

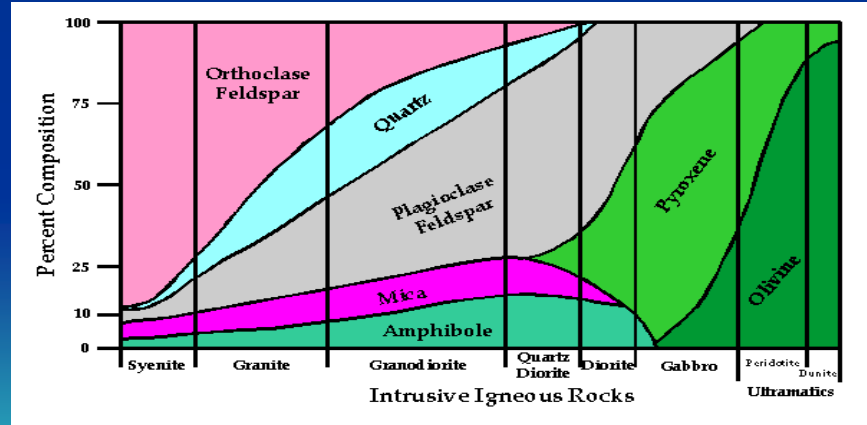


Minerals Laboratory



Intro to Earth Systems ENVI 110 Lab

Ray Rector - Instructor



Preview of Mineral Lab

I. Nature of Minerals

Where are minerals found?

How do minerals form?

What types of minerals are there?

Minerals' relation to rocks?

The common rock-forming minerals?

Determining the density of minerals & rocks



II. The Physical Properties of Minerals

III. Determining the Identify of a Mineral

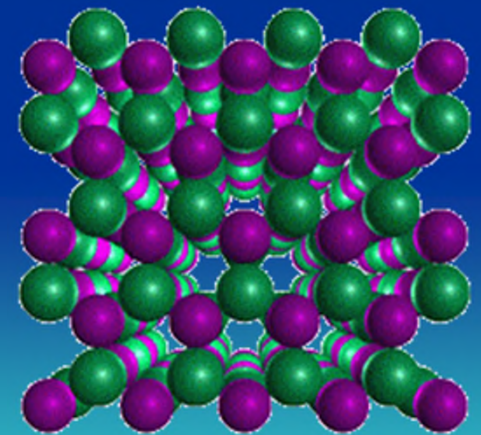
What are Minerals?

Definition: any *naturally-occurring*, homogeneous solid that has a distinctive internal *crystalline* structure, a *definite chemical composition* and a set of *unique physical properties*. Minerals are usually *formed by inorganic processes*.



What Makes Each Mineral Unique?

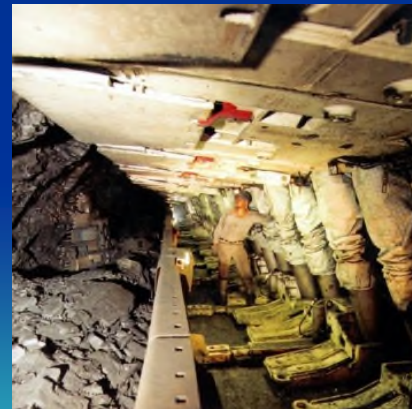
A mineral's *crystal structure* and *chemical composition* together determine the mineral's *unique physical properties*



Where are Minerals Found?

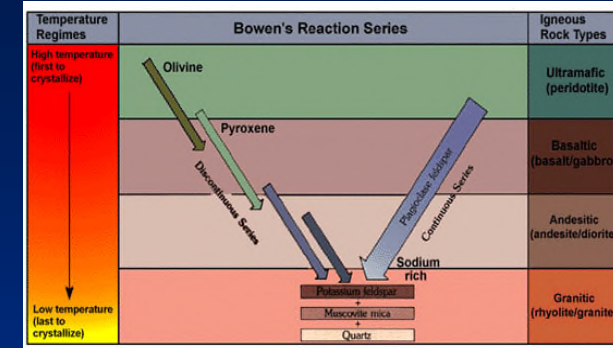
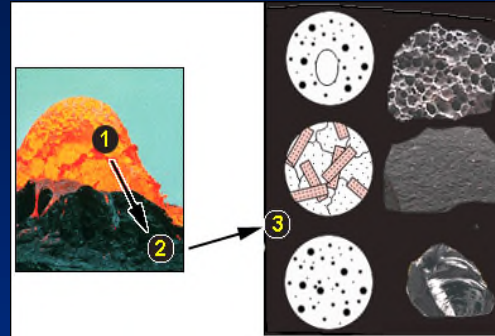
Short Answer = **Everywhere!**

- 1) Igneous Rocks
- 2) Sedimentary Rocks
- 3) Metamorphic Rocks
- 4) Sediment



How do Minerals Form?

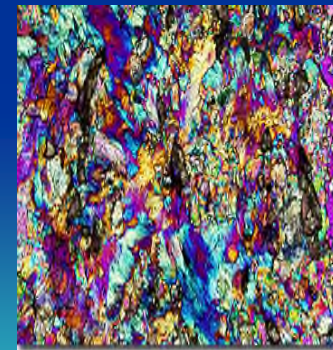
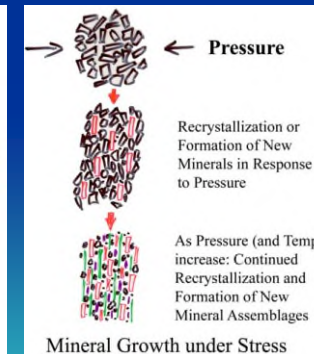
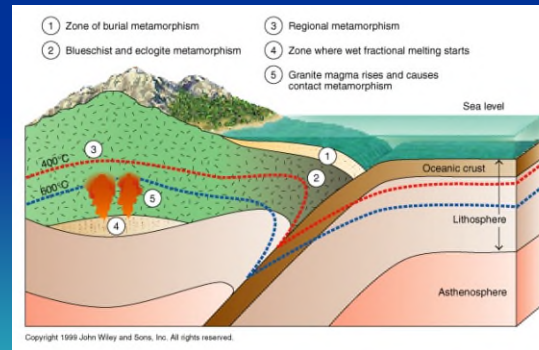
1) Crystallization from a cooling magma or lava



2) Crystallization from aqueous solutions



3) Crystallization from preexisting minerals



Bowen's Reaction Series

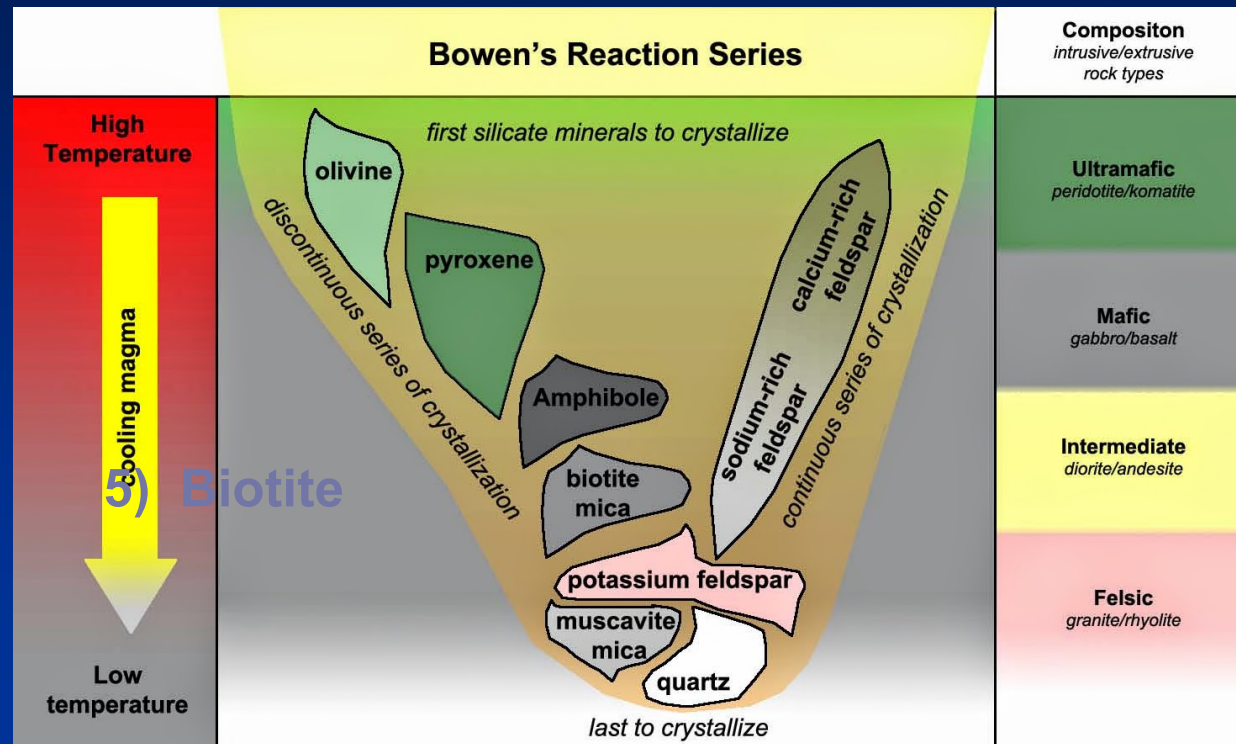
Common Igneous Rock-forming Minerals Crystallizing from a Magma

Mafic, Higher-Temp Minerals

- 1) Ca-Plagioclase
- 2) Olivine
- 3) Augite (pyroxene)
- 4) Hornblende (amphibole)

Felsic/Silicic, Lower-Temp Minerals

- 1) Na-Plagioclase
- 2) Biotite
- 3) Potassium Feldspar
- 3) Quartz
- 4) Muscovite



Types of Rocks

Igneous Rocks

Sedimentary Rocks

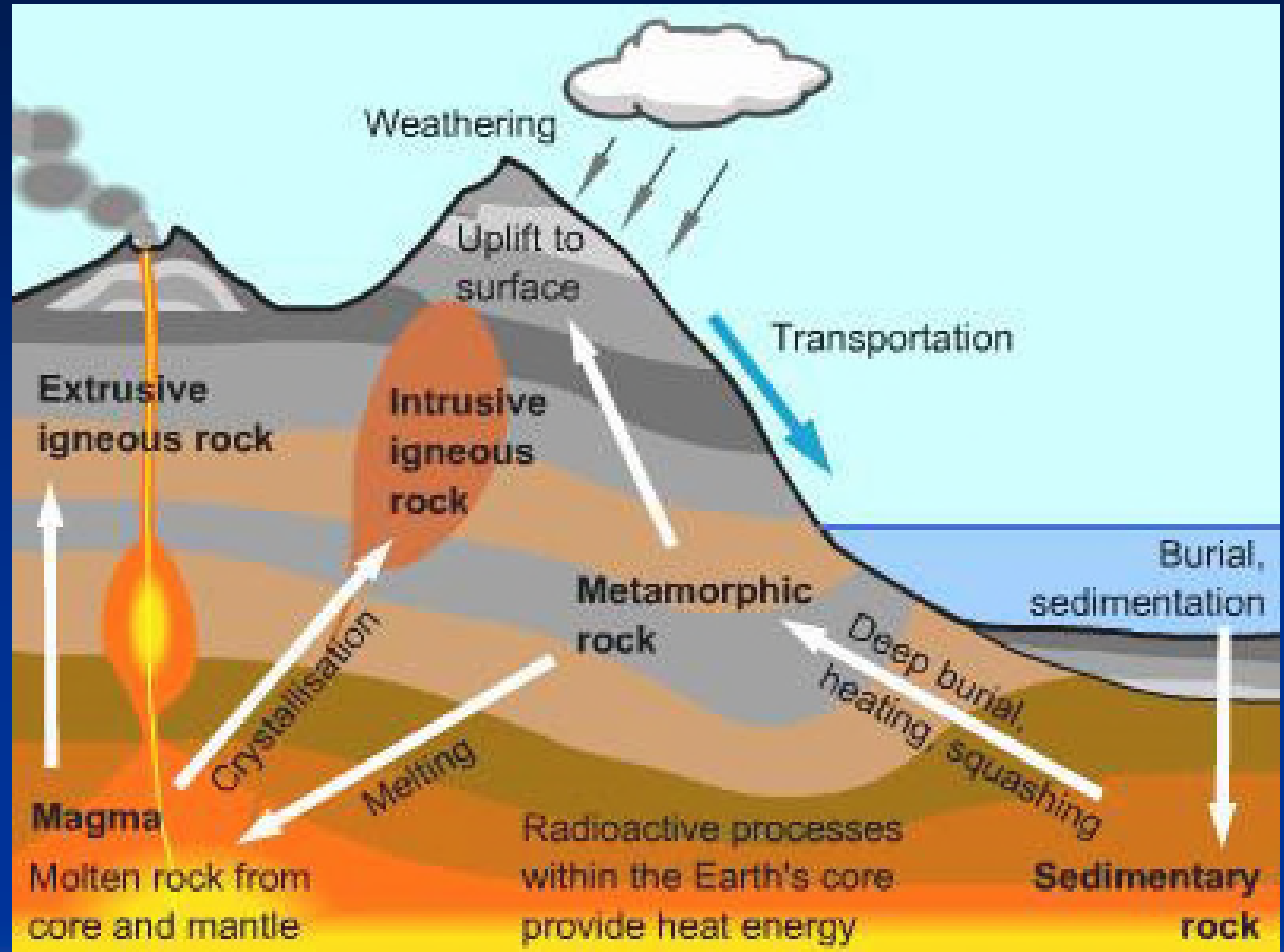
Metamorphic Rocks

Texture	Composition		
	Felsic (Granitic)	Intermediate (Andesitic)	Mafic (Basaltic)
Phaneritic (coarse-grained)	 Granite	 Diorite	 Gabbro
Aphanitic (fine-grained)	 Rhyolite	 Andesite	 Basalt
Porphyritic	 Granite porphyry	 Andesite porphyry	 Basalt porphyry

The Rock Cycle

Three Primary Rock Types

- 1) **Igneous**
- 2) **Metamorphic**
- 3) **Sedimentary**

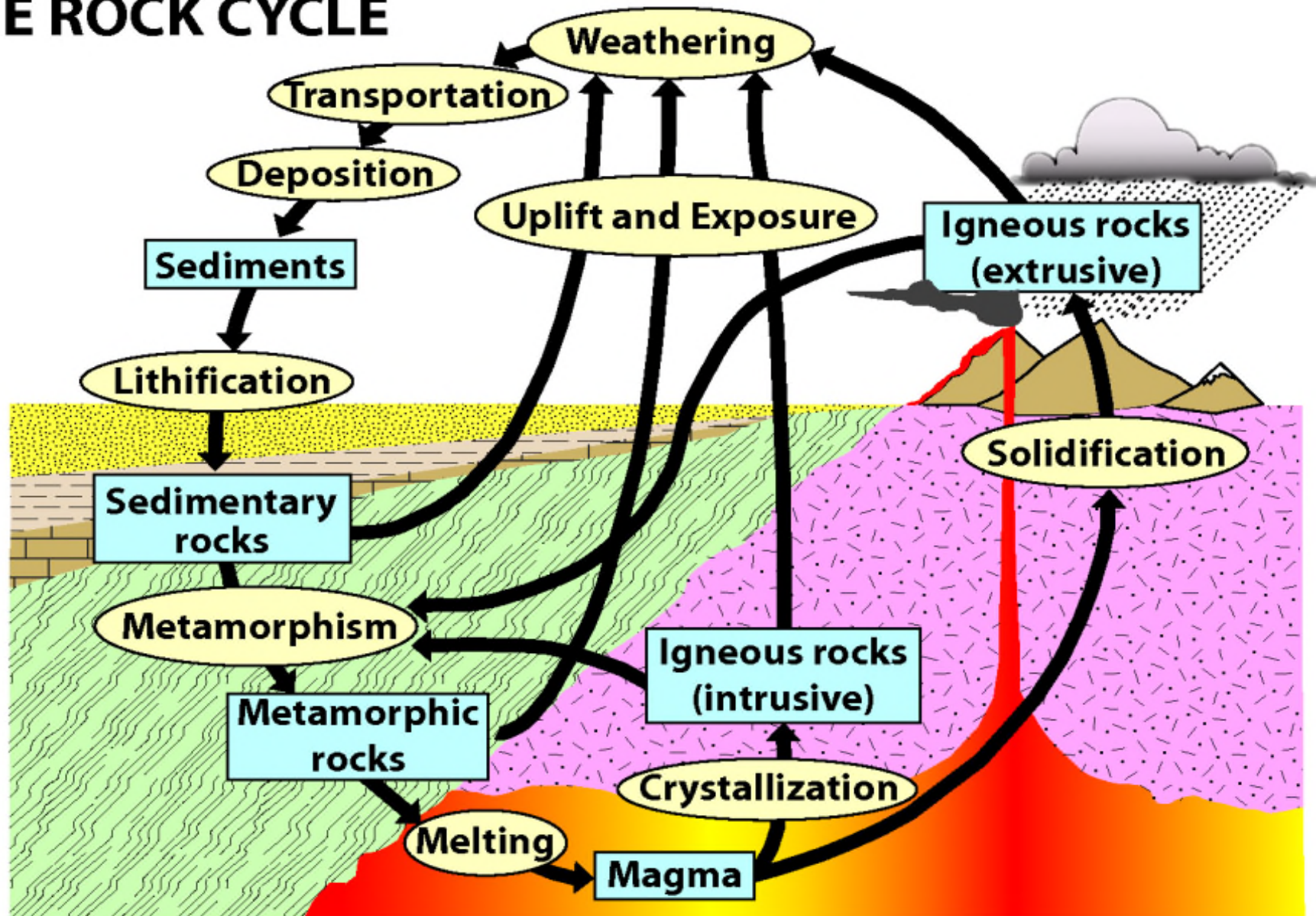


Key Concept:

The Rock Cycle is Perpetuated by Several Major Processes

- 1) Magmatic Activity
- 2) Uplift and Mountain Building
- 3) Weathering, Erosion, Deposition, and Burial of Sediment

THE ROCK CYCLE



Igneous Rocks -

Rocks that form from the cooling of molten rock (magma), Example: granite and basalt

Sedimentary Rocks -

Rocks that are formed from pieces of other rocks, Example: sandstone, or that are deposited from the ocean by chemical processes, Example: limestone

Metamorphic Rocks -

Rocks that are changed by heat and pressure without melting, Example: gneiss

Mineral Density

- 1) Mineral density is an important intensive property
- 2) Mineral density is a function of mineral's mass and volume
- 3) The density of a mineral is a measure of how much mass is present in a given unit of volume.
 - The more mass a substance has per unit volume, the greater the substance's density.
 - The less mass a substance has per unit volume, the lesser the substance's density.

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \quad \text{or} \quad D = \frac{m}{v}$$



Elements - Mass and Density

Periodic Table of Elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																
1	H Hydrogen 1.00794	<div style="display: flex; justify-content: space-between;"> <div style="width: 15%;"> <p>Atomic # Symbol Name Atomic Mass</p> </div> <div style="width: 30%;"> <p>C Solid Hg Liquid H Gas Rf Unknown</p> </div> <div style="width: 45%;"> <table border="1"> <tr> <th colspan="4">Metals</th> <th colspan="2">Nonmetals</th> </tr> <tr> <td rowspan="2">Alkali metals</td> <td rowspan="2">Alkaline earth metals</td> <td>Lanthanoids</td> <td rowspan="2">Transition metals</td> <td rowspan="2">Poor metals</td> <td>Other nonmetals</td> </tr> <tr> <td>Actinoids</td> <td>Noble gases</td> </tr> </table> </div> </div>																	Metals				Nonmetals		Alkali metals	Alkaline earth metals	Lanthanoids	Transition metals	Poor metals	Other nonmetals	Actinoids	Noble gases	2	He Helium 4.002602
Metals				Nonmetals																														
Alkali metals	Alkaline earth metals	Lanthanoids	Transition metals	Poor metals	Other nonmetals																													
		Actinoids			Noble gases																													
2	Li Lithium 6.941	Be Beryllium 9.012182															10	Ne Neon 20.1797																
3	Na Sodium 22.98976928	Mg Magnesium 24.3050															18	Ar Argon 39.948																
4	K Potassium 39.0983	Ca Calcium 40.078	Sc Scandium 44.955912	Ti Titanium 47.867	V Vanadium 50.9415	Cr Chromium 51.9961	Mn Manganese 54.938045	Fe Iron 55.845	Co Cobalt 58.933195	Ni Nickel 58.6934	Cu Copper 63.546	Zn Zinc 65.38	Ga Gallium 69.723	Ge Germanium 72.64	As Arsenic 74.92160	Se Selenium 78.96	Br Bromine 79.904	Kr Krypton 83.798																
5	Rb Rubidium 85.4678	Sr Strontium 87.62	Y Yttrium 88.90585	Zr Zirconium 91.224	Nb Niobium 92.90638	Mo Molybdenum 95.96	Tc Technetium (97.9072)	Ru Ruthenium 101.07	Rh Rhodium 102.90550	Pd Palladium 106.42	Ag Silver 107.8682	Cd Cadmium 112.411	In Indium 114.818	Sn Tin 118.710	Sb Antimony 121.760	Te Tellurium 127.60	I Iodine 126.90447	Xe Xenon 131.293																
6	Cs Caesium 132.9054519	Ba Barium 137.327	57-71		Hf Hafnium 178.49	Ta Tantalum 180.94788	W Tungsten 183.84	Re Rhenium 186.207	Os Osmium 190.23	Ir Iridium 192.217	Pt Platinum 195.084	Au Gold 196.966569	Hg Mercury 200.59	Tl Thallium 204.3833	Pb Lead 207.2	Bi Bismuth 208.98040	Po Polonium (208.9824)	At Astatine (208.9871)	Rn Radon (222.0176)															
7	Fr Francium (223)	Ra Radium (226)	89-103		Rf Rutherfordium (261)	Db Dubnium (262)	Sg Seaborgium (266)	Bh Bohrium (264)	Hs Hassium (277)	Mt Meitnerium (268)	Ds Darmstadtium (271)	Rg Roentgenium (272)	Uub Ununbium (285)	Uut Ununtrium (284)	Uuq Ununquadium (289)	Uup Ununpentium (288)	Uuh Ununhexium (292)	Uus Ununseptium	Uuo Ununoctium (294)															

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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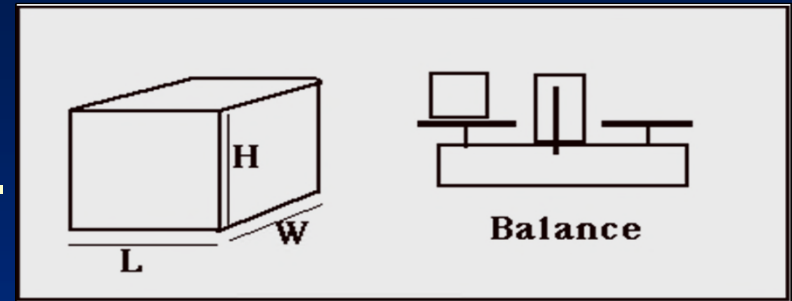


La Lanthanum 138.90547	Ce Cerium 140.116	Pr Praseodymium 140.90766	Nd Neodymium 144.242	Pm Promethium (145)	Sm Samarium 150.36	Eu Europium 151.964	Gd Gadolinium 157.25	Tb Terbium 158.92535	Dy Dysprosium 162.500	Ho Holmium 164.93032	Er Erbium 167.259	Tm Thulium 168.93421	Yb Ytterbium 173.054	Lu Lutetium 174.9668
Ac Actinium (227)	Th Thorium 232.03806	Pa Protactinium 231.03588	U Uranium 238.02891	Np Neptunium (237)	Pu Plutonium (244)	Am Americium (243)	Cm Curium (247)	Bk Berkelium (247)	Cf Californium (251)	Es Einsteinium (252)	Fm Fermium (257)	Md Mendelevium (258)	No Nobelium (259)	Lr Lawrencium (262)

Determining Material Densities

Metal and Wood Block Densities:

- 1) Determine Mass (grams) with flattop scale.
- 2) Determine Volume (cubic cm) with ruler
 - ✓ Length x height x width
- 3) Only measure the thick redwood block and oak blocks

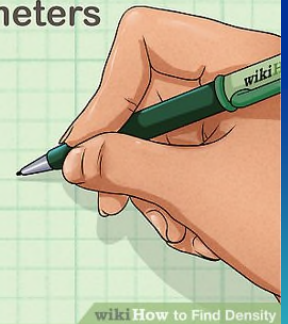


$$\text{Density} = \frac{\text{mass}}{\text{volume}} \quad \text{or} \quad D = \frac{m}{v}$$

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

For a 20-gram mass that takes up a volume of 5 cubic centimeters

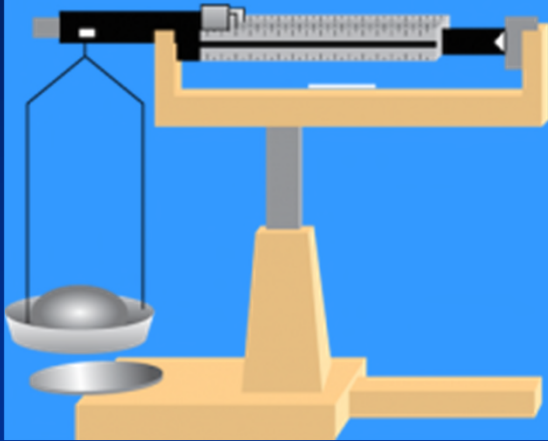
$$\begin{aligned} \text{density is: } & \frac{20}{5} \text{ gm/cm}^3 \\ & = 4 \text{ gm/cm}^3 \end{aligned}$$



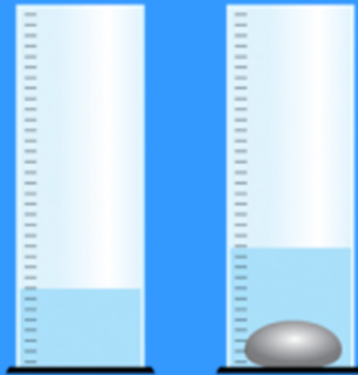
wiki How to Find Density

Determining Rock Sample Density

A Determine mass of sample with balance.



B Determine volume with graduated cylinder.



C Calculate density.

$$\frac{\text{mass}}{\text{vol}} = \frac{\text{g}}{\text{cm}^3} = \text{density}$$

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

For a 20-gram mass that takes up a volume of 5 cubic centimeters

$$\begin{aligned} \text{density is: } & \frac{20}{5} \text{ gm/cm}^3 \\ & = 4 \text{ gm/cm}^3 \end{aligned}$$



Rock Densities:

- 1) Determine Mass (grams) with flattop scale
- 2) Determine Volume (cubic cm) with graduated cylinder
 - ✓ Displacement method
- 3) Calculate Density by Dividing Mass by Volume

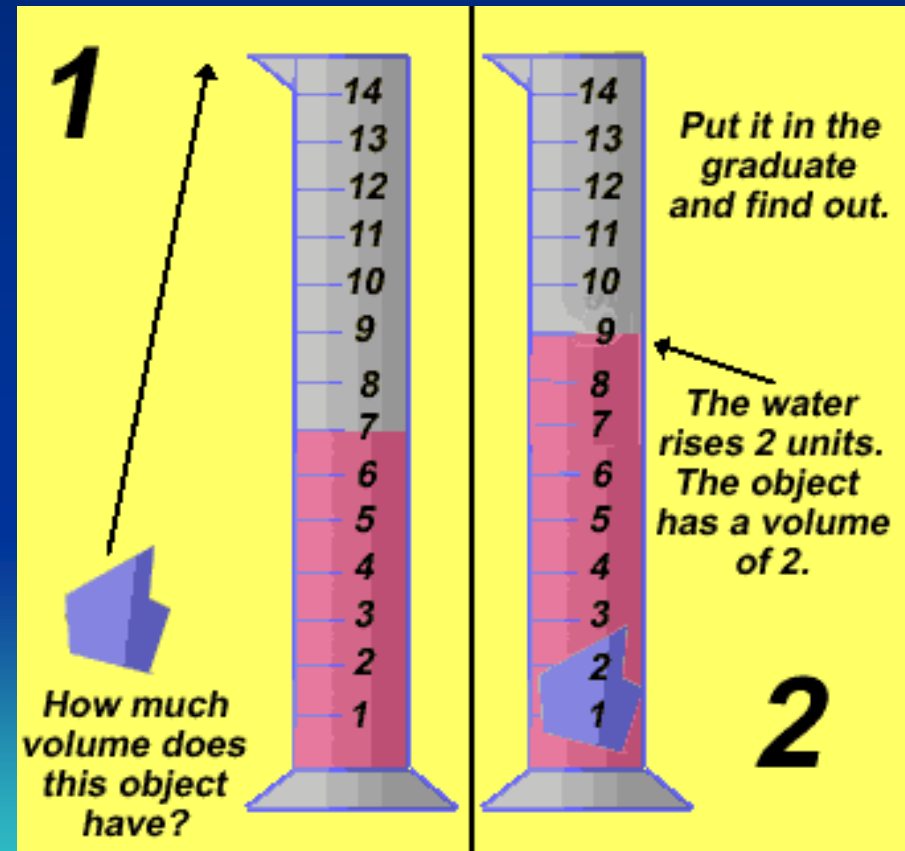


The Water Displacement Method

- 1) Useful for determining the volume of irregular solid objects.
- 2) You need a graduated cylinder and water.
- 3) An object's volume will displace an equal volume of water in the graduated cylinder.

The Lab Model:

- 1) Dark Rock as Ocean Crust
- 2) Light Rock as Continental Crust



Suspended Immersion Method

Step 1 – Weigh dry rock sample

Step 2 – Fill 300 ml beaker with $\frac{3}{4}$'s full of water and weigh

Step 3 – Place dry rock sample (in mesh bag) into beaker and reweigh

Step 4 – Place bag with rock in beaker of water and reweigh

Step 5 – Calculate difference in weights = equals the sample volume

Step 6 - Calculate the density of the sample by dividing the sample mass (in g) by the volume (in cm^3).



Various Types of Minerals

- ✓ Over 4000 Species
- ✓ Grouped into Categories
- ✓ Silicate group is by far the largest and most important mineral group
- ✓ Only about 20 minerals make up 95%+ of all rocks
- ✓ Minerals are identified by their Chemical and Physical Properties



Common Rock-Forming Minerals

- 1) Quartz
- 2) Na- Plagioclase
- 3) Ca- Plagioclase
- 4) K-Feldspar
- 5) Hornblende (amphibole)
- 6) Augite (pyroxene)
- 7) Olivine
- 8) Tourmaline
- 9) Garnet
- 10) Biotite
- 11) Muscovite
- 12) Chlorite
- 13) Kaolin (clay)
- 14) Calcite
- 15) Dolomite
- 16) Gypsum
- 17) Halite
- 18) Magnetite
- 19) Hematite
- 20) Limonite
- 21) Pyrite
- 22) Epidote
- 23) Serpentine



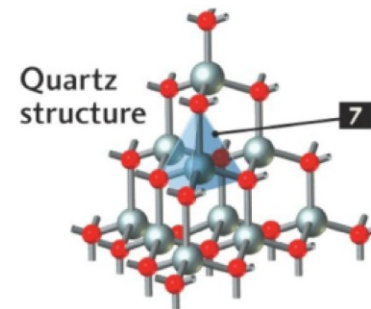
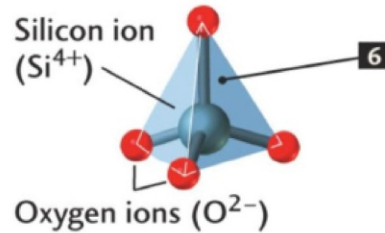
Most of the Common Rock-Forming Minerals are Silicates

Rock-Forming Minerals

- ◆ Clay
- ◆ Quartz
- ◆ Calcite
- ◆ Olivine
- ◆ Dolomite
- ◆ Pyroxene
- ◆ Amphibole
- ◆ Biotite, Muscovite Micas
- ◆ Orthoclase, Plagioclase Feldspars

Although there are very many rock types, they are mainly built from one or more of 11 rock-forming minerals. Others are uncommon to rare.

Silicate ion (SiO_4^{4-})



Isolated tetrahedra



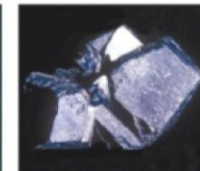
Olivine

Single chains



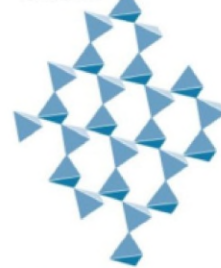
Pyroxene

Double chains



Amphibole

Sheet



Muscovite

Framework



Feldspar

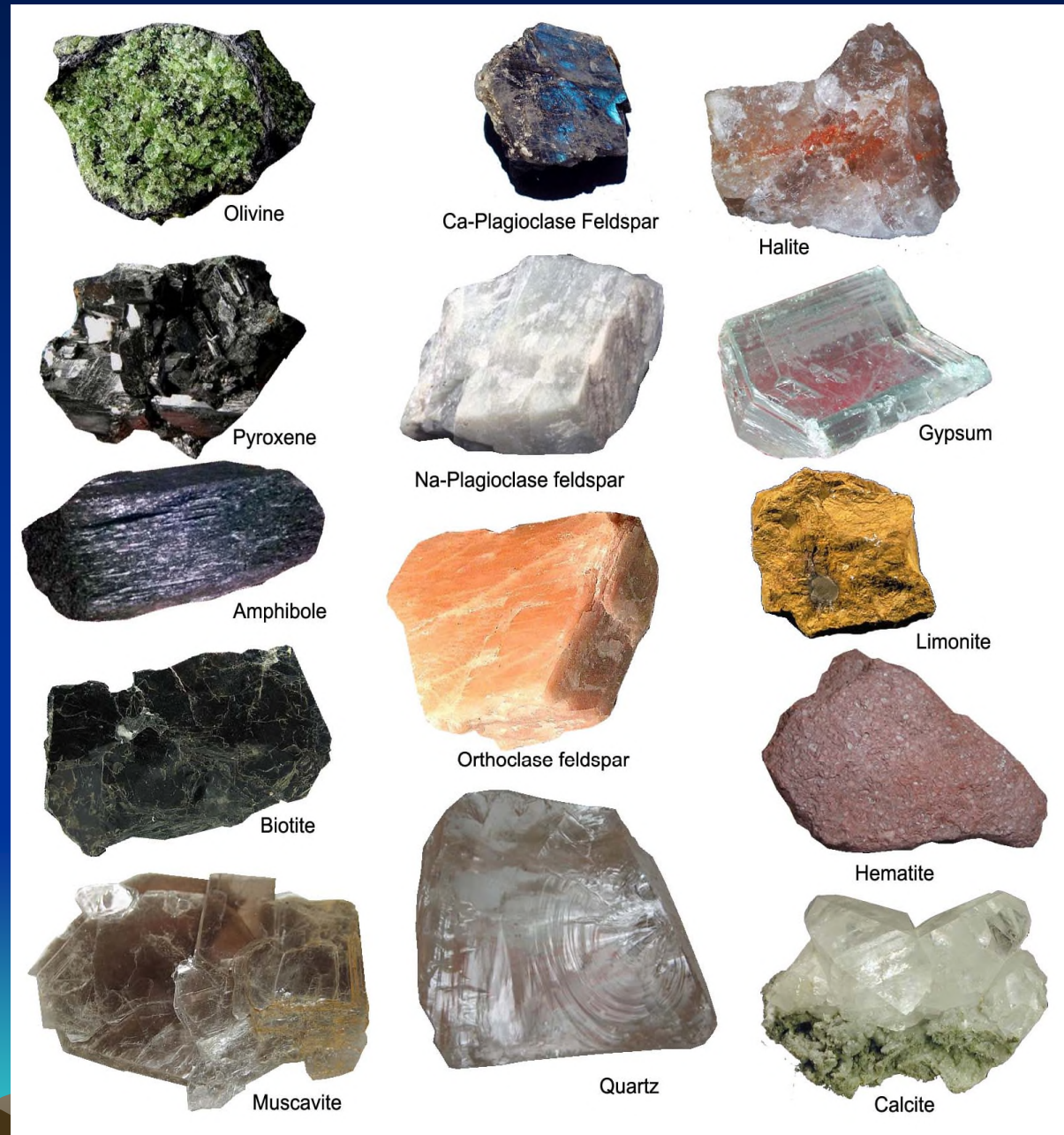
Common Rock-Forming Minerals by Color

Dark-Colored Minerals

- 1) Ca-Plagioclase
- 2) Hornblende (amphibole)
- 3) Augite (pyroxene)
- 4) Olivine
- 5) Biotite

Light-Colored Minerals

- 1) Na-Plagioclase
- 2) Potassium Feldspar
- 3) Quartz
- 4) Muscovite
- 5) Calcite
- 6) Gypsum



Mineral Reference Samples



Mineral Reference Samples



Important Mineral ID Properties

1) Crystal Form & Habit

2) Luster

3) Color

4) Hardness

5) Cleavage

6) Other properties

- Specific Gravity
- Streak
- Reaction to acid
- Magnetic
- Taste



Mineral Habit

Defined:

Characteristic external habit or shape of an individual crystal or groups of crystals

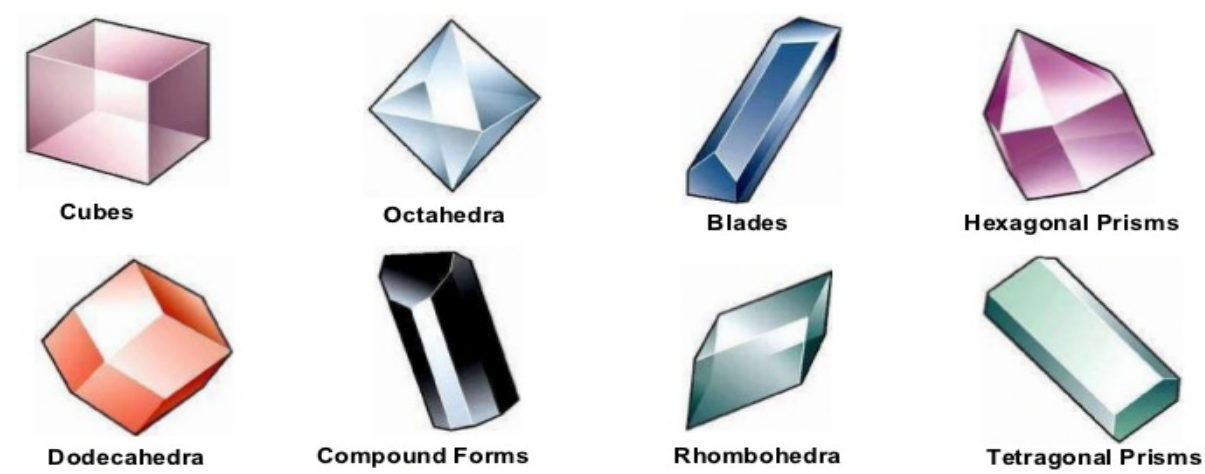
Crystal habit is divided into several categories, based on:

- Internal crystal structure
- External crystal shape

Habit is useful for mineral ID

Crystal Habit

- Crystal habit is the ideal shape of crystal faces.
- Ideal faces require ideal growth conditions.
- Many descriptive terms are used to characterize habit.



Essentials of Geology, 3rd edition, by Stephen Marshak | Chapter 3: Patterns in Nature: Minerals

						
Isometric	Hexagonal	Tetragonal	Trigonal	Orthorhombic	Monoclinic	Triclinic
						
Isometric	Hexagonal	Tetragonal	Trigonal	Orthorhombic	Monoclinic	Triclinic

Mineral Luster

Defined: The quality of reflected light emitted by a mineral crystal

Luster can be divided into two useful categories:

- Metallic and Nonmetallic

Nonmetallic lusters can be further subdivided into:

- Glassy, Pearly, Waxy, and Dull

Luster is useful for mineral ID



Mineral Streak

Defined: The color of the crushed powder of a mineral left on a porcelain plate

✓ Very useful for determining the metallic minerals

✓ Only works is mineral has lower hardness than the streak plate

✓ Only useful for the metallic minerals



Mineral Color

Defined: The hue and shade of the reflected light emitted by a mineral crystal

Mineral color can be divided into two useful shade categories:

- Dark-colored and Light-colored

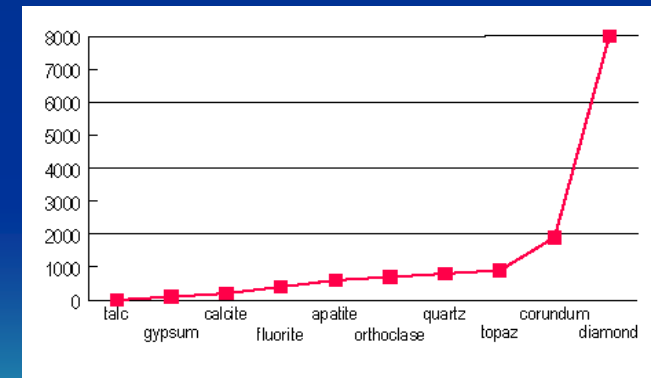
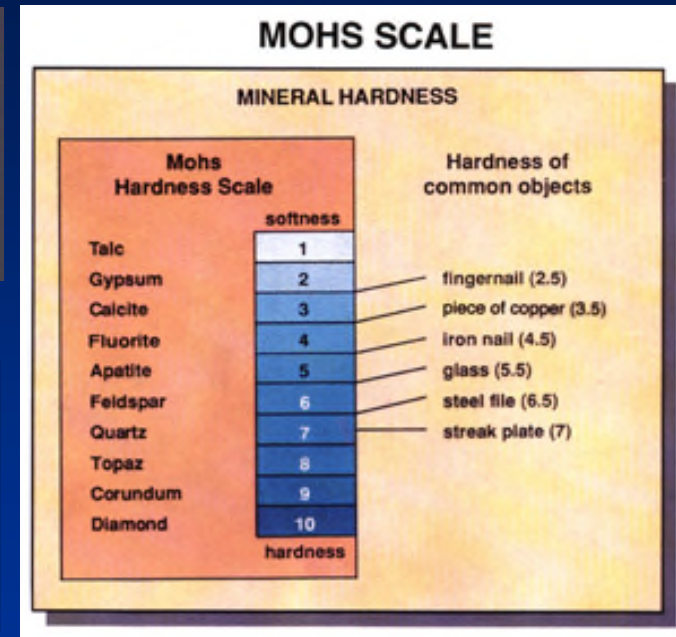
Color can also be divided into the hue categories:

- White, Gray, Black, Red, Orange, Yellow, Green, Blue, Purple, etc.
- Color is useful for mineral ID



Mineral Hardness

- ✓ Mohs Hardness Scale
- ✓ Identify Mineral by Testing for Hardness
- ✓ Doing the Scratch Test
- ✓ Other Testing Objects



Mineral Cleavage

Defined: Geometric planes of inherent weakness through a mineral crystal

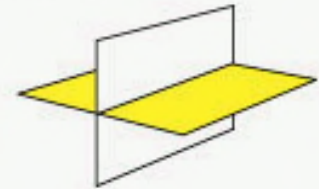
- ✓ Each mineral has a unique identifying cleavage property
- ✓ A mineral has either none, one, two, four, or six sets of cleavage
- ✓ Cleavage is observed as shiny parallel planes on the surfaces of a mineral crystal



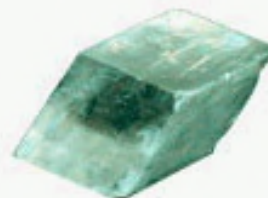
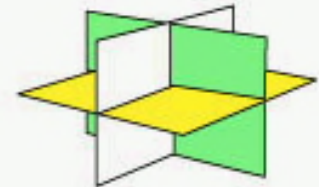
Cleavage in one direction. Example: MUSCOVITE



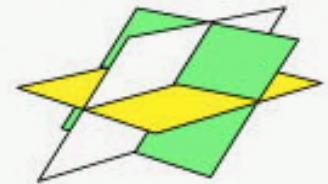
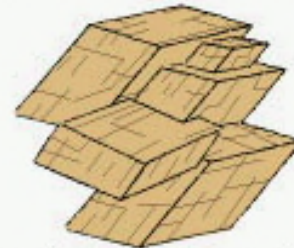
Cleavage in two directions. Example: FELDSPAR



Cleavage in three directions. Example: HALITE



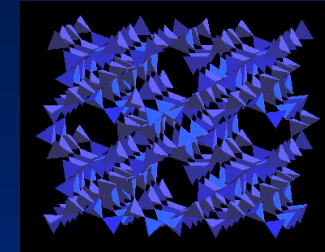
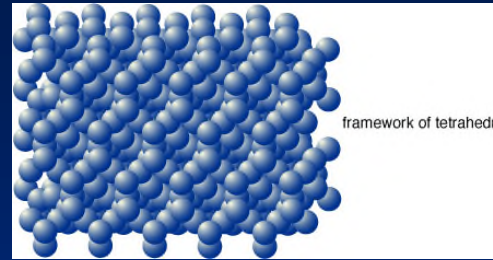
Cleavage in two directions. Example: CALCITE



Determining Mineral Cleavage

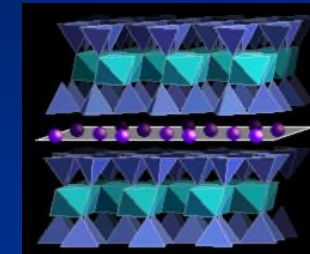
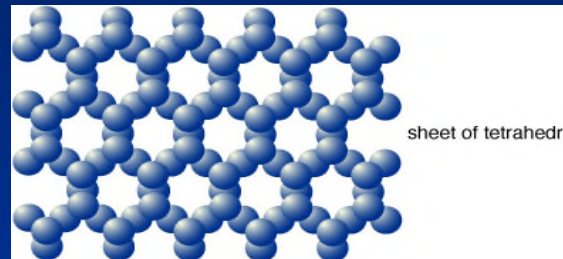
No Cleavage

Example = Quartz



One Set of Cleavage

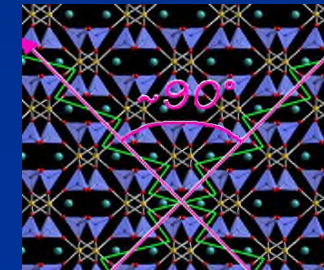
Example = Muscovite



Two Sets of Cleavage

✓ 90 degrees

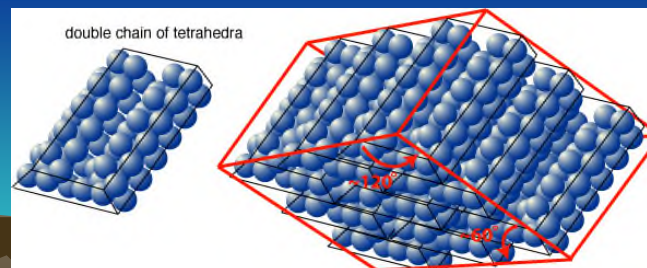
✓ Example = Augite



Two Sets of Cleavage

✓ 120 & 60 degrees

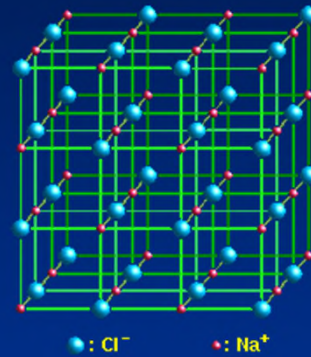
✓ Example = Hornblende



Determining Mineral Cleavage

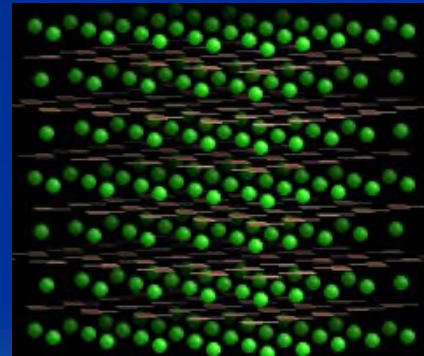
Three Sets of Cleavage

- ✓ 90 degrees
- ✓ Example = Halite



Three Sets of Cleavage

- ✓ 120 & 60 degrees
- ✓ Example = Calcite



Reaction to Acid – The “Acid” Test

Defined: Some minerals react to acid solution (HCl) - they start to bubble and dissolve

✓ Good for determining the **carbonate** minerals

✓ Use the acid test only if you think that your unknown mineral has low hardness – close to 3.

✓ Typically either calcite or dolomite



Magnetism – The “Magnet” Test

Defined: Some minerals are magnetic – some weakly, some strongly. A magnet will stick to a magnetic mineral.

✓ Good for determining the certain ***magnetite and hematite***

✓ Need a hand-held magnet.



Fluorescence— The “Black-light” Test



Defined: Some minerals fluoresce under ultraviolet light.

- ✓ Good for determining the certain **ore and gem** minerals
- ✓ Need a hand-held black-light instrument.

Distinguishing Between K-Feldspar and Plagioclase



Potassium Feldspar

- ✓ Salmon pink to cream colored
- ✓ Wavy “flame-like” streaks



Plagioclase Feldspar

- ✓ Dark grey to off-white colored
- ✓ Sets of thin, straight, groove-like striations on some cleavage faces

Density of Minerals

- 1) Density is an important physical property of minerals and rocks
- 2) Density is a function of a substance's mass and volume
- 3) The density of a substance is a measure of how much mass is present in a given unit of volume.

- The more mass a substance has per unit volume, the greater the substance's density.
- The less mass a substance has per unit volume, the lesser the substance's density.

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \quad \text{or} \quad D = \frac{m}{v}$$

- 4) Gravity controls the weight of a given volume of a substance, based on the substance's density
 - The more dense the material, the heavier it weighs.
 - The less dense the material, the less it weighs.

Mineral and Rock Density

A mineral's color and density is primarily attributed to its elemental composition:

Abundant lighter elements = Lighter-colored silicate = Lower density

Abundant heavier elements = Darker-colored silicate = Higher density

A rock's density is controlled by its mineral composition


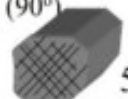







Which is denser? Granite or Gabbro?

Comparison of Common Silicates

SYSTEMATIC CLASSIFICATION OF SILICATE MINERALS

Dr. James Martin-Hayden, EEES-1010

Silicate Structure	Example Mineral	Silica Content (%SiO ₂)	Fe/Mg [‡] Content	Al [†] content	Cleavage ↓ Hardness	Density Color	‡Ferromagnesian †Alluminosilicates
Isolated Silicates	Olivine	~16%	~50%	0%	none  6½	~4 g/cm ³ green	Comprises most of the Mantle
Single Chain Silicates	Pyroxene [#] Group (e.g., Augite)	25-50%	18-26%	0-16% (†)	2 (90°)  5½	~3.3 black	Found in basalt Oceanic Crust with Ca-Plag. [#]
Double Chain Silicates	Amphibole [°] Group (e.g., Hornblende)	50-60%	15-22%	0-9%	2 (120°-60°)  5½	~3.3 black	Found in Continental Crust [°]
Sheet Silicates	Mica Group (e.g., Biotite [°])	39%	18-33%	6%	1 (perfect)  2½	~3.0 black	Found in Continental Crust [°]
	(e.g., Muscovite [°])	39%	0%	20%	Microscopic platelets 	2.6 green or gray	From chemical weathering of silicates [*]
	Clay Group (e.g., Kaolinite)	46%	0%	21%			
Framework Silicates	Feldspar Group , Plagioclase (Na [°] -Ca [#])	43-69%	0%	10-19%	2 (90°)  6	2.6 wht-blk	Ca Plag. [#] in Oceanic Crust
	Orthoclase (K [°])	76%	0%	10%		2.7 pink	Others Contin. [°]
	Quartz (pure SiO₂[°])	100%	0%	0%	none (fracture)  7	2.6 white to gray	Concentrated in Continental Environments

General trends toward bottom: **Increasing SiO₂, Decreasing Fe/Mg, Lighter in density, Lighter in Color**

Other Trends

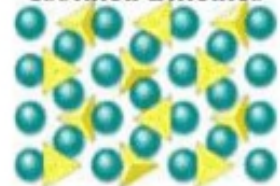
- [#]**Oceanic crust** (basalt) is mostly **pyroxene** and **Ca-plagioclase** (Ca-Feldspar) and thus **more dense** and **dark**.
- [°]**Continental crust** (e.g., granite) contains minerals **rich in silica, low in iron**, and thus **less dense** and **light in color**.

◀ Silicon-oxygen tetrahedron apex toward you

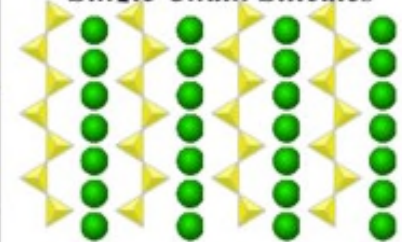
◀ Silicon-oxygen tetrahedron apex away from you

Mg⁺⁺ or Fe⁺⁺

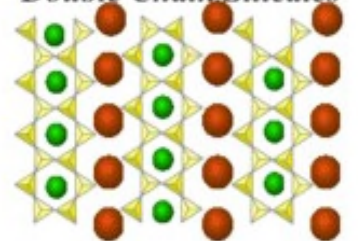
Isolated Silicates



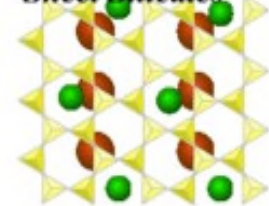
Single Chain Silicates



Double Chain Silicates

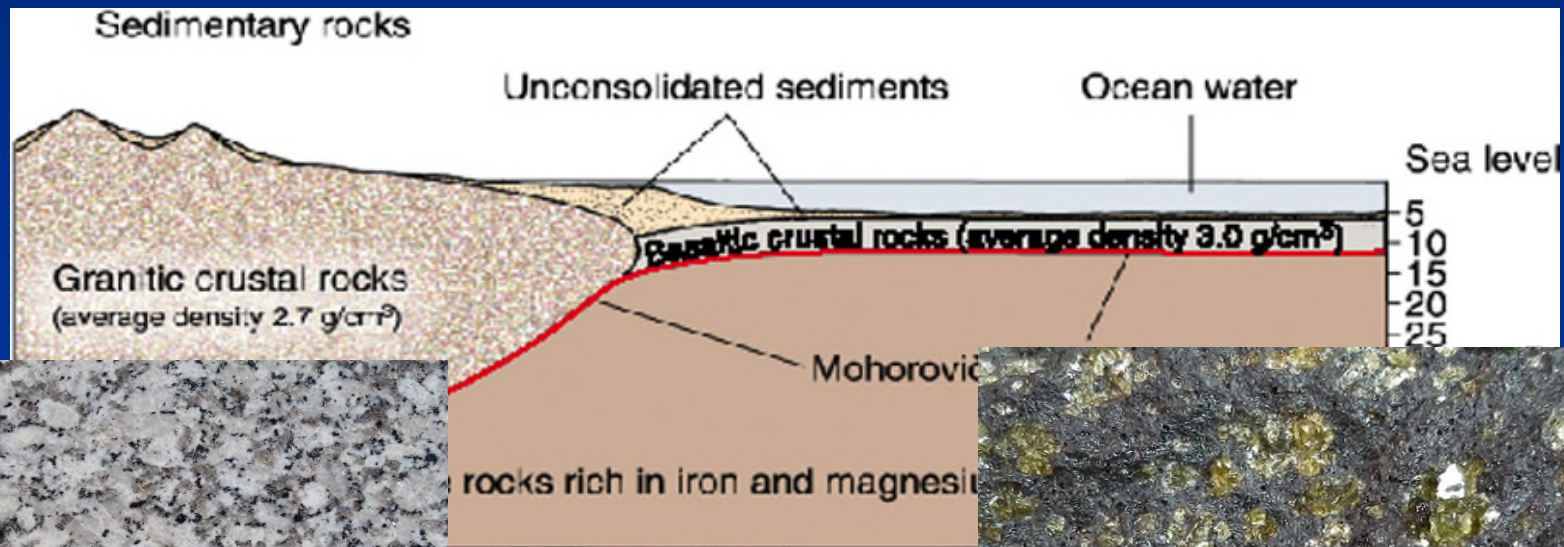


Sheet Silicates

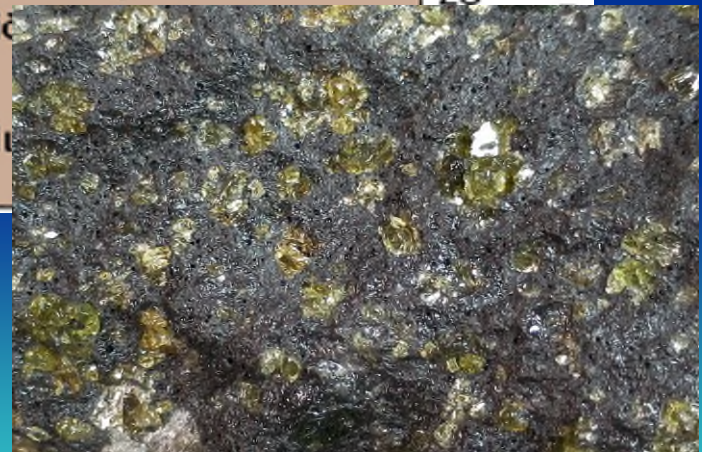


Earth Has Two Types of Crust:

- 1) Less dense, thicker continental crust made up of mainly light-colored granitic (felsic) rocks
- 2) More dense, thinner, oceanic crust made up of mainly dark-colored, basaltic (mafic) rocks



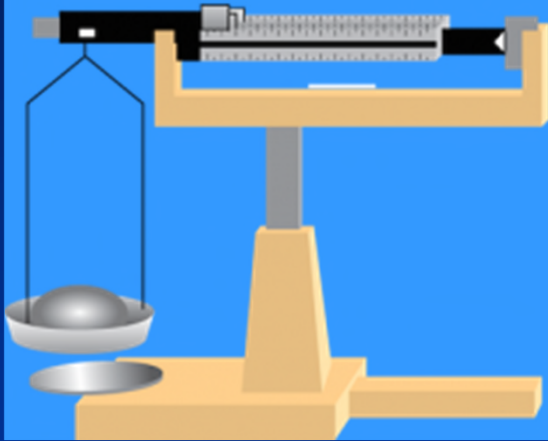
Granite



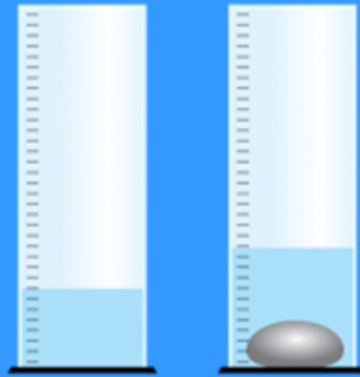
Basalt

Determining Mineral Rock Sample Density

A Determine mass of sample with balance.



B Determine volume with graduated cylinder.



C Calculate density.

$$\frac{\text{mass}}{\text{vol}} = \frac{\text{g}}{\text{cm}^3} = \text{density}$$

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

For a 20-gram mass that takes up a volume of 5 cubic centimeters

$$\begin{aligned} \text{density is: } & \frac{20}{5} \text{ gm/cm}^3 \\ & = 4 \text{ gm/cm}^3 \end{aligned}$$



Procedure to Determine Density:

- 1) Determine Mass (grams) with flattop scale
- 2) Determine Volume (cubic cm) with graduated cylinder
 - ✓ Displacement method
- 3) Calculate Density by Dividing Mass by Volume

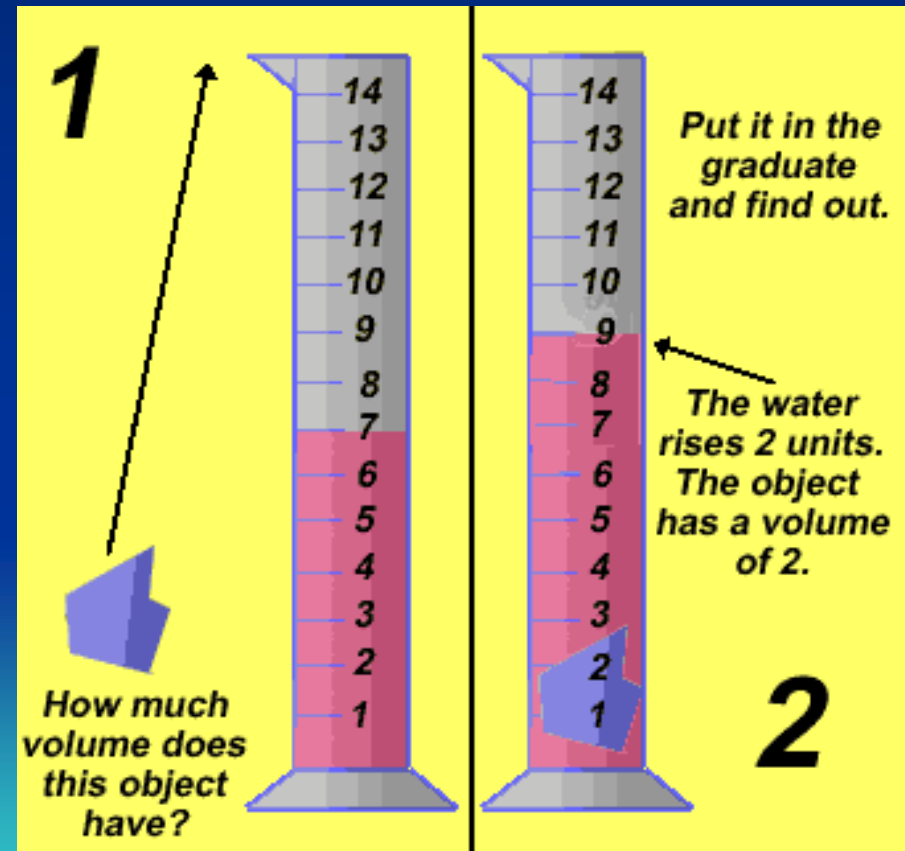


The Water Displacement Method

- 1) Useful for determining the volume of irregular solid objects.
- 2) You need a graduated cylinder and water.
- 3) An object's volume will displace an equal volume of water in the graduated cylinder.

The Lab Model:

- 1) Dark Rock as Ocean Crust
- 2) Light Rock as Continental Crust



Hypothesize on Rock Density Determinations

1) Make a hypothesis on which rock will be denser and which rock will be less dense.

Granite (continental) versus Gabbro (oceanic)?

2) Determine the densities of the two rock types

3) Analyze your results for a conclusion



Mineral Identification Procedure

Step #1 Mineral Luster?

Step #2 Mineral Color? – Light or Dark? Hue?

Step #3 Mineral Hardness?

Step #4 Mineral Cleavage?

Step #5 Other Defining Properties?

Step #6 Mineral Name?



Unknown Minerals

- 1) Pyroxene (hornblende)
- 2) Muscovite
- 3) Plagioclase Feldspar
- 4) Calcite
- 5) Quartz
- 6) Tourmaline
- 7) Halite
- 8) Pyroxene (augite)
- 9) Potassium-Feldspar
- 10) Garnet
- 11) Biotite
- 12) Gypsum
- 13) Olivine



ENVI110 REFERENCE MINERALS

<u>Sample#</u>	<u>luster</u>	<u>color</u>	<u>hardness</u>	<u>cleavage</u>	<u>other</u>	<u>Name the Mineral</u>
T001	_____	_____	_____	_____	_____	Calcite
T002/T037	_____	_____	_____	_____	_____	Ca-Plagioclase/Labradorite
T011	_____	_____	_____	_____	_____	Tourmaline
T013	_____	_____	_____	_____	_____	Garnet
T015	_____	_____	_____	_____	_____	K-spar/Microcline Feldspar
T017	_____	_____	_____	_____	_____	Muscovite mica
T024	_____	_____	_____	_____	_____	Gypsum
T035	_____	_____	_____	_____	_____	Biotite mica
T040	_____	_____	_____	_____	_____	Hornblende amphibole
T044	_____	_____	_____	_____	_____	Olivine
T045	_____	_____	_____	_____	_____	Augite pyroxene
T048	_____	_____	_____	_____	_____	K-spar/Orthoclase Feldspar
T050	_____	_____	_____	_____	_____	Quartz
T051	_____	_____	_____	_____	_____	Na-Plagioclase/Albite