Allegheny College Department of Geology
Student Handbook

This handbook is designed as a resource for all geology majors and minors. The material contained in the handbook includes foundation principles and topics that are learned in introductory geology courses (e.g., Physical and Environmental Geology, Historical Geology). Each geology student is expected to be familiar with this material for each of their upper level geology courses.

The age of the Earth is about 4.65 billion years which represents geologic time. This is a vast amount of time to comprehend – the spiral diagram to the right is useful for understanding the relative proportion of geologic time compared to known events.

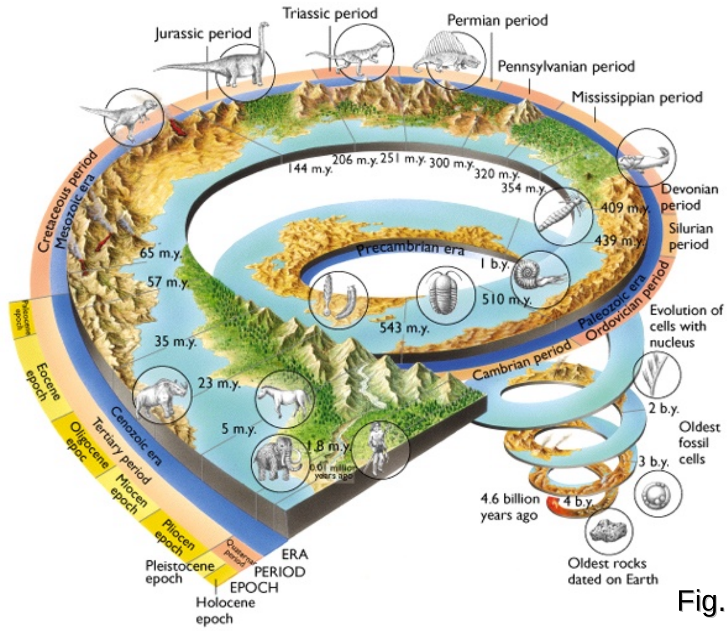
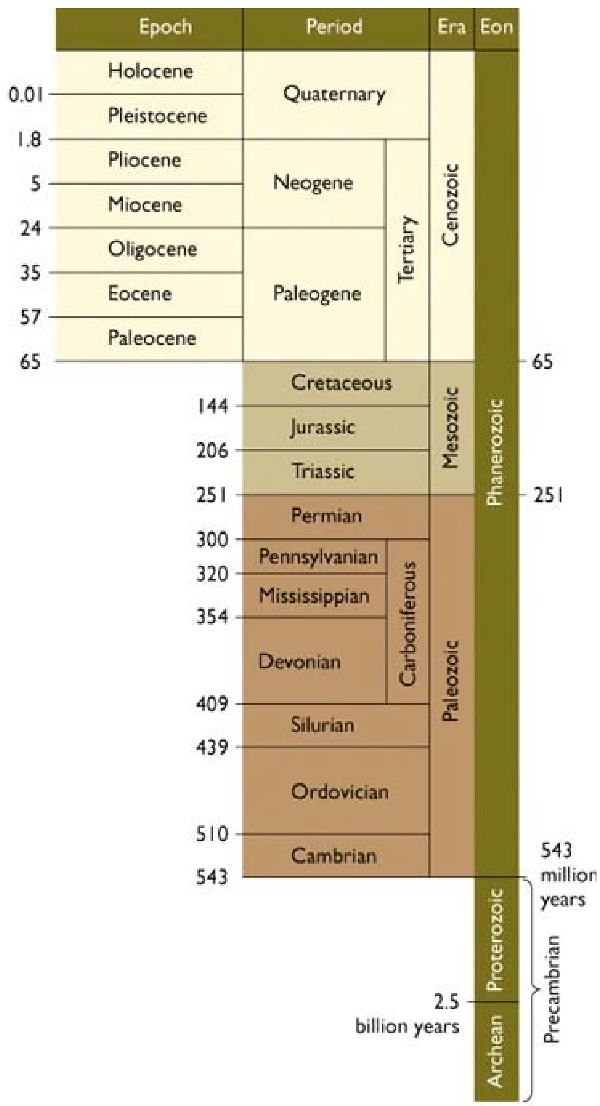
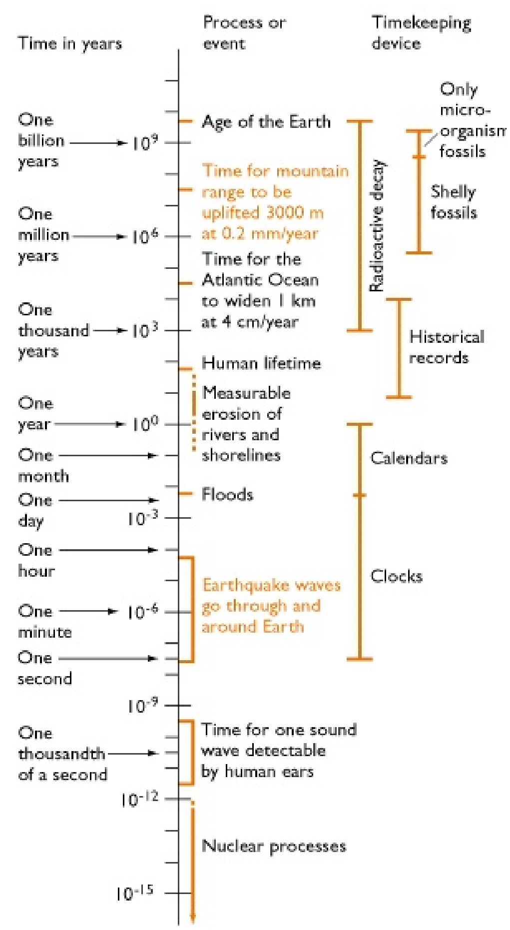


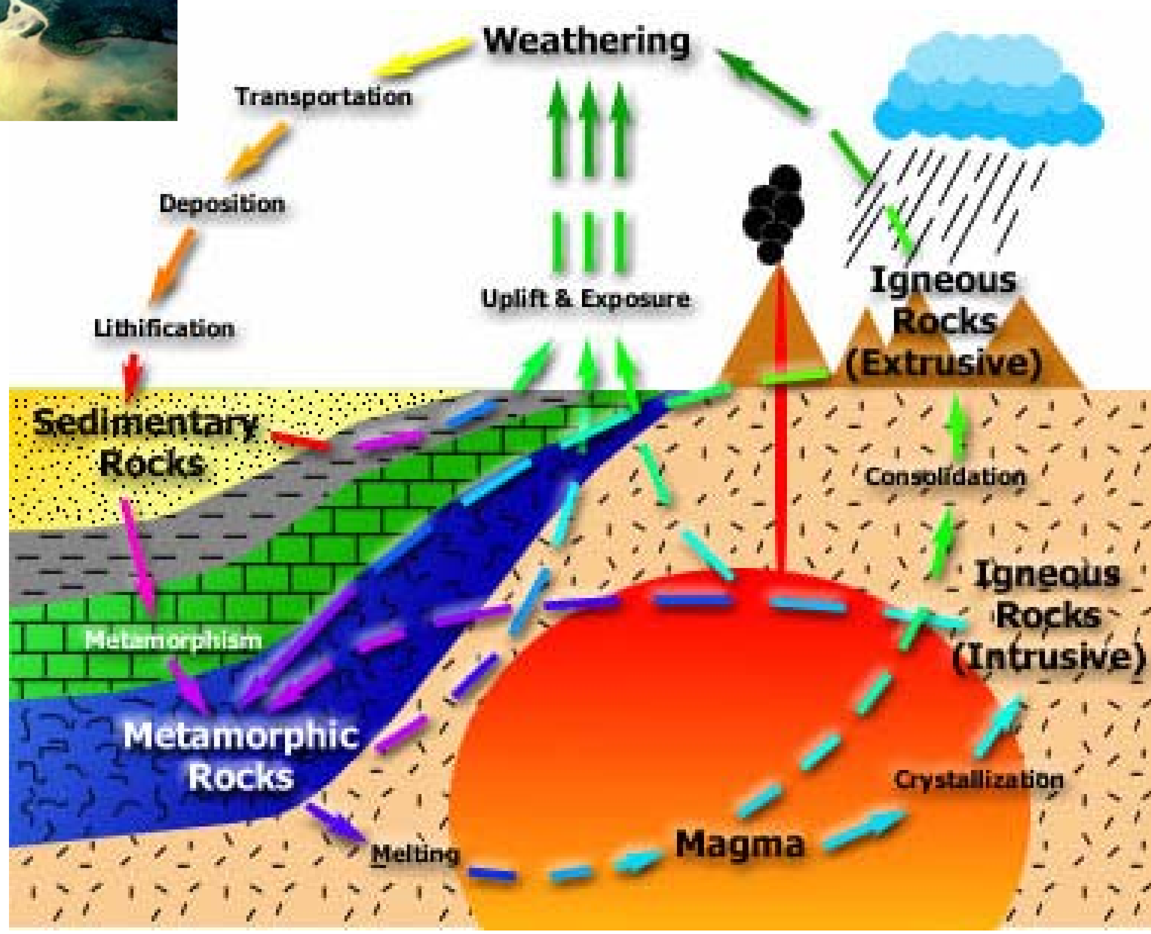
Fig. 9.18

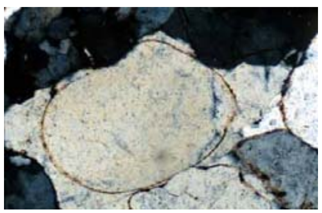


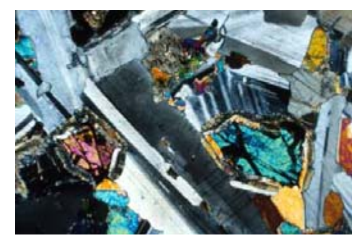
The geologic time scale is a convenient way to subdivide the events and ages of rocks that were formed throughout Earth history. This scale covers only about 12% of geologic time in detail (from the present back to about 600 million years). We know much less about events and rock units that are older than 600 million years, so that part of the time scale is not subdivided. Another facet of geologic time is that different geologic processes take place at different rates. For example, a volcanic eruption is an instantaneous event (hours to days) but uplift of a mountain takes millions of years (at rates of a few mm per year).

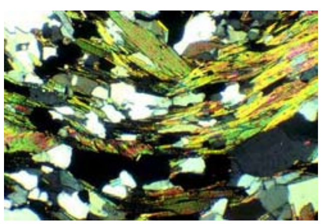


Earth's Lithosphere System – Rock Cycle









ALLEGHENY COLLEGE DEPT. OF GEOLOGY
MINERALS

A **mineral**, by definition, must satisfy five conditions:

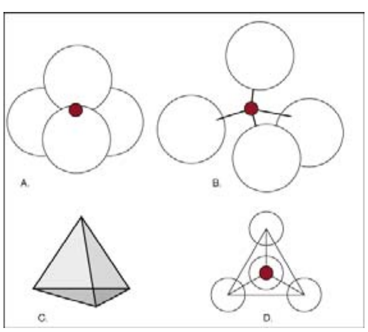
1. It must be naturally occurring.
2. It must be inorganic.
3. It must be a solid element or compound.
4. It must have a definite composition.
5. It must have a regular internal crystal structure.

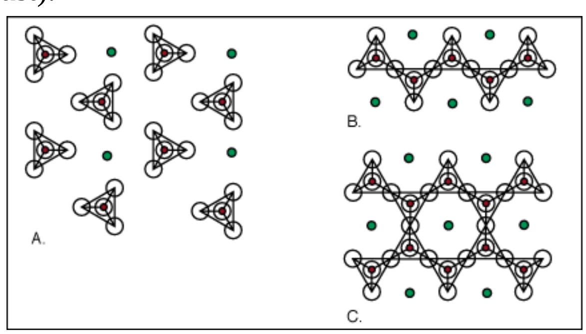
COMMON ROCK-FORMING MINERALS

The silicate group of minerals are the most abundant in the Earth's crust. Of the silicate minerals, 9 types are most common among all the rock types. In addition, calcite and dolomite are relatively abundant rock-forming carbonate minerals.

	Mineral	**Chemical Composition** **(simplified for some mineral groups)**
Silicate Minerals	Quartz	SiO_2
	K-feldspar (orthoclase)	$KAlSi_3O_8$
	Plagioclase feldspar (2 end-members)	
	Albite	$NaAlSi_3O_8$
	Anorthite	$CaAl_2Si_2O_8$
	Mica (2 end-members)	
	Biotite	$K_2(Fe,Mg)_{4\text{-}6}(FeAl)_{0\text{-}2}Si_{5\text{-}6}O_{20\text{-}22}$
	Muscovite	$K_2Al_4(Si_6Al_2)O_{20}(OH)_4$
	Amphibole (includes hornblende)	$(Mg,Fe,Ca)AlSiO(OH)$
	Pyroxene	$(Ca,Mg,Fe)SiO_{2,3}$
	Olivine	$(Fe,Mg)SiO_3$
Carbonate Minerals	Calcite	$CaCO_3$
	Dolomite	$(Ca,Mg)CO_3$

The building block of the silicate minerals is the silicate tetrahedron made from Si and O atoms (the two most abundant elements in the Earth's crust).

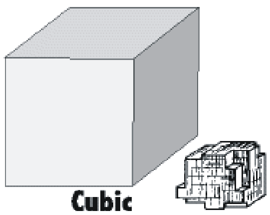




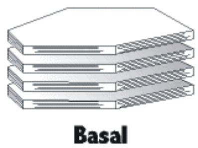
ALLEGHENY COLLEGE DEPT. OF GEOLOGY
MINERAL IDENTIFICATION

Minerals are identified in hand samples by their physical properties. The physical properties of a mineral are related to chemical composition and atomic structure; these properties do not change with mineral size or shape.

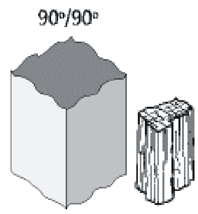
CLEAVAGE AND FRACTURE: how a mineral tends to break.
Cleavage: splitting of a mineral along planar (flat) surfaces; determined by planes of weakness in its atomic structure. The number, quality, and angles between cleavage surfaces differ between minerals. Don't confuse cleavage with crystal faces; a crystal face is an external feature and cleavage occurs throughout a mineral.



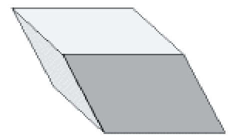
3 cleavages at right angles
(e.g., halite, galena)



1 cleavage; sheets
(e.g., biotite, muscovite)



2 cleavages at right angles; third side fractures irregularly
(e.g., pyroxene, feldspars)



2 cleavages at 60 and 120 degrees; third side fractures irregularly (e.g., amphibole)

Fracture: irregular, rough surface along which a mineral breaks; atomic bonding is equal in all directions.

HARDNESS: resistance of a mineral to scratching; related to the strength of a minerals chemical bonds. Hardness is based upon a relative scale from 1 to 10 called the Mohs scale of hardness. *(1 = softest; 10 = hardest)*

Hardness	Index Mineral	Common Material	Hardness	Index Mineral	Common Material
1	Talc		5.5		Glass
2	Gypsum		6	Orthoclase	
2.5		Fingernail	7	Quartz	
3	Calcite		8	Topaz	
4	Fluorite		9	Corundum	
5	Apatite		10	Diamond	
5 to 5.5		Knife blade			

STREAK: the color of a mineral's powder. Determined by scratching a mineral on a piece of white porcelain
Dark streaks: mostly metallic minerals Light streaks: mostly non-metallic minerals

REACTION WITH ACID: carbonate minerals can be highly reactive with acid. Calcite bubbles strongly with a drop of dilute hydrochloric acid (HCl).

MAGNETISM: Some minerals are magnetic and attract a magnet (e.g., magnetite).

STRIATIONS: Fine parallel striations may be present on cleavage traces; a good example is plagioclase.

COLOR: an obvious property, but not always too useful. Color is based upon the main chemical elements of a mineral. Minerals can exhibit a wide range in color as a result of small amounts of trace elements or other minor constituents (e.g., water, carbon dioxide) – so, the same mineral can have a range of colors. For example plagioclase can range from white to dark blue, or even nearly black.

IDENTIFICATION CHART FOR SOME COMMON ROCK-FORMING MINERALS

Non-metallic light-colored (Non-metallic minerals appear glassy, pearly, satiny, etc.)	Hard (scratches glass)	Shows cleavage	White to cream to pink; hardness 6; cleavage two planes at nearly 90 degrees	Orthoclase (K-feldspar)
			Color varies from white to gray, dark gray-blue or reddish brown; hardness 6, cleavage two planes at nearly 90 degrees; striations diagnostic	Plagioclase
		No cleavage	Colorless or white, but almost any color can occur; hardness 7; conchoidal fracture; crystal form is hexagonal, otherwise massive	Quartz
			Color green to yellow-greeen; hardness 6.5-7	Olivine
	Soft (does not scratch glass)	Shows cleavage	Colorless, also white, gray, yellow, or red; hardness 2.5; perfect cubic cleavage; salt taste	Halite
			Colorless and transparent, white, variety of color possible; hardness 3; perfect rhombohedral cleavage; effervesces in dilute HCl	Calcite
			Colorless, white, gray, greenish, yellow-brown; hardness 3.5-4; rhombohedral cleavage; powder effervesces in dilute HCl	Dolomite
			Colorless to white, gray, yellow-orange, or light brown; hardness 2; cleavage good in one direction producing sheets; may be fibrous or may not show cleavage	Gypsum
			Pearly to greasy luster; color usually pale green, white, or gray; hardness 1; one direction of cleavage or massive with no evident cleavage	Talc
			Colorless to shades of green, gray, light brown; hardness 2.5-4; perfect sheet cleavage	Muscovite
			Colorless to wide range of colors (including purple); hardness 4; perfect octahedral cleavage (4 planes)	Fluorite
Non-metallic, dark-colored	Hard (scratches glass)	Shows cleavage	Color black; hardness 5-6; cleavage two planes at nearly 90 degrees; may or may not scratch glass	Pyroxene
			Color black; hardness 5-6; cleavage two planes at ~60 and 120 degrees; may or may not scratch glass	Ambhibole
			Color varies from white to gray, dark gray-blue or reddish brown; hardness 6, cleavage two planes at nearly 90 degrees; striations diagnostic	Plagioclase
		No cleavage	Color varies but dark red to reddish brown common; hardness 6.5-7.5; typically abundant fractures that may resemble cleavage planes	Garnet
			Color green to yellow-greeen; hardness 6.5-7	Olivine
			Colorless or white, but almost any color can occur; hardness 7; conchoidal fracture; crystal form is hexagonal, otherwise massive	Quartz
	Soft (does not scratch glass)	Shows cleavage	Color dark brown to black; hardness 2.5-4; perfect sheet cleavage	Biotite
			Color green to greenish black; hardness 2.5; perfect sheet cleavage	Chlorite
		No cleavage	Earthy to submetallic luster; color red to red-brown; hardness 5-6 but apparent hardness may be as low as 1; streak red	Hematite
			Earthy luster; color yellow, yellow-brown, brownish-black; apparent hardness 1; streak brownish yellow to orange-yellow	Limonite
Metallic luster (shiny, opaque)	Black, green-black, or dark green streak	Shows cleavage	Color dark gray to black; hardness 1-2; perfect sheet cleavage, but sometimes not well developed; greasy feel, smudges fingers; streak black	Graphite
			Color shiny lead-gray; hardness 2.5; perfect cubic cleavage (3 directions); streak lead-gray	Galena
		No cleavage	Color black; hardness 6; streak black; strongly magnetic	Magnetite
			Color brass-yellow; goldish-yellow; hardness 6-6.5; streak greenish or brownish black; cubic crystals with striated faces common (but no cleavage)	Pyrite
	Red streak		Color steel-gray; hardness 5-6; streak red-brown	Hematite
	Yellow, brown, or white streak		Color yellow-brown to dark brown, may be almost black; hardness 1-6; streak brownish-yellow to orange-yellow	Limonite

ALLEGHENY COLLEGE DEPT. OF GEOLOGY
ROCK CLASSIFICATION TABLES

	Igneous Rocks		
Texture	*Light-colored (felsic)* Quartz, orthoclase, biotite, muscovite	*Intermediate* Hornblende, plagioclase, quartz, biotite	*Dark colored (mafic)* Pyroxene, plagioclase, olivine
Coarse-grained (phaneritic)	Granite	Diorite	Gabbro
Fine-grained (aphanitic)	Rhyolite	Andesite	Basalt
Glassy	Obsidian		
Highly vesicular	Pumice		Scoria
Fragmental	Pyroclastic: tuff ($\leq$ 2mm grains); tuff-breccia (> 2 mm grains)		

Porphyritic: Scattered macroscopic minerals (***phenocrysts***) in a matrix (***groundmass***) of microscopic minerals.

Clastic Sedimentary Rocks	
Grain Size	*Rock Type*
> 2 mm (gravel)	Conglomerate (rounded grains) Breccia (angular grains)
0.062 to 2 mm (sand; grains clearly visible)	Sandstone Quartz sandstone (mostly quartz grains; tan color) Arkose (>25% feldspar; typically red-brown color)
0.004 to 0.062 mm (silt; feels slightly gritty; grains barely visible with hand lens)	Siltstone
<0.004 mm (mud; feels smooth, not gritty)	Shale (mudstone is mix of mud and silt)
Chemical and Biochemical Sedimentary Rocks	
Texture/composition	*Rock Type*
Coarse to fine crystalline; $CaCO_3$ (reacts with acid) Contains fossil fragments Massive, very fine-grained, usually gray	Limestone (general name) Bioclastic or fossiliferous limestone Micrite
Coarse to fine crystalline; cubic cleavage; gray to red; salt	Halite (rock salt; NaCl)
Soft (hardness <2.5), light colored; rhombic cleavage	Gypsum

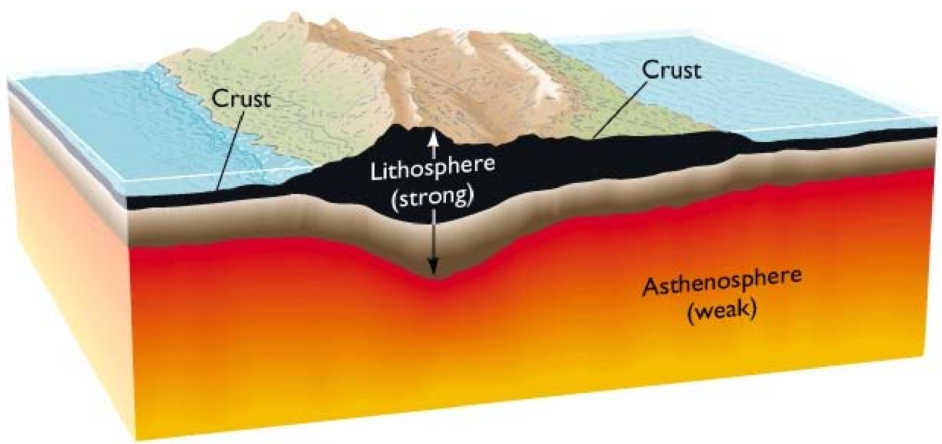
Foliated Metamorphic Rocks		
Texture (type of foliation)	Rock Type	Relative Metamorphic Grade
Distinct compositional banding; typically alternating light and dark layers	Gneiss	High grade ↑ ↓ Low grade
Parallel alignment of platy minerals (micas)	Schist	
Very closely spaced fractures; alignment of chlorite; green, shiny surfaces	Phyllite	
Very closely spaced fractures, not shiny, gray to green	Slate	
Non-Foliated Metamorphic Rocks		
Crystalline, light colored, comprised of quartz	Quartzite	Typically contact metamorphic (high temperature relative to pressure)
Crystalline, light colored, comprised of calcite	Marble	
Crystalline, fine-grained, dark colored, hard and dense	Hornfels	

ALLEGHENY COLLEGE DEPT. OF GEOLOGY
EARTH LAYERS AND WHOLE EARTH STRUCTURE

Geology students should know the definitions and characteristics (chemical and physical) of the following parts of "whole Earth structure":

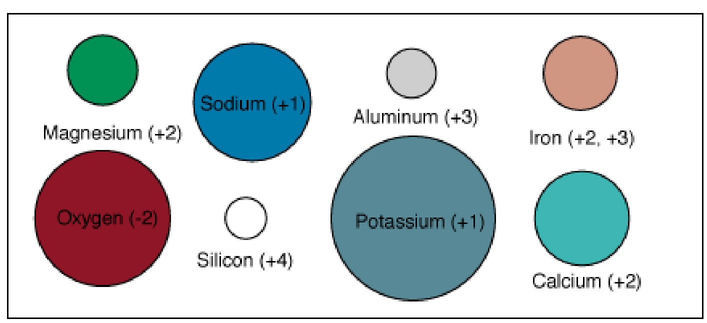
- Crust
- Mantle
- Core
- Lithosphere
- Asthenosphere

Earth's Crust, Lithosphere, and Asthenosphere



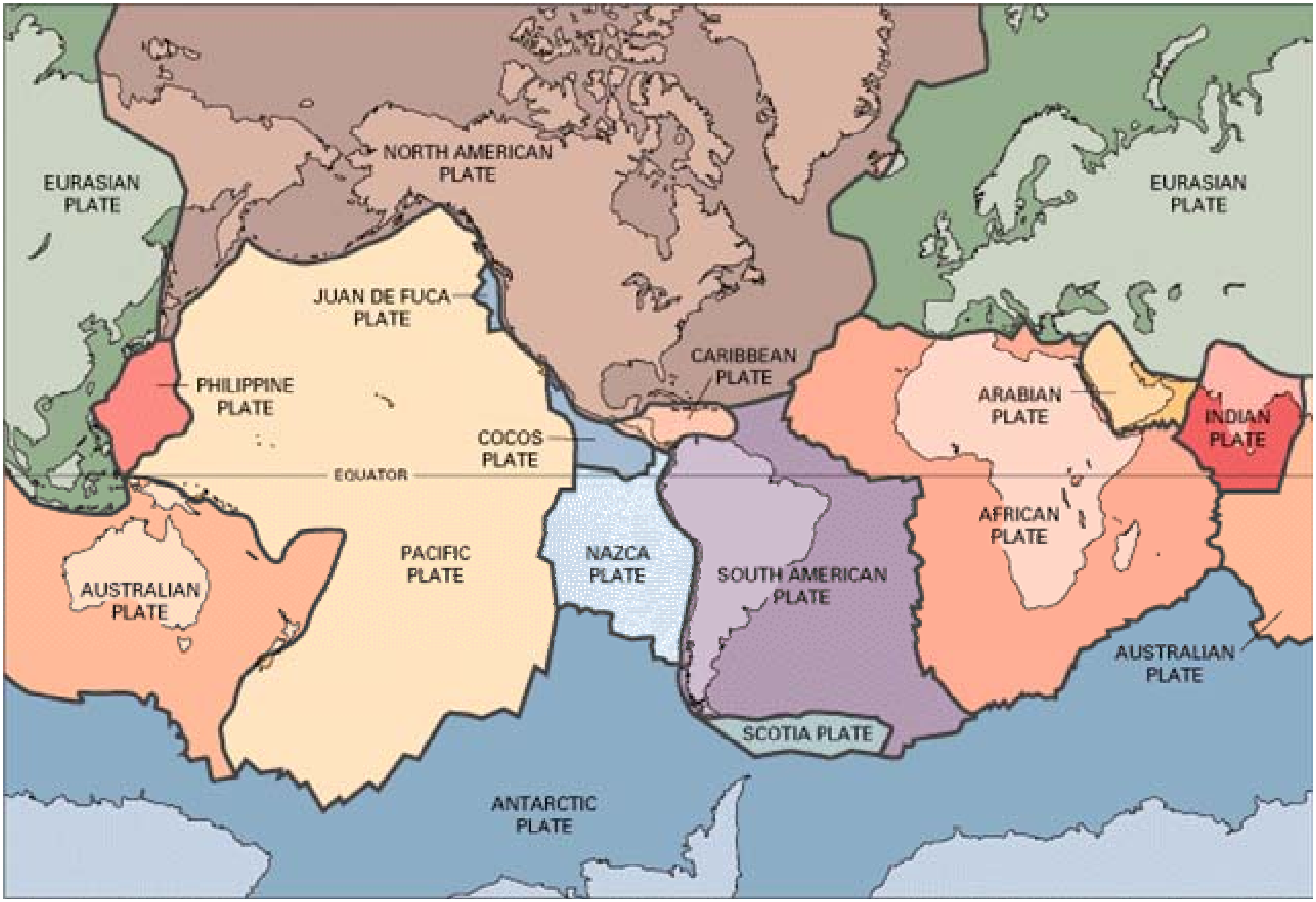
Average Composition of Earth's Crust

Element (Symbol)	Weight percent
Oxygen (O)	46.6
Silicon (Si)	27.7
Aluminum (Al)	8.1
Iron (Fe)	5.0
Calcium (Ca)	3.6
Sodium (Na)	2.8
Potassium (K)	2.6
Magnesium (Mg)	2.1



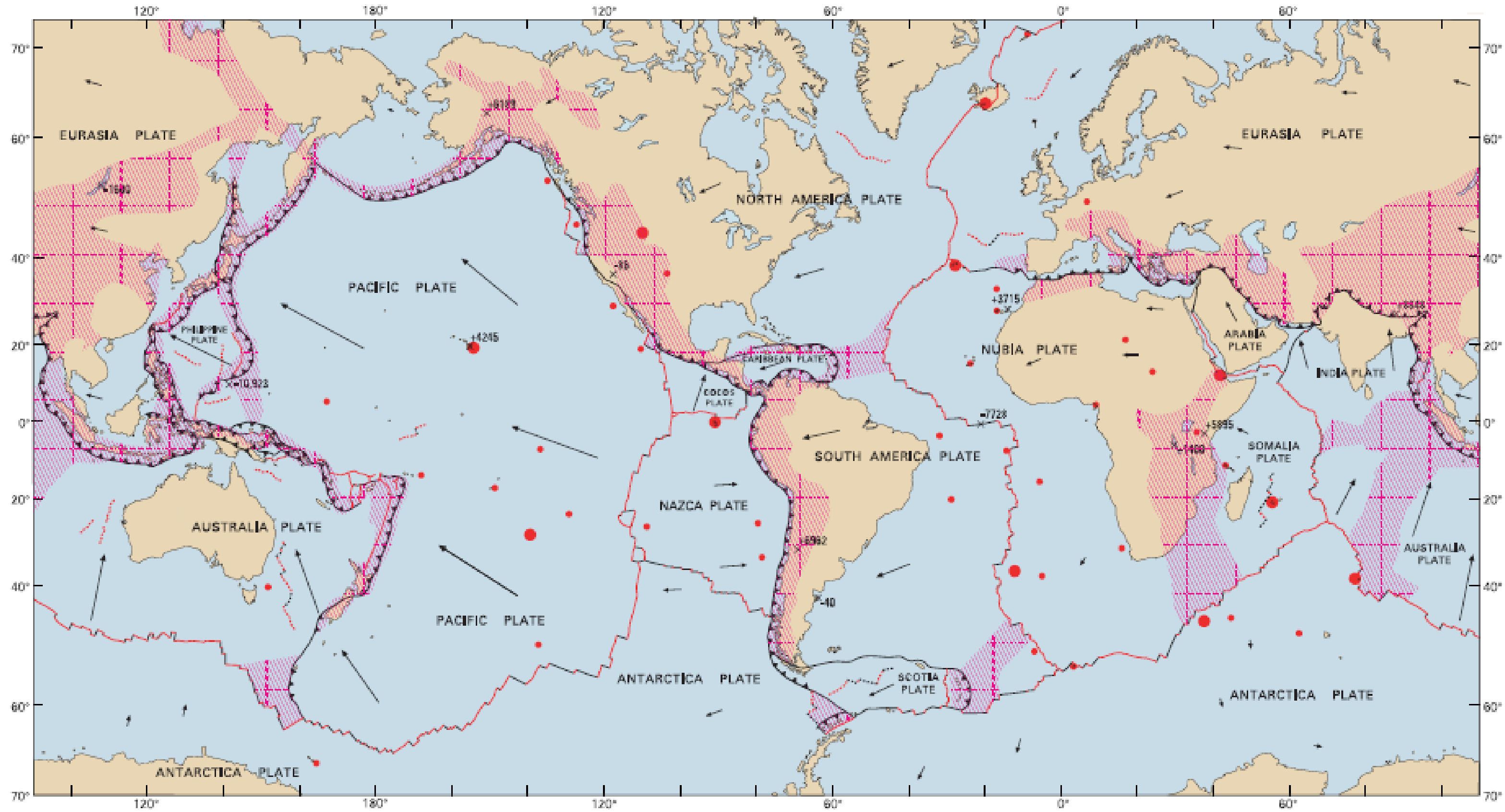
ALLEGHENY COLLEGE DEPT. OF GEOLOGY
MAJOR TECTONIC PLATES OF THE EARTH

Source: Kious and Tilling, 1996, This Dynamic Earth, U.S. Geological Survey, http://pubs.usgs.gov/gip/dynamic/dynamic.html



ALLEGHENY COLLEGE DEPT. OF GEOLOGY
INTERPRETIVE MAP OF PLATE TECTONICS

Source: This Dynamic Planet (U.S. Geological Survey, Smithsonian Institute, U.S. Naval Research Laboratory) http://www.minerals.si.edu/tdpmap/index.htm



INTERPRETIVE MAP OF PLATE TECTONICS

Divergent plate boundary—Where new crust is generated as the plates pull away from each other

Convergent plate boundary—Where crust is recycled as one plate dives under another (in the direction shown by sawteeth)

Transform plate boundary—Where crust is neither produced nor consumed as plates slide horizontally past each other

Selected fossil boundary—Former plate boundary, now inactive; evidence that plate boundaries are not permanent

Diffuse boundary zone—Broad belt in which deformation occurs over a wide region (from Gordon, 2000); may encompass one or more smaller plates

Selected hotspots—Larger symbol indicates major hotspot; smaller symbol indicates minor hotspot

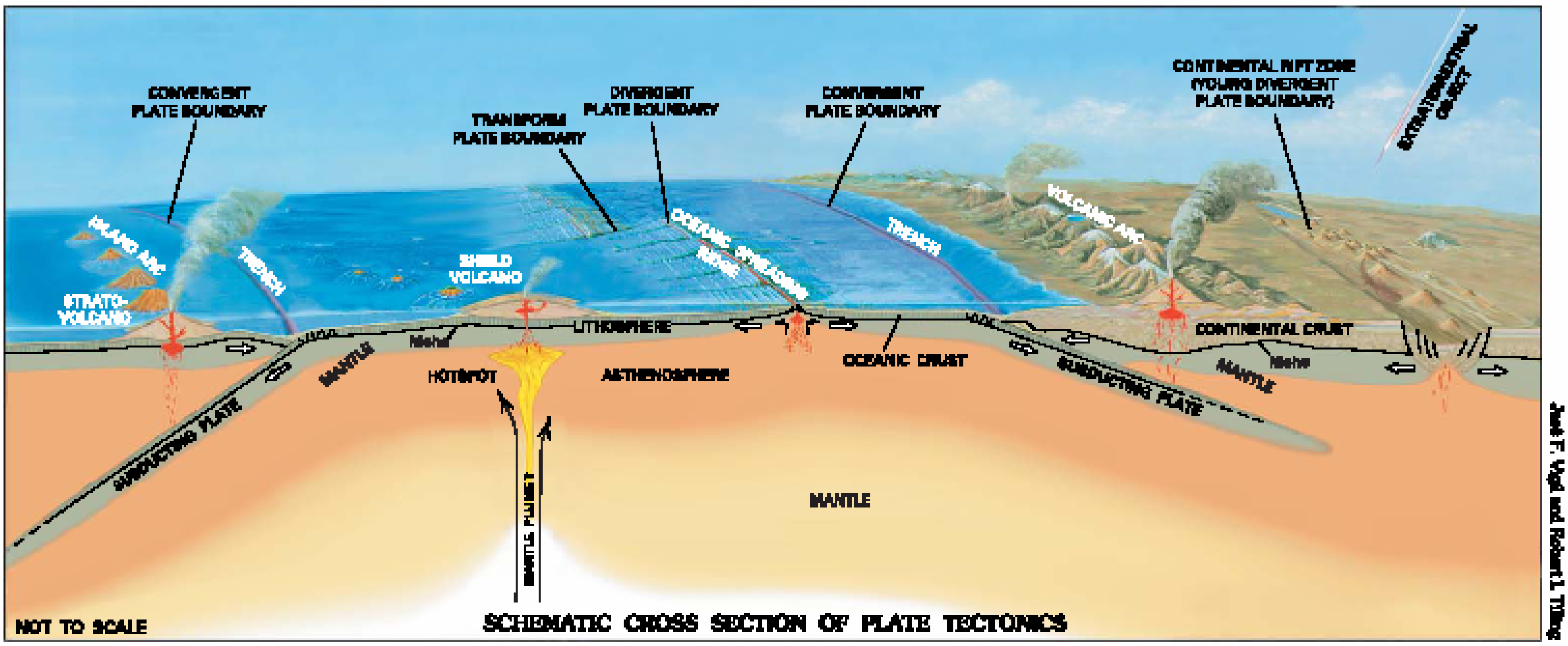
Plate motion—Length of arrow is roughly proportional to the rate of plate motion (longer=faster; see main map for details)

+4245 **Elevation**—Highest (+) and lowest (–) points, in meters, on four largest continents and in two oceans

USGS Smithsonian Institution U.S. Naval Research Laboratory

ALLEGHENY COLLEGE DEPT. OF GEOLOGY
PLATE TECTONIC BOUNDARIES

Geology students need to know the three categories of plate boundaries: convergent, divergent, and transform. In addition, they should understand the variations of these types of boundaries and the associated rock-forming processes of each boundary.



USGS Smithsonian Institution U.S. Naval Research Laboratory

Source: This Dynamic Planet (U.S. Geological Survey, Smithsonian Institute, U.S. Naval Research Laboratory) http://www.minerals.si.edu/tdpmap/index.htm