Geology and Art, Fall 2004
Sedimentary Rocks and Weathering, Lecture 4
Dynamic Earth, Chapter 4

Weathering: the breakdown of rocks and the first step in making sedimentary rocks
Erosion, tranportation, deposition (clastic sediments)
Precipitation of dissolved solids (chemical and biogenic sediments)

Mechanical (physical) and Chemical Weathering

Mechanical: physical disintegration of rock into smaller pieces. This does not change the chemical composition, just the size and shape.

Frost wedging: due to 9% expansion of water during freezing. This is the most effective mechanism of mechanical weathering, it frequently produces talus slopes.

Crystal growth: crystallization of salts can pry minerals and rocks apart. This is common in arid regions and adjacent to seawater.

Thermal expansion and contraction: each mineral expands and contracts at a different rate. When a surface is heated and cooled certain minerals dislodge others. Rocks in desert regions are most susceptible. (Columnar basalt an example?)

Exfoliation: when plutons are exposed and confining pressure is decreased sheets break loose parallel with the exposed surface.

Plant roots: roots can pry or wedge rocks apart.

Abrasion during transport: rivers, ice and wind abrade clastic particles

Chemical: decomposes minerals from unstable to stable forms and does change the chemical composition. Water is a (the) catalyst for chemical weathering; it transports ions toward and away from the reaction site.

Low-temperature chemical reactions occur at or near the Earth's surface, a process which evolves toward an equilibrium assemblage involving rocks (minerals), water and air.

Kinetics (rates) may be very slow (especially in cold and dry regions).

Reactions: dissolution, oxidation, and hydrolysis

Dissolution: ions or complex ions are removed as solutes in water. Water is the universal solvent for ions due to its polar nature.

$NaCl$ +	$H_2O \rightarrow$	Na^+	+	Cl^-
Halite	water	sodium ion		chloride ion

Water reacts with the CO_2 in the atmosphere to create an acid:

$H_2O + CO_2 \rightarrow H_2CO_3$

water carbon dioxide carbonic acid

$CaCO_3$	+	$H_2CO_3 \rightarrow$	Ca^{2+}	+	$2HCO^{3-}$
calcite		carbonic acid	calcium ion		bicarbonate

Carbonate dissolution produces **Karst** features

Oxidation: ions combine with oxygen (loss of electrons). This is dependent on the Eh (concentration of oxygen) and pH (concentration of H^+ ions) of the environment.

$4Fe^{2+}$	+	$3O_2$	$\rightarrow$	$2Fe_2O_3$
iron ion		oxygen		hematite

When water is present (and free oxygen) iron hydroxides (OH-) are usually formed:

$FeO(OH)$	goethite
$FeO(OH)\ nH_2O$	limonite

Fe_2SiO_4	+	$0.5O_2 + 2H_2O$	$\rightarrow$	Fe_2O_3	+	H_4SiO_4
fayalite (olivine)				hematite		silicic acid

Fayalite is usually broken down in a reducing environment and then the Fe^{2+} is oxidized to hematite.

$2FeCO_3 + 0.5O_2 + 2H_2O$	$\rightarrow$	Fe_2O_3	+	$2H_2OO_3$
siderite		hematite		carbonic acid

Mn (manganese) is oxidized in a similar manner as Fe but it is slightly less susceptible to oxidation. Oxidized Mn is pyrolusite (MnO_2), a black mineral that is used in glazes.

Hydrolysis: H^+ or OH^- replaces other ions in a mineral

$2KAlSi_3O_8 + 2H^- + 9H_2O \rightarrow$	$Al_2Si_2O_5(OH)_4 + 4H_4SiO_4 + 2K^+$
K-feldspar	kaolinite

$MgCO_3 + 2H_2O$	$\rightarrow$	$Mg(OH)_2 + HCO_3^- + H^+$
magnesite		brucite

These reactions are very sensitive to pH changes.
Hydrolysis typically leads to the formation of clay minerals.

Chemical Weathering Rates

Climate: water is extremely important in chemical weathering and heat increases reaction rate (approximately doubles with every 10 degree C increase in temperature).

Plants: produce organic acids that accelerate chemical weathering (hydrolysis reactions).

Mineral composition: different minerals weather at different rates (quartz slow, pyroxene fast). In general, minerals that crystallize at high temperatures and pressures are most unstable at surface temperatures and pressures and chemically weather more quickly.

Sedimentary Process

Weathering, erosion and transportation: the driving forces behind sediment accumulation and the development of sedimentary rocks.

There is a balance between uplift and erosion. Increased uplift usually initiates increased erosion and sediment deposition (slope and velocity of rivers)

"Sedimentary record" contains information about paleogeography, paleotectonics, and the evolution of a region after the original structures have been removed by erosion.

Basins that retain the sediments over long periods of time are usually ocean basins.

Sedimentary Rocks: detrital, chemical and biogenic

Detrital (clastic) sediment: These sediments are composed of transported, solid fragments of preexisting rocks (igneous, sedimentary, metamorphic)

weathering (physical and/or chemical)
erosion
transport

water (fluvial = rivers, lacustrine = lakes, marine = marine)
air (dunes, loess, tuff or ash)
ice (glaciers)

transportation and mineral composition
transportation tends to expose detrital grains to physical and chemical weathering, thus the more distance detritus is transported the more it breaks down and only the most resistant rocks or minerals will remain.

deposition

deposition occurs when transporting medium looses the energy needed to transport the clastic particle.

sediments are deposited in a fashion that is characteristic of the medium which allows one to evaluate what the medium, or environment was.

speed and viscosity of the transporting medium are a factor in the character of the sedimentary rock (influences the size and distance a particle travels).

high velocity river = conglomerate

low velocity river = sand & silt

texture: size (distribution), shape, and arrangement
grain size:

clasts	rock	diameter (mm)
boulder	boulder conglomerate	> 256
cobble	cobble conglomerate	256 – 64
pebble	pebble conglomerate	64 – 2
sand	sandstone	2 - 1/16
silt	siltstone	1/16 - 1/256
clay	mudstone (shale)	<1/256

shale (<.004 mm)
- deposited in low-energy environments
- red - oxygen and iron present
- green - iron but no oxygen present
- black - organic-rich

sand (0.064 - 2 mm or 1/16 mm - 2 mm)
- matrix
- arkose - contains >25% feldspar
- graywacke - poorly sorted, “dirty sandstone”
- quartz arenite - over 90% quartz

conglomerate (over 2 mm)
breccia
sorting:
grain shape:

sedimentary structures:
stratification: arrangement of rock particles in distinct layers
- stratum (singular)
- strata (plural)

graded bedding (turbidity currents - turbidites)
cross-bedding (asymmetric, symmetric)
mudcracks (desiccation cracks)

Chemical sediment: These sedimentary rocks contain minerals that crystallized directly from ions in solution, usually sea water. They are not transported like clastic particles, but accumulate in the basin that they crystallize.

weathering - dissolution (chemical weathering)
transportation - as dissolved solids
deposition
- change in physical/chemical conditions (T, P, composition

limestone, evaporite, dolostone, chert
- limestone: decreased temp., decreases dissolved CO_2

H_2O	+	CO_2	$\rightarrow$	H_2CO_3		
water		carbon dioxide		carbonic acid		

$CaCO_3$	+	H_2CO_3	$\rightarrow$	Ca^{2+}	+	$2HCO^{3-}$
calcite		carbonic acid		calcium		bicarbonate

photosynthesis removed CO_2
ooliths (oolitic limestone)
tufa (mineral springs) and travertine (caves)

evaporite: evaporation of seawater
order of precipitation consistent with solubility

gypsum $CaSO_4 \cdot 2H_2O$	66% evaporation
halite NaCl	90% evaporation
sylvite KCl	99% evaporation
$MgCl_2$	99% evaporation

dolostone: dolomite ($CaMg(CO_3)_2$)
replacement of limestone

chert: precipitation from silica-rich water
jasper - trace amounts of iron
chert nodules in limestones

Biogenic sediment: Organisms are responsible for removing ions from water, usually sea water, and secreting them as hard parts such as shells.

organic: limestone, chert, coal*
limestone: invertebrates (benthic and plankton), algae, sponge

chert: radiolaria and diatoms secrete silicic tests

coal: peat, lignite, bituminous, anthracite

lithification (diagenesis - less than 200°C)
compaction
cementation (calcite, silica, hematite, clays)
secondary porosity
alteration/recrystallization