From Atoms to Minerals to Rocks: The building blocks of the Earth
Questions your students might ask?

What are rocks made of?
What are minerals?
What are minerals?
What is the difference between Fool’s Gold and real gold?
What is the difference between glass and crystals?
What are the three kinds of Igneous Rocks?
What are the Silicate minerals and why are they important?
What is the difference between Oceanic and Continental Crust?
What is the difference between Plutonic and Volcanic rocks and where can we find both in Montana?
Questions your students might ask? [Continued]

What are Sedimentary rocks made of?
What are the different kind of Sedimentary rocks?
What are different kinds of Clastic rocks?
What are Limestones made of?
If you see a coal bed what does it mean was once at this place?
What causes rocks to change (metamorphose)?
What is meant by ‘metamorphic grade’?
If marble is a metamorphic rock, what was it before it became marble?
ATOMS
Atom

- Electron
- Nucleus
  - Proton
  - Neutron
Atom

• Atomic number
  – Number of protons
  – Unique to element

• Atomic Weights
  – Mass of protons and neutrons
Isotope

- Different atomic weights of same element
Chemical Bonds

• Molecules
  – Two or more atoms interact to form a molecule

• Ionic Bond
  – One atom loses an electron to another atom

• Covalent Bond
  – Two atoms share an electron
Minerals
Crystal Lattice

• 3-D molecular structure of a mineral

• Configuration reflects relative sizes and numbers of ions

It is like really small tinker toys

External shape is a reflection of internal structure!
Mineral Types

• Silicates (Olivine, Quartz) most common!
• Carbonate minerals (Calcite, Aragonite)
• Sulfate minerals (Gypsum, Anhydrite)
• Oxides (Hematite, Magnetite)
• Native elements (Gold, Copper, Platinum, Palladium… [Stillwater and Butte mines]
Silicates

• Most abundant group of minerals

• Silicate tetrahedra
  – 4 oxygen atoms (−) surrounded by 1 silicon atom (+)
  – Bond with other atoms to form silicate minerals
Silicate Minerals

• Silica tetrahedron may *polymerize*
  • Isolated tetrahedron
  • Single chains
  • Double chains
  • 2-D sheet
  • 3-D frameworks
Isolated tetrahedra

Single Chain

Double Chain

Sheets

Solids
Augite (an isolated silicate tetrahedra)
Tremolite (a chain silicate)
Biotite Mica (a sheet silicate)
Feldspar and Quartz
(solid silicates)
Rock-Forming Minerals

- About 20 minerals make up most rocks
  - Silicates dominate
    - Quartz, Feldspars, Mica, Amphiboles, Pyroxenes
  - Carbonates are common (limestones)
  - Evaporite minerals (Halite, Gypsum)
  - Secondary minerals formed during weathering Clays, Iron Oxides
Felsic Minerals

- Silicate minerals rich in silicon and aluminum
  - Quartz
  - Feldspars
  - Mica - muscovite

This is what continents are made of. It's lighter.
Mafic Minerals

- Silicate minerals rich in iron and magnesium
  - Olivine
  - Pyroxenes
  - Amphiboles
  - Mica - biotite

This is what ocean basins are made of. It’s heavier.
Carbonate Minerals

- Carbonate minerals contain a positive ion (Ca, Mg, Fe) bonded to carbonate ion (CO$_3^{2-}$).
ROCKS
Three Basic Rock Types

- Igneous rock
- Metamorphic rock

- Cooling of a magma
- Squeezing and heating other rocks

- Melting
- Pressure temperature

- Weathering, erosion
- Sediment

- Small pieces of other rocks
- Sedimentary rock
Igneous Rocks

• Classified by composition and grain size
  – Composition
    • Minerals
  – Cooling rate
    • Rapid: fine grained
    • Slow: large grained
Same compositions (minerals)

Cooled fast
Small Xtals

Cooled slowly
Big Xtals

- Basalt
- Gabbro
- Rhyolite
- Granite
Igneous Rocks

- Magma cools within the Earth and at the surface
- Intrusions
  - Slow cooling
  - Plutons
    - Sills
    - Dikes
Volcanic Rocks
Igneous Rocks

• Lava
  – Molten rock that appears at a vent

• Tuff
  – Loose volcanic debris

• Fissures
  – Lava flowing out of cracks
Aa flow

Pahoehoe flow
Igneous Rocks

• Flood basalts
  – Extensive areas covered by mafic lava

• Pillow basalts
  – Rocks formed by cooling rapidly beneath the sea
pillow lavas

Flood basalts with several thick and thin layers. Each layer represents a separate eruption.
Columnar basalt flows across from Tower Falls
Devil’s Tower; a volcanic neck, a feeder pipe
Columnar basalts
Shiprock, New Mexico; a volcanic neck
Volcanic bombs
Plutonic Rocks
Half Dome; part of the Sierra Nevada batholith
Sill; parallels layers in the country rock
Dike; cuts across layers in the country rock
Coarse grained igneous rock
Fine grained igneous rock
Pegmatite:

Very coarse grained igneous rock
Porphyritic igneous rock:
Big xtals in a fine grain matrix
Figure 4.2. Distribution of igneous rocks in North America
Figure 7. Plutons, diatremes and other intrusive rock. Compiled from Plate 1 and Heam and others (1989).

Figure 8. Volcanic rock. Compiled from Plate 1.

Sedimentary Rocks
Sedimentary Rocks

• Sediments produced by:
  – Weathering, erosion of other rocks
  – Crystals precipitated from seawater
  – Skeletal debris from organisms

• Siliciclastic rocks
  – Sedimentary rocks composed of clasts of silicate minerals
    • Quartz is most resistant to weathering
    • Mafic minerals less stable at Earth’s surface
Types of Sedimentary Rocks

Clastic

Made up of pieces of other rocks

Precipitated by organisms or remains of plants, e.g., Limestones and coals

Biologic

When seawater dries up

Chemical
Clastic Sedimentary Rocks are classified by size of the fragments
Siliciclastic Rocks

Classification based on grain size and shape:

- **Gravel**
  - >2 mm diameter
  - Granules, pebbles, cobbles, boulders

- **Conglomerate**
  - Rounded grains

- **Breccia**
  - Angular grains
Siliciclastic Rocks (cont.)

• Sand
  – 1/16-2 mm diameter
  – Often quartz
  – Sandstone

• Silt
  – 1/256-1/16 mm

• Clay
  – Smaller than 1/256 mm
Conglomerate
Sandstone
Shales
Shales
Lithification

• Process by which sediments become rock
  – First compaction
  – Then cementation
Evaporites

• Form from evaporation of seawater
  – Anhydrite
  – Gypsum
  – Halite
Other Chemical Sedimentary Rocks

• Chert
  – Flint
  – Opal, Chalcedony, Agate, Jasper, etc.

One of the first important commercial minerals
Biologic Rocks

• Limestone
  – Chemical and biogenic bodies of rock
Carbonate Rocks

- Carbonate sediments
  - Often skeletal particles
- Carbonate muds
  - Mainly aragonite needles
    - Direct precipitation
    - Collapse of carbonate algal skeletons
Limestones
Limestones
Limestones
Chalk
(Coccolithophores)
Coccolithophores: calcareous phytoplankton (photosynthetic/autotrophs)
Foramifera: calcareous (CaCO₃) heterotrophs
Foramifera: calcareous \((\text{CaCO}_3)\) heterotrophs

http://www.ucl.ac.uk/GeolSci/micropal/calcnanno.html
Diatoms: siliceous (SiO$_2$) phytoplankton (photosynthetic/autotrophs)

http://www.ucl.ac.uk/GeolSci/micropal/calcnanno.html
Radiolarians: siliceous (SiO$_2$) heterotrophs

http://www.ucl.ac.uk/GeolSci/micropal/calcnanno.html
Travertine (Limestone)
Strip mine near Colstrip
Lagoons
Coal mining in Wyoming
Evaporites:
Bonneville Salt Flats, Utah

Rock
Gypsum

Rock Salt
Metamorphic Rocks
Metamorphic Rocks

- Form by alteration of other rocks at temperatures and pressures greater than at the Earth’s surface
- Grade
  - Level of temperature and pressure of metamorphism
- Regional Metamorphism
  - Transforms deeply buried rocks over great distances
- Foliation
  - Alignment of platy minerals caused by applied pressures
Three types of Metamorphism

• Contact Metamorphism
  – Igneous intrusion “bakes” surrounding rocks

• Hydrothermal Metamorphism
  – Results from percolation of hot watery fluids

• Burial Metamorphism
  – (Similar to regional metamorphism)
  – Rocks are altered when they are buried so deep that they are exposed to very high temperatures and pressures
Change in metamorphic grade with depth
Foliated metamorphic rocks

Progressive metamorphism of a shale

Shale
Foliated metamorphic rocks

Progressive metamorphism of a shale

Slate
Foliated metamorphic rocks

Progressive metamorphism of a shale

Phyllite
Foliated metamorphic rocks

Progressive metamorphism of a shale

Schist
Foliated metamorphic rocks

Progressive metamorphism of a shale

Gneiss
Flattened Pebble Conglomerate = flattening
Nonfoliated metamorphic rocks

Sample of quartzite

Thin section of quartzite

Photomicrograph (26.6x)
Sample width is 1.23 mm
Nonfoliated metamorphic rocks

Marble
The origins of igneous, sedimentary, and metamorphic rocks are interrelated through the rock cycle.

Igneous rocks form from the solidification of magma or lava. They can be either intrusive (formed below the surface) or extrusive (formed above the surface).

Sedimentary rocks are formed from the accumulation of sediment, which is then compacted and cemented. This process can be influenced by chemical processes and energy levels.

Metamorphic rocks are formed when existing rocks are subjected to high pressure and temperature, which changes their mineral composition and texture.

Any of the three basic types of rocks—igneous, sedimentary, and metamorphic—can be transformed into another rock belonging to any of the three basic types.