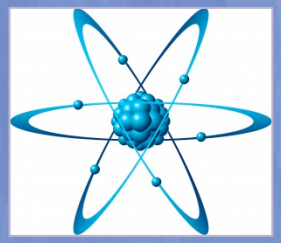
Earth Materials

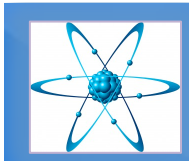


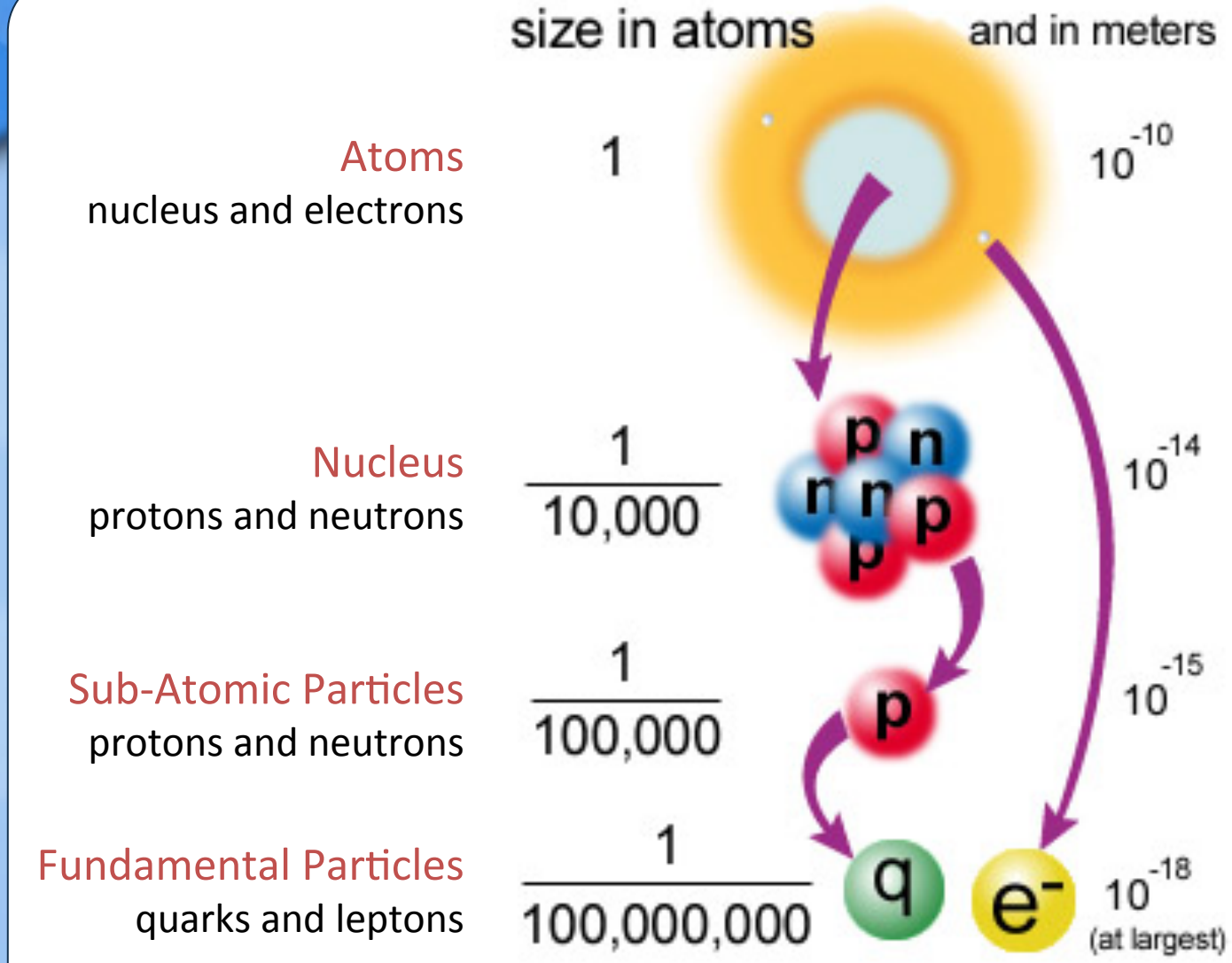
Atoms

http://www.free-pictures-photos.com/

Minerals

Rocks

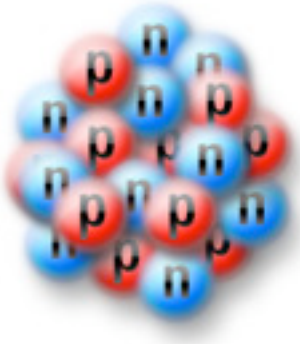




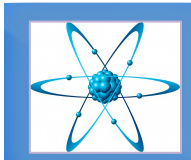
http://particleadventure.org/

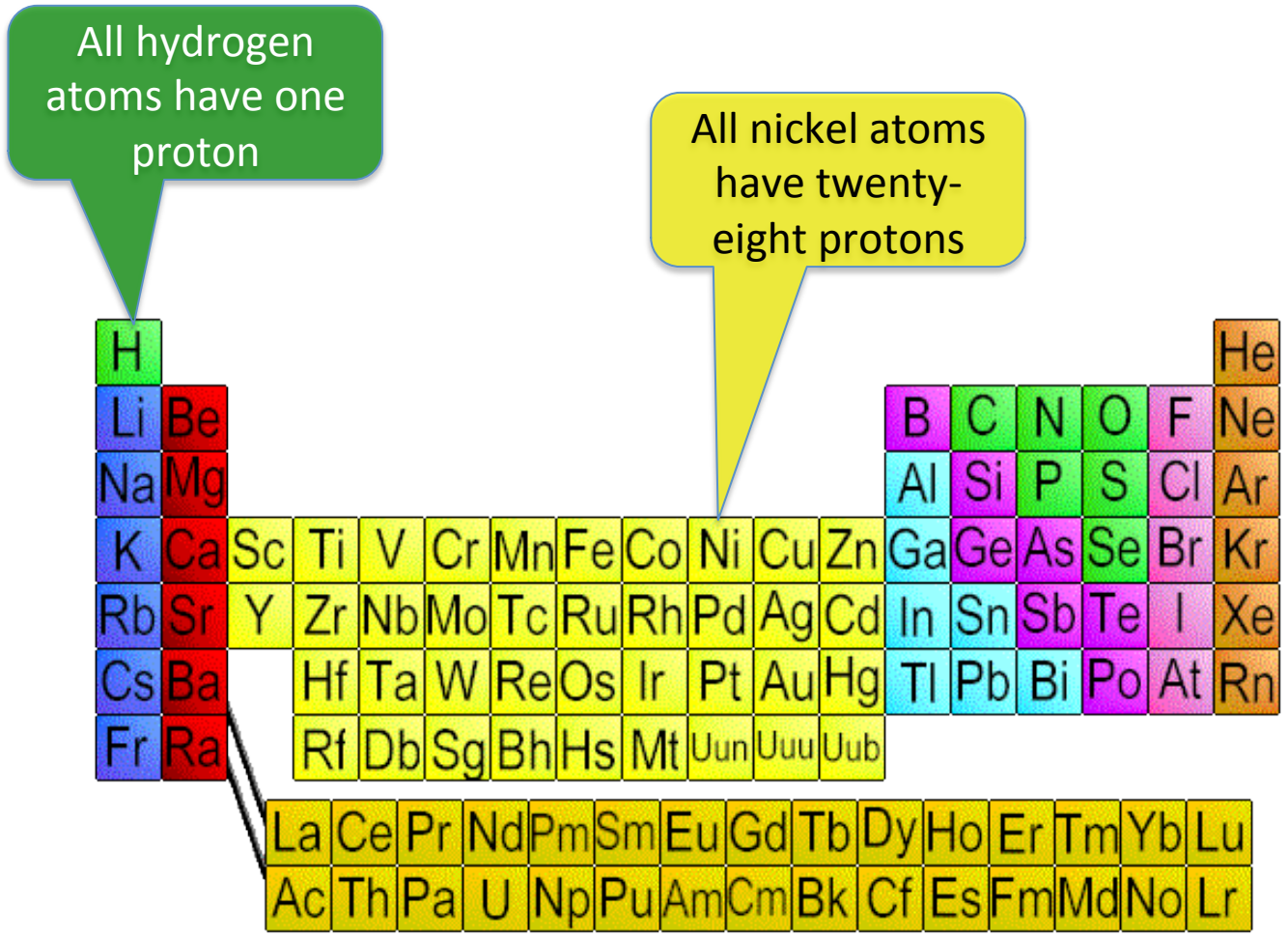
Atoms arethe fundamental particle of chemistry. They are composed of three smaller types of particles

Electrons are negatively charged particles with very little mass that are attracted to the positively charged nucleus of the atom



Protons (positively charged particles) and neutrons (particles with no charge) are bound together in the relatively massive nucleus of the atom.

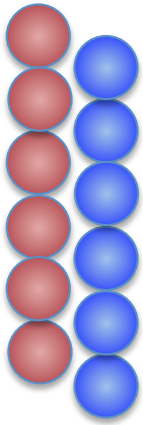




An element name refers to all atoms with the same number of protons in the nucleus.

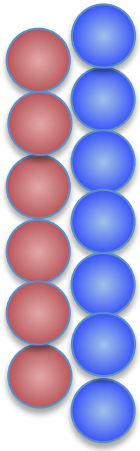
The number of neutrons in the nucleus can vary from atom to atom in an element. These variations, called isotopes, have different atomic weights, and some are not stable, and thus can radioactively decay. The isotopes are chemically identical.

All carbon atoms have six protons



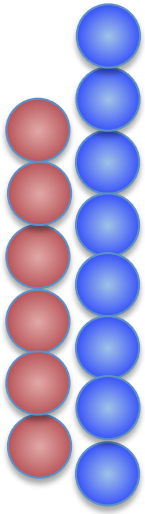
Carbon-12 has 6 neutrons

Stable



Carbon-13 has 7 neutrons

Stable



Carbon-14 has 8 neutrons

UNSTABLE!

Atoms bond together to make molecules, which are described with chemical formulas. Molecular structures can be simple, or very complex.

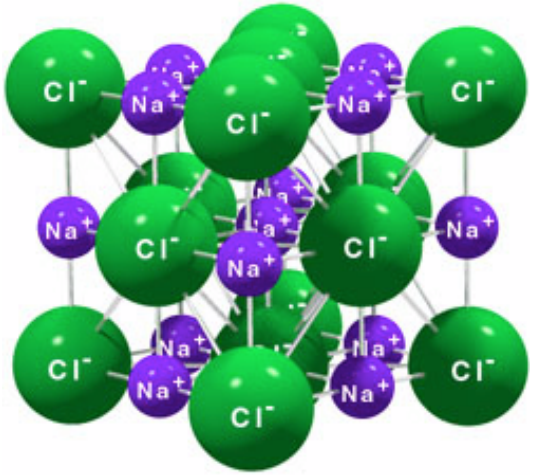
Caffeine

1,3,7-trimethyl-1H-purine-2,6(3H,7H)-dione

$C_8H_{10}N_4O_2$

http://www.mylot.com/w/image/2435174.aspx

Table Salt



Sodium Chloride

NaCl

http://www.chemistry.wustl.edu/~edudev/LabTutorials/Water/PublicWaterSupply/PublicWaterSupply.html

Mineral - A naturally occurring, inorganic, homogeneous solid with a definite chemical composition and an ordered atomic arrangement.

naturally occurring - materials synthesized in laboratory do not count, must be formed by natural processes in wild

inorganic - not formed by organic chemistry (e.g., sugars, etc.)

homogeneous solid - single substance in solid phase which cannot be physically separated into simpler compounds

definite chemical composition - composition can be represented as chemical formula (e.g., NaCl), although variation in exact composition is possible (e.g., $(Mg, Fe)_2SiO_4$)

ordered atomic arrangement – repeating structure at the atomic level, which expresses as symmetry in large specimens, i.e., crystalline structure.

Mineral Formation

Minerals found at the Earth's surface formed from natural processes both within the Earth and at the Earth's surface. Environments vary greatly, and include:

- High temperature and pressure typical of the upper mantle.
- Evaporation basins
- Ocean bottoms
- Volcanic calderas and lava flows
- A host of stressful environments in mountain building zones

And thousands of others!

Mineral Classes

Earth's crust is composed primarily of silicates (>95%)

Earth naturally produces thousands of different minerals, which are classified into 78 mineral classes, including these important groups:

Native Elements – minerals naturally composed of only one element (e.g., diamond, sulfur, gold)

Sulfides and Sulfates – minerals containing SO_4^{-2} or S^{-2} anions (e.g., galena, pyrite, gypsum)

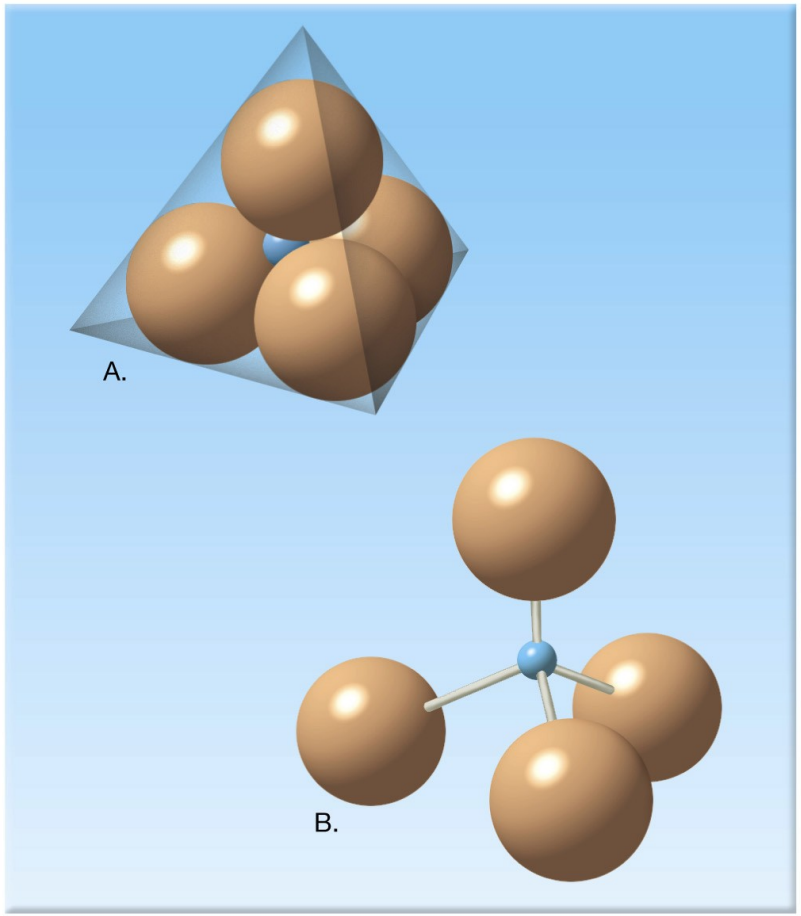
Oxides – minerals containing O^{-2} anions (e.g., hematite, magnetite, rutile)

Silicates – huge family of minerals which all contain some variant of SiO_2 (e.g., quartz, garnets, micas, feldspars, clay minerals).

Carbonates – minerals containing the CO_3 anion (e.g., calcite, barite)

Others – including salts (fluorite, halite), and a several other groups.

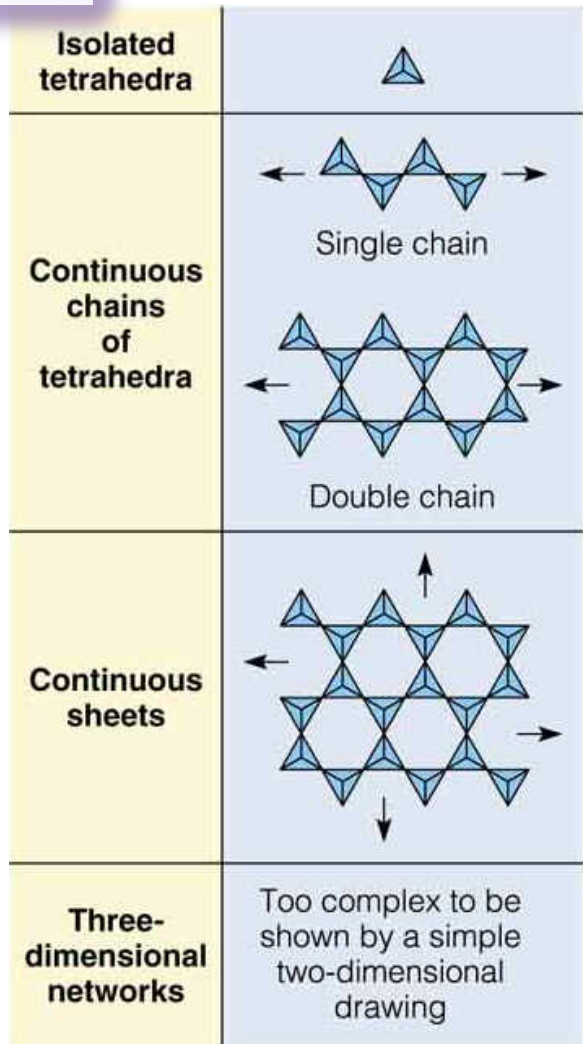
Silicate Minerals



Each silicate mineral is built around a silica tetrahedon – a silicon atom bonded to four oxygen atoms. Aluminum can substitute for silicon in some minerals.

A third of all known minerals on Earth are silicates – including the vast number of clay minerals.

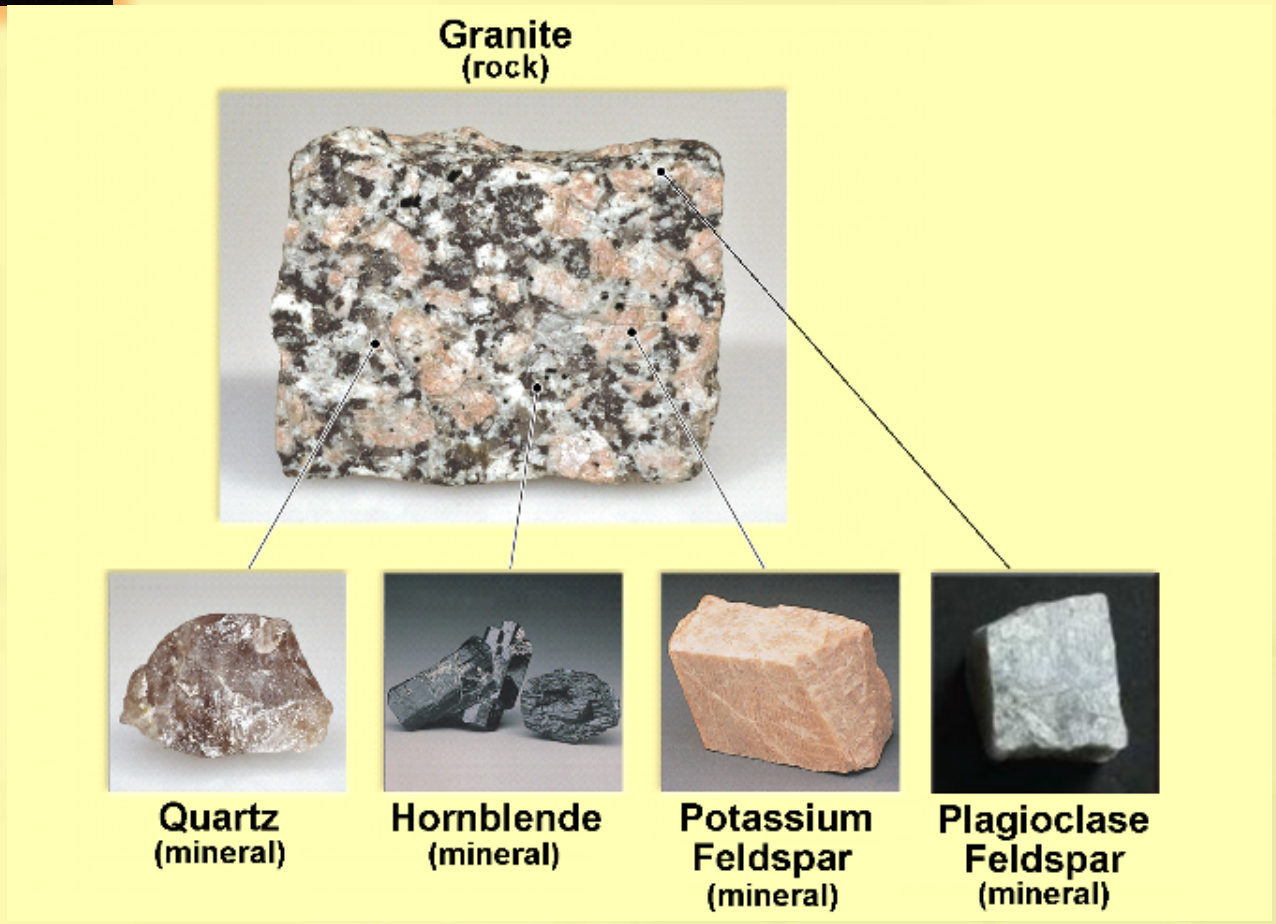
Silicate Minerals



The silica tetrahedra can bond to each other and other molecules to form a very wide range of minerals, from hard, glassy quartz to soft, crumbly kaolin clay.

These minerals are formed in all sorts of different environments on Earth, from the crushing, hot mantle to the top of the highest point on Earth.

Rocks are naturally formed solid aggregates usually (but not always) composed of minerals.



Rocks are classified by their mode of formation. There are three major rock forming processes on Earth, producing three kinds of rocks.

Igneous Rocks

Formed when magma (molten rocks) solidifies

Environment: Hot enough to melt rock, pressure varies

Sedimentary Rocks

All non-igneous rocks formed by processes acting on the surface of the Earth

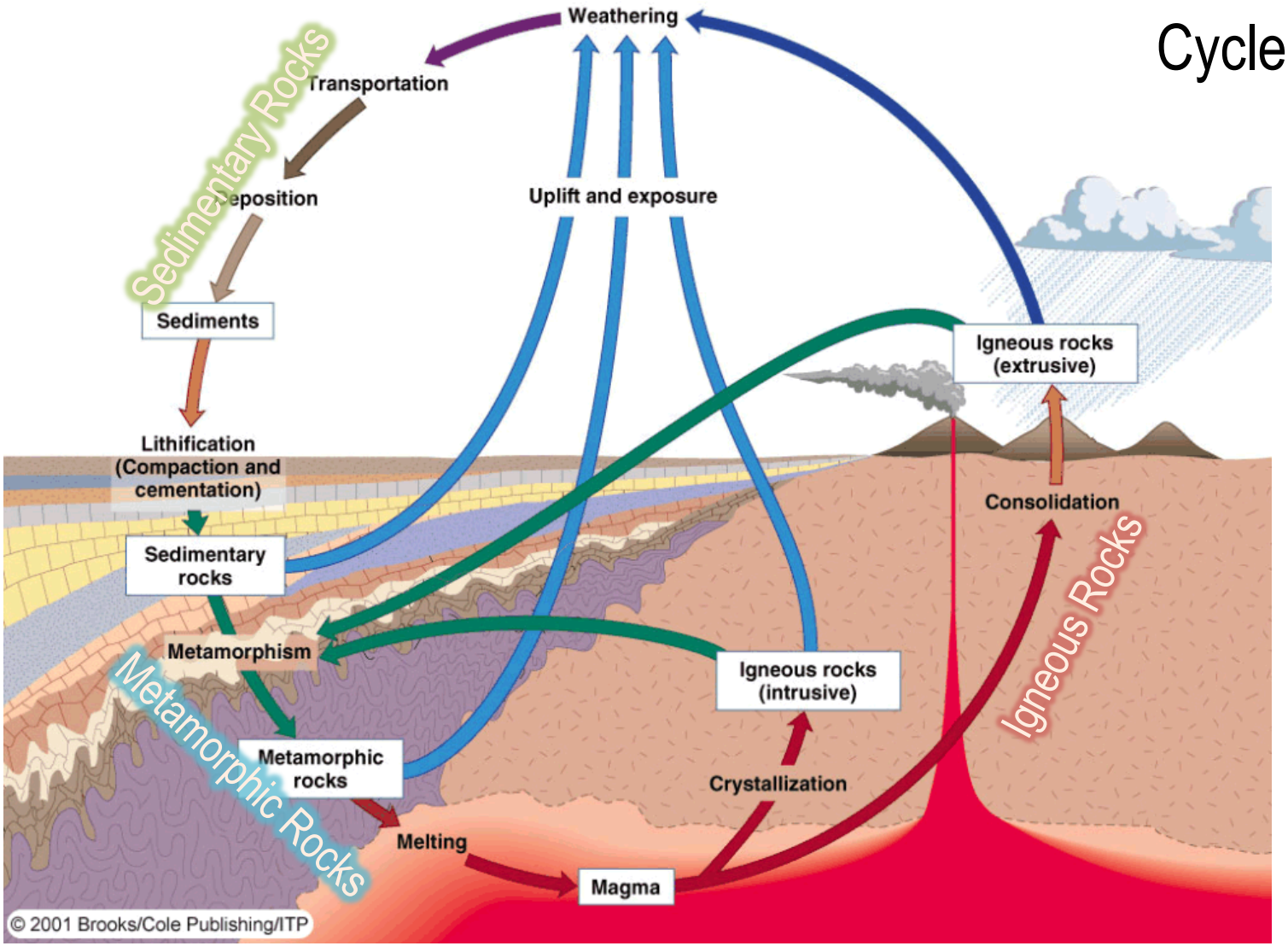
Environment: normal for Earth's surface

Metamorphic Rocks

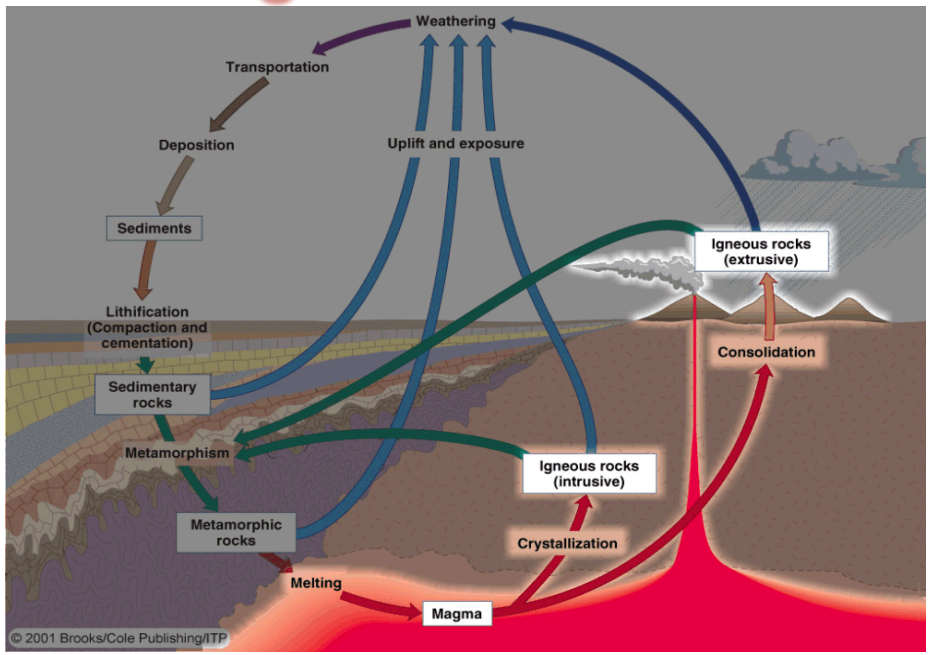
Formed by chemically and physically altering rocks under heat and pressure deep within the Earth's crust.

Environment: High pressure, not hot enough to melt rock

The Rock Cycle



Igneous Rocks



Igneous rocks form from magma (a complex mix of molten rock with dissolved gases and other materials)

Magmas that cool slowly inside the Earth form plutonic igneous rocks. The mineral crystals in these rocks are usually large because they had lots of time to grow.

Magmas that erupt onto Earth's surface are called lavas and very quickly. As they cool, volcanic igneous rocks form. If mineral crystals form, they tend to be small because they had little time to form. If cooling is fast enough, no minerals form and the lava solidifies to form a solid glass, with no crystalline structure.

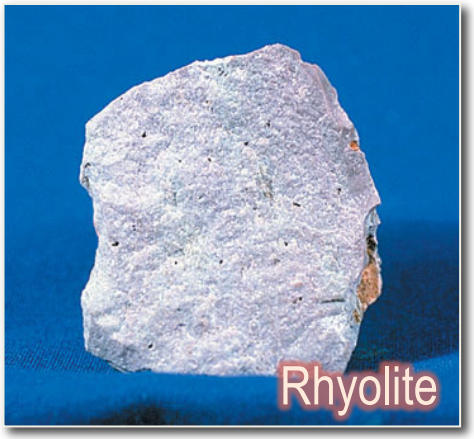
Igneous Rocks

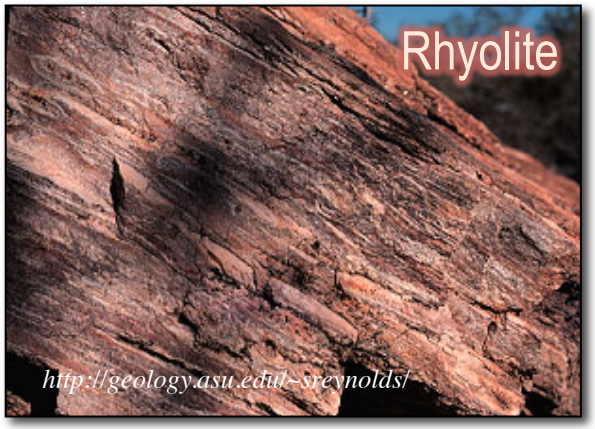
Different magma bodies have different chemical compositions. These chemical compositions are usually described by the total percentage of silica tetrahedra in the magma.

Felsic Igneous Rocks - Silica rich (>69%)
Iron, calcium and magnesium poor

Contain minerals formed at relatively low temperatures. They are low density and tend to be light colored.

Common minerals: K-feldspar, mica, quartz





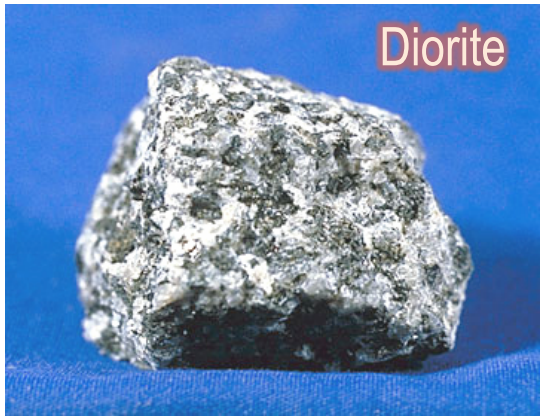
Igneous Rocks

Different magma bodies have different chemical compositions. These chemical compositions are usually described by the total percentage of silica tetrahedra in the magma.

Intermediate Igneous Rocks - Silica rich (52% - 69%)
Intermediate elemental composition

Contain minerals formed at intermediate temperatures. They are intermediate density and tend to contain an equal combination of dark and light colored minerals.

Common minerals: plagioclase feldspar, mica, hornblende



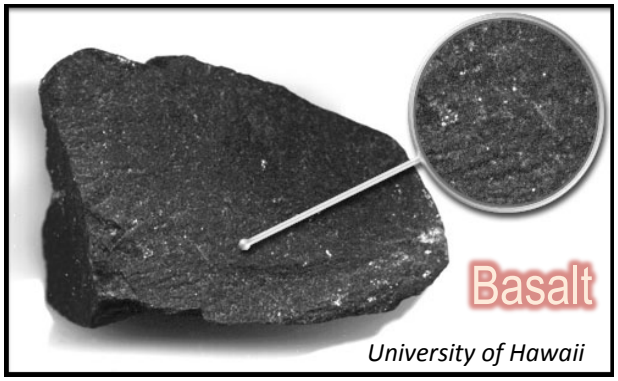
Igneous Rocks

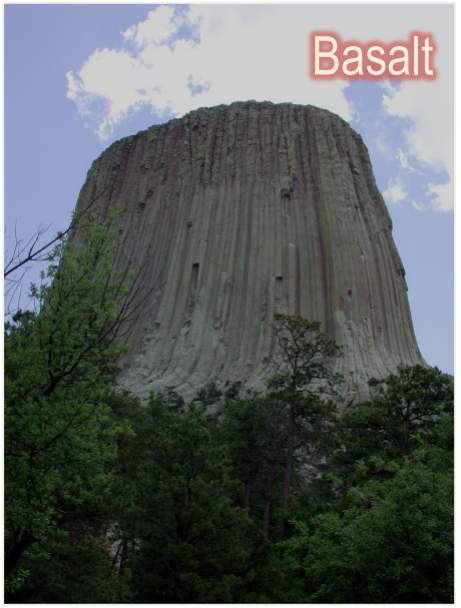
Different magma bodies have different chemical compositions. These chemical compositions are usually described by the total percentage of silica tetrahedra in the magma.

Mafic Igneous Rocks - Silica poor (<52%)
Iron, calcium and magnesium rich

Contain minerals formed at relatively high temperatures. They are high density and tend to be dark colored.

Common minerals: olivine, augite, calcium-rich plagioclase feldspar





Devil's Tower National Monument

Volcanic Igneous Rocks with no Minerals

Some magmas cooled too fast for minerals to form. The rocks are made of glass and contain no minerals, so are NOT described using the felsic-intermediate-mafic system.

obsidian

Photo by C. C. Plummer

glassy – obsidian and other volcanic glass

scoria

Photo by C. C. Plummer

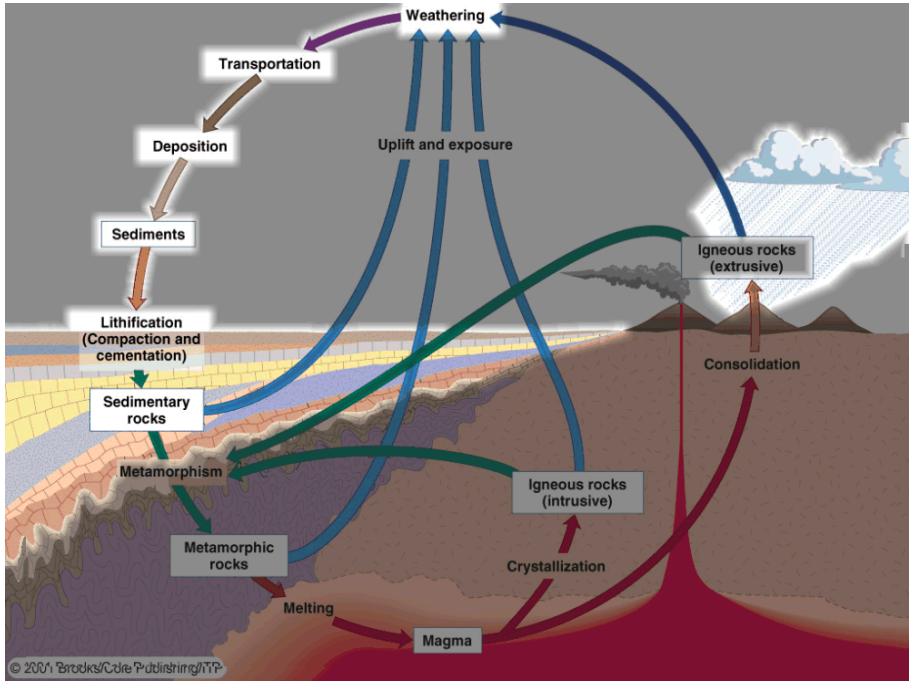
vesicular – full of holes formed by bubbles in the magma.

bombs!

Photo by C. C. Plummer

fragmental or pyroclastic – formed from debris spewed out by the volcano.

Sedimentary Rocks



Sedimentary rocks are composed of detrital grains derived from weathering rocks and/or minerals precipitated on Earth's surface.

Sedimentary rocks that form from detrital grains weathered from rocks on the surface of the Earth are called clastic sedimentary rocks.

Sedimentary rocks composed of material precipitated (or grown) on Earth's surface are called non-clastic or chemical sedimentary rocks. Salts formed in evaporating basins, minerals secreted on the ocean floor, shells and bones secreted by living organisms, and wood produced by plants are common materials in non-clastic sedimentary rocks.

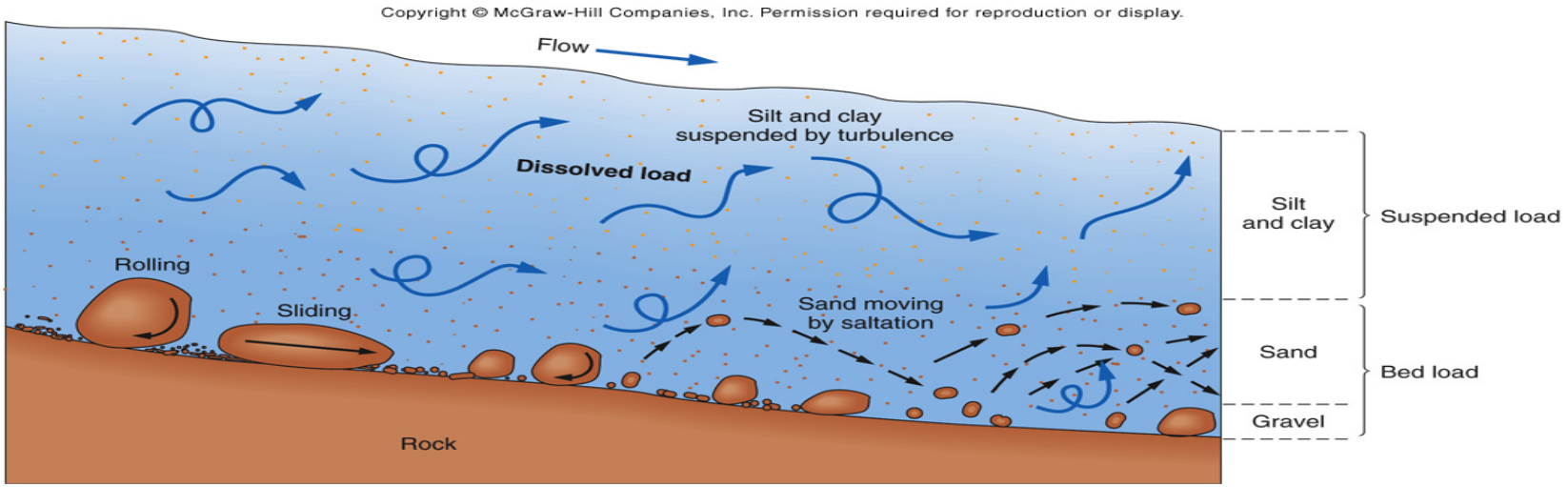
Commonly, clastic rocks contain a very small non-clastic component, e.g., precipitated cement or fossils.

Clastic Sedimentary Rocks

Formed from detrital material weathered from rocks on Earth's surface.

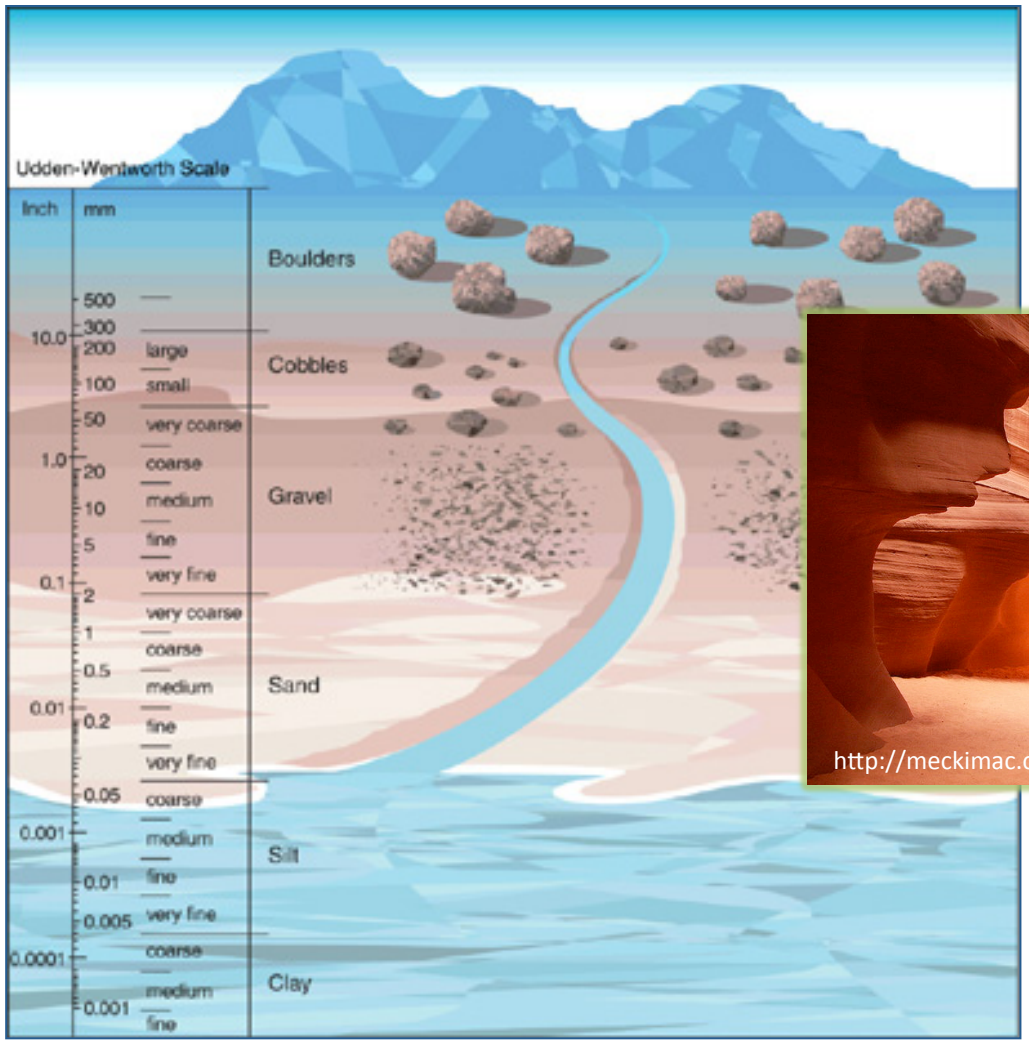
Formed from clasts (bits and pieces of pre-existing rocks). The major processes in clastic rock formation are:

- Weathering of clasts from pre-existing rock
- Transport of clasts
- Deposition of clasts
- Lithification of clasts

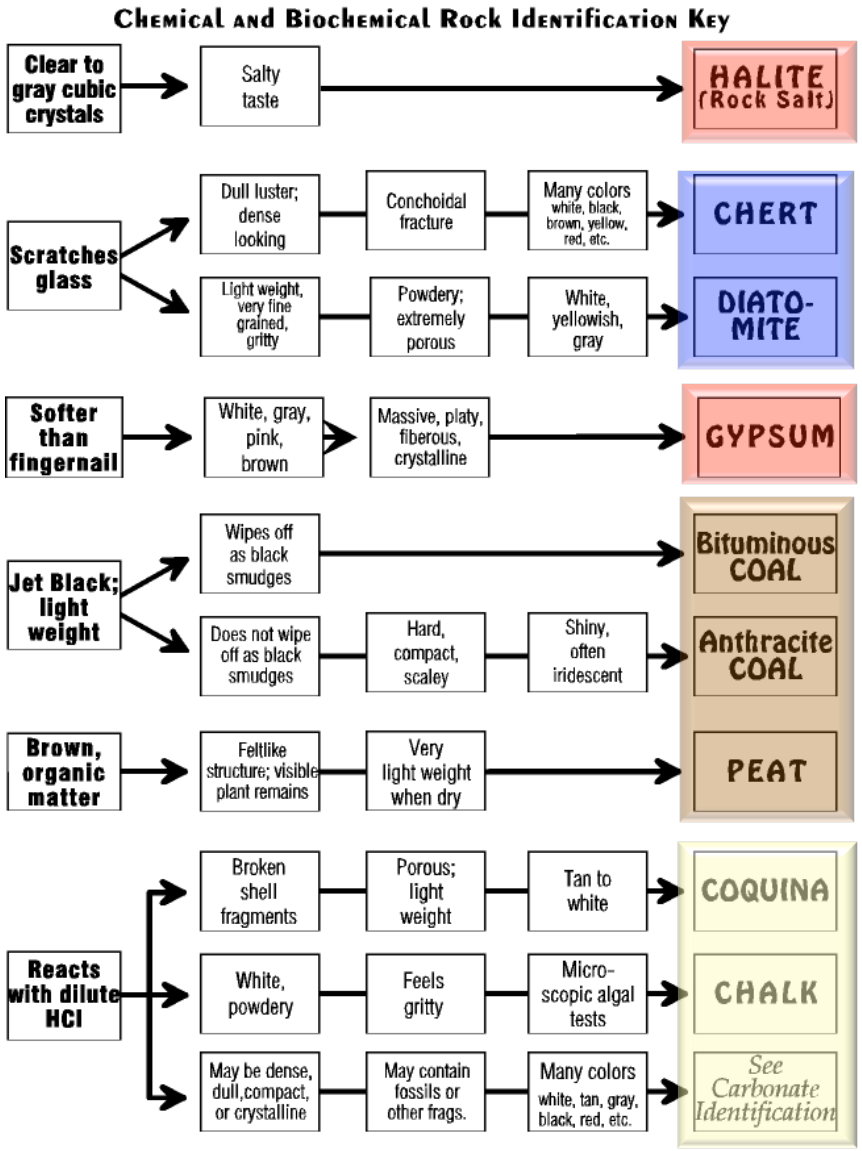


Clastic Sedimentary Rocks

Formed from detrital material weathered from rocks on Earth's surface.



Non-clastic Sedimentary Rocks



Evaporites

minerals precipitated from evaporating water

Siliceous Rocks

Silica and opalline silica precipitate either organically or inorganically

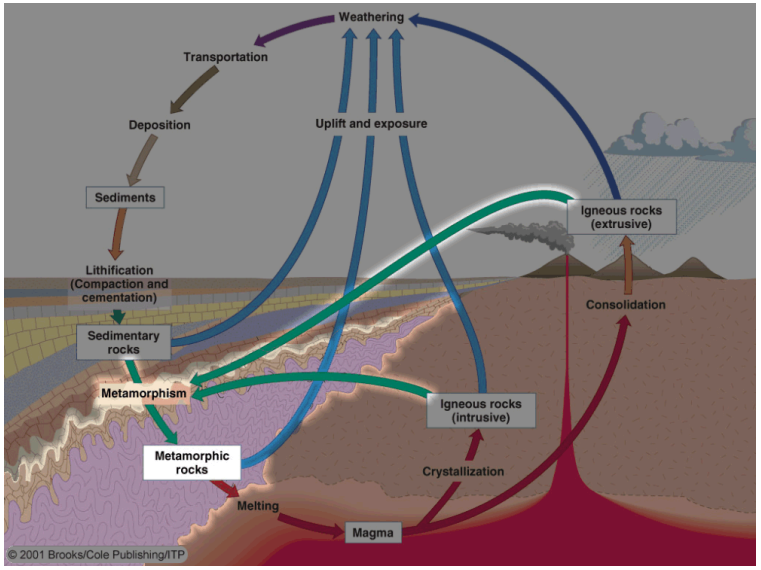
Coal and Peat

Carbon-rich deposits formed from build-up of plant material in swamps

Carbonates

Variety of limestones composed of calcite, aragonite, and dolomite precipitated either organically or inorganically

Metamorphic Rocks



Metamorphic rocks form deep within Earth's crust under high pressure and temperature. The buried rock (protolith) undergoes solid state transformation, altering the mineral composition and texture of the rock. The rock can not melt, or it would become an igneous rock after cooling.

Metamorphism that occurs around igneous intrusions is called contact metmorphism.

Metamorphism occurring due to stresses caused by mountain building is called regional metamorphism. These complex metamorphic environments may include zones of contact metamorphism if igneous intrusions occur.

The type of metamorphic rock produced is controlled by the composition of the protolith and the temperature, pressure and duration of the metamorphism. Metamorphic rocks come in two flavors – foliated and non-foliated.

Foliated Metamorphic Rocks

Metamorphic rock with aligned flat minerals

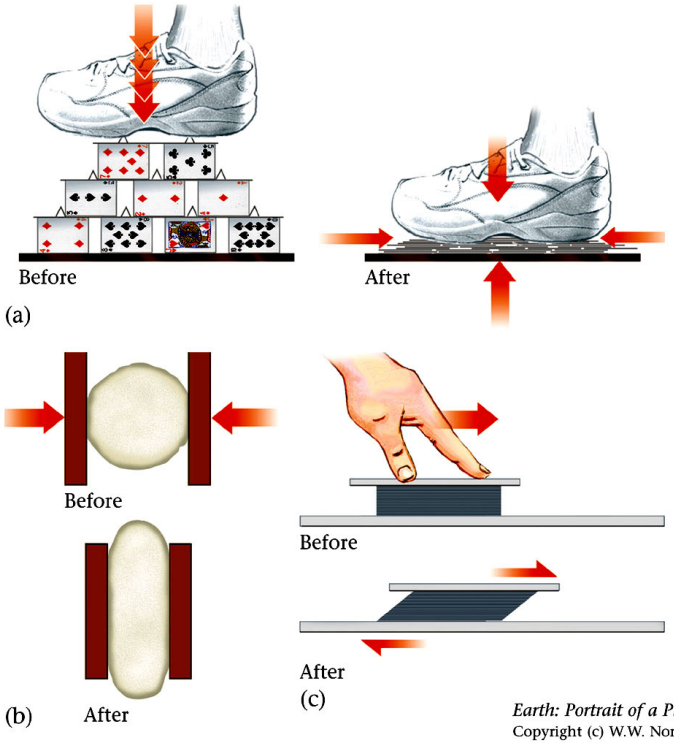


FIGURE 8.4

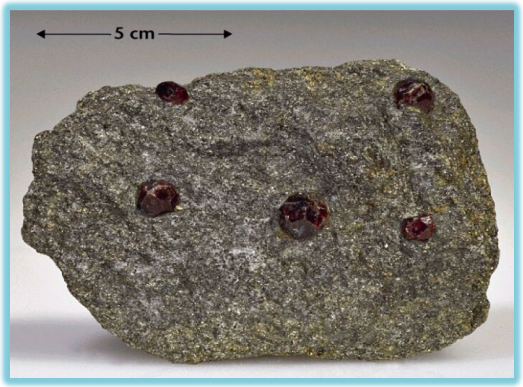
Earth: Portrait of a Planet, 2nd Edition

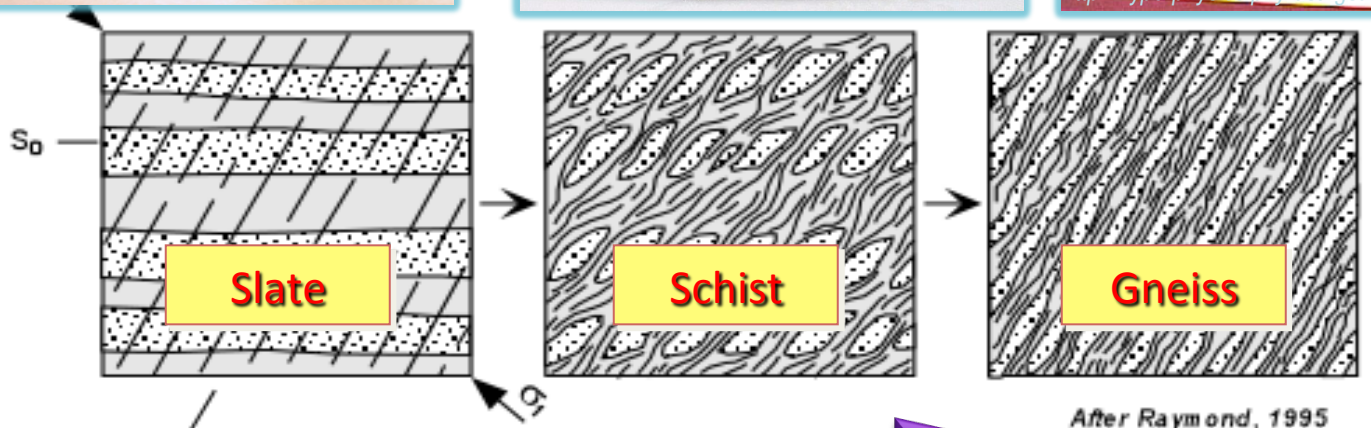
Foliation occurs when a protolith with flat minerals like mica is subjected to deviatoric stress. The flat minerals align perpendicular to the direction of maximum stress.

Increasing metamorphism causes more severe reordering and alteration of the rock's metamorphic texture.

Foliated Metamorphic Rocks

Metamorphic rock with aligned flat minerals





Low Grade → **High Grade**

Foliation perpendicular to direction of maximum differential stress

Foliation and **crystallization** perpendicular to direction of maximum differential stress

Foliation, **crystallization** and **differentiation** perpendicular to direction of maximum differential stress

http://www.tulane.edu/~sanelson/geol212/contactmeta.htm

Non- Foliated Metamorphic Rocks

Metamorphic rock without minerals that can be foliated

	Marble	Quartzite	Anthracite	Amphibolite
Protolith	limestone	quartz sandstone	coal	mafic rocks
Mineralogy	carbonates	quartz	none	amphiboles

Marble

Quartzite

Anthracite

Amphibolite