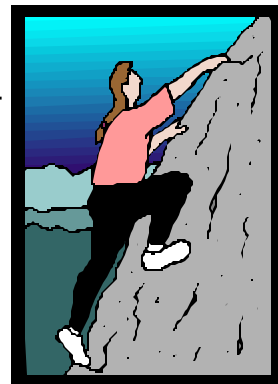


## Chapter 3: Minerals, Rocks and Natural Resources

Rocks and minerals help us understand Earth's historical development and its dynamics. They are important to us because of their availability and properties. The use and distribution of mineral resources and fossil fuels have important economic and environmental impacts. As non-renewable resources, they must be used wisely.

Observation and classification have helped us understand the great variety and complexity of Earth materials. Matter is made up of particles whose properties determine the observable characteristics of matter and its chemical reactivity.



### MINERALS

**Minerals are the naturally occurring inorganic solid elements, compounds, and mixtures from which rocks are made.** Minerals are formed inorganically by the process of crystallization as a result of specific environmental conditions. These include:

- the cooling and solidification of magma
- precipitation from water caused by such processes as evaporation, chemical reactions, and temperature changes
- the rearrangement of atoms in existing minerals subjected to conditions of high temperature and pressure.

**We classify minerals on the basis of their chemical composition and observable properties, such as crystal structure. The properties of Earth materials can be explained in terms of the arrangement and properties of the atoms that compose them.** For example:

- Minerals have physical properties determined by their chemical composition and crystal structure.
- Minerals can be identified by well-defined physical and chemical properties, such as cleavage, fracture, color, density, hardness, streak, luster, crystal shape, and reaction with acid.
- Chemical composition and physical properties determine how minerals are used by humans.

#### Physical properties (\* best for mineral ID)

**Color** - of surface

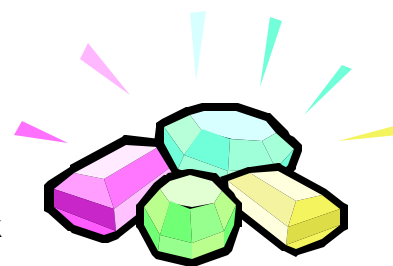
**Streak** - the color of the *powdered* mineral

**Luster** - the way it reflects light (*metallic vs. Non-metallic*)

**\*Hardness** - resistance to being scratched

**\*Breakage** - cleavage or fracture - cleavage is the tendency to split along flat, shiny planes of weakness. Fracture is where the break is irregular or uneven.

**\*Crystal form** - (txt. P.35) when the mineral forms, it "grows" into particular, characteristic crystal shapes. Flat, smooth surfaces are called "faces" ("facets" of gems are cut).



#### Chemical properties

Minerals are made of elements which have chemical properties, which determine how the mineral reacts with other substances.

## Composition

Minerals are made of **elements** - 92 different “types of atoms,” or substances which cannot be broken down into simpler substances chemically. Most minerals are **compounds** - which means 2 or more elements chemically combined. Of all naturally-occurring elements, only a relative few make up most minerals. In Earth’s crust, only 8 elements constitute 98.5% of its mass! O & Si (= 75%), Al, Fe, Ca, Na, Mg, K (ESRT p11).

We classify minerals based on the elements and compounds they’re made of, and their crystal structure.

**Sulfides** - compounds of sulfur and a metal (galena=PbS)

**Oxides** - oxygen and a metal (cuprite =  $\text{Cu}_2\text{O}$ )

**Carbonates** - Carbonate ion and a metal (calcite= $\text{CaCO}_3$ ). Carbonates (like calcite) react with acid.

**Silicates** - **make up 90+% of all minerals** in Earth’s crust. The silicates are made of silicon and oxygen, which form pyramid-shaped “tetrahedras,” combined with other elements. The arrangement of the silicon-oxygen tetrahedra in the crystal structure determines which silicate family a mineral is in.

- **Isolated tetrahedra** - negative tetrahedra are linked by positive atoms of Fe or Mg (ex: olivine)
- **Chains** - tetrahedra share oxygens to form single chains (ex: augite) or double chains (ex: hornblende).
- **Sheets** - tetrahedra share oxygens to form sheets (ex: mica).
- **Network** - when tetrahedra share all their oxygen atoms, the result is a 3-D network that is strongly-bonded in all directions (Ex: quartz, feldspar).

## Rocks

Rocks are a solid combination of one or more minerals. Rocks are generally classified by their origin (igneous, metamorphic, and sedimentary), texture, and mineral content. Rocks are usually composed of one or more minerals. Rocks are classified by their origin, mineral content, and texture. Conditions that existed when a rock formed can be inferred from the rock’s mineral content and texture. The properties of rocks determine how they are used and also influence land usage by humans.

Rocks can either be:

**Polymineralic** - composed of 2+ minerals (most Rx)

**Monomineralic** - made of only one type of mineral.

**Most rocks have a number of minerals in common called rock-forming minerals** - the most common rock-forming minerals in rocks (~40). Most are silicates. (ex: feldspar, quartz, mica, calcite)

## Classes of rocks

The three major rock classes are based on their **origin** (the way they are formed). The three classes are sedimentary, igneous, and metamorphic.

**Sedimentary rocks** are formed by the compaction and/or cementation of sediments, or by various chemical or biological processes. Sedimentary rocks are classified based on **texture** (type of particles or crystals and grain size) and **mineral composition** (see ESRT p. 7).

1. **Clastic (particle) sedimentary rock** is formed from “**clasts**” (particles) from weathered rock (ex: sandstone, shale). The sediments are usually deposited in water, then **cemented** together by calcite or quartz, which precipitates between the grains. Some sediments, such as the muds which form shale, are **compacted** together by pressure after being buried by overlying sediments. Clastic sedimentary rocks are usually **layered**, and may contain **fossils** - the remains, traces or imprints of an organism preserved in Earth’s crust. They are identified based on particle size.
2. **Crystalline sedimentary rock** forms when minerals **crystallize** out of a **saturated** solution (precipitate) by evaporation or chemical action (ex: halite, limestone). These include **evaporites**, which are formed when minerals crystallize as a shallow sea evaporates (ex: halite, gypsum), and **precipitates**, formed when minerals crystallize in the deep ocean and fall to the bottom (ex: chemical limestone, dolostone). All crystalline sedimentary rocks are monomineralic.
3. **Bioclastic sedimentary rock** is formed by the deposition, compaction and cementation of inorganic minerals produced by organisms, sometimes including parts of the organisms (ex: fossil limestone, coquina).

**Igneous rocks** are formed by the cooling and solidification of hot, molten **magma** inside the Earth, or of **lava** on the surface. We classify igneous rocks based on the **environment of formation** (where solidification occurs - see ESRT p. 6), and **mineral composition**.

**Intrusive (or “plutonic”)** - igneous rocks harden inside the Earth. This results in a slow rate of cooling which produces a **coarse texture (large grain size)**.

**Extrusive (or “volcanic”)** igneous rocks solidify on the surface of the Earth. This results in a fast rate of cooling, which produces a **fine texture (small grain size)**, or, if cooled very rapidly, like when lava is thrown from a volcanic vent, a **glassy texture**.

Other characteristics of igneous rocks can be found on the Scheme for Igneous Rock Identification of the ESRT (on page 6):

- **Color - light or dark**
- **Density - low or high**
- **Composition - felsic or mafic**
- **Mineral composition** (relative % by volume)

**Metamorphic rocks** are formed when existing rocks are “**recrystallized**” (minerals and crystals change without melting) by enormous **pressure** and **heat**, usually over a long period of time. There are two major types of metamorphism:

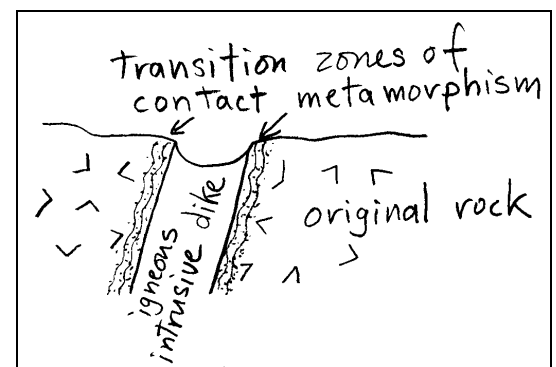
**Regional metamorphism** occurs when metamorphism affects a large region of buried rock during the formation of mountains.

**Contact metamorphism** occurs when molten rock contacts solid rock, and a **transition zone** of altered (“baked”) rock is created between them.

Metamorphic rocks are classified by texture and mineral composition. Metamorphic rocks have textures which are either **foliated** or **nonfoliated**.

**Foliated** - a parallel alignment of minerals, usually from compression or shearing forces.

**Nonfoliated** - where the minerals are not aligned, but are



oriented randomly in the rock.

Other common characteristics of metamorphic rocks include **distortion** - where the original structure is **folded**, compressed or twisted - on either a large or a small-scale. **Increased density** results when recrystallized minerals are subjected to pressure and the associated loss of pore space. **Chemical change** occurs when new minerals are created by recrystallization.



## Rock cycle

Earth's limited supply of solid rock material is constantly changing from one form to another. The "rock cycle" provides a model of these changes (ESRT p. 6).

Geology facts illustrated by rock cycle:

- Nearly all rocks form from other rocks...rocks of one type change to another.
- There's more than one path through the rock cycle.
- Rocks are classified by their origin (and structure).
- Each rock type can remain relatively stable for long periods of time.