Earth's external processes

- Weathering – the disintegration and decomposition of material at or near the surface
- Mass wasting – the transfer of rock material downslope under the influence of gravity
- Erosion – the incorporation and transportation of material by a mobile agent, usually water, wind, or ice
Weathering

Two kinds of weathering
• Mechanical weathering
• Chemical weathering
Frost wedging
Talus Slope

Before Unloading
Unloading and exfoliation of igneous rocks
Exfoliation Domes

Biologic activity

Root breaking rock

• http://www.rossway.net/root_wedging.htm
Mechanical weathering

- Breaking of rocks into smaller pieces
- Processes of mechanical weathering
  - Frost wedging
  - Unloading
  - Biological activity
Chemical weathering

- Alters the internal structures of minerals by removing or adding elements
- Most important agent is water
Water as chemical weathering agent

- Oxygen dissolved in water oxidizes materials
- Carbon dioxide (CO₂) dissolved in water forms carbonic acid and alters the material
- \( \text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{H}_2\text{CO}_3 \)
Chemical weathering

Weathering of granite

- Composed of potassium feldspar and quartz
- Accomplished by water turned into carbonic acid
Weathering of potassium feldspar

\[ \text{KAISi}_3\text{O}_8 + \text{H}_2\text{CO}_3 + \text{H}_2\text{O} \rightarrow \]
Feldspar carbonic acid

\[ \text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4 + \text{KHCO}_3 + \text{SiO}_2 \]
Clay mineral dissolved ions

potassium bicarbonate silica
Balanced equation

\[ 2 \text{ KAlSi}_3\text{O}_8 + 2 \text{ H}_2\text{CO}_3 + \text{ H}_2\text{O} \rightarrow \]
\[ \text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4 + 2 \text{ KHCO}_3 + 4 \text{ SiO}_2 \]
Weathering of Granite

• Produces clay minerals, soluble salt (potassium bicarbonate), and silica in solution
• Quartz remains substantially unaltered
• Weathering of silicate minerals produces insoluble iron oxides and clay minerals
Spheroidal Weathering

Rates of weathering

Important factors

• Rock characteristics

• Climate
Different Rock Types weather differently
Increase of surface area by mechanical weathering

- Initial cube: 4 square units
- After mechanical weathering: 48 square units, 96 square units

Mathematical calculations:

- 4 square units × 6 sides × 1 cube = 24 square units
- 1 square unit × 6 sides × 8 cubes = 48 square units
- .25 square unit × 6 sides × 64 cubes = 96 square units
Rock characteristics

- Mineral composition and solubility
- Physical features such as joints
Chemical Weathering

- Advanced mechanical weathering aids chemical weathering by increasing the surface area
- Allows chemical weathering greater access to rock surfaces
- Results in spheroidal shape of rocks
Joint-controlled weathering in igneous rocks
Climate

Rainfall

Temperature

http://earthobservatory.nasa.gov/Observatory/Datasets/rainfall.gpcp.html

http://news.bbc.co.uk/1/hi/sci/tech/4210629.stm
Climate

• Temperature and moisture are the most crucial factors

• Chemical weathering is most effective in areas of warm temperatures and abundant moisture
Differential Weathering

Bryce Canyon National Park
Differential weathering

- Caused by variations in composition
- Creates unusual and spectacular rock formations and landforms
Soil

• That portion of the regolith (rock and mineral fragments) that supports the growth of plants
• An interface in the Earth system
SOIL: An interface in the Earth system

Soil is a combination of

- Mineral matter
- Water
- Air
- Biologic components of Earth
Typical components in a soil that yields good plant growth

- 45% mineral matter
- 25% air
- 25% water
- 5% organic matter
Soil texture and structure

Texture refers to the proportions of different particle sizes

- Sand (large size)
- Silt
- Clay (small size)

Loam (a mixture of all three sizes) is best suited for plant life
Controls of soil formation

• Parent material
• Time
• Climate
• Plants and animals
• Slope
Controls of soil formation

Parent material

- Original mineral makeup
- Important in young soils
- Residual soil – from bedrock
- Transported soil – carried from elsewhere
Controls of soil formation

Time

- varies for soils in different climates, locations
Controls of soil formation

Climate

• Amount of moisture available
• Temperature
  • Chemical reaction speed
  • Rate of plant growth
Controls of soil formation

Plants and animals

• Organisms influence the soil's physical and chemical properties
• Furnish organic matter to soil
Controls of soil formation

Slope

Angle

• Steep: poorly developed soils
• Flat to undulating surface: best

Orientation (direction the slope is facing)

• Soil temperature
• Moisture
An idealized soil profile

- O = organic
- A = with roots
- E = leached
- B = accumulation
- C = partly weathered bedrock
- R = unweathered bedrock
Soil Profile

Soil forming processes operate from the surface downward

- Horizons – zones or layers of soil
- Mature soils show differences in color and texture from one horizon to another
A soil profile showing different horizons
Soil types

• Hundreds of soil types worldwide
• Five very general types
  • Arid area soils
  • Humid warm soils
  • Humid temperate soils
  • Poorly drained soils
  • Highly weathered soils
**Arid area soils**

**Calcium carbonate**

- Associated with drier grasslands and deserts
- Pale tan with hardpan layer

http://www.casdn.neu.edu/~geology/department/staff/colgan/dinos/dino.htm
Humid temperate soils

- Iron oxides and Al-rich clays in the B-horizon
- Forest vegetation
- Rich brown soil with well developed horizons

Poorly Drained soils

- Dark grey to greenish
- Ashy appearance
- Bogs or permafrost areas

http://soilgc.job.affrc.go.jp/Archive/PhotoPrf/page_thumb84.html
**Highly weathered soils**

- Hot, wet, tropical climates
- Intense chemical weathering
- Often red or very pale

[Image of a diagram showing the processes of leaching and the formation of iron and aluminum oxides in laterite soil.]

**Sources:**
- [http://ruby.colorado.edu/~smyth/G1010-06.html](http://ruby.colorado.edu/~smyth/G1010-06.html)
Mineral Enrichment by weathering

Diagrammatic section illustrating the enrichment of a copper-ore body. Soluble sulphide minerals (such as chalcopyrite) were leached, transported and redeposited above the water table as oxidised minerals. Enriched copper minerals (such as chalcocite and bornite) were formed below the water table.

- http://www.geology.ohio-state.edu/~vonfres/gs100/lect24/index.html