Earth Science

Mini-Class

ACE Quizbowl Camp

Cabrini University

July, 2017

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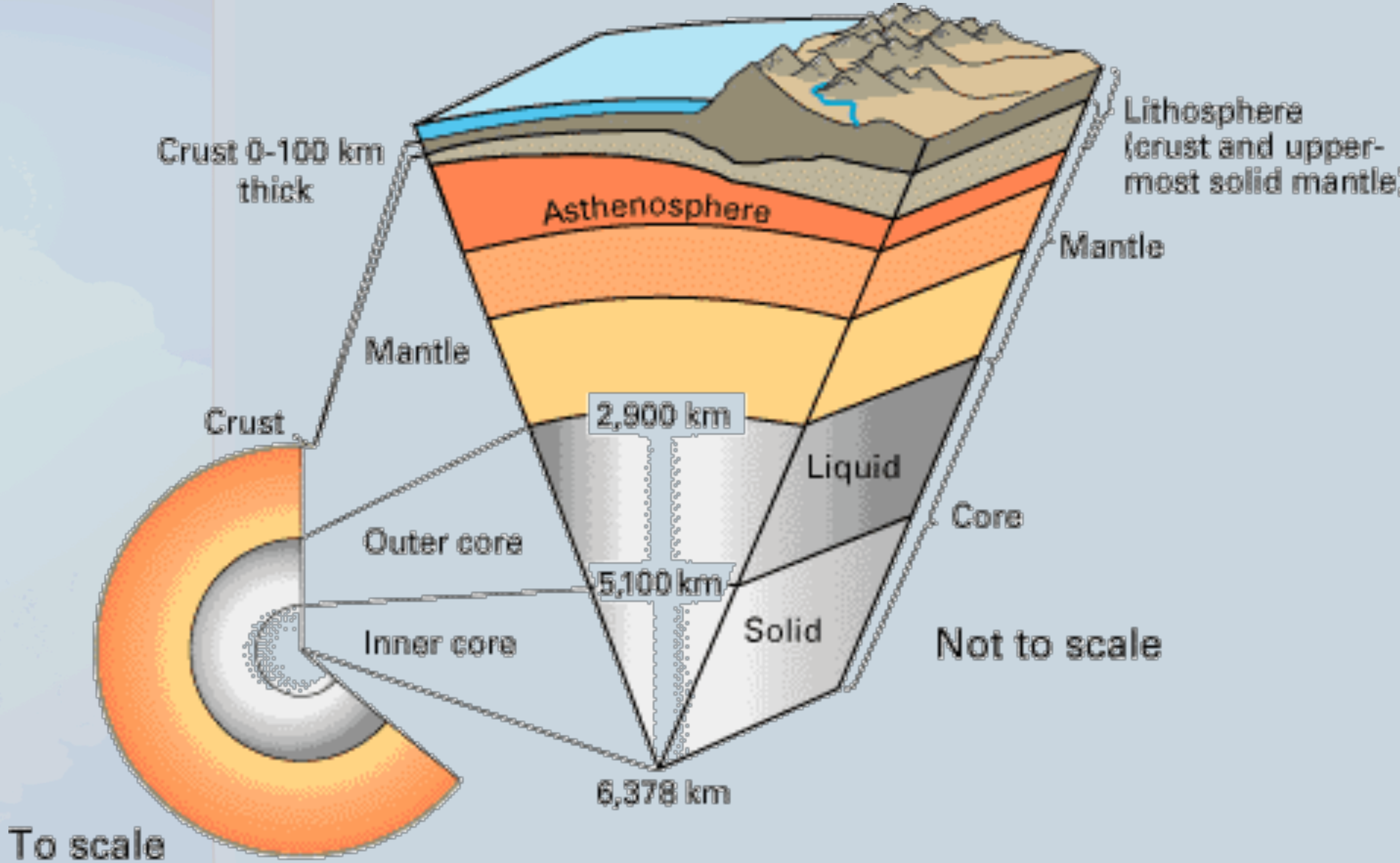
- **Layers of the Earth**



Layers of the Earth

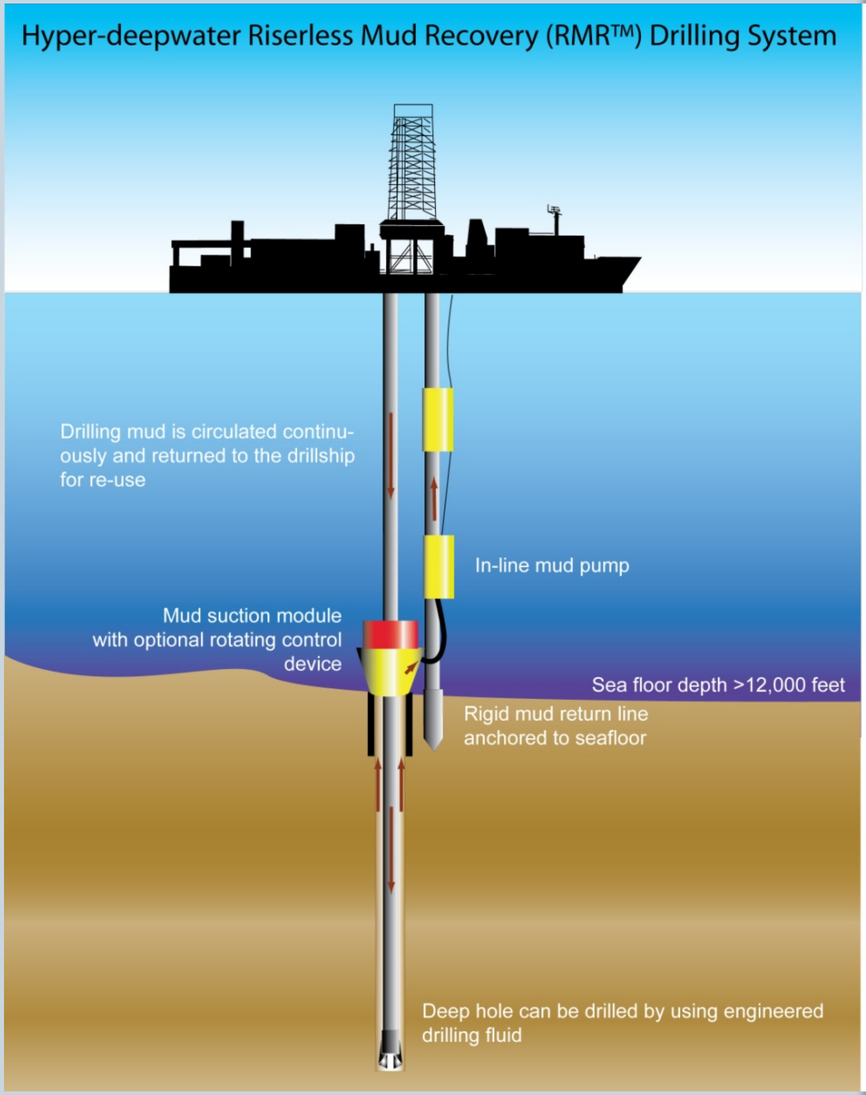
- CRUST:
  - The Basics –
    - The crust is the outermost and thinnest (8-40 km) of Earth’s layers.
    - It contains the continents and the oceans lie on top of it.
  - Clues to Know –
    - Most abundant elements are oxygen (46.6%), silicon (27.7%), aluminum (8.1%), and iron (5.0%).
    - The crust and uppermost part of the mantle form the lithosphere, the rocky shell surrounding the Earth.
    - The crust and lithosphere can be divided into continental and oceanic types by mineral composition.

•Layers of the Earth

- MANTLE:
  - The Basics –
    - The mantle is the middle layer of the Earth between the crust and core. It is about 2900 km thick.
    - The upper mantle is divided between the rigid lithosphere and the more plastic asthenosphere below it. The equilibrium between them is called an isostasy.
    - The boundary between the crust and mantle is called the Mohorovicic discontinuity, more commonly called the Moho. It is named for the Croatian seismologist who discovered that it refracts earthquake waves.
    - The core-mantle boundary (CMB) is also known as the Gutenberg discontinuity.
  - Clues to Know –
    - The lowest layer of the mantle, just above the core, is called the D'' (D double-prime) and was named by mathematician Keith Bullen. Bullen assigned letters to each layer of the Earth, which later had to be amended. D'' is the last remaining vestige of Bullen's system.

•Layers of the Earth

- MANTLE:
  - More Clues to Know –
    - The mantle contains numerous upwellings of hot, low-density rock called <u>mantle plumes</u>.
    - The upper mantle is rich in the mineral olivine.
    - The Russian Kola Superdeep Borehole was, and the Japanese Chikyu Hakken is, an exploration project for drilling into the mantle.



Layers of the Earth

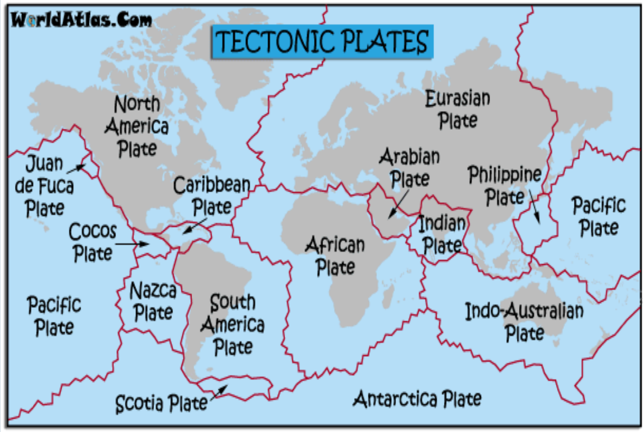
- CORE:
  - The Basics –
    - The Earth has a liquid outer core (2250 km thick) and a solid inner core (1300 km thick).
    - Both cores are composed of a nickel-iron alloy.
  - Clues to Know –
    - According to the geodynamo theory (AKA dynamo effect), the rotation of the outer core generates the Earth's magnetic field.
    - The inner core was discovered by Inge Lehmann who detected a P-wave shadow zone and the boundary between the core layers is called the "mushy zone".

•Plate Tectonics

- CONTINENTAL DRIFT:
  - In 1912, Alfred Wegener presented his theory of continental drift to explain the shape and position of the continents. He coined the name Pangaea for the supercontinent that once contained all land on Earth about 250 mya. Pangaea was surrounded by a single huge ocean called Panthalassa.
  - Wegner's idea that the continents were moving did not gain wide acceptance until the 1960s. Although right in this respect, his explanation (solid landmasses floating on a liquid rock layer) was incorrect. A competing theory of the time was called polar wandering.
- TECTONIC THEORY:
  - The movement of continents is today explained by plate tectonics—the division of the crust into huge pieces that are constantly growing, shrinking, or sliding past each other at their boundaries.
  - The most stable parts of continents, located near the center of plates and containing the oldest rocks, are called cratons or shields.

•Plate Tectonics

- Clues to Know –
  - There are about 12 major plates and many smaller ones. The largest are named after continents (*North American*, *Eurasian*, *Indo-Australian*, etc.) or oceans (*Pacific*). Small plates include the *Philippine*, *Arabian*, *Scotia* (between South American and Antarctica), *Nazca* (west of South America), *Cocos* (west of Central America), *Caribbean*, and *Juan de Fuca* (the smallest plate, just west of Washington and Oregon).



- PLATE BOUNDARIES:
  - Where the edges of plates meet, three things can happen—the plates move away from each other (divergent boundary), the plates move toward each other (convergent boundary), or the plates slide horizontally past each other (transform boundary).

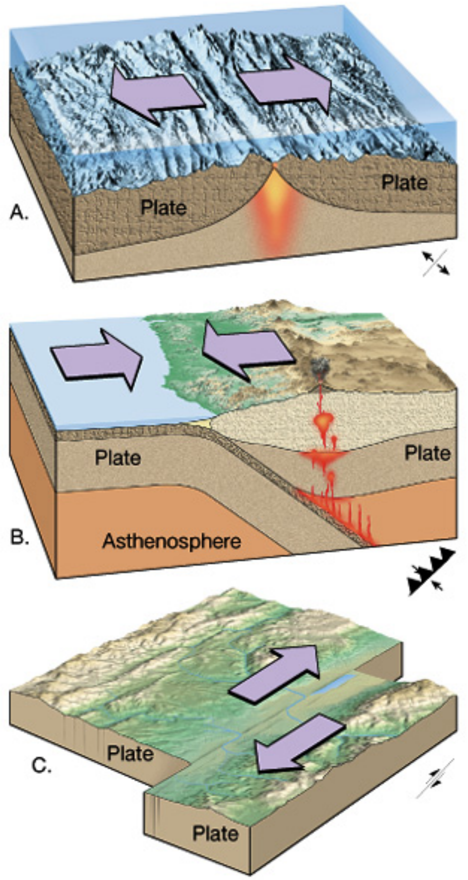
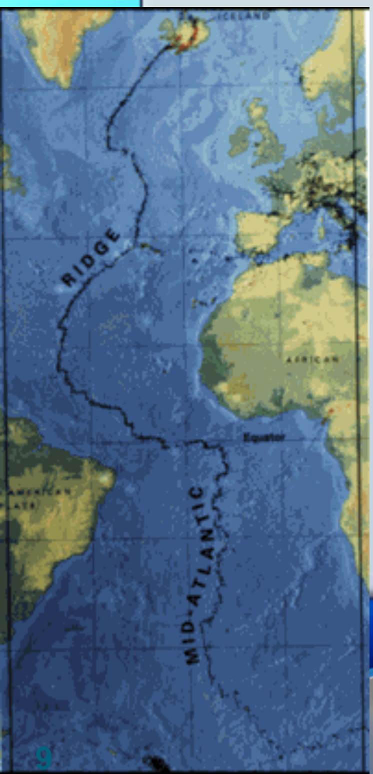
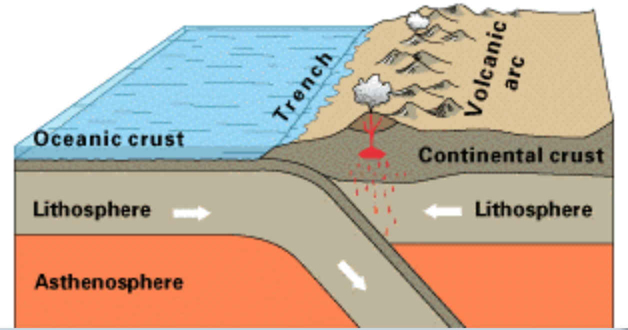


Plate Tectonics

- PLATE BOUNDARIES:
  - The Basics –
    - At divergent boundaries, the newly formed crust pushes the plates apart, resulting in mid-ocean ridges underwater and rift valleys on land or in the seafloor.
  - Clues to Know –
    - The Mid-Atlantic Ridge is the longest mountain chain on Earth (10,000 mi), running from the Arctic to the tip of Africa. The tallest peaks in the ridge include the islands of Ascension, St. Helena, and Iceland. Another important ridge is the East Pacific Rise.
    - The most significant rift on land is Africa’s Great Rift Valley, running through the east side of the continent. It contains a plate triple junction (the Afar Triangle) and many dormant volcanoes like Mt. Kenya and Mt. Kilimanjaro. Eventually, east Africa will break away from the rest of the continent.



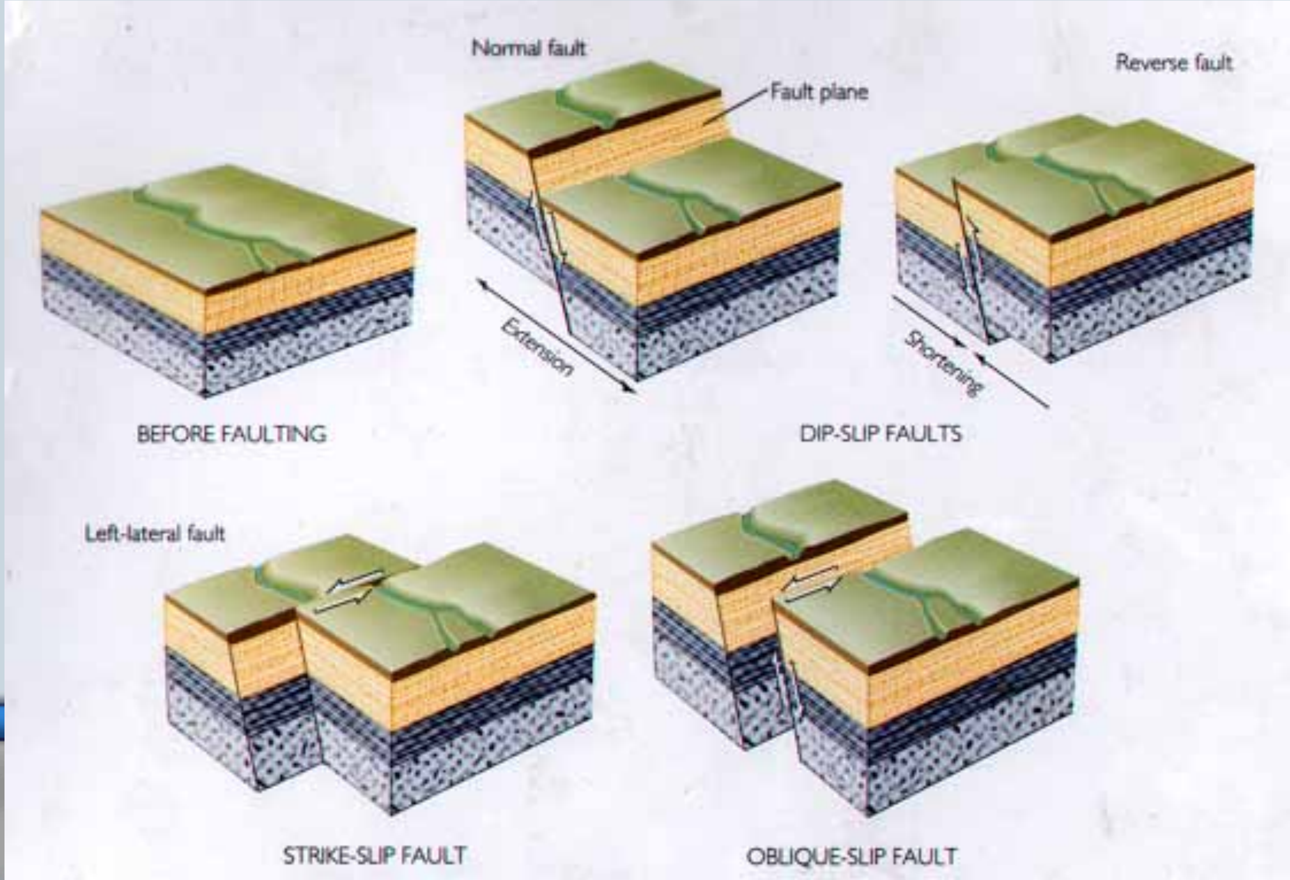
•**Plate Tectonics**



- PLATE BOUNDARIES:
  - The Basics –
    - At convergent boundaries, two plates collide and the denser plate descends below the other one in a process called subduction.
    - 3 types of convergent boundaries:
      - Oceanic-Oceanic (e.g. Aleutian islands)
      - Oceanic-Continental (e.g. Andes mountains)
      - Continental-Continental (e.g. Himalayas, Appalachians)
  - Clues to Know –
    - Subduction zones are typically marked by volcanic island arcs, deep trenches (e.g. Mariana Trench), and piles of rock scraps called melanges.
    - Oceanic plates subduct under continental plates because basalt is denser than granite.
    - When continental plates of similar density collide, the edges fold and uplift. This orogeny (mountain formation) creates the tallest ranges in the world.

•Plate Tectonics

- PLATE BOUNDARIES:
  - The Basics –
    - At transform boundaries, the plates slide past each other horizontally along fault lines. The San Andreas fault in California is the most famous example—the Pacific plate is sliding north relative to the North American plate.
- FAULTS:

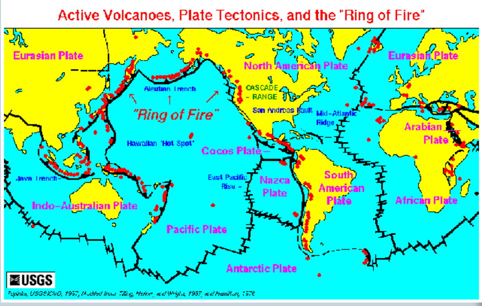


•Plate Tectonics

- FAULTS:
  - Clues to Know –
    - The San Andreas is an example of a strike-slip fault, which can be classified as dextral or sinistral. J. Tuzo Wilson first explained them using origami models.
    - Horsts and grabens are landforms that can develop between faults and the slow movement of land along one is called creep.
    - The New Madrid fault in Missouri was responsible for a series of large earthquakes in 1811-12. For a time, they caused the Mississippi River to flow backwards.
- SEAFLOOR SPREADING:
  - The Basics –
    - Seafloor spreading is the modern theory of landmass movement in which new crust forms at mid-ocean ridges and old crust is destroyed at deep-sea trenches. The continents ride along as if on a conveyer-belt.
  - Clues to Know –
    - It is powered by convection currents in the upper mantle. It was proposed by Henry Hess in the 1960s and is supported by the “zebra skin” pattern in the cooled basaltic magma caused by periodic reversals of Earth’s magnetic field.

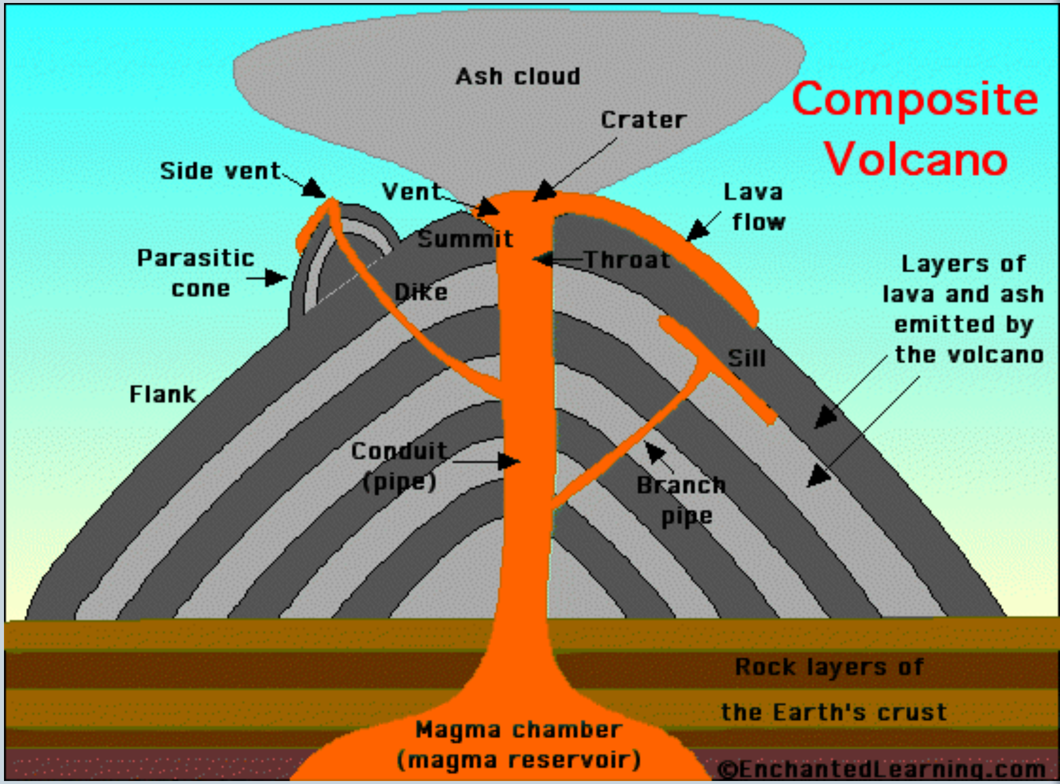
•Volcanology

- VOLCANOES:
  - The Basics –
    - Land volcanoes are largely confined to two major belts associated with convergent plate boundaries: the Circum-Pacific Belt (AKA Ring of Fire) and Mediterranean Belt.
    - Most volcanism occurs underwater along divergent boundaries at the mid-ocean ridges.
    - Volcanoes can form far from plate boundaries at places where high-temperature mantle plumes breach the surface called hot spots. The Hawaiian islands formed as the Pacific plate moved over a hot spot and the erupting magma cooled.
    - Hot spots under the continental crust can form long cracks called fissures out of which flow enormous volumes of lava known as flood basalts. Important examples include the Columbia River Basalts of the NW United States (170,000 km^3) and the Deccan Traps of India (512, 000 km^3). Eruption of the Deccan Traps 65 mya is an alternative theory for the extinction of the dinosaurs.



•Volcanology

- VOLCANO ANATOMY:
- The Basics –
- When the magma chamber empties , the summit or side can collapse, creating a depression up to 50 km wide called a caldera. Calderas can fill with water forming lakes such as Oregon's Crater Lake.



3 Types of Volcanoes:

Shield – largest type, with gently sloping sides and a nearly circular base; layers of lava build up through non-explosive eruptions.

Cinder Cone – small particles of magma called tephra are ejected into the air and fall in piles around the vent; not high but with very steep sides.

Composite/Stratovolcano – result from violent eruptions that create concave slopes; because of their explosive potential, these are the most dangerous to humans.

•Volcanology

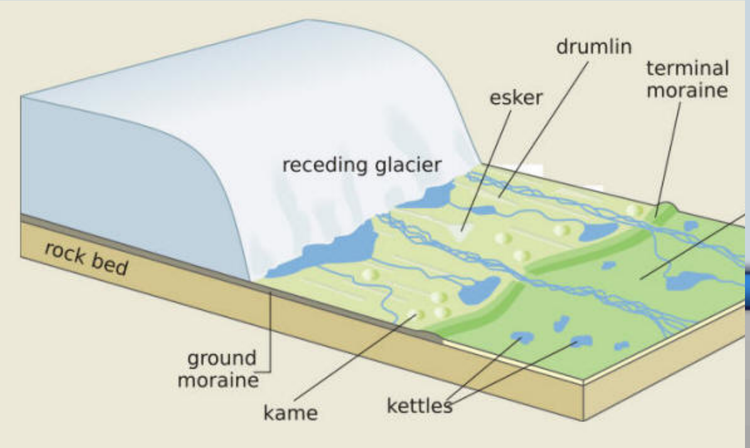
- VOLCANIC ERUPTIONS:
  - The Basics –
    - Magma is molten rock beneath the surface of the Earth, while lava is molten rock flowing along the surface.
  - Clues to Know –
    - The properties of magma/lava are determined by its silica content and important types include basaltic (<50%), andesitic (50-60%), and rhyolitic (>60%). Generally, the more silica magma contains, the more gas it traps and the more explosively it erupts.
    - Cooled lava types include *'a'a* (sharp, spiny), *pahoehoe* (smooth), and *pillow* (large blobs formed underwater).
    - The most violent eruptions can produce pyroclastic flows, mixtures of tephra and hot gases that travel down a volcano's slopes faster than 100 mph.
    - When snow-covered volcanoes erupt, the sudden temperature increase melts all the ice simultaneously, creating a lahar: a mudflow with the density of concrete than can carry away almost anything in its path.

•Glaciology

- GLACIERS:
  - The Basics –
    - Glaciers are large, moving masses of ice that form in high, mountainous areas (valley/alpine glaciers) and near the Earth's poles (continental glaciers).
  - Clues to Know –
    - The movement of glaciers is modeled by the Glen-Nye flow law. Cracks in glaciers are called crevasses.
    - Moving glaciers can carve out deep depressions called cirques by the process of mass wasting. Where two cirques meet, they form a sharp, steep ridge called an arête. Glaciers on three or more sides of a mountain will create a steep, pyramidal peak called a horn (e.g. Switzerland's Matterhorn).
    - As a glacier grinds the underlying rock, the small particles get carried along as till. When a retreating glacier melts, it leaves behind a ridge of till called a moraine, which can be terminal (front edge) or lateral (along the sides).

•Glaciology

- GLACIERS:
  - Clues to Know –
    - When continental glaciers move over older moraines, they shape them into elongated forms called drumlins. Streams flowing under melting glaciers carry deposits that will form long winding ridges called eskers. Small, cone-shaped mounds left by receding glaciers are called kames.
    - Large blocks of ice can break off glaciers and melt, forming kettle lakes.
    - The back end of a cirque is called the headwall and the erosion that forms them begins at a crevasse called a bergschrund. If a cirque fills with water, it becomes a mountain lake called a tarn.
    - Drumlins are named for the Gaelic word for "rounded hill" and a group of them together form "basket of eggs" topography. Two theories that attempt to explain their formation are the flood theory and mobile bed theory.

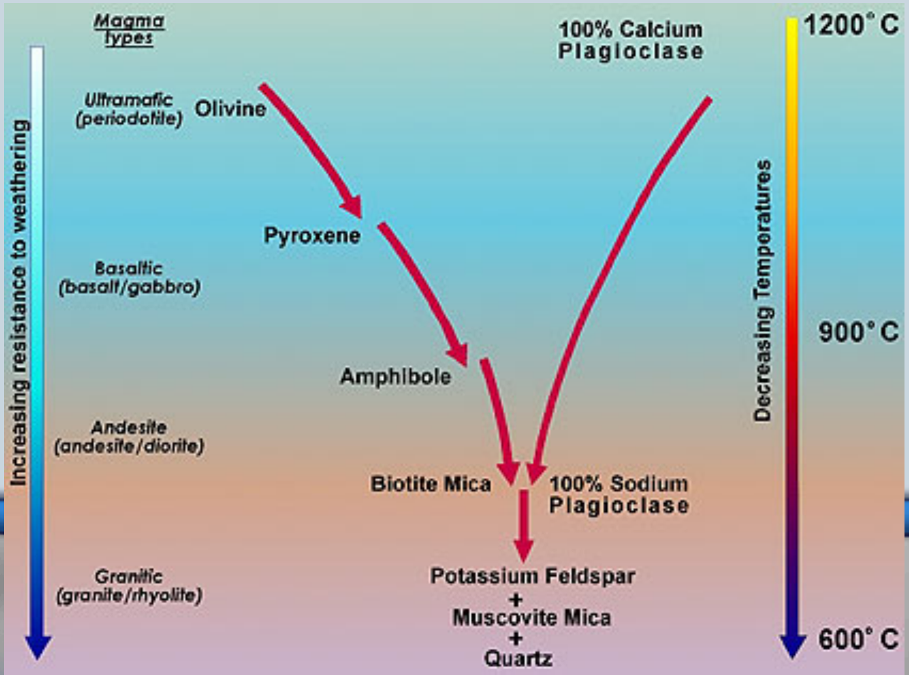


•Mineralogy

- CLASSIFICATIONS OF ROCK:
  - The Basics –
    - There are three major types of rock:
      - Igneous – forms when lava/magma cools and minerals crystallize.
        - Ex: andesite, basalt, diorite, gabbro, granite, obsidian, pegmatite, peridotite, pumice, rhyolite, scoria, tuff
      - Sedimentary – forms when small pieces of rock accumulate after being deposited by water, wind, glaciers, and gravity.
        - Ex: breccia, chert, coal, conglomerate, dolomite, limestone, rock salt, sandstone, shale
      - Metamorphic – forms when igneous or sedimentary rock is exposed to heat, pressure, and chemical processes, altering the rock’s composition.
        - Ex: amphibolite, gneiss, hornfels, marble, quartzite, schist, slate, soapstone

•Mineralogy

- CLASSIFICATIONS OF ROCK:
  - Clues to Know –
    - Igneous rocks can be classed as intrusive (plutonic) or extrusive (volcanic) depending on whether they form below ground or on the surface, respectively.
    - Bowen's reaction series – shows the relationship between cooling magma and the formation of minerals in igneous rock. The left, discontinuous branch shows Fe/Mg-rich mafic minerals and the right, continuous branch shows felsic minerals rich in lighter elements.



•Mineralogy

- TESTING MINERALS:
- Mohs hardness scale
    - Based on a mineral's ability to scratch other minerals.
    - There is also a Vickers hardness scale.
- Streak test
    - An unknown mineral is dragged across an unglazed porcelain tile and the color it leaves behind can be used to identify it.
    - Ex: hematite leaves a red streak and galena leaves a gray streak.

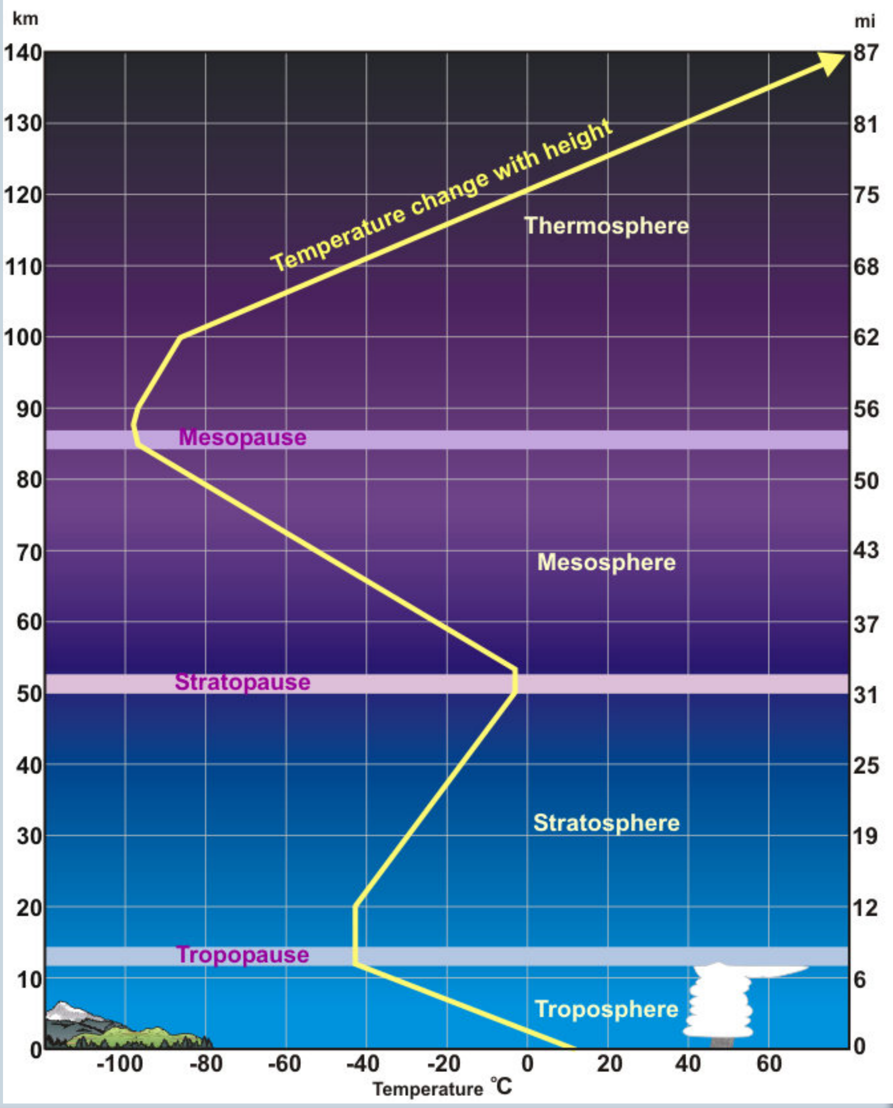
Mineral	Hardness	Hardness of Common Object
Talc	1 (softest)	
Gypsum	2	Fingernail (2.5)
Calcite	3	Penny (3.5)
Fluorite	4	Iron nail (4.5)
Apatite	5	Glass (5.5)
Feldspar	6	Steel file (6.5)
Quartz	7	Porcelain (7)
Topaz	8	Scratches quartz
Corundum	9	Scratches topaz
Diamond	10 (hardest)	Scratches all common materials

Luster – the way light reflects off a mineral; can be dull, greasy, metallic, pearly, silky, waxy, or adamantine (diamond-like).

Specific gravity – the ratio of the density of a mineral to the density of a reference, usually H_2O.

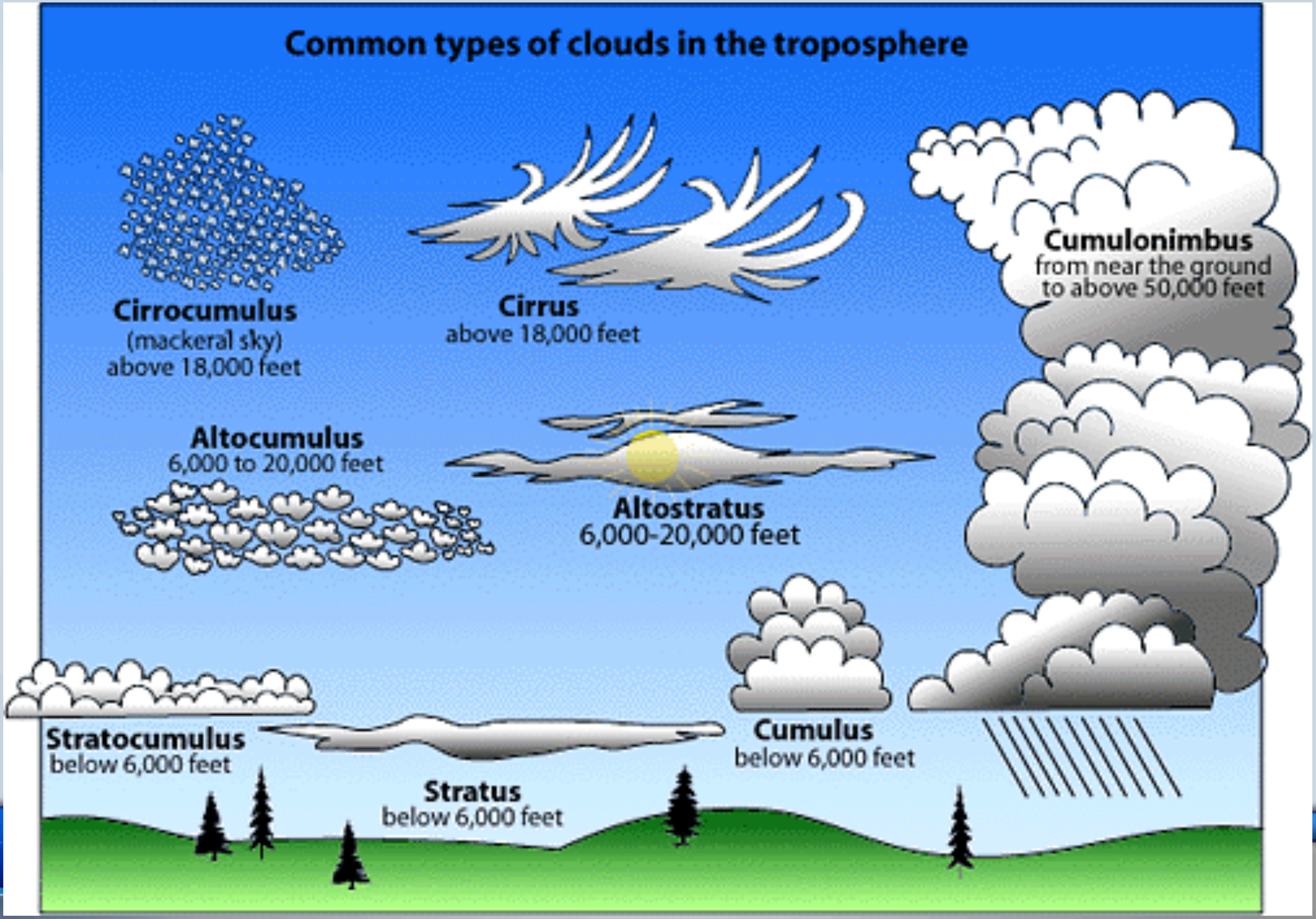
•Meteorology & Climatology

- THE ATMOSPHERE:
  - The Basics –
  - The atmosphere contains 78% nitrogen, 21% oxygen, 0-4% water vapor, 0.93% argon, and 0.038% carbon dioxide.
  - Clues to Know –
  - Troposphere – closest layer to Earth's surface; all weather occurs here.
  - Stratosphere – layer where airplanes cruise; contains the ozone (O_3) layer that absorbs UV rays from the Sun.
  - Thermosphere – temps can exceed 1000°C; contains the electrically charged ionosphere where auroras occur.



•Meteorology & Climatology

- CLOUDS:



Meteorology & Climatology

- CLOUDS:
  - Clues to Know –
    - Clouds begin with condensation nuclei, small particles in the atmosphere around which water droplets can form. Cloud seeding to encourage rain is often done with dry ice or silver iodide. The height of a cloud base is measured with a device called a ceilometer.
    - Cumulus – fluffy, cotton ball-looking clouds at low altitude.
    - Stratus – thin, sheet-like cloud at low altitude that covers much of the sky in a given area; can form when fog lifts away from the Earth's surface.
    - Cirrus – wispy, high altitude clouds made up of ice crystals; the contrails left by high-flying aircraft are also cirrus clouds; nicknamed "mare's tails"; their orientation indicates wind direction.
    - Cumulonimbus – tall thunderstorm clouds that sometimes reach as high as the tropopause; the flattened top of the cloud is called the anvil.

•Meteorology & Climatology

- ATMOSPHERIC PHENOMENA:
  - Clues to Know –
    - Severe weather begins with the formation of a powerful storm called a supercell, which is marked by fast, rotating updrafts.
    - Supercells can become tornadoes when the whirling column of air reaches the ground. A tornado that does not reach the ground is called a funnel cloud.
    - A common way to measure the intensity of wind is the Beaufort scale, which looks at the effects of the wind on the sea or land. It ranges from 0 (calm, no waves, smoke rises vertically) to 12 (hurricane, huge waves, widespread damage to vegetation and property).
    - The intensity of tornadoes is measured by the Fujita scale (or Enhanced Fujita scale in the US), which surveys the damage done to vegetation and manmade structures. It ranges from F0 (up to 72 mph winds, light damage) to F5 (>260 mph winds, entire houses lifted from foundations, cars thrown more than 100 yd, trees debarked). Less than 0.1% of tornadoes are classified F5.

•Meteorology & Climatology

- ATMOSPHERIC PHENOMENA:
  - Clues to Know –
    - In the summer and fall, large, rotating, low-pressure storms called cyclones often develop in the tropics. In the Atlantic, tropical cyclones are called hurricanes and in the Pacific they are called typhoons.
    - Such storms have a calm center called the eye surrounded by a tall band of very strong winds known as the eyewall.
    - Most of the damage done by a cyclone is caused by the storm surge: the large volume of ocean water driven onto the land by the intense winds.
    - Hurricanes are classified by the Saffir-Simpson scale, which accounts for wind speed, change in sea level, and potential for property damage. It ranges from Category 1 (winds < 95 mph, storm surge < 5 ft) to Category 5 (winds > 155 mph, storm surge > 18 ft).
    - The last Category 5 hurricane to hit the US was Katrina in 2005. It had winds of 175 mph and a storm surge of 28 ft. It killed over 1,800 people and caused property damage estimated at over $100 billion.