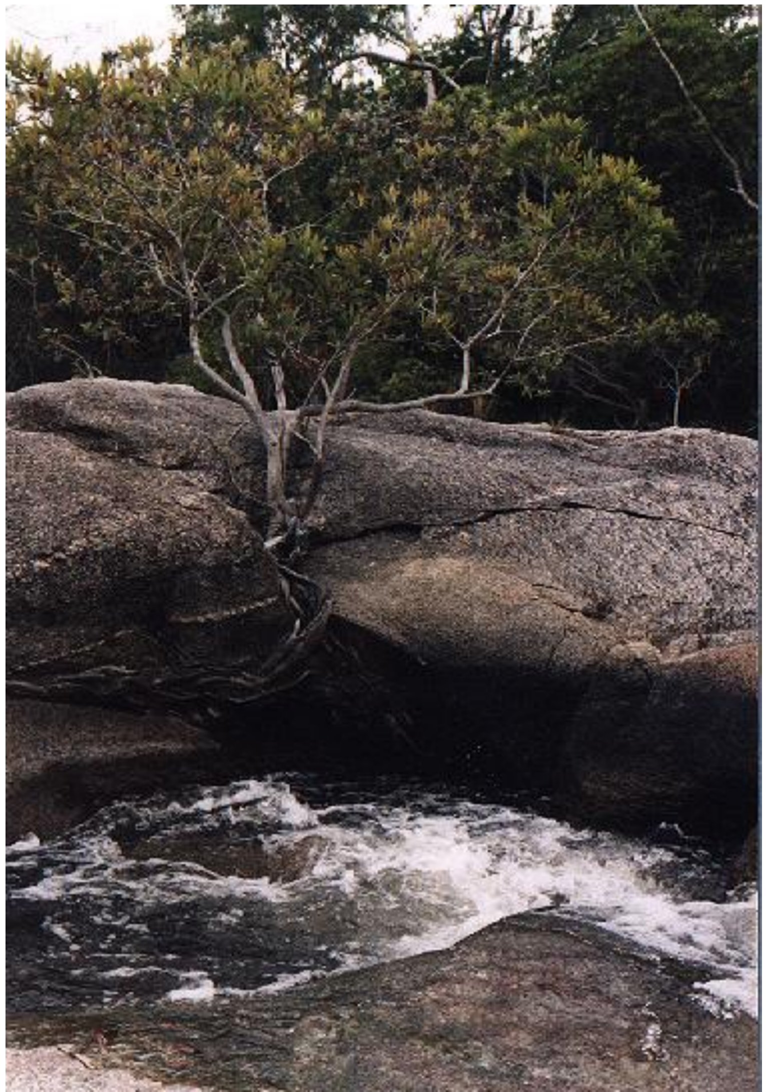
- *Action of plants and animals:*
  - *Lichens and mosses grow on rocks*
    - *They wedge their tiny roots into spores and crevices.*
    - *When the roots grow, the rock splits.*

- Action of plants and animals:
  - Lichens and mosses grow on rocks
    - They wedge their tiny roots into spores and crevices.
    - When the roots grow, the rock splits.

Types of Mechanical Weathering

- Action of plants and animals:
  - Larger trees and shrubs may grow in the cracks of boulders.
  - Ants, earthworms, rabbits, woodchucks, and other animals dig holes in the soil.
    - These holes allow air and water to reach the bedrock and weather it.

Types of Mechanical Weathering



Types of Mechanical Weathering

Types of Mechanical Weathering

- Loss of Overlying Rock and Soil
  - Sheet jointing on a granite outcrop produces cracks in the rock, thereby exposing more of the rock surface to weathering.

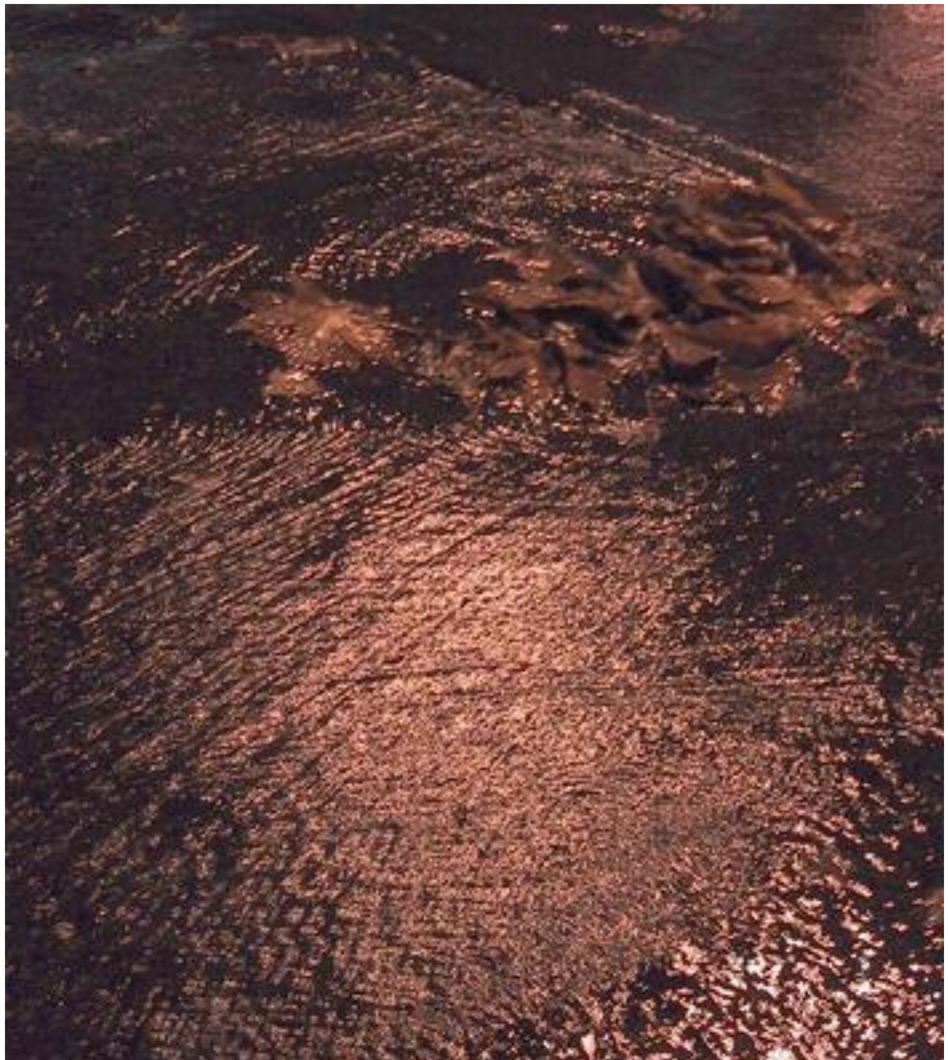
Types of Mechanical Weathering

Granite exfoliation

Types of Chemical Weathering

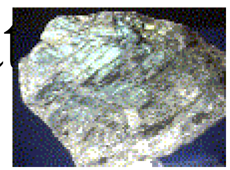
- Results mainly from the action of rainwater, oxygen, carbon dioxide, and acids of plant decay.

Agents of Chemical Weathering



Agents of Chemical Weathering

- The chemical reaction of water with other substances is called **hydrolysis**.
- Common mat undergoing hydrolysis:
  - Feldspar
  -
  - Hornblende
  - Augite



Agents of Chemical Weathering

- The chemical reaction of oxygen with other substances is called **oxidation**.
  - Iron-bearing minerals are the ones most easily attacked by oxygen.
  - Examples:
    - Magnetite
    - Pyrite
    - Dark-colored ferromagnesian silicates

Agents of Chemical Weathering

- Oxidation of these minerals results in kinds of rust, or iron oxides.

Agents of Chemical Weathering

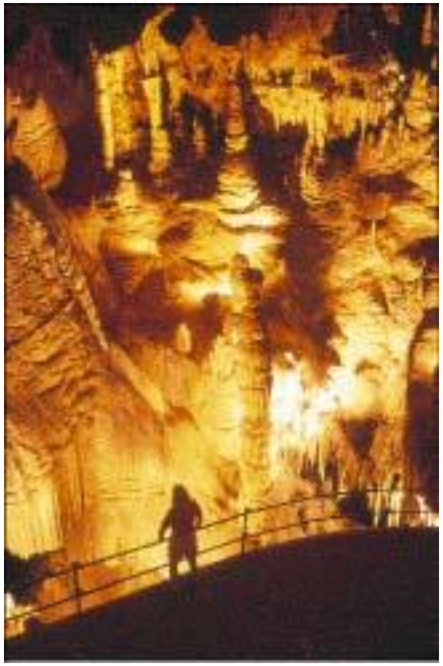
- Carbon dioxide dissolves easily in water.
  - It forms a weak acid called **carbonic acid**
  - This is the same compound that is in carbonated drinks.
  - Attacks many common minerals such as feldspar, hornblende, augite and biotite mica.
  - The original mineral is changed into a clay mineral.

Agents of Chemical Weathering

- Has the greatest effect on calcite than any other mineral.
- It dissolves it completely, with no clay left over.

Agents of Chemical Weathering

- Hollows out great caverns in limestone bedrock.



Agents of Chemical Weathering

- Acids are formed from the decay of plants and animals.
- These acids are dissolved by rainwater and carried through the ground to the bedrock.

Agents of Chemical Weathering

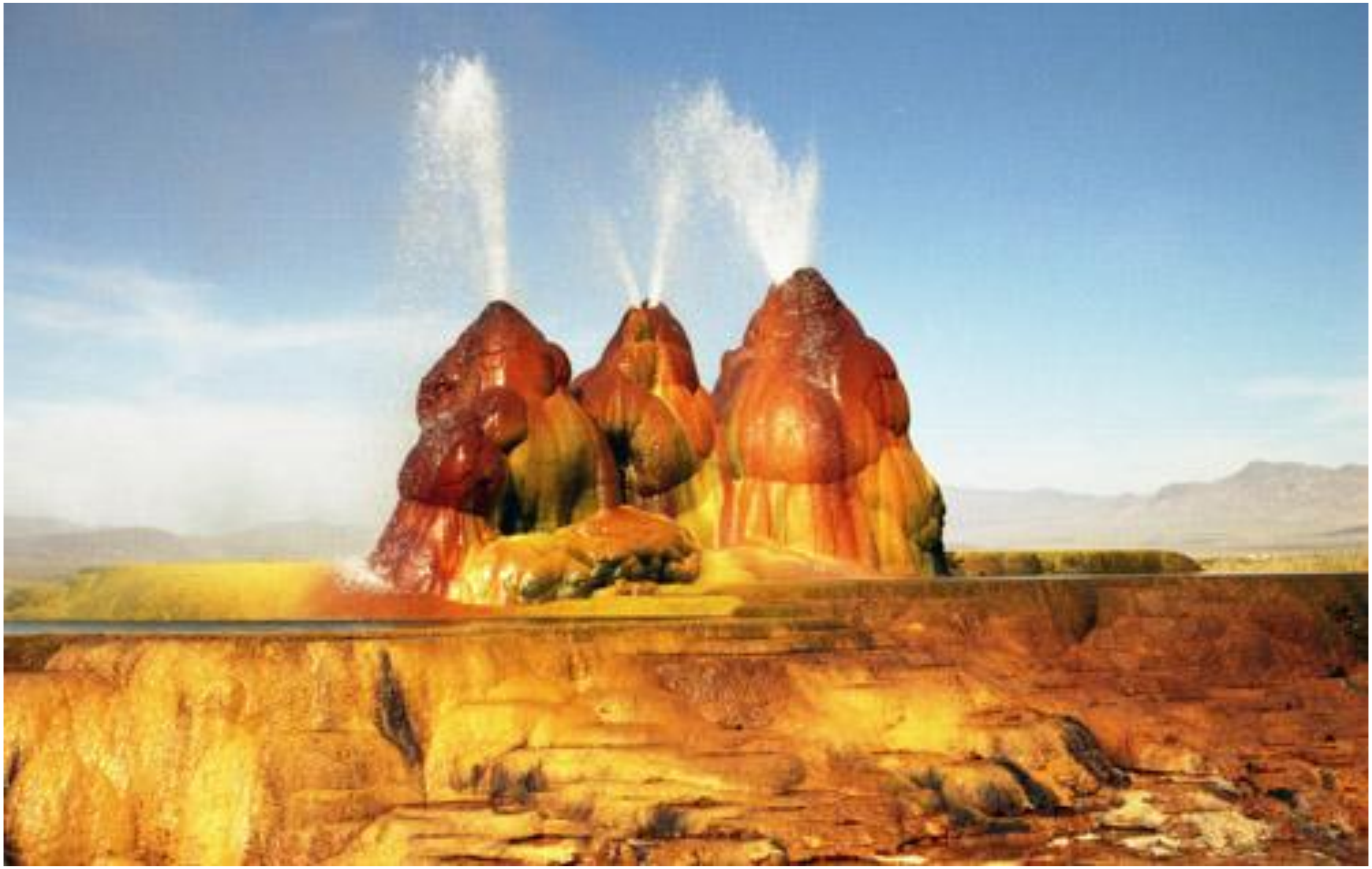
- Carbon dioxide and sulfur compounds released by industries unite with water in the atmosphere to form **acid rain**.
- Increasing amounts of acid rain in the environment increase the rate of chemical weathering.

Agents of Chemical Weathering

Chemical Weathering

- Occurs most quickly at the corners and edges of rock outcrops and boulders.
- These areas are more exposed to chemicals.
- This process rounds the rock and is called spheroidal weathering.
- Boulders rounded this way are called spheroidal boulders

Ground Water



Today's Plan: Groundwater

- Groundwater
- Aquifer / aquitard
- Water table
- Groundwater flow
- Wells & springs
- Groundwater contamination

What is Groundwater?

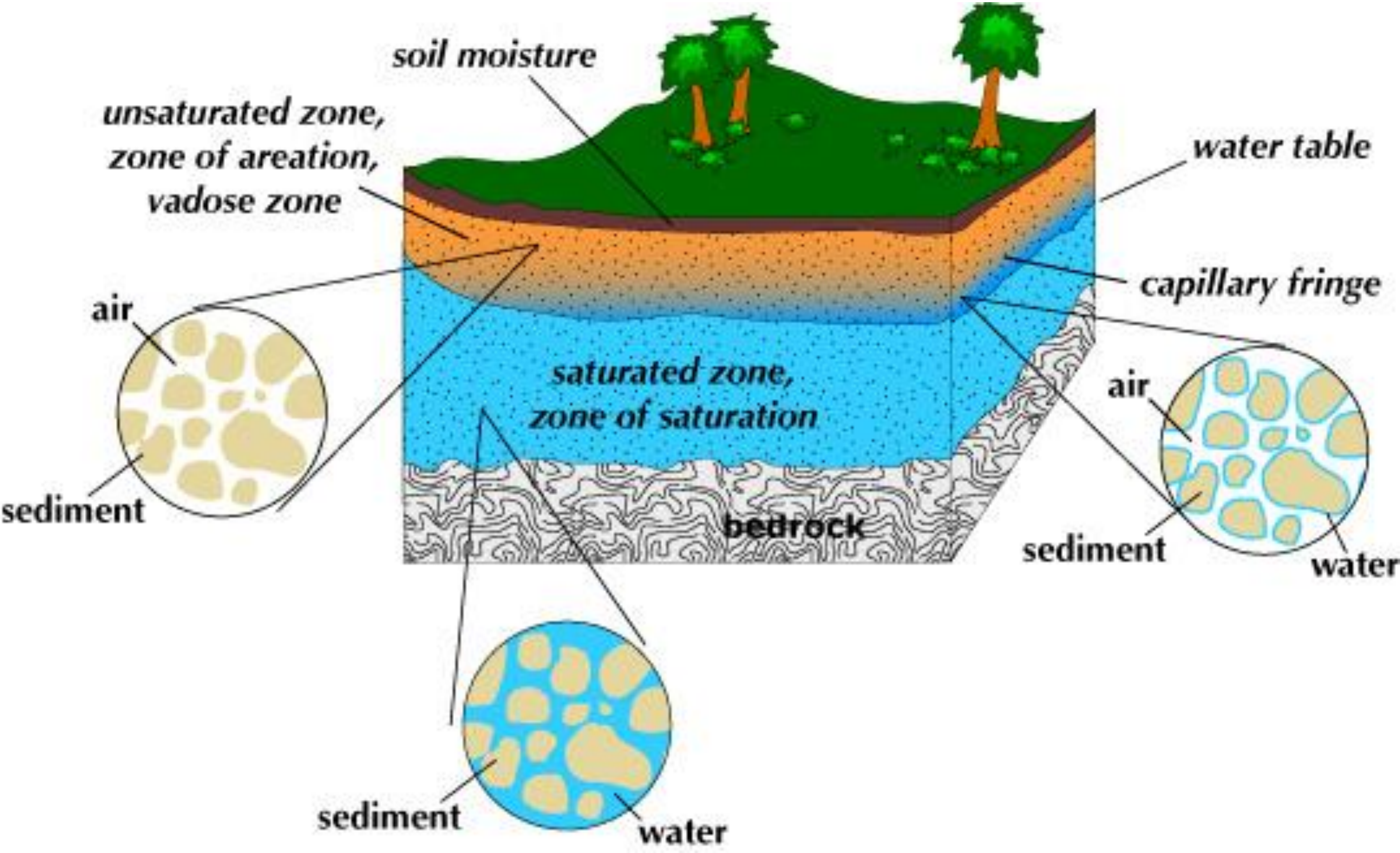
- Rain and snowmelt that infiltrate the ground.

- Soil and rock act as giant sponges, they are full of tiny pores and cracks that are usually less than millimeters in size which allows water to infiltrate and collect underground.

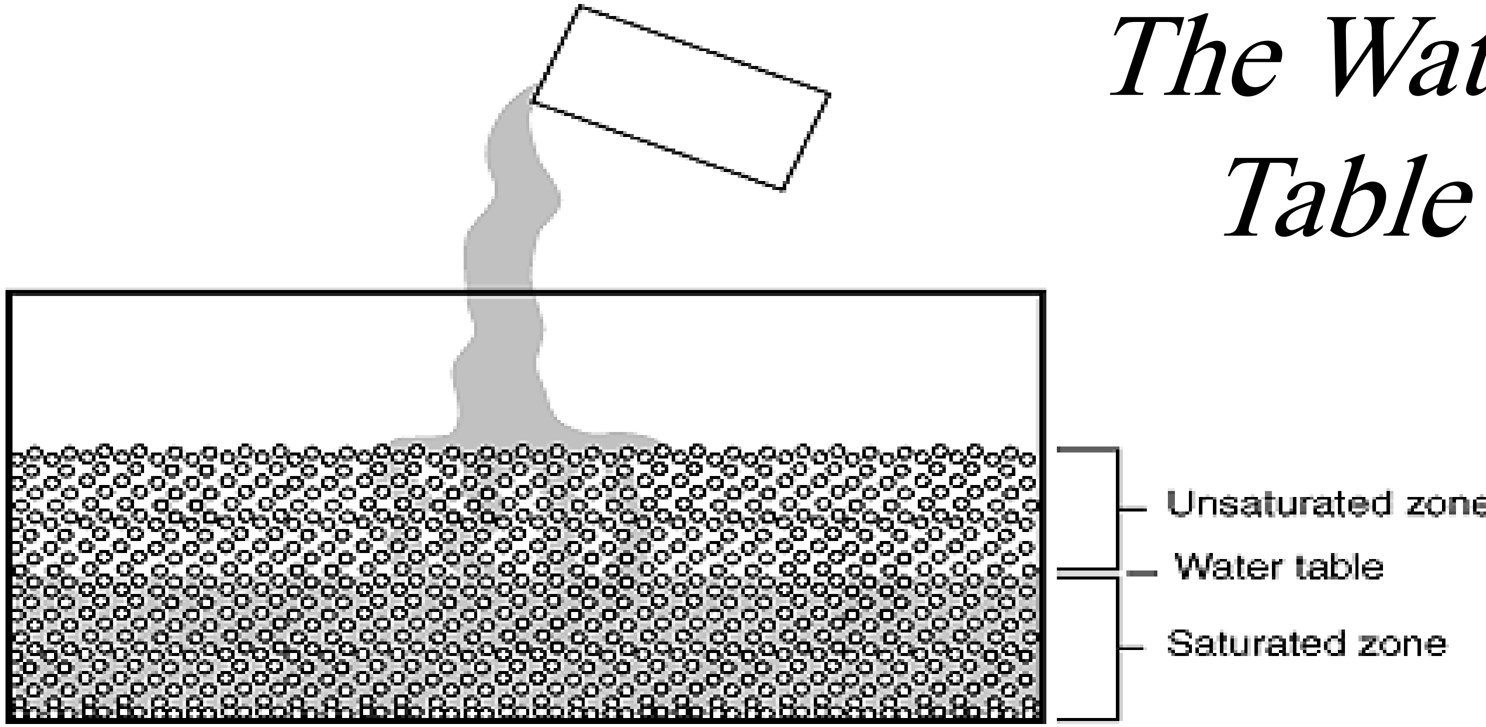
Groundwater Feeds the River Systems

- Groundwater and surface water are one connected water system.
- Water wells intercept groundwater that may be on its way to springs that feed streams and rivers.

The Water Table



The Water Table



- ***Unsaturated zone****: through which water moves downward and whose pore space is not completely filled.*
- ***Saturated zone****: in which water collects and whose pore space is completely filled.*
- *The plane of separation between these two zones is the* ***water table****.*

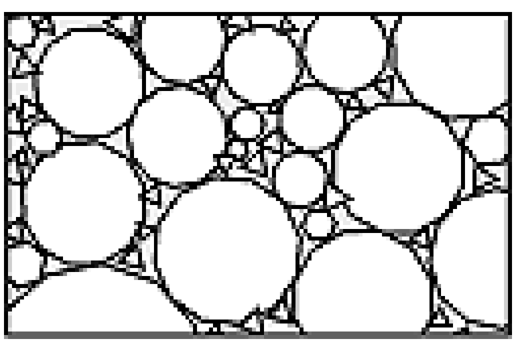
Groundwater Basics

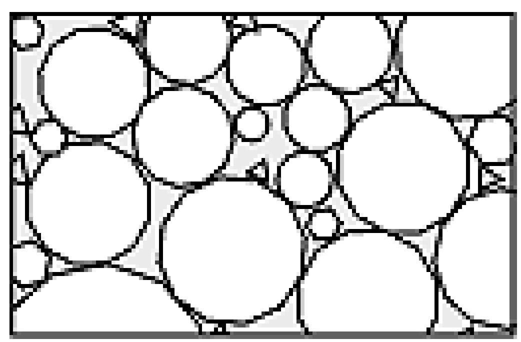
Beds of rock, sediment, and regolith with high **porosity** (% of pore space) are better suited to holding groundwater.

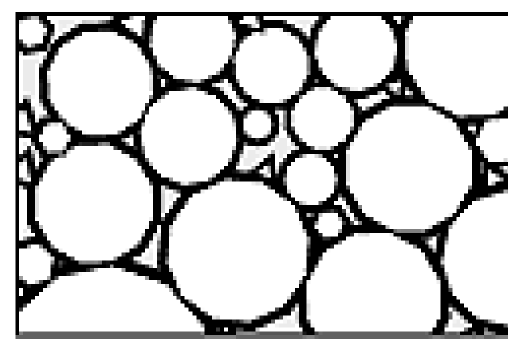
- **Aquifers**: Beds that hold large amounts of groundwater.
- **Types of pore space**:
- Space between grains. (E.g Oglala aquifer.)

Permeability:

- Just because pore space exists doesn't mean that water can flow through it. Pores may be isolated.
- Permeability: the ability of a solid to allow fluids to pass through.


Low porosity


High porosity
High permeability

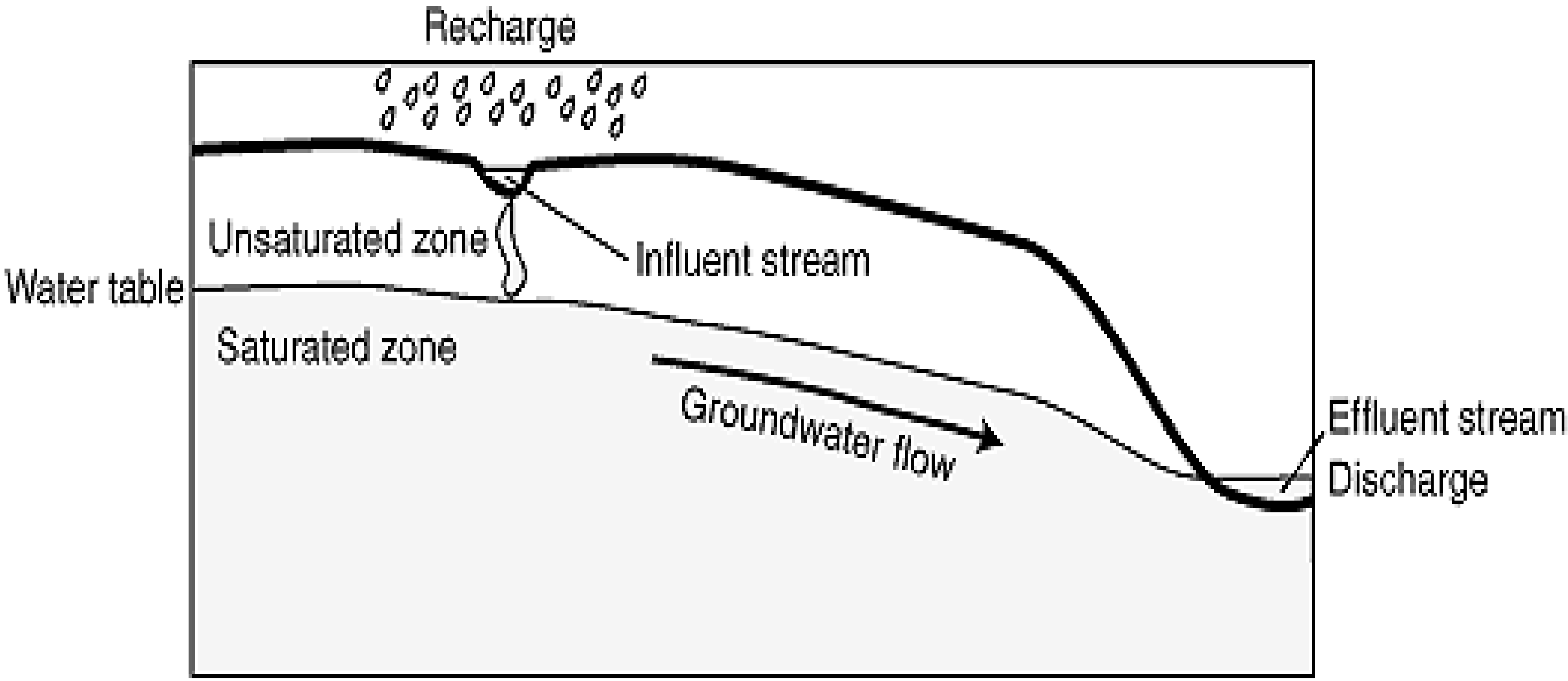

High porosity
Low permeability

Big concept I:

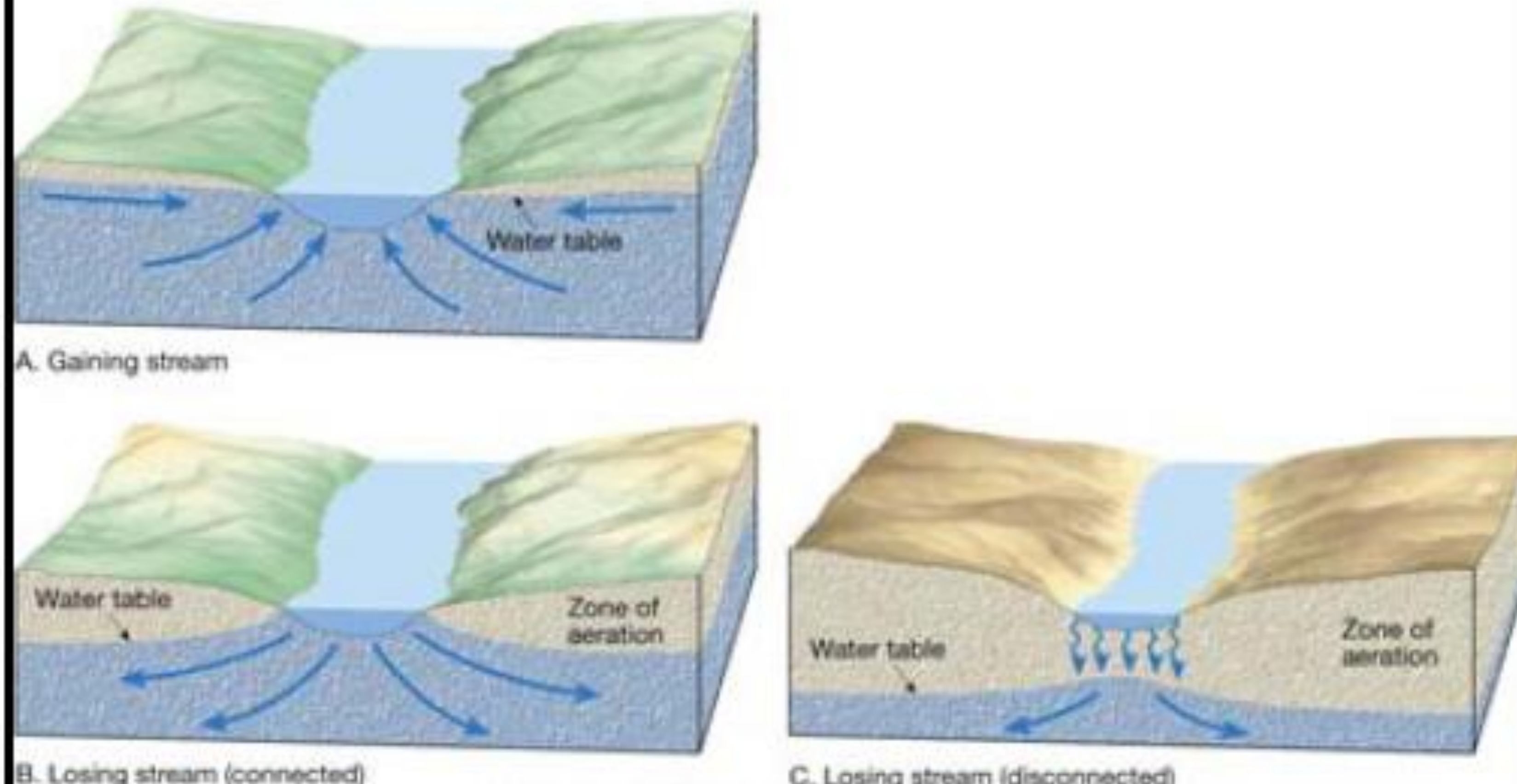
- **The Water Table is the basic description of how groundwater interacts with rocks**.
- If I pour water into a bucket of unconsolidated sand, the water won't spread evenly through the bucket. It will collect at the bottom. As a result, we will have two hydrologic zones in the bucket:

Big concept I:

- **Equilibrium:** Water enters and leaves saturated zone.
  - **Recharge**: process by which water enters. (e.g. stream flows over rock fractures, allowing water to percolate in.)
  - **Influent stream**: a stream that recharges groundwater.
  - **Discharge**: Process by which water leaves. (e.g through a spring)
- **Effluent stream**: A stream which picks up water from saturated zone.



Aquifers are permeable layers of rock and sediment that have groundwater in enough quantity to supply wells.

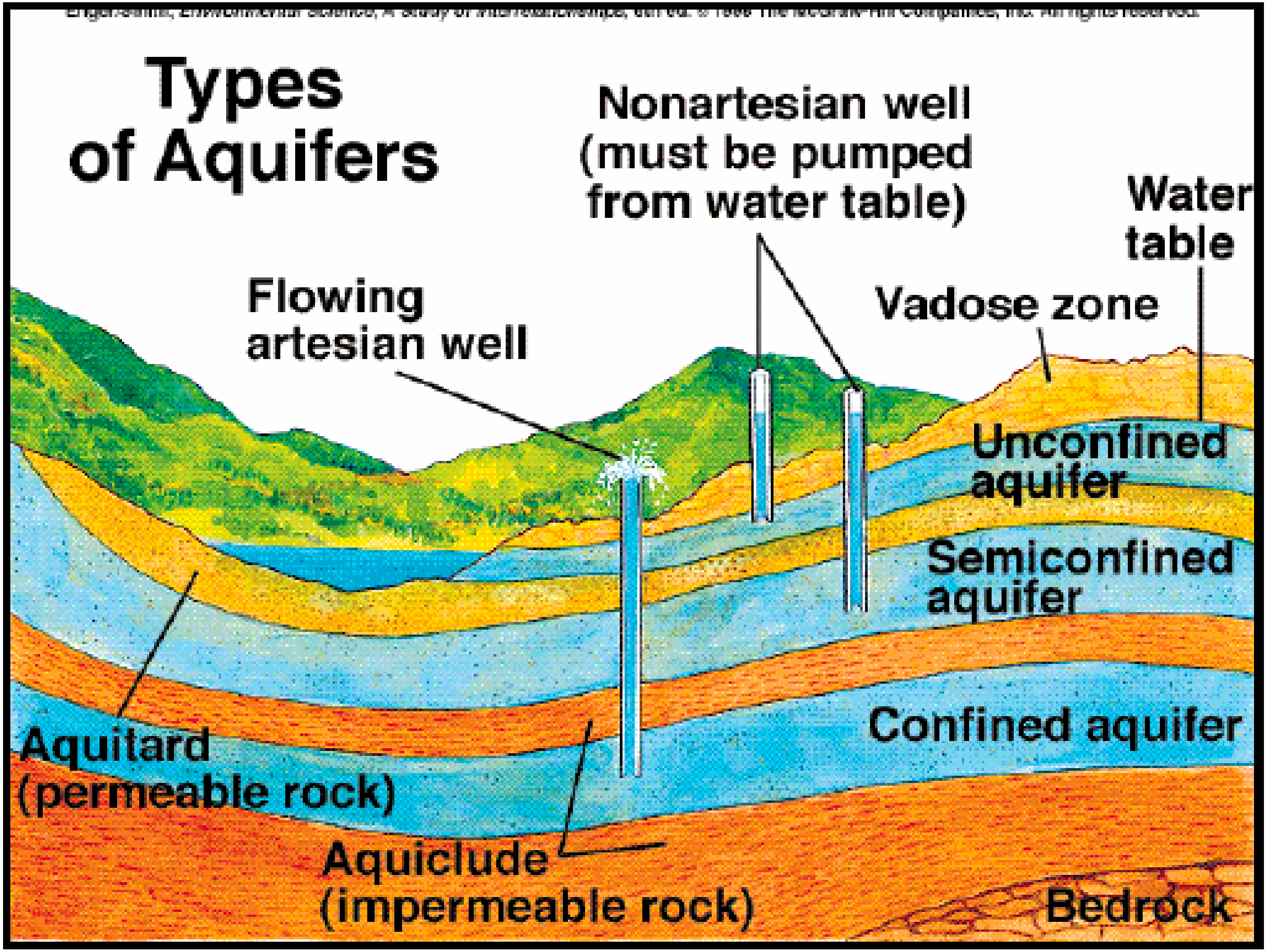

Water table
A. Gaining stream
Water table
Zone of aeration
B. Losing stream (connected)
Water table
Zone of aeration
C. Losing stream (disconnected)

Aquifers:

- Aquifers can be unconfined or confined by impermeable rock layers called aquicludes.
- In an **unconfined aquifer**, water flows freely. The water table tends to approximate the topography of the landscape.
- In a **confined aquifer**, water flow is restricted by impermeable layers called **aquicludes**. Their presence can have two consequences:

Opposite of an aquifer?

- Aquitard / aquiclude
  - retards the flow of groundwater (it’s almost never really zero



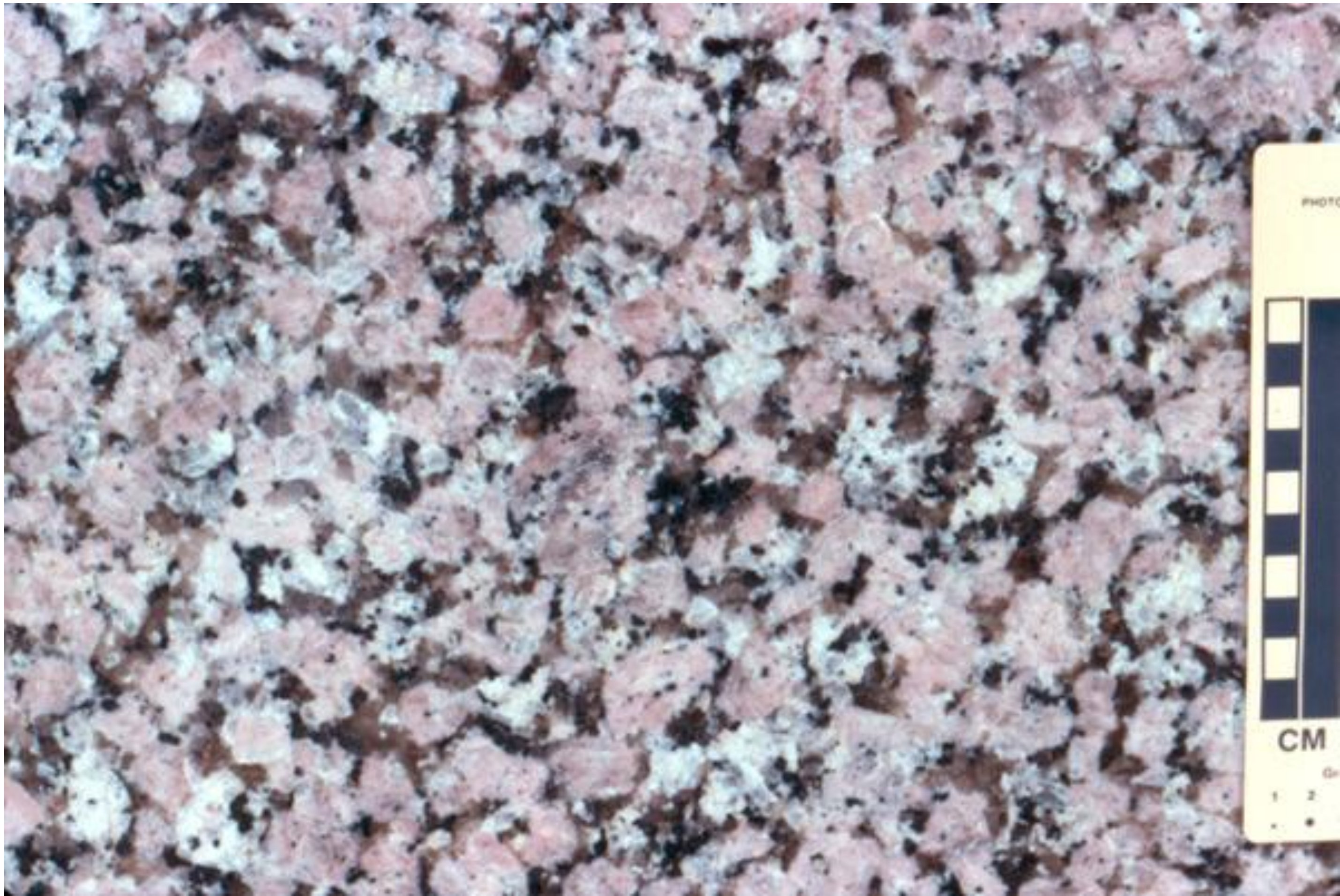
Types of Aquifers
Nonartesian well (must be pumped from water table)
Water table
Flowing artesian well
Vadose zone
Unconfined aquifer
Semiconfined aquifer
Confined aquifer
Aquitard (permeable rock)
Aquiclude (impermeable rock)
Bedrock

Groundwater: aquifers

- What would be the properties (porosity/permeability) of conglomerate?
- High porosity, high permeability

Groundwater: aquifers

- What would be the properties (porosity/permeability) of un-fractured granite?
- **Low porosity, low permeability**



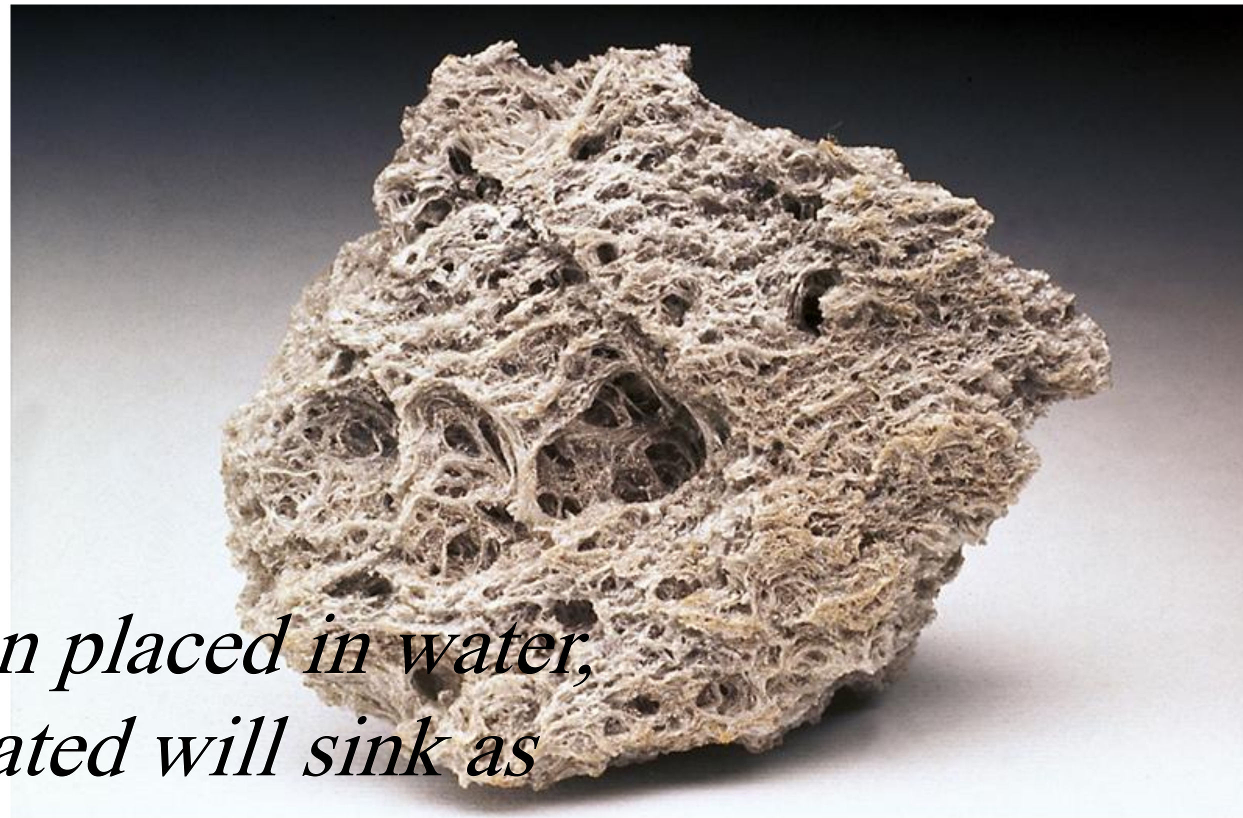
Groundwater: aquifers

- Can you think of a rock/sediment with high porosity and low permeability?

Groundwater: aquifers

- Can you think of a rock/sediment with high porosity and low permeability?

Pumice:



Will float when placed in water, but once saturated will sink as any rock would.

Groundwater: aquifers

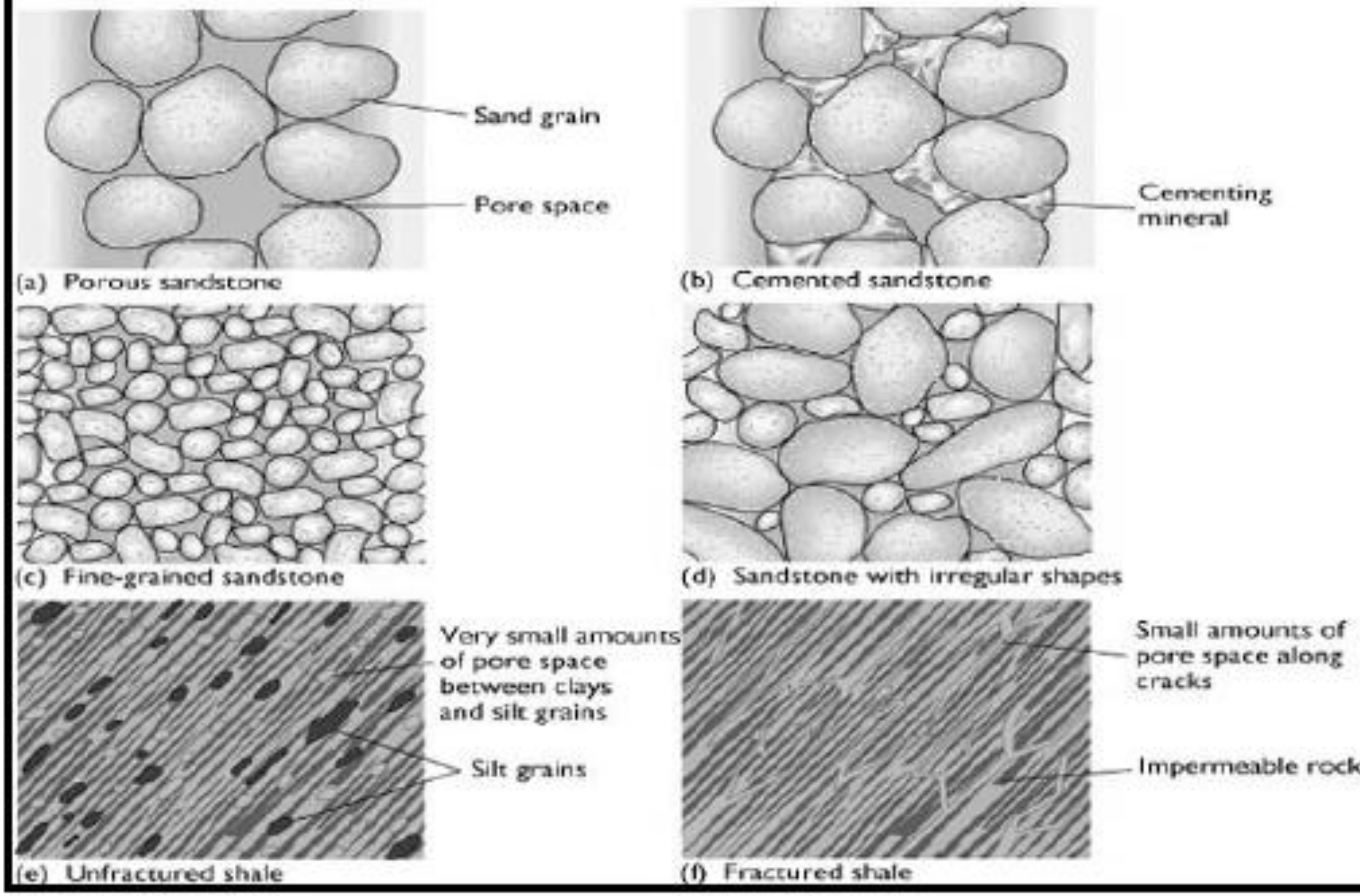
- Can you think of a rock/sediment with low porosity and high permeability?

Groundwater: aquifers

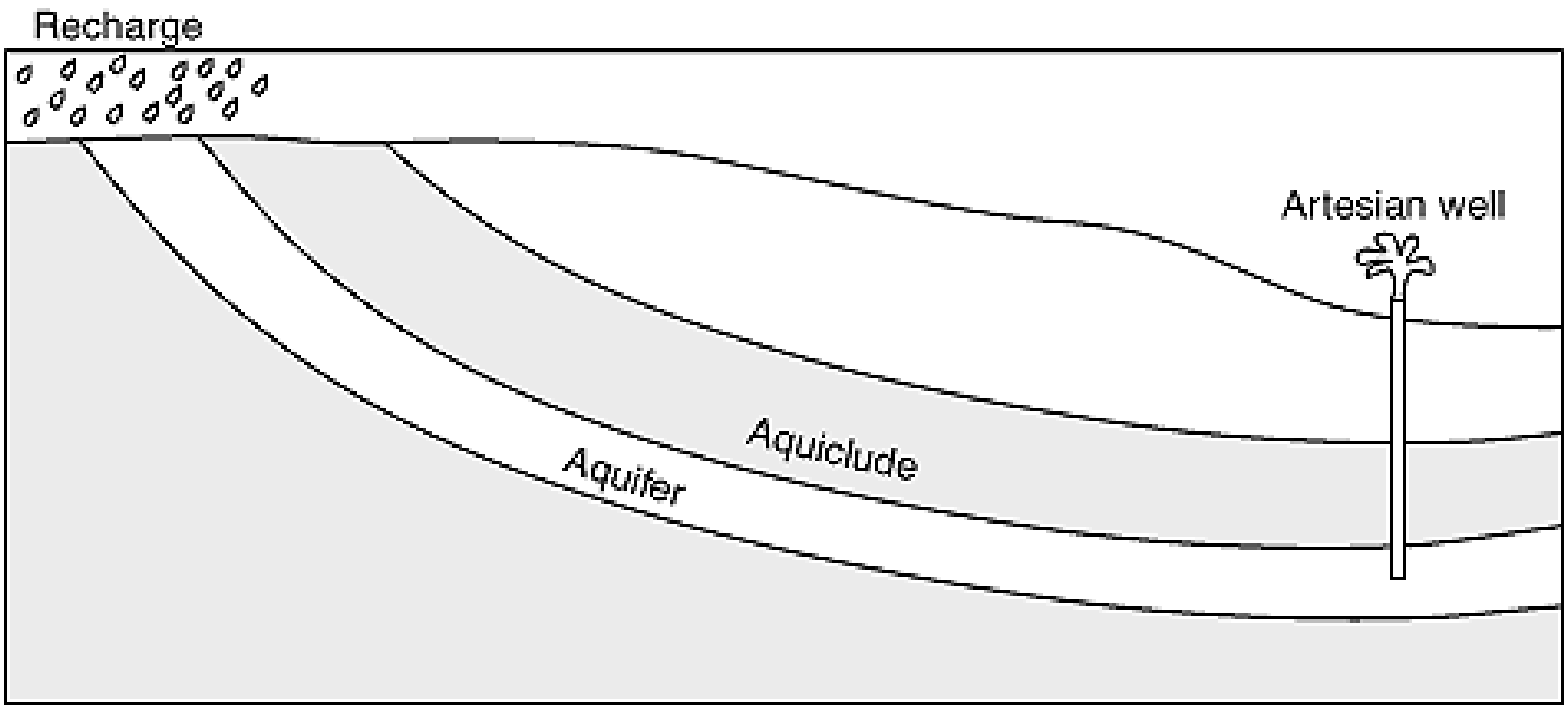
- Can you think of a rock/sediment with low porosity and high permeability?

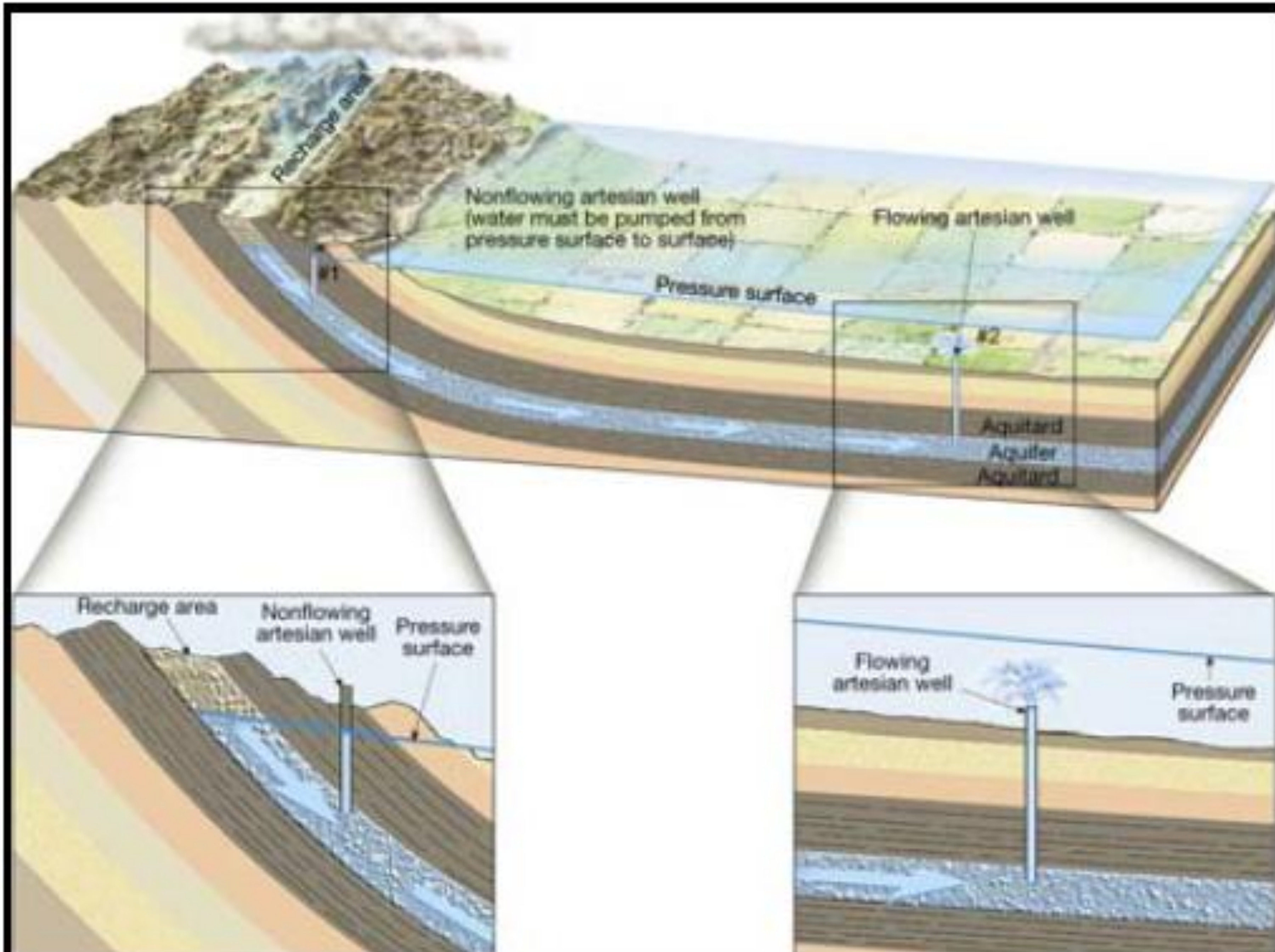
Sandstone

Porosity and Permeability



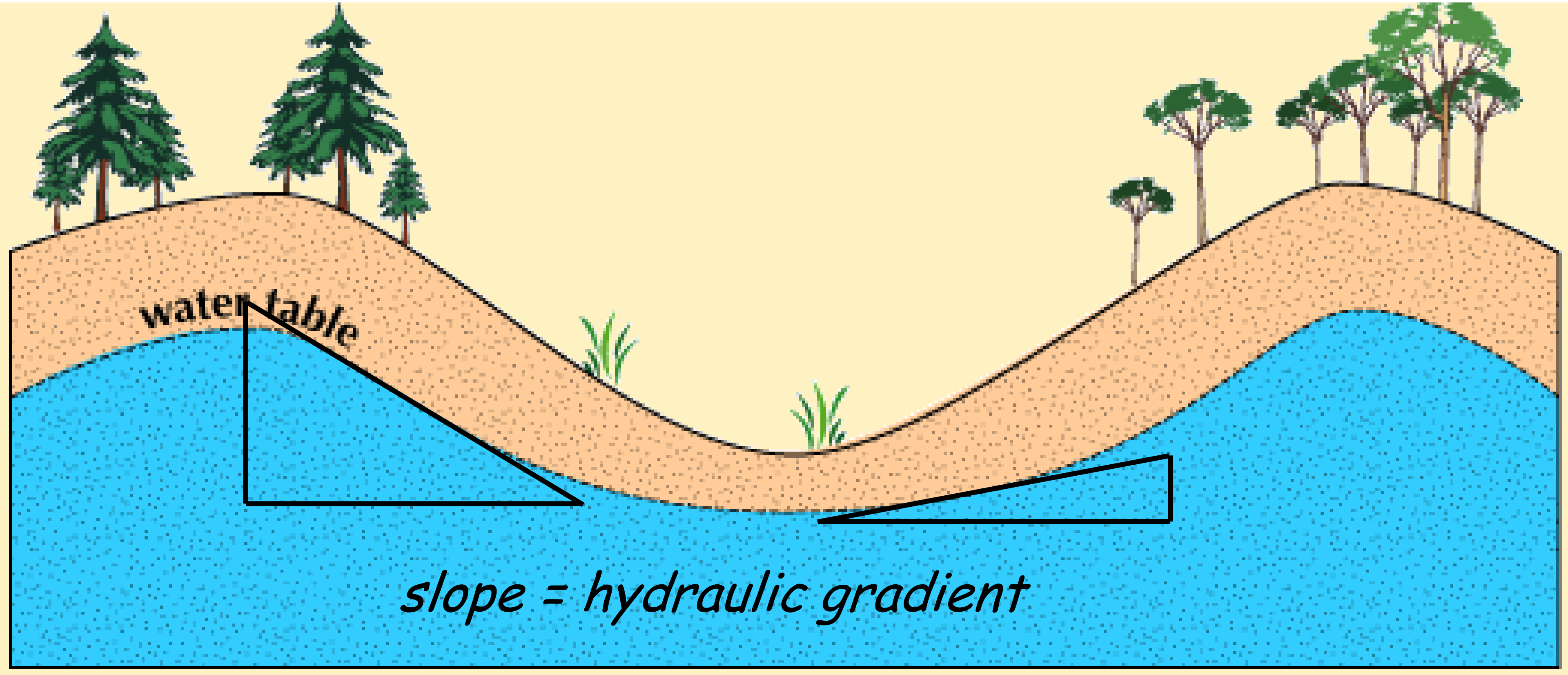
Water flowing downhill beneath an aquiclude may be under pressure. This is ***artesian flow.*** *Drilling into it will create an artesian well, through which water will flow spontaneously.*



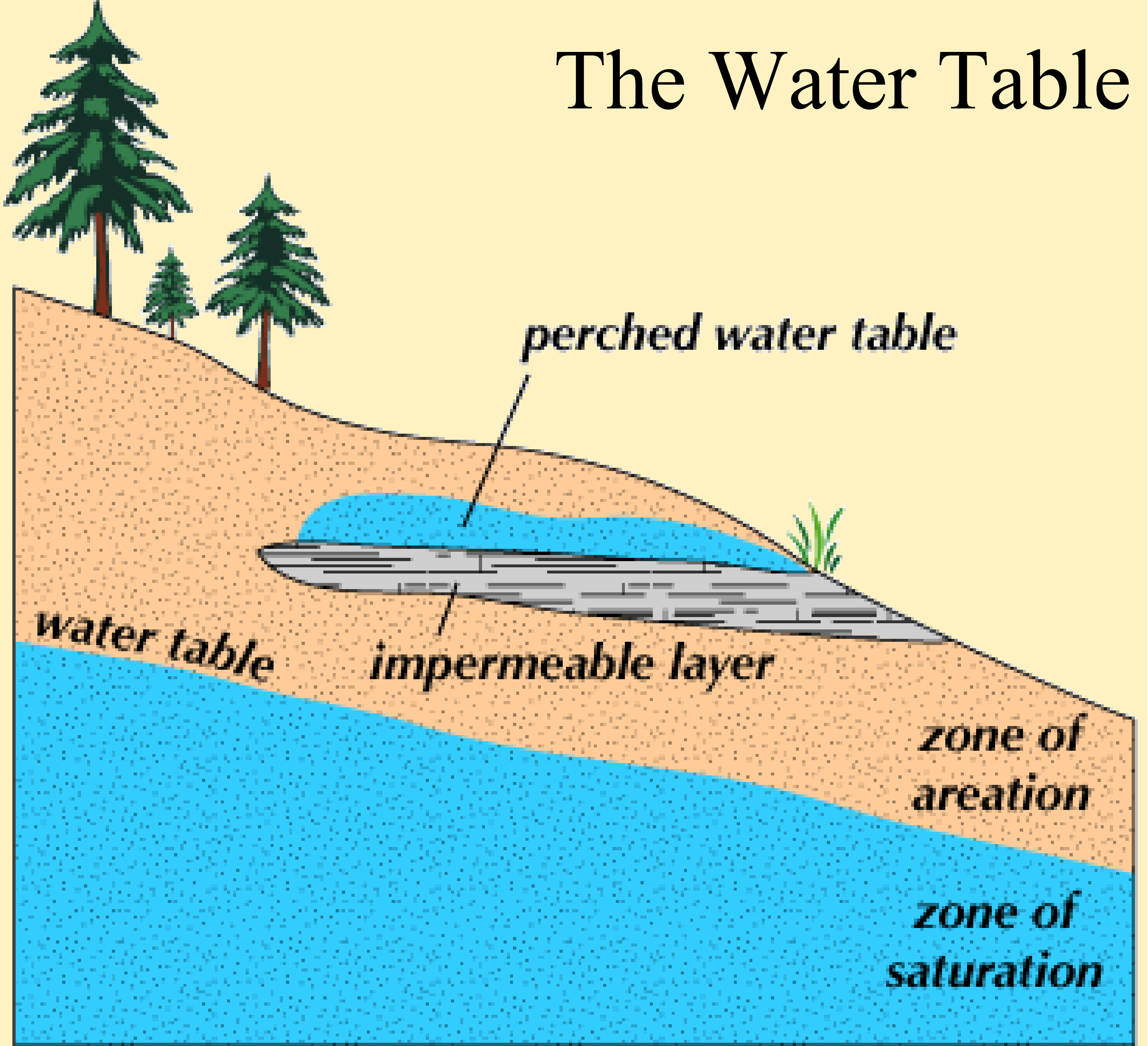


Recharge area
Nonflowing artesian well
(water must be pumped from
pressure surface to surface)
Flowing artesian well
#1
Pressure surface
#2
Aquitard
Aquifer
Aquitard
Recharge area
Nonflowing
artesian well
Pressure
surface
Flowing
artesian well
Pressure
surface

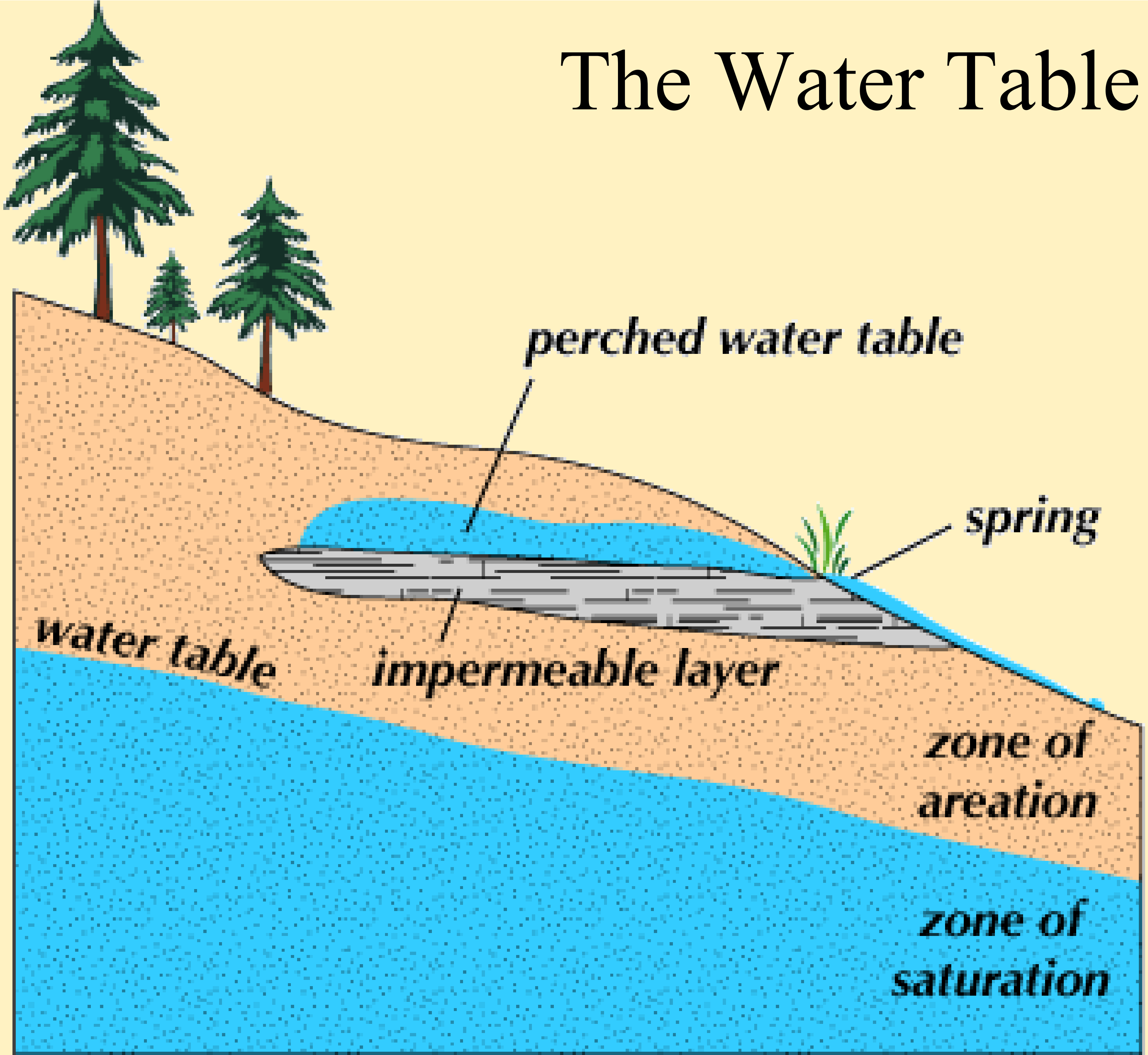
Water Table Topography



The Water Table



The Water Table

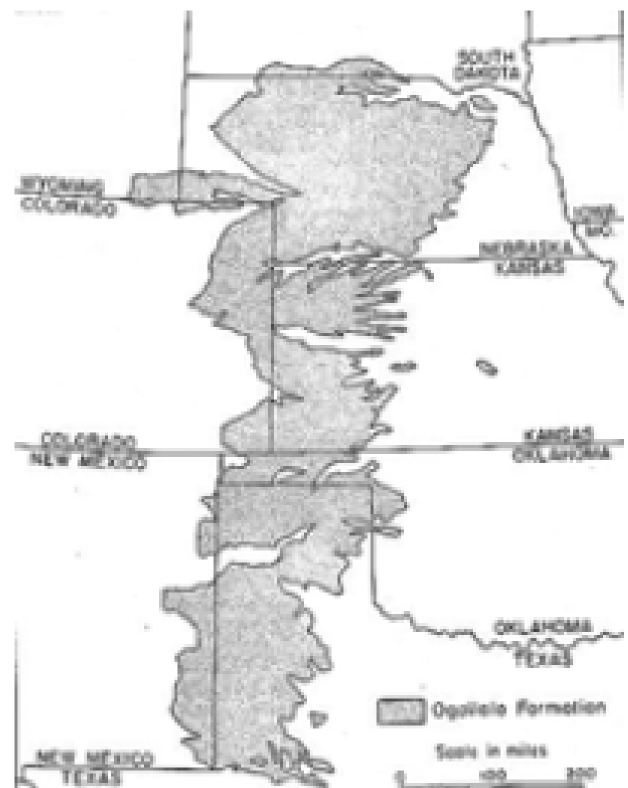


Some definitions

- Groundwater = water in the zone of saturation
- Porosity = the space between solid particles of soil or rock that can be filled by fluids.
- Permeability = the ease with which fluids can pass through a body of soil or rock.
- Infiltration = the movement of water from the surface into the ground.
- Aquifer = a body of soil or rock that can hold a useable amount of water.
- Aquiclude = a body of soil or rock that blocks the flow of water (Aquitard slows the flow).

Ogallala ("High Plains") Aquifer

- Buried erosional remnant of Rocky Mts.
- Largest single water bearing unit in North America.
- Holds enough water to fill Lake Huron.




SD
MN
WY
ROCKY MOUNTAINS
IA
NE
Ogallala Formation
CO
KS
NM
OK
TX
Mexico

Groundwater and Geology

VOCABULARY

mineral deposit

cavern

karst topography

As water moves through the ground, it dissolves minerals. When the groundwater cools or evaporates, the dissolved minerals are often left behind as deposits such as travertine, geyserite, petrified wood, stalactites, stalagmites, and the cement that binds sedimentary rocks.

Travertine is a calcite deposit.

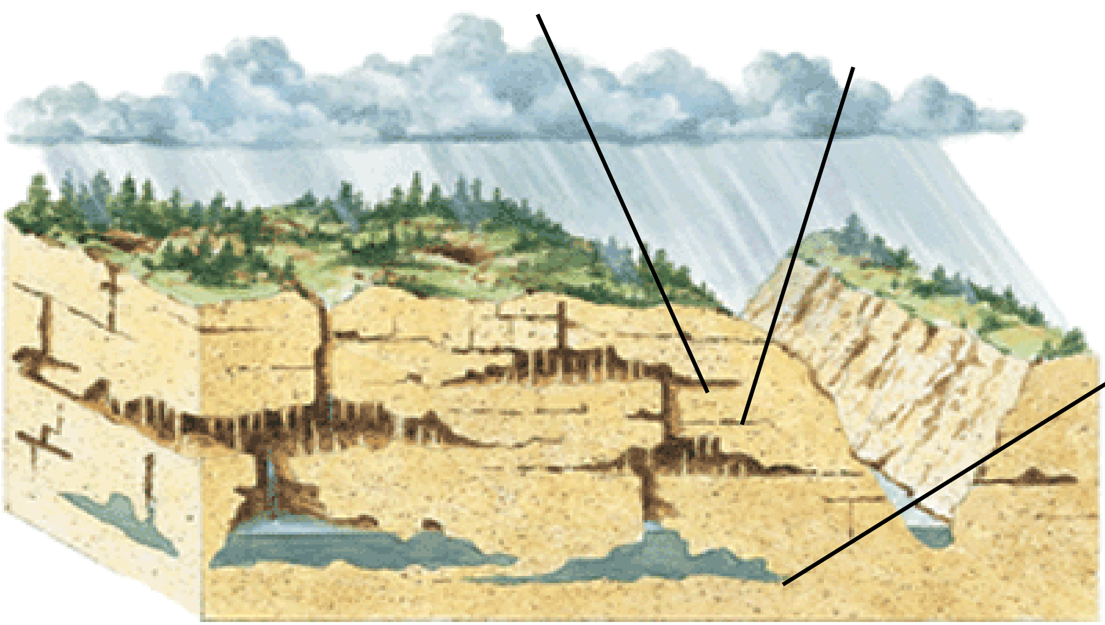
Groundwater and Geology

Groundwater containing carbonic acid dissolves limestone, forming caverns and features of karst topography.

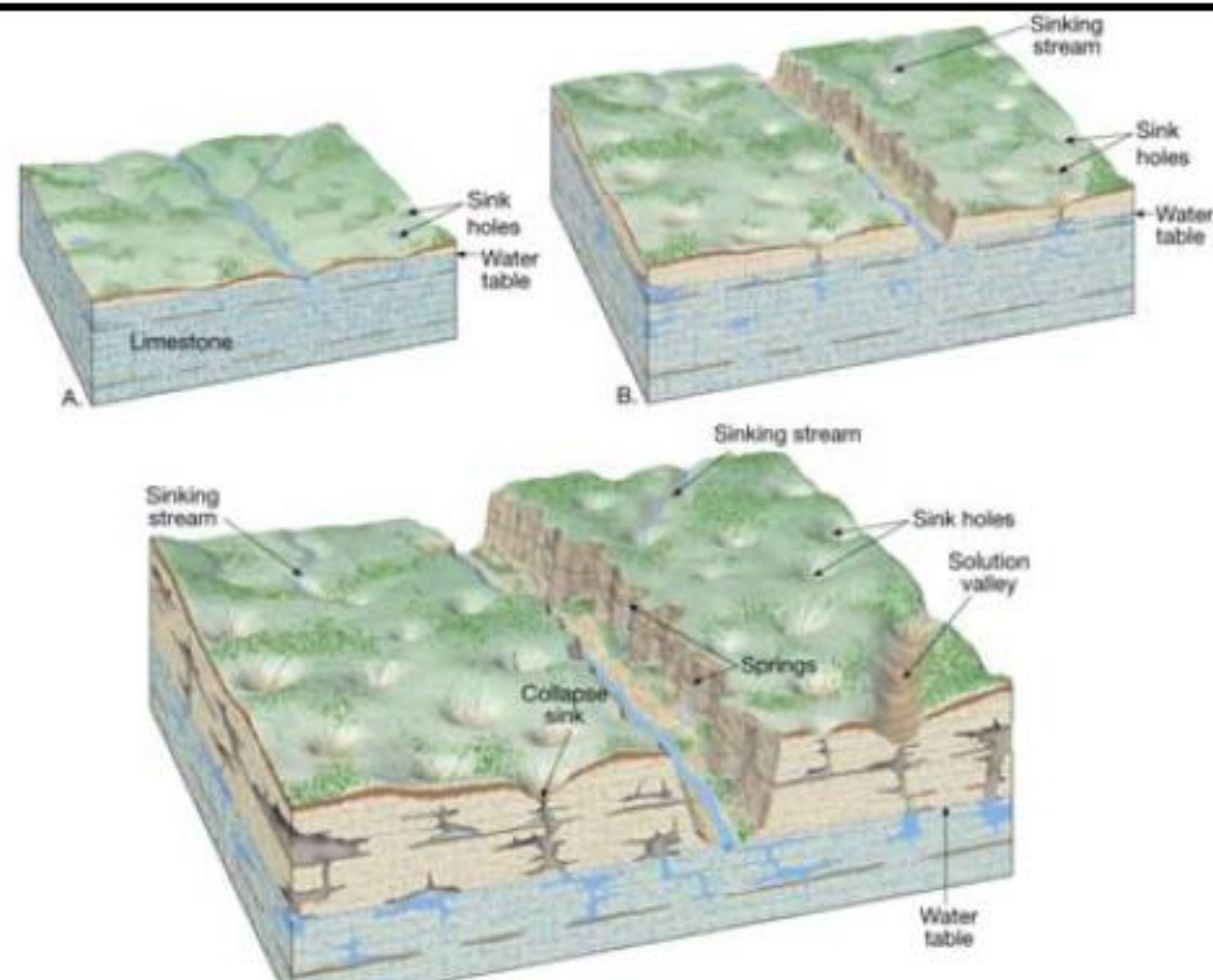
1. Rainwater containing carbonic acid seeps into the ground.

2. Limestone dissolves, forming underground caves.

3. Below the water table, the cave is filled with water.



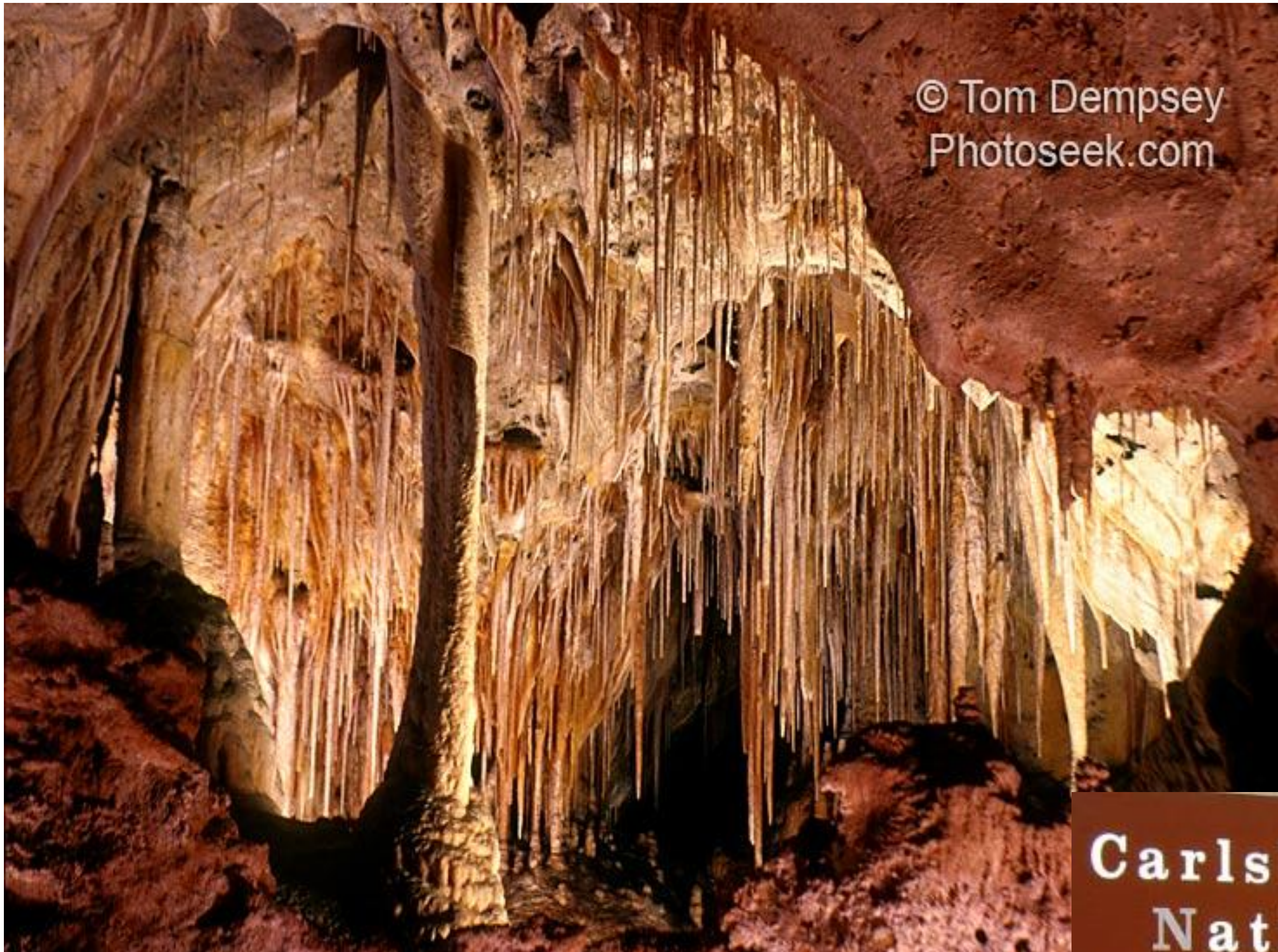
Limestone Cave Formation

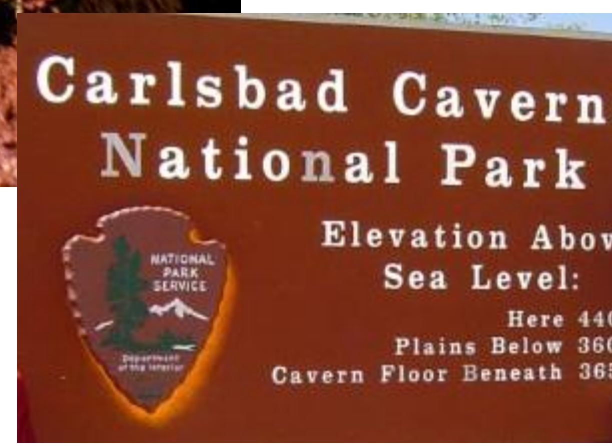

Sinking
stream
Sink
holes
Water
table
Limestone
A.
Sink
holes
Water
table
B.
Sinking stream
Sinking
stream
Sink holes
Solution
valley
Springs
Collapse
sink
Water
table

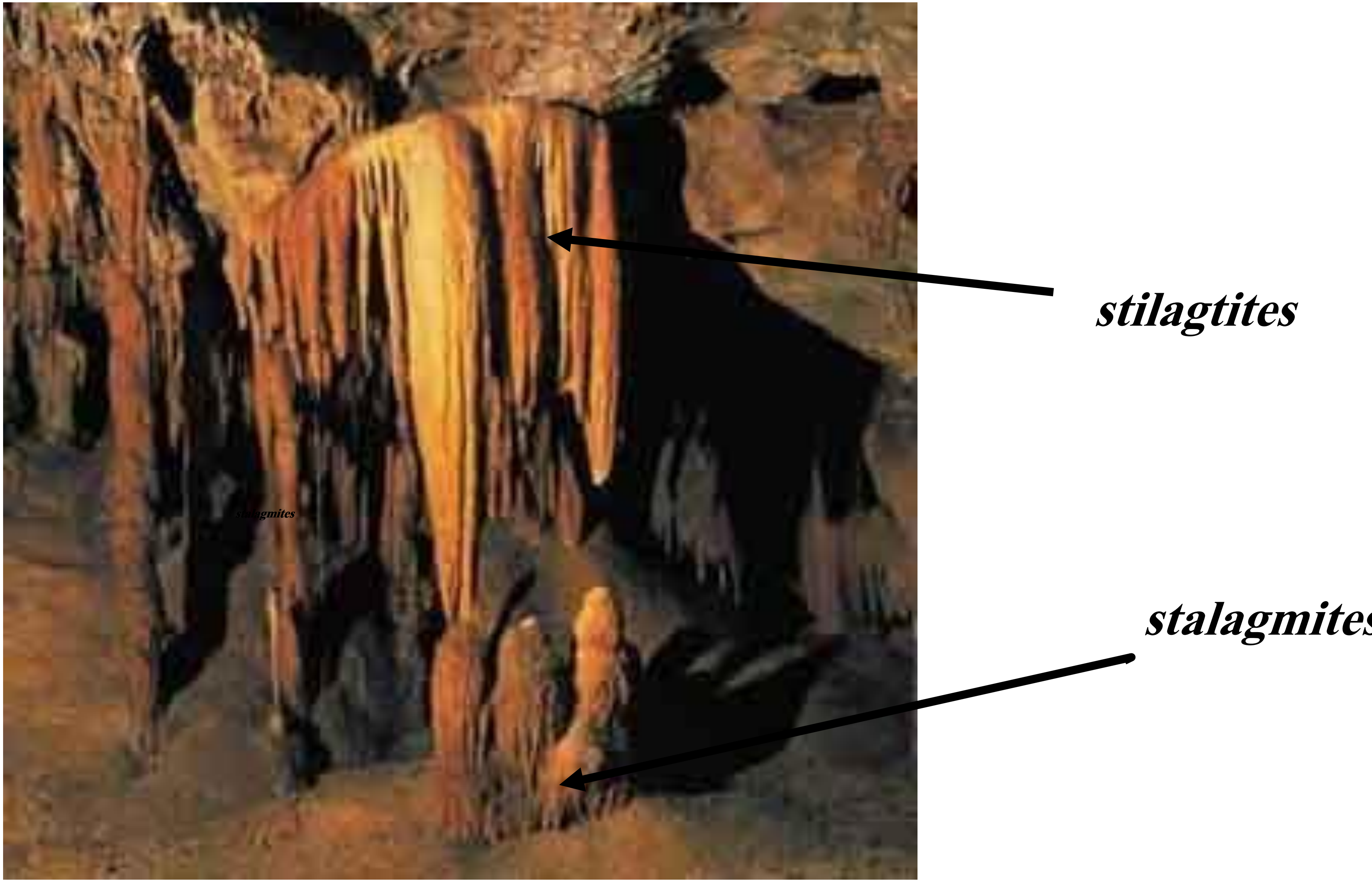
- Mineral deposit: A deposit that is left behind when groundwater that contains minerals cools or evaporates.
- Cavern: A large underground chamber.
- Karst topography: Topography characterized by sinkholes, sinkhole ponds, lost rivers, and underground drainage; forms in areas with bedrock made of calcite, dolomite, or other minerals that dissolve easily.

A aerial photograph of a classic karst terrain north of Lewisburg, WV.

Underground spring comes to the surface.

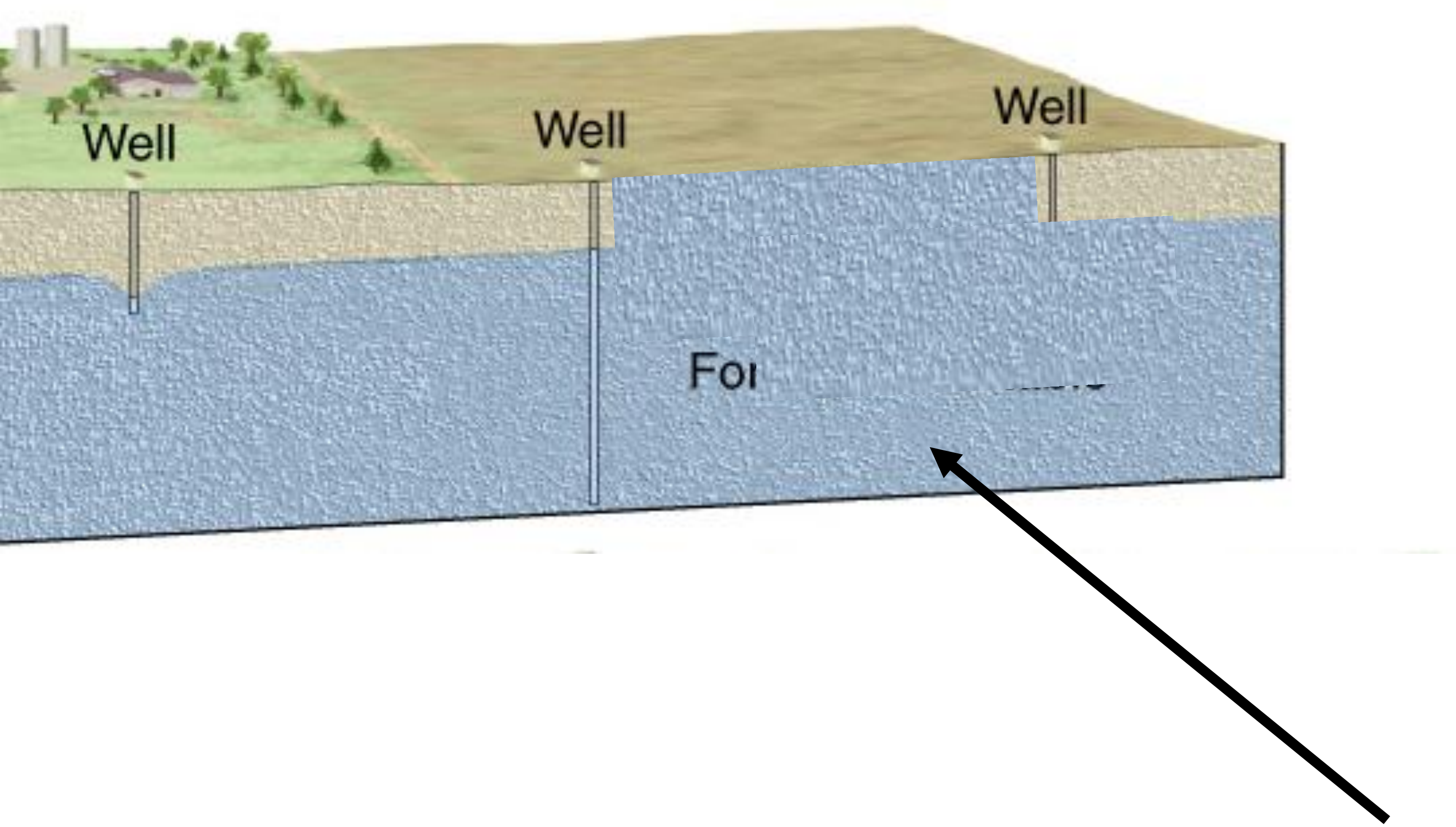

© Tom Dempsey
Photoseek.com


Carlsbad Cavern
National Park
NATIONAL PARK SERVICE
Elevation Abov
Sea Level:
Here 440
Plains Below 360
Cavern Floor Beneath 365

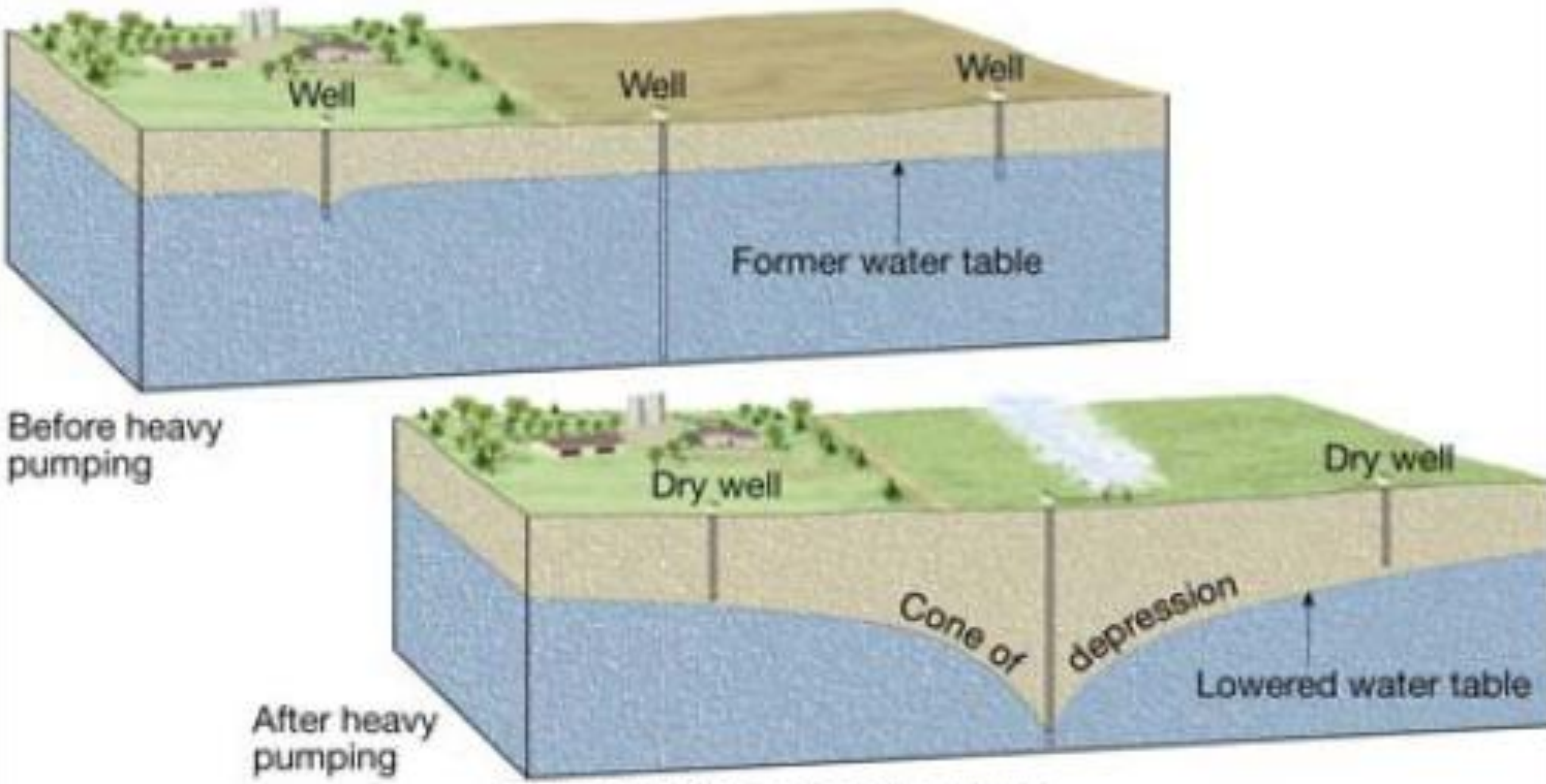


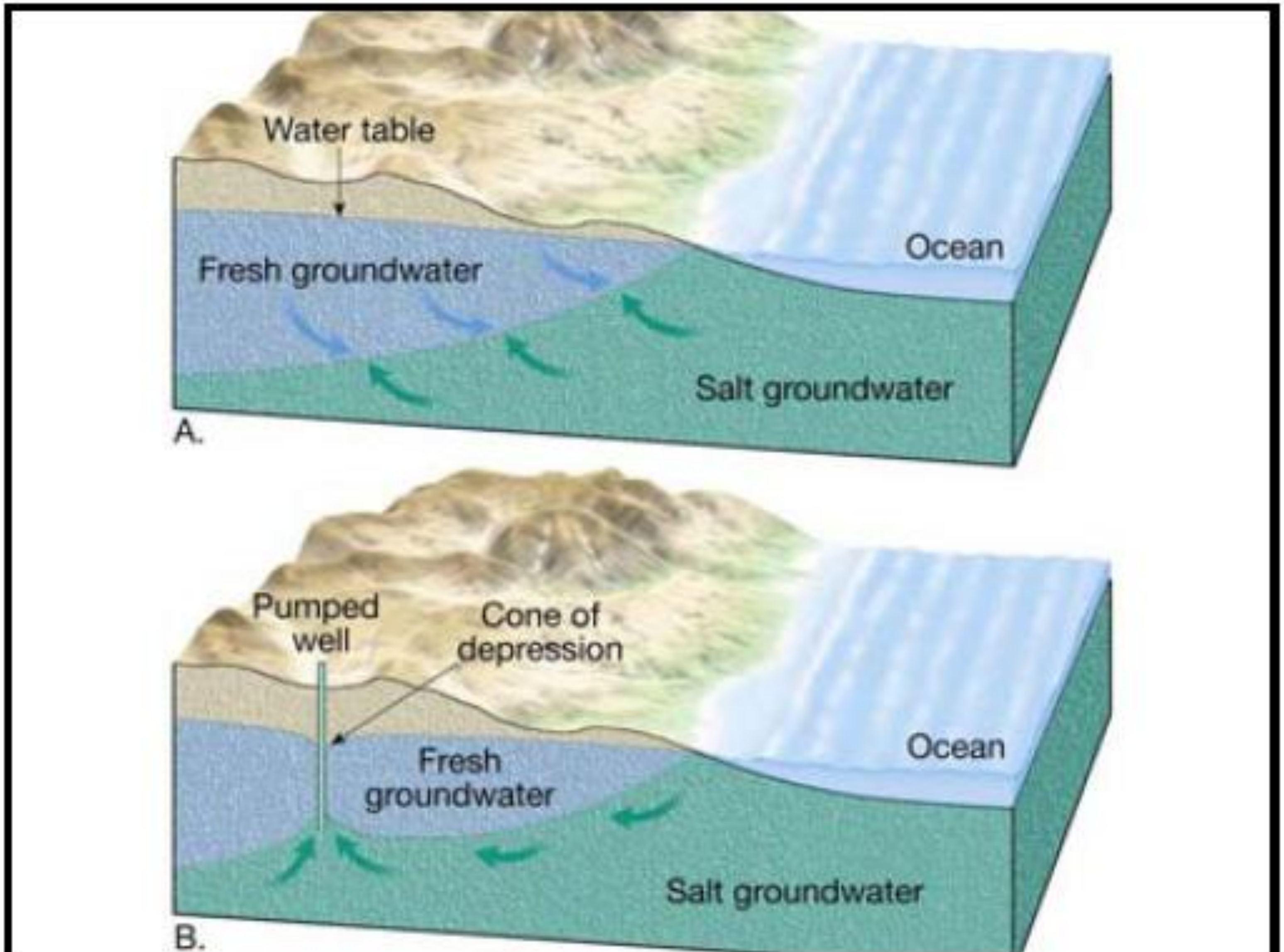
- *Kartchner Caverns: Limestone deposit*

Wells

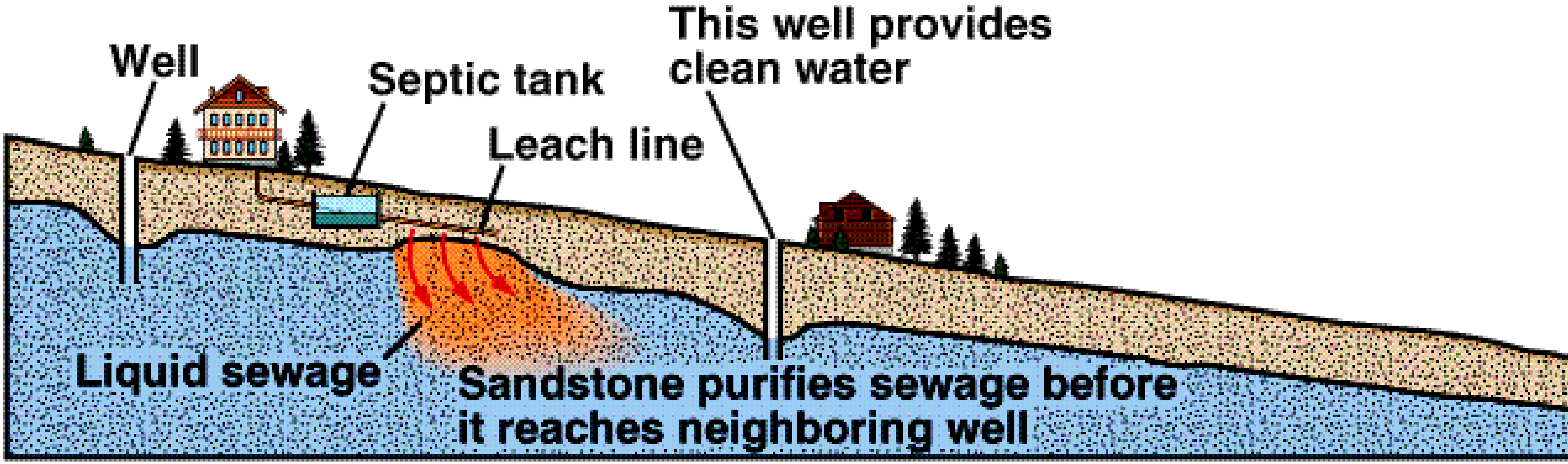


- What happens when this well is heavily pumped?

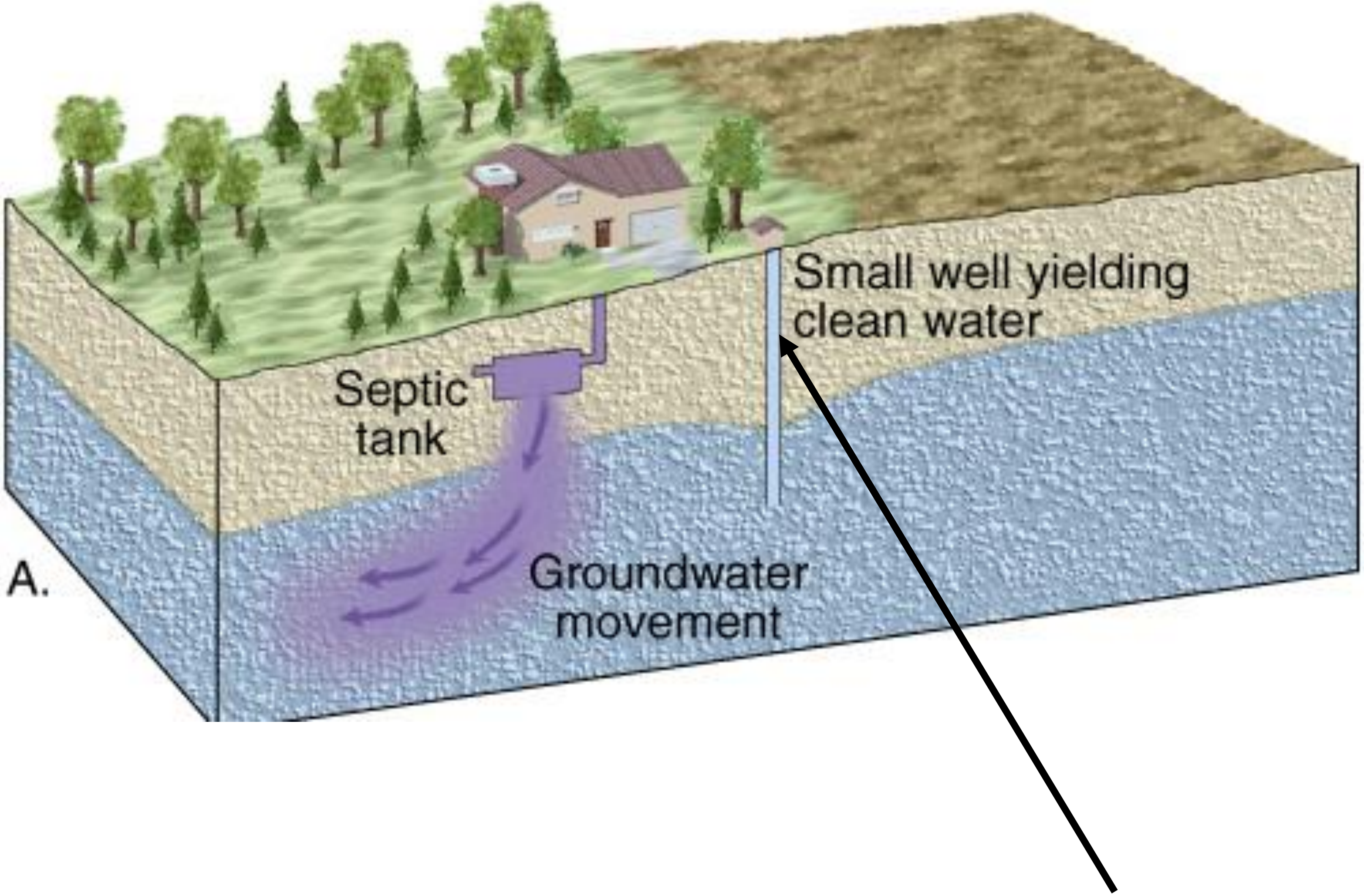

Well
Well
Well
Former water table
Before heavy pumping
Dry well
Dry well
Cone of depression
Lowered water table
After heavy pumping


Water table
Fresh groundwater
Ocean
Salt groundwater
A.
Pumped well
Cone of depression
Fresh groundwater
Ocean
Salt groundwater
B.

Sewage Contamination

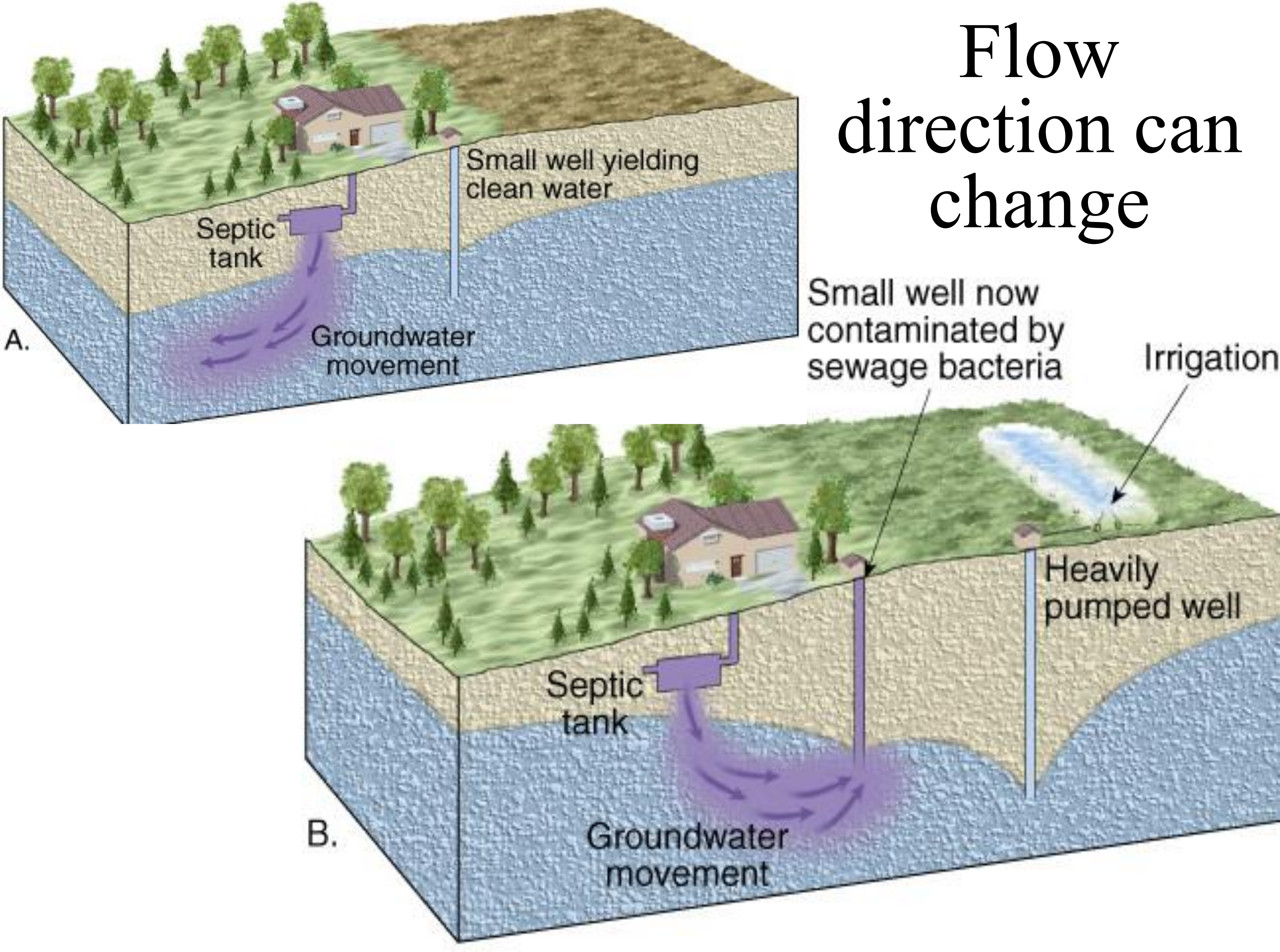


A



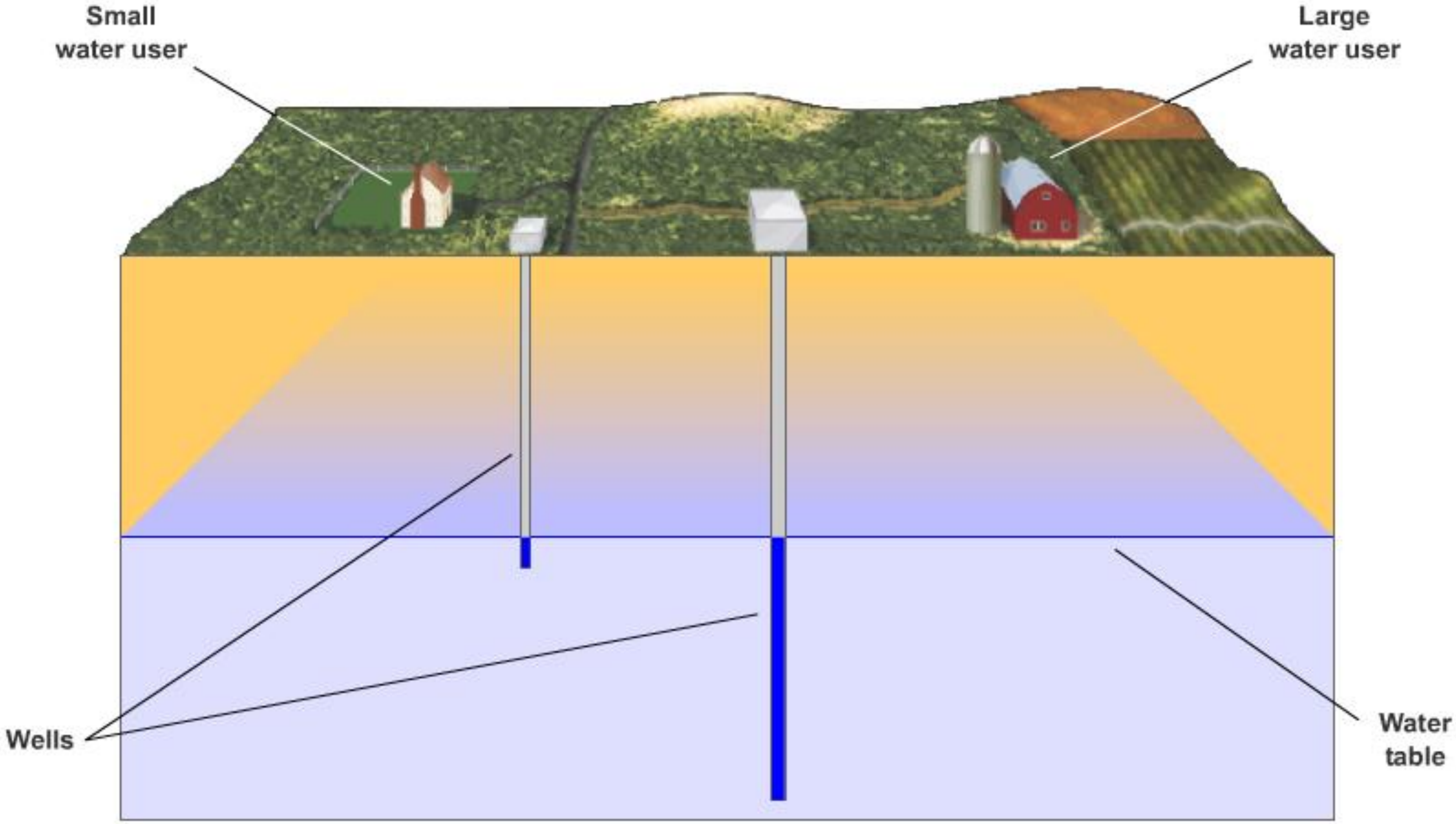
- What happens when a new well here is heavily pumped?

Flow direction can change



License Credits

Formation of a cone of depression



Conserving Groundwater

VOCABULARY

water budget

recharge

surplus

usage

deficit

A water budget relates the recharge, surplus, usage, and deficit of soil water to the moisture needs and the moisture supply of an area. Overuse of groundwater leads to problems such as subsidence. Groundwater pollution is a serious threat to supplies of usable water.

A worker sorting hazardous waste for safe disposal.