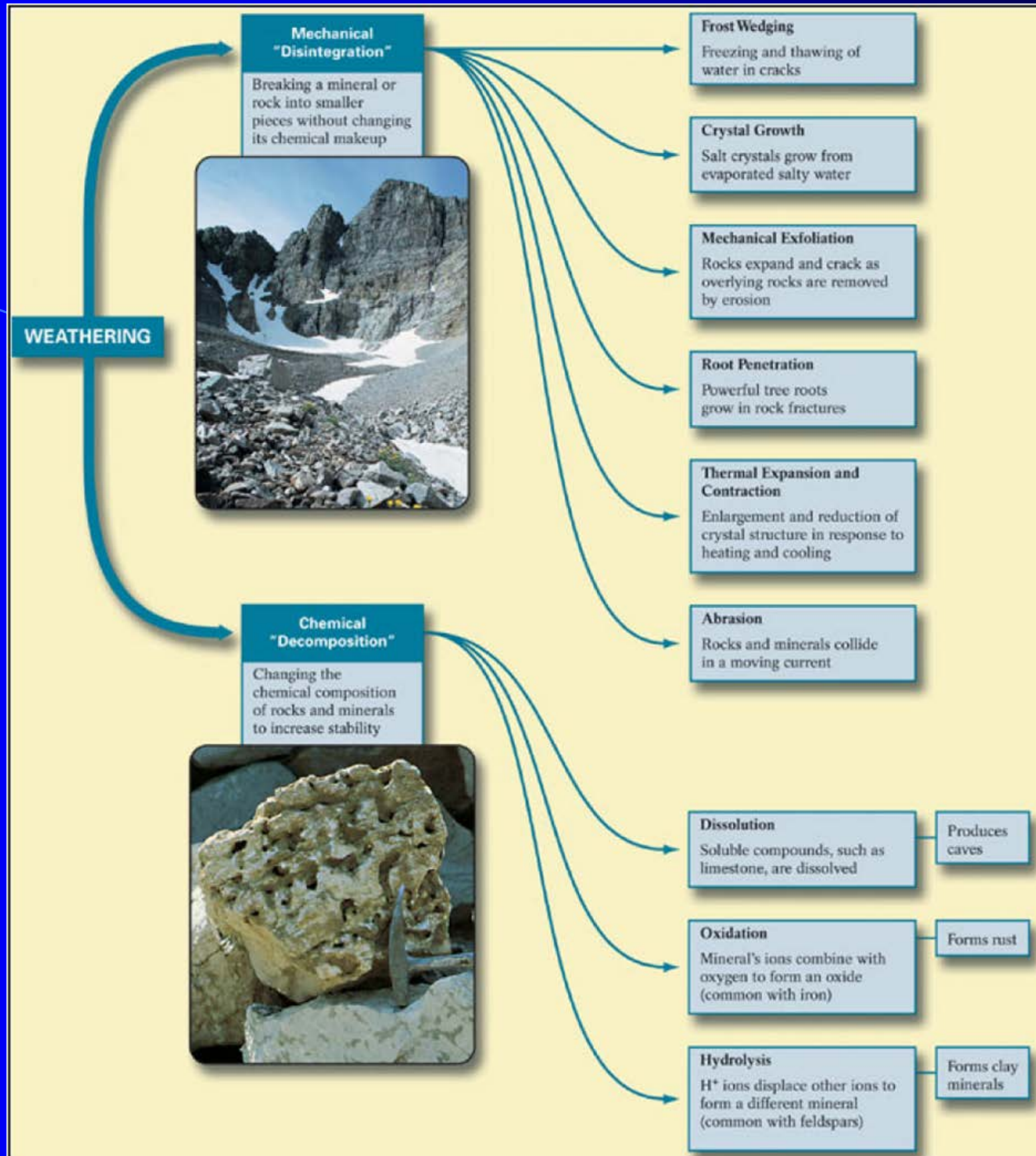
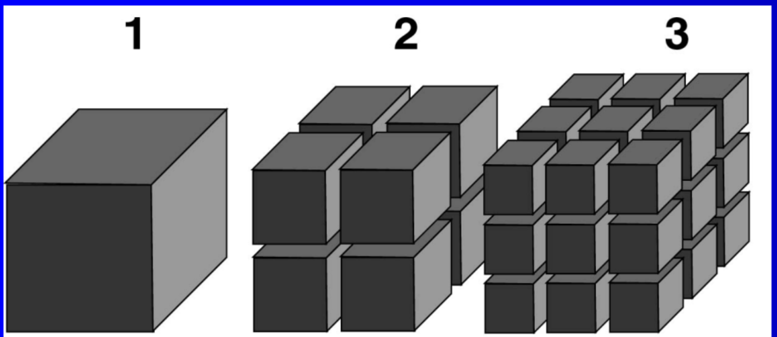
Weathering


WEATHERING
Mechanical "Disintegration"
Breaking a mineral or rock into smaller pieces without changing its chemical makeup
Frost Wedging
Freezing and thawing of water in cracks
Crystal Growth
Salt crystals grow from evaporated salty water
Mechanical Exfoliation
Rocks expand and crack as overlying rocks are removed by erosion
Root Penetration
Powerful tree roots grow in rock fractures
Thermal Expansion and Contraction
Enlargement and reduction of crystal structure in response to heating and cooling
Abrasion
Rocks and minerals collide in a moving current
Chemical "Decomposition"
Changing the chemical composition of rocks and minerals to increase stability
Dissolution
Soluble compounds, such as limestone, are dissolved
Produces caves
Oxidation
Mineral's ions combine with oxygen to form an oxide (common with iron)
Forms rust
Hydrolysis
H+ ions displace other ions to form a different mineral (common with feldspars)
Forms clay minerals

Weathering – Physical and Chemical

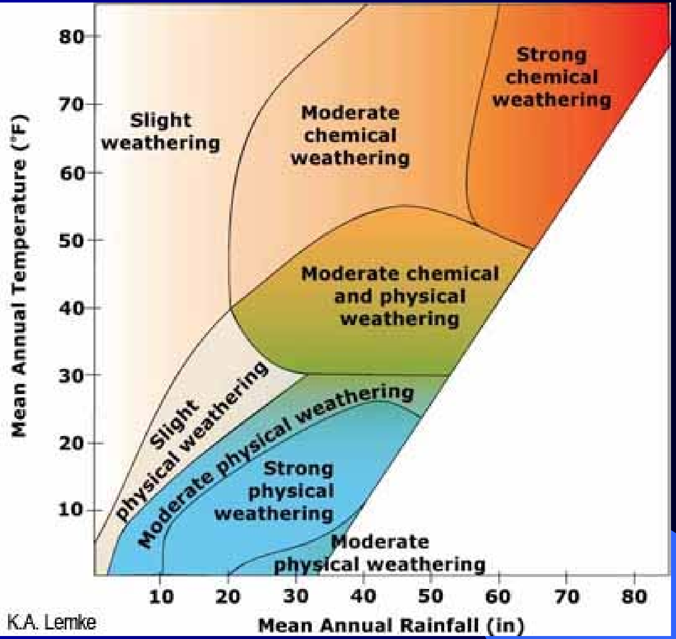
Physical weathering

- Pressure reduction
- Frost wedging
- Salt wedging
- Thermal Stress
- Biological – e.g., plant roots



SA (surface area) = # blocks x SA of each block

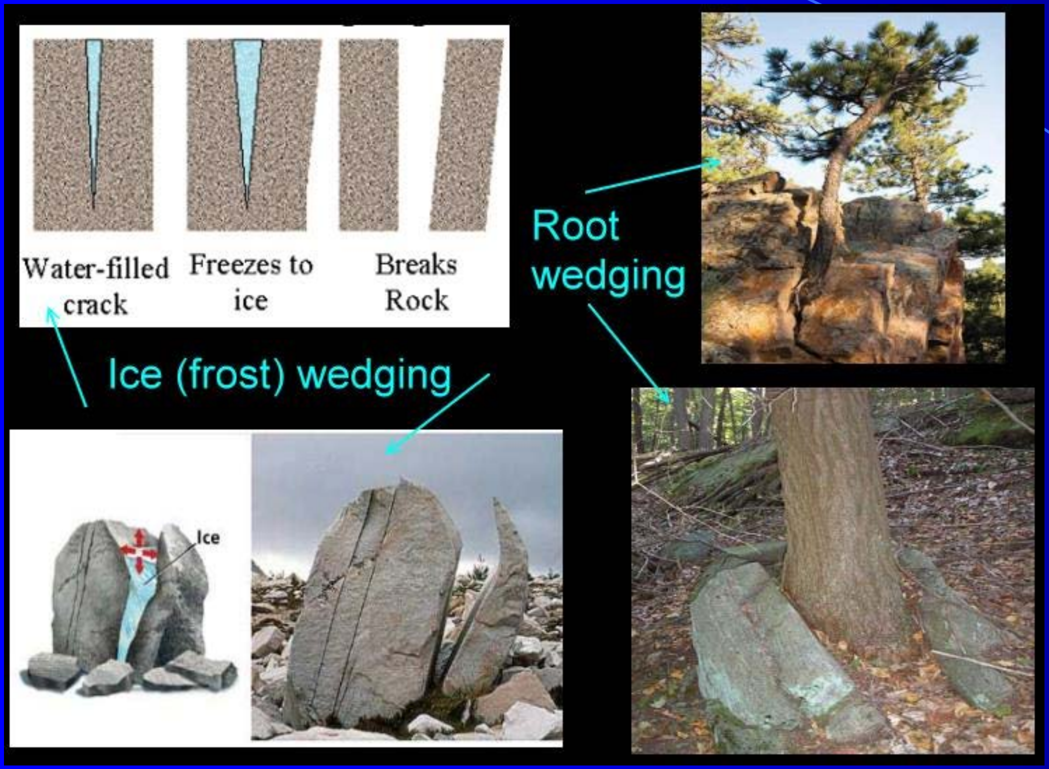
1. area of each face = l x w = 3" x 3" = 9 in^2
   total SA = 6 faces x 9 in^2 = 54 in^2
2. area of each face = l x w = 1.5" x 1.5" = 2.25 in^2
   total SA = 6 faces x 8 blocks x 2.25 in^2 = 108 in^2
3. area of each face = l x w = 1" x 1" = 1 in^2
   total SA = 6 faces x 27 blocks x 1 in^2 = 162 in^2

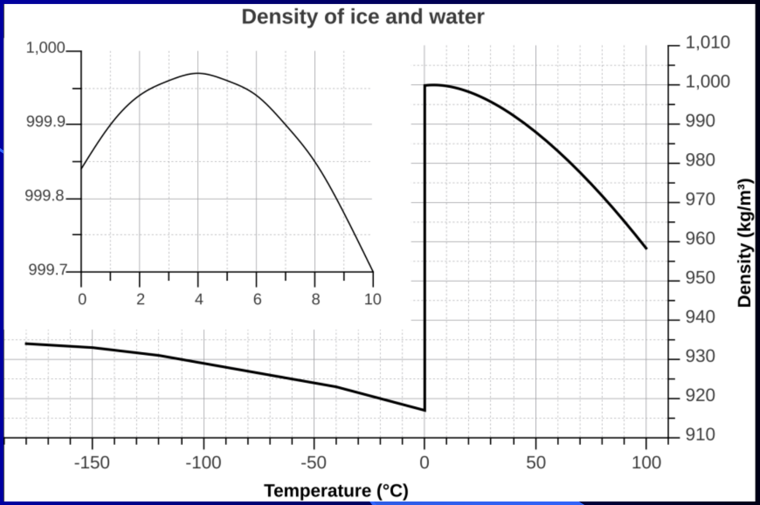


Chemical weathering

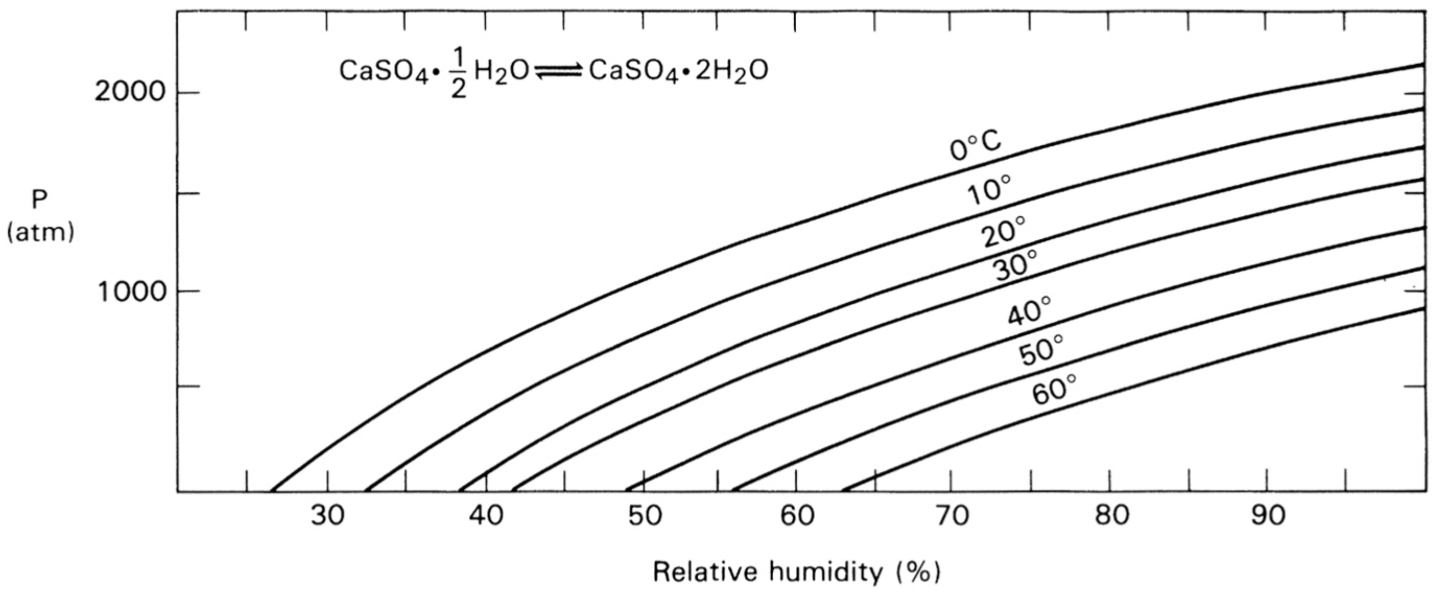
- Dissolution and carbonation
- Hydration
- Hydrolysis – silicates and carbonates
- Oxidation
- Biological Weathering

Physical Weathering

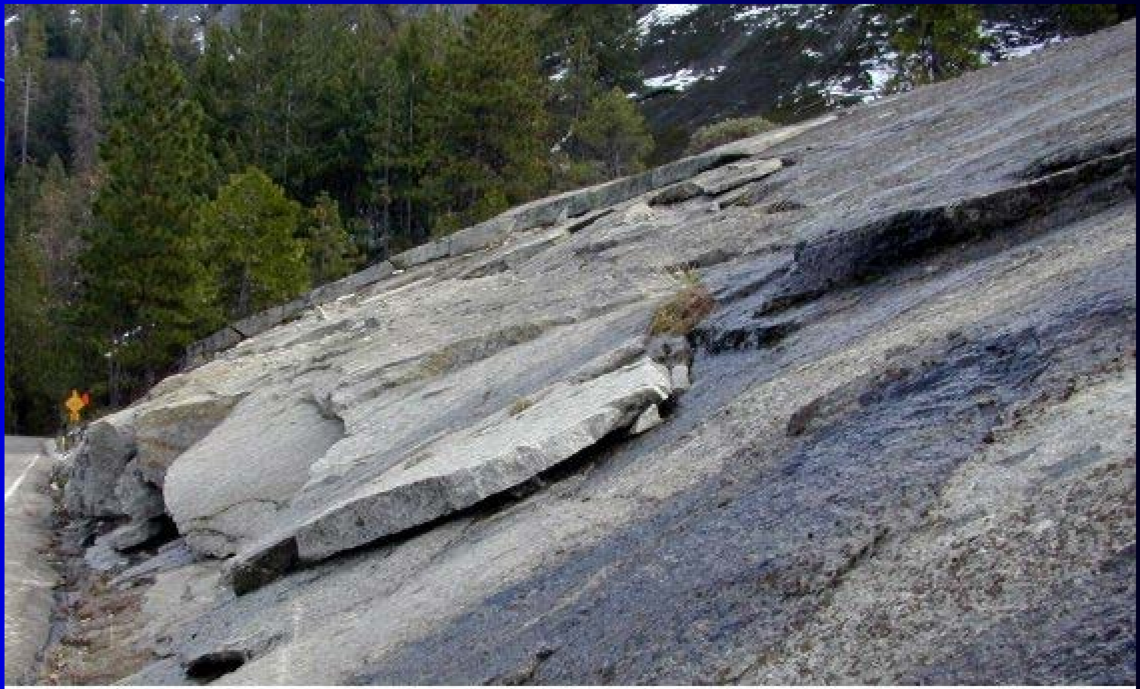




Salt weathering



Physical Weathering



Exfoliation slabs, Yosemite National Park, California

Tarbuck & Lutgens

These rocks have been exposed to temperature extremes in desert surroundings which caused them to disintegrate.

Chemical Weathering Reactions

$$Mg_2SiO_4 + 4\,H^+ + 4\,OH^- \rightleftharpoons 2\,Mg^{2+} + 4\,OH^- + H_4SiO_4$$

$$Mg_2SiO_4 + 4\,CO_2 + 4\,H_2O \rightleftharpoons 2\,Mg^{2+} + 4\,HCO_3^- + H_4SiO_4$$

$$2\,KAlSi_3O_8 + 2\,H_2CO_3 + 9\,H_2O \rightleftharpoons Al_2Si_2O_5(OH)_4 + 4\,H_4SiO_4 + 2\,K^+ + 2\,HCO_3^-$$

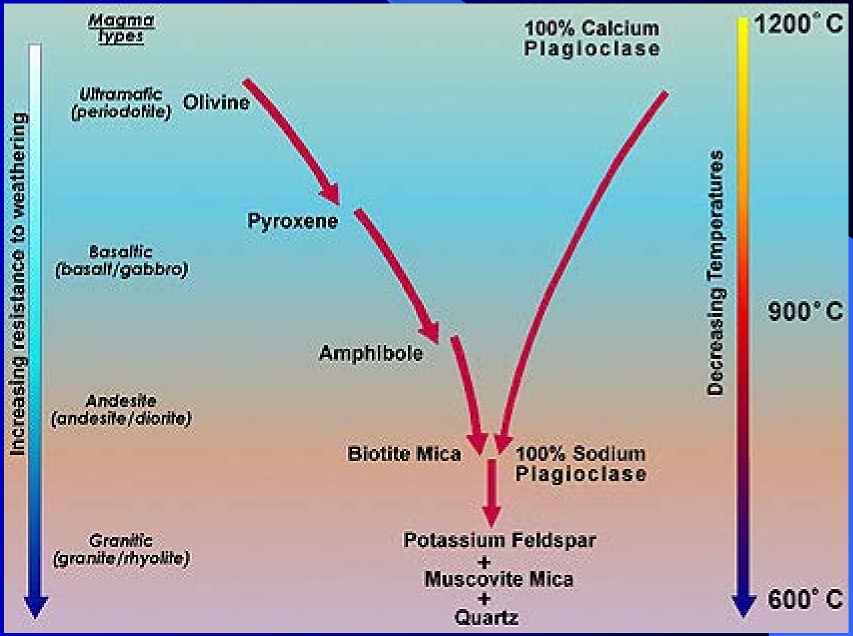
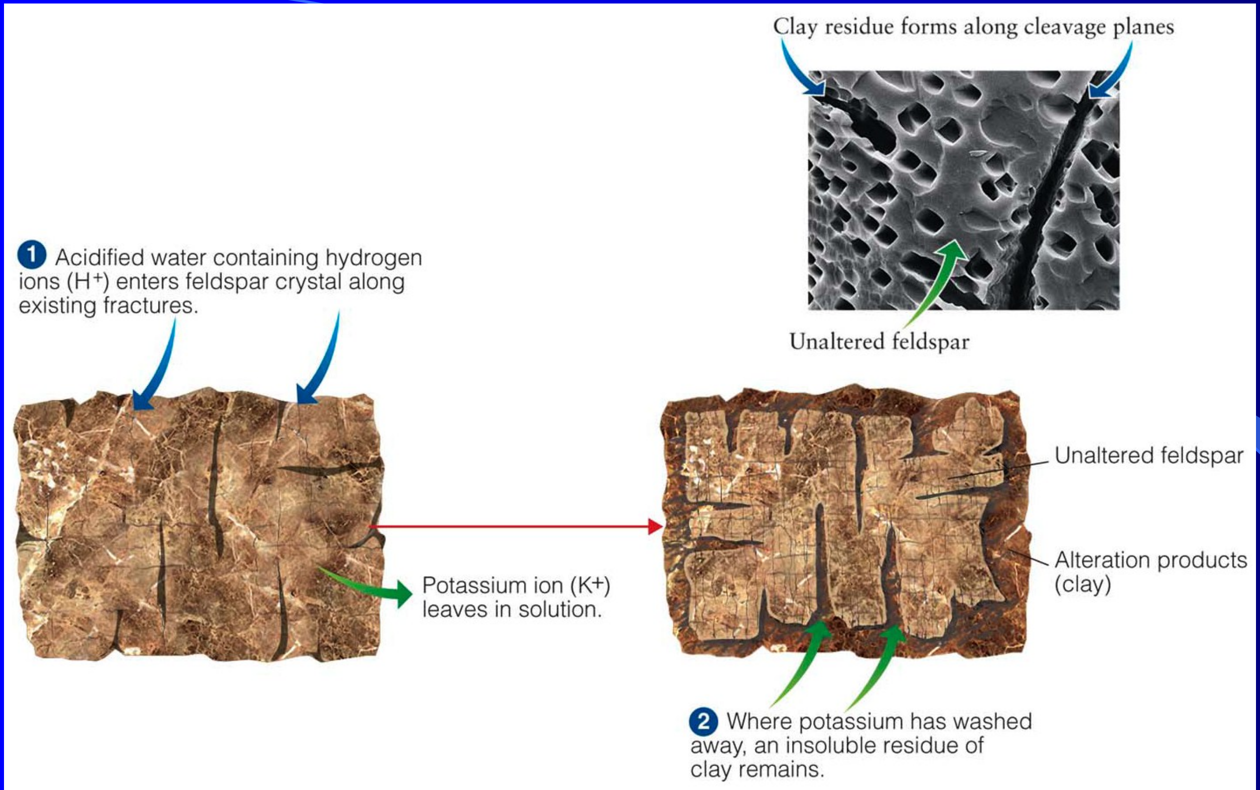
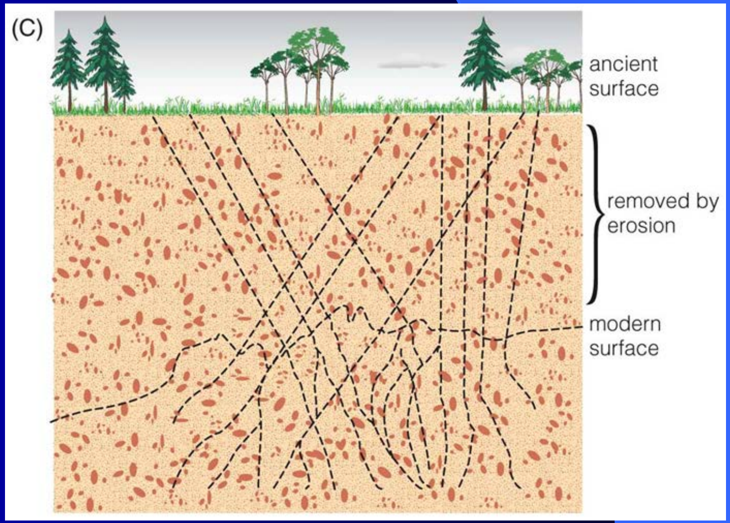


Table 10.1 Relative stabilities of some igneous rock-forming minerals during weathering.

High stability	Quartz	
Increasing stability ↑	Muscovite	
	K-feldspar	
	Biotite	Albite
	Hornblende	Intermediate plagioclase compositions
	Augite	Anorthite
Low stability	Olivine	


Clay residue forms along cleavage planes
Unaltered feldspar
1 Acidified water containing hydrogen ions (H+) enters feldspar crystal along existing fractures.
Potassium ion (K+) leaves in solution.
Unaltered feldspar
Alteration products (clay)
2 Where potassium has washed away, an insoluble residue of clay remains.


(C)
ancient surface
removed by erosion
modern surface

Hydrolysis of Potassium Feldspar and Olivine in an **arid** climate

$2KAlSi_3O_8$ (Feldspar) + $2Mg_2SiO_4$ (Olivine) + $4H_2CO_3$ (Carbonic Acid) ----->

-----> $2K^+ + Mg^{2+}$ (Dissolved ions) + $Mg_3Al_2Si_8O_{20}(OH)_4$ (A smectite* - a clay mineral) + $4HCO_3^-$ (Bicarbonate)

No dissolved silica

Hydrolysis of Potassium Feldspar and Olivine in a **moderate** climate

$2KAlSi_3O_8$ (Feldspar) + Mg_2SiO_4 (Olivine) + $6H_2CO_3$ (Carbonic Acid) + $9H_20$ (Water) ----->

-----> $2K^+ + 2Mg^{2+}$ (Dissolved ions) + $Al_2Si_2O_5(OH)_4$ (Kaolinite - a clay mineral) + $6HCO_3^-$ (Bicarbonate) + $5H_4SiO_4$ (Dissolved silica ("Silicic acid"))

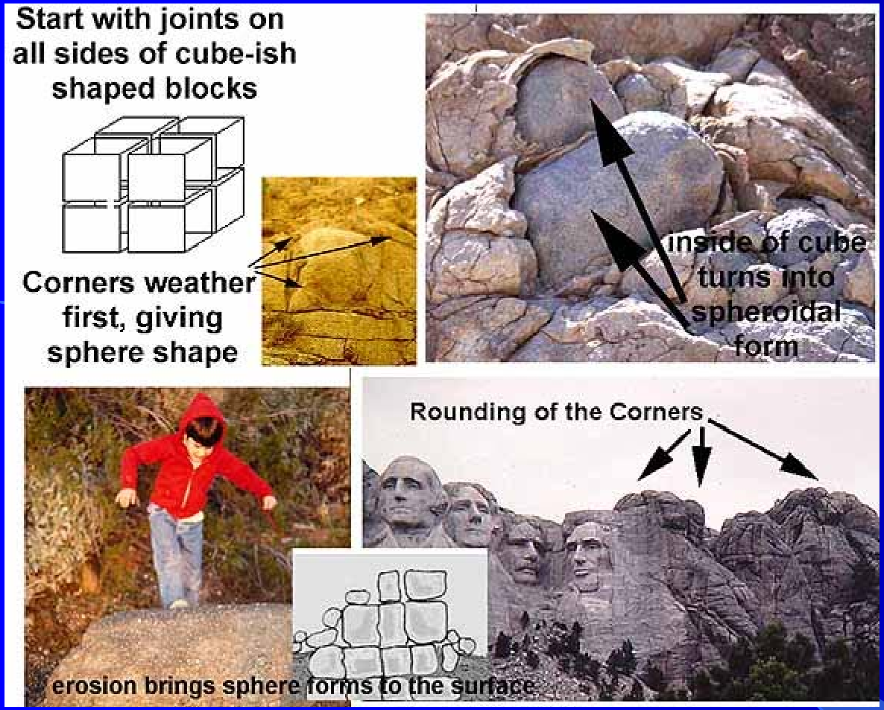
Hydrolysis of Potassium Feldspar and Olivine in a **very wet** climate

$2KAlSi_3O_8$ (Feldspar) + Mg_2SiO_4 (Olivine) + $6H_2CO_3$ (Carbonic Acid) + $14H_20$ (Water) ----->

-----> $2K^+ + 2Mg^{2+}$ (Dissolved ions) + $2Al(OH)_3$ (Gibbsite) + $6HCO_3^-$ (Bicarbonate) + $7H_4SiO_4$ (Dissolved silica ("Silicic acid"))

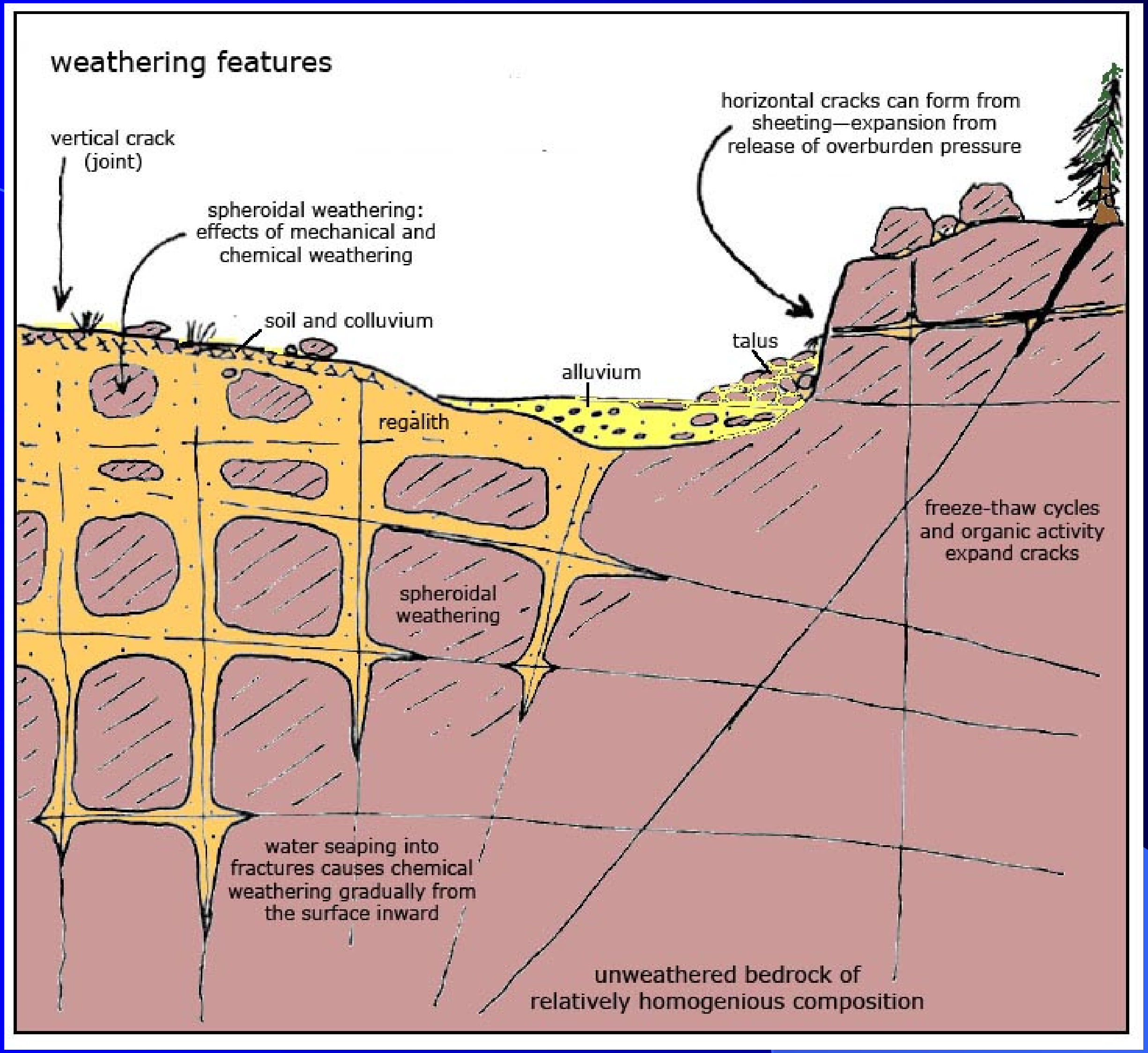
*Clay mineralogists: This "smectite" would be something like a dehydrated wierd beidellite. Leave me alone - this is for introductory students in a general class!

LBR 3/2002



Spheroidal weathering

Depth of weathering is a function of time and access (fractures)



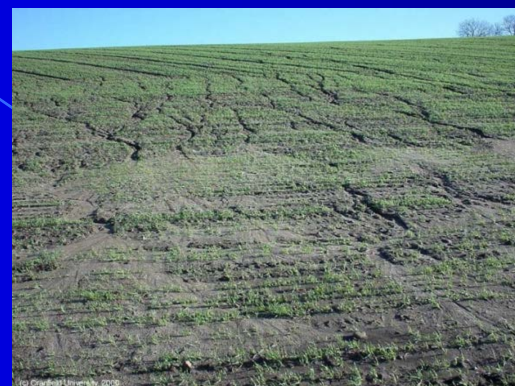
Factors Controlling Rates of Weathering

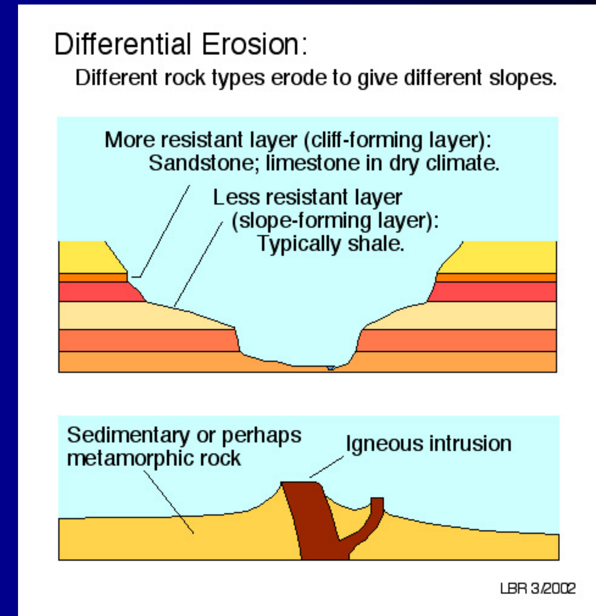
Table 7.1 Major Factors Controlling Rates of Weathering

	Weathering Rate: Slow →		→ Fast
PROPERTIES OF PARENT ROCK			
Mineral solubility in water	Low (e.g., quartz)	Moderate (e.g., pyroxene, feldspar)	High (e.g., calcite)
Rock structure	Massive	Some zones of weakness	Very fractured or thinly bedded
CLIMATE			
Rainfall	Low	Moderate	High
Temperature	Cold	Temperate	Hot
PRESENCE OR ABSENCE OF SOIL AND VEGETATION			
Thickness of soil layer	None—bare rock	Thin to moderate	Thick
Organic content	Low	Moderate	High
LENGTH OF EXPOSURE			
Short	Moderate	Long	

Table 9.3 Erosional Agents

Gravity (mass wasting)
Water (fluvial erosion)
Wind (aeolian erosion)
Glacial ice
Waves

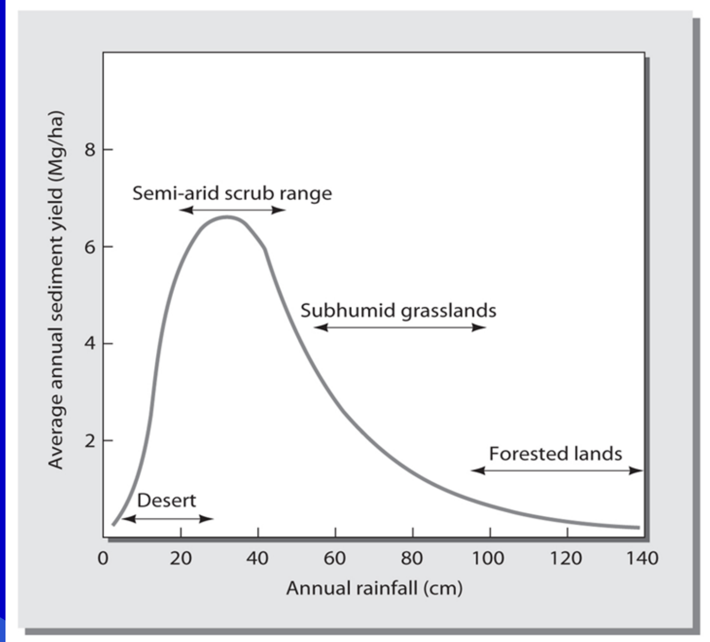




Erosion

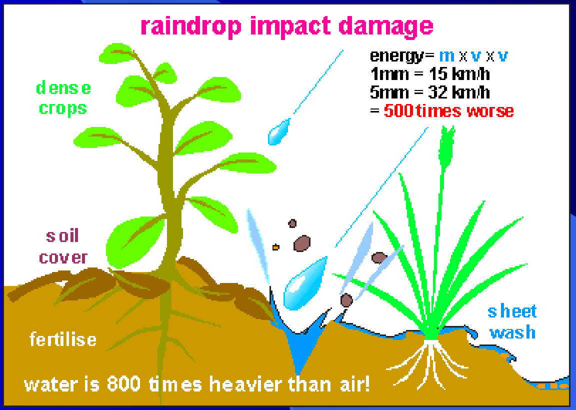
Table 9.4 Variables Affecting Soil Erosion

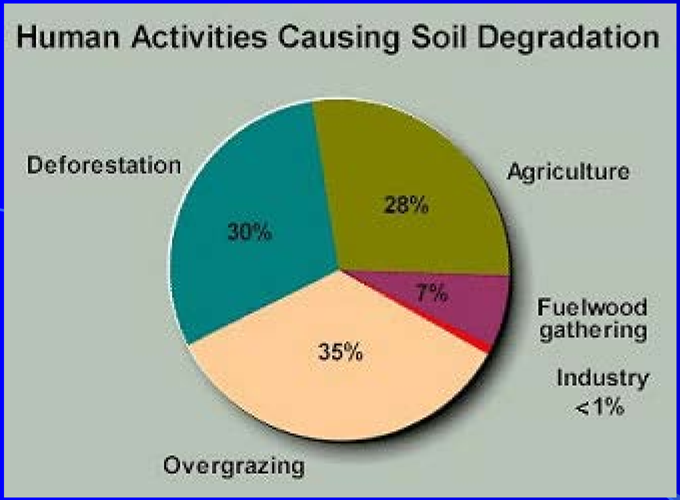
- Rainfall
  - Intensity
  - Duration
- Soil Characteristics
  - Porosity
  - Permeability
  - Moisture content
  - Grain size and shape
- Topography
  - Orientation of slope
  - Slope angle
  - Length of slope
- Vegetation
  - Type and distribution on slope

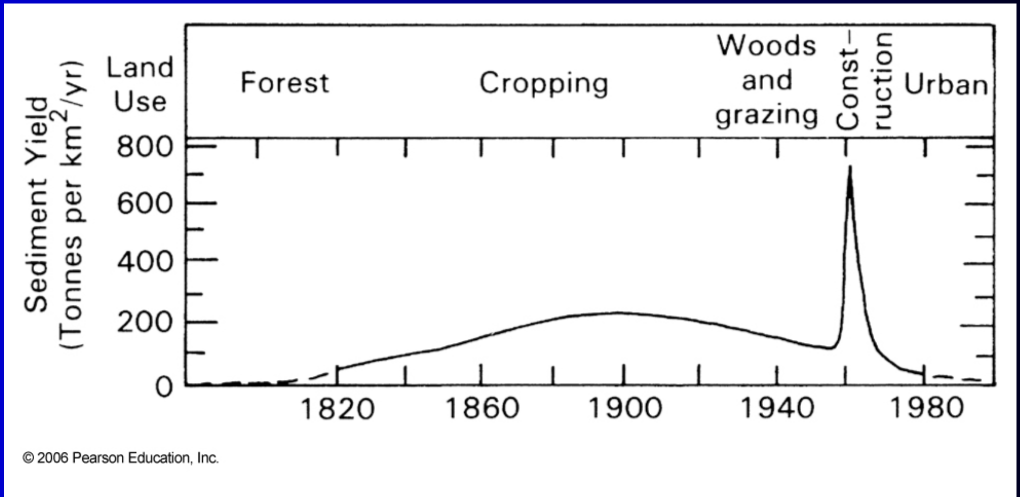


A = RKLSCP

A = average annual soil loss (tons/acre)
R = rainfall factor (see map)
K = soil-erodibility factor
LS = slope length – steepness factor
C = cropping factor
P = conservation factor




Human Activities Causing Soil Degradation
Deforestation
30%
Agriculture
28%
Fuelwood gathering
7%
Industry <1%
35%
Overgrazing


Land Use
Forest
Cropping
Woods and grazing
Const–ruction
Urban
Sediment Yield (Tonnes per km^2/yr)
800
600
400
200
0
1820
1860
1900
1940
1980
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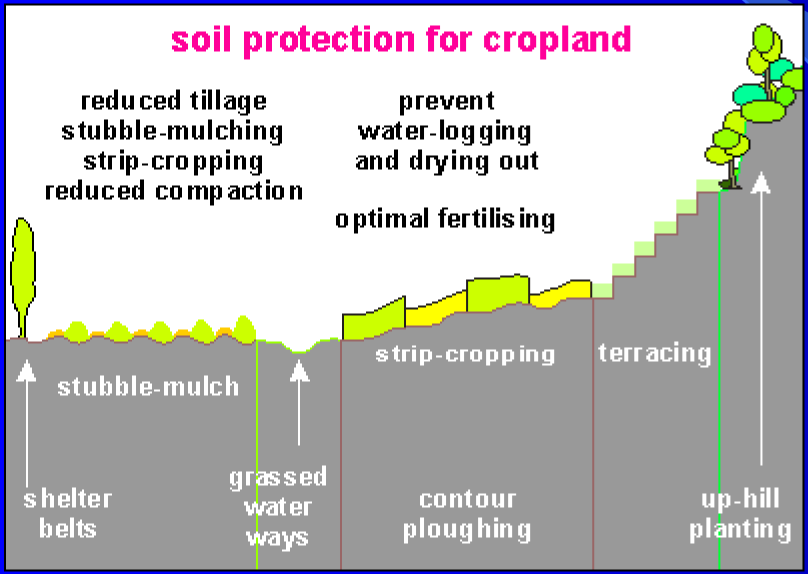
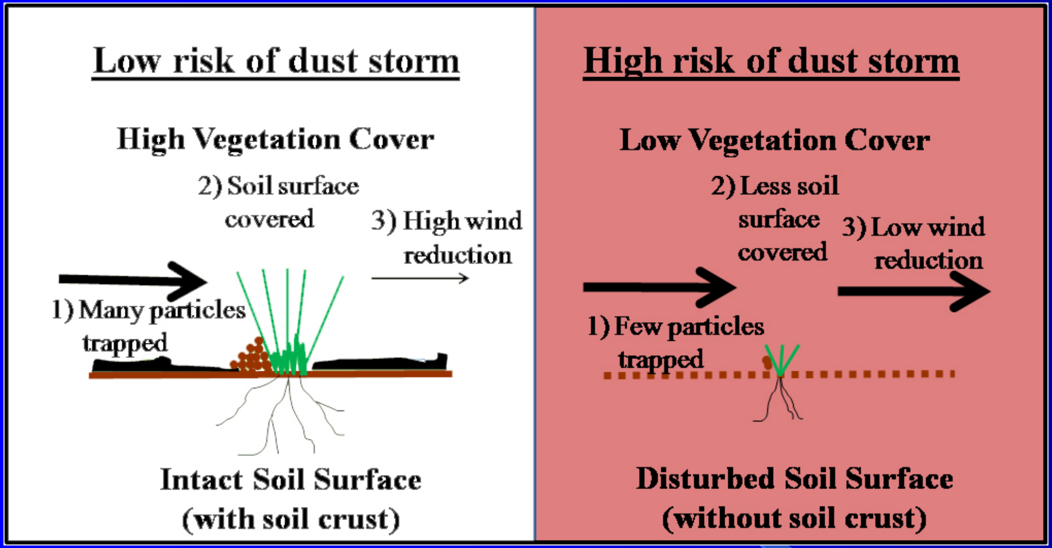
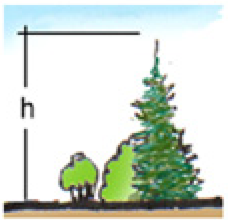

soil protection for cropland
reduced tillage
stubble-mulching
strip-cropping
reduced compaction
prevent
water-logging
and drying out
optimal fertilising
stubble-mulch
strip-cropping
terracing
shelter belts
grassed water ways
contour ploughing
up-hill planting

Erosion control





Open Wind Speed 20 mph
40 to 60% Density

Downwind Zone of Protection

h distance from windbreak	5h	10h	15h	20h	30h
miles per hour	6	10	12	15	19
% of open wind speed	30%	50%	60%	75%	95%