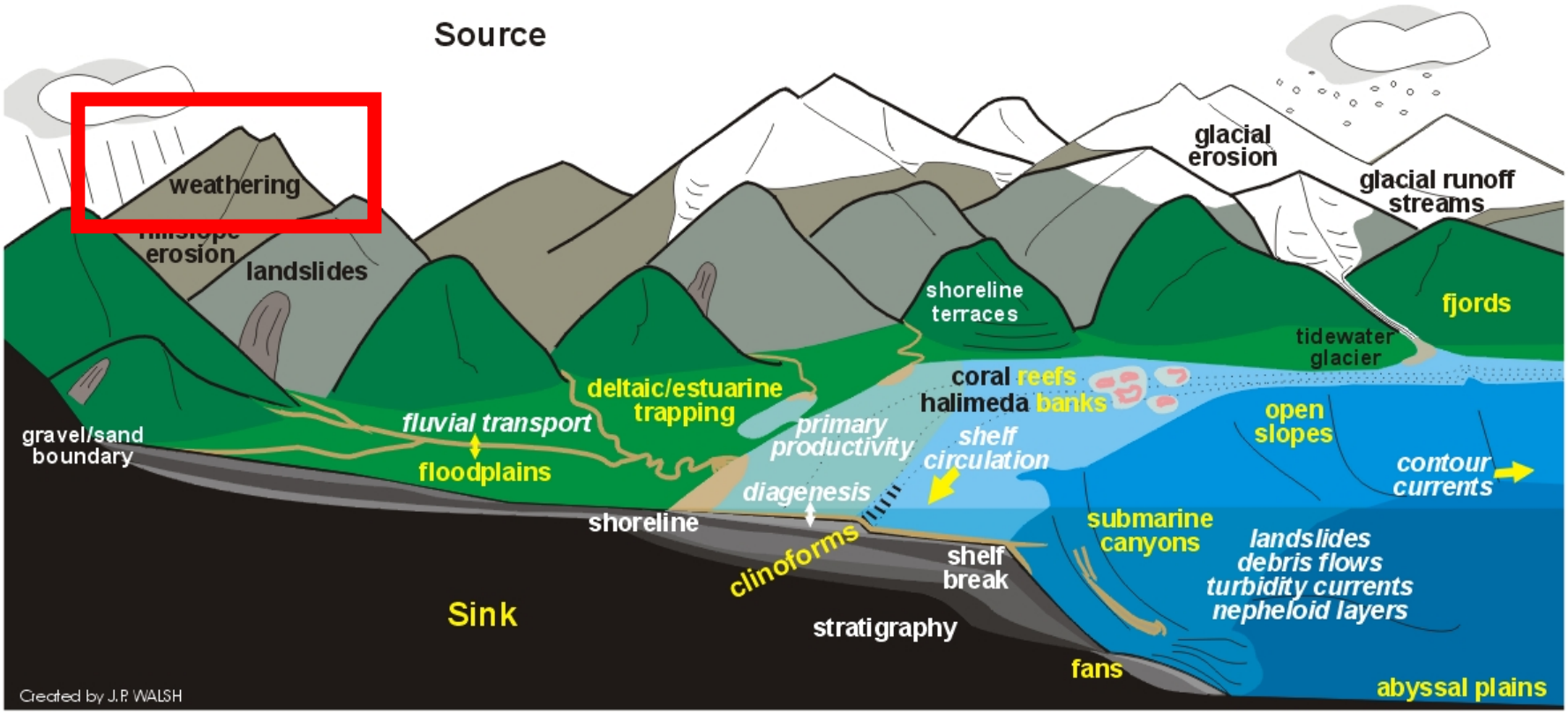
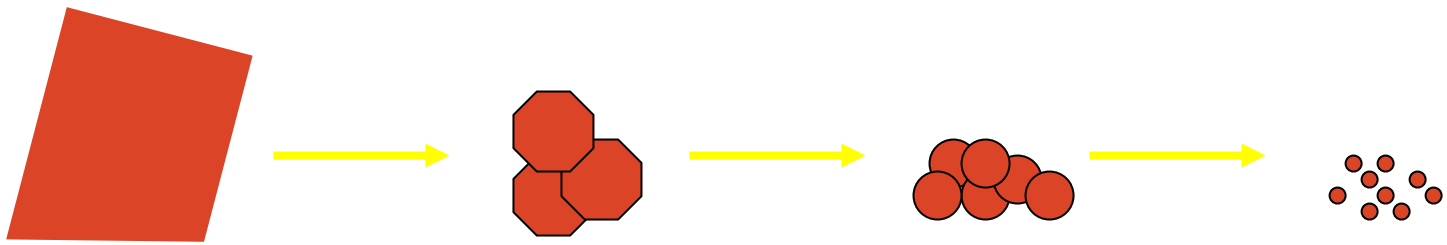
Weathering


Source
weathering
erosion
landslides
glacial erosion
glacial runoff streams
shoreline terraces
fjords
tidewater glacier
deltaic/estuarine trapping
fluvial transport
floodplains
gravel/sand boundary
coral reefs
halimeda banks
primary productivity
shelf circulation
open slopes
contour currents
diagenesis
shoreline
clinoforms
submarine canyons
landslides
debris flows
turbidity currents
nepheloid layers
shelf break
Sink
stratigraphy
fans
abyssal plains
Created by J.P. WALSH

Weathering: the disintegration, or breakdown of rock material

Mechanical Weathering: no change in chemical composition--just disintegration into smaller pieces



Chemical Weathering: breakdown as a result of chemical reactions

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca^{2+} + 2HCO^{3-}$$

Mechanical Weathering

Physical breakup

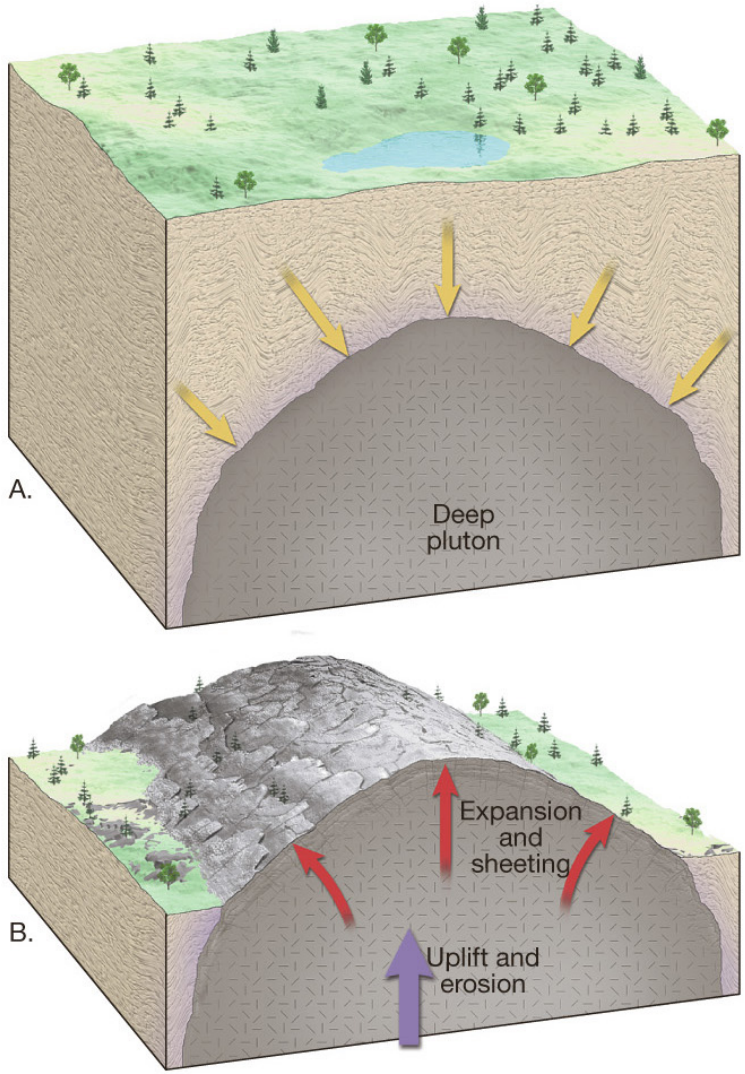
- pressure release
- water: freeze - thaw cycles
- crystallization of salt in cracks
- thermal expansion and contraction

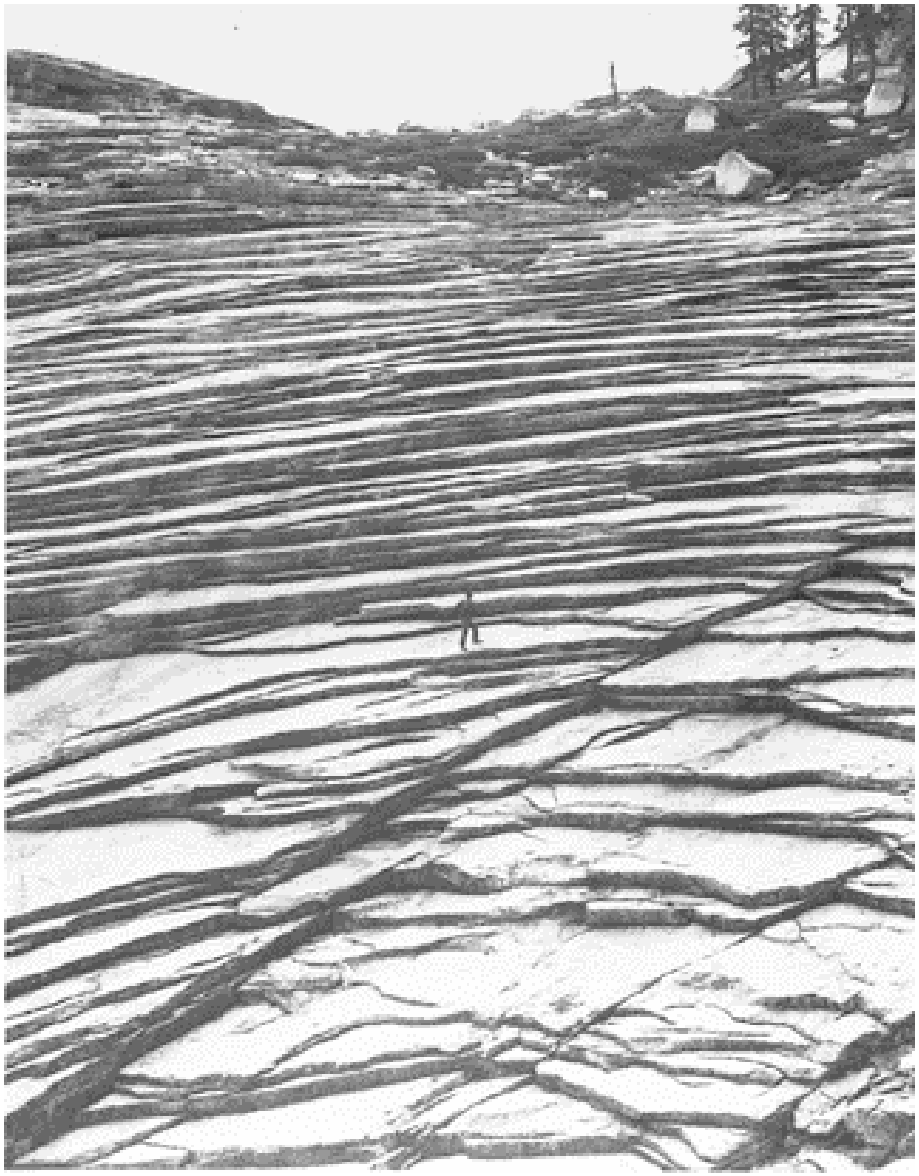
All this increases the total surface area exposed to weathering processes.

Mechanical Weathering

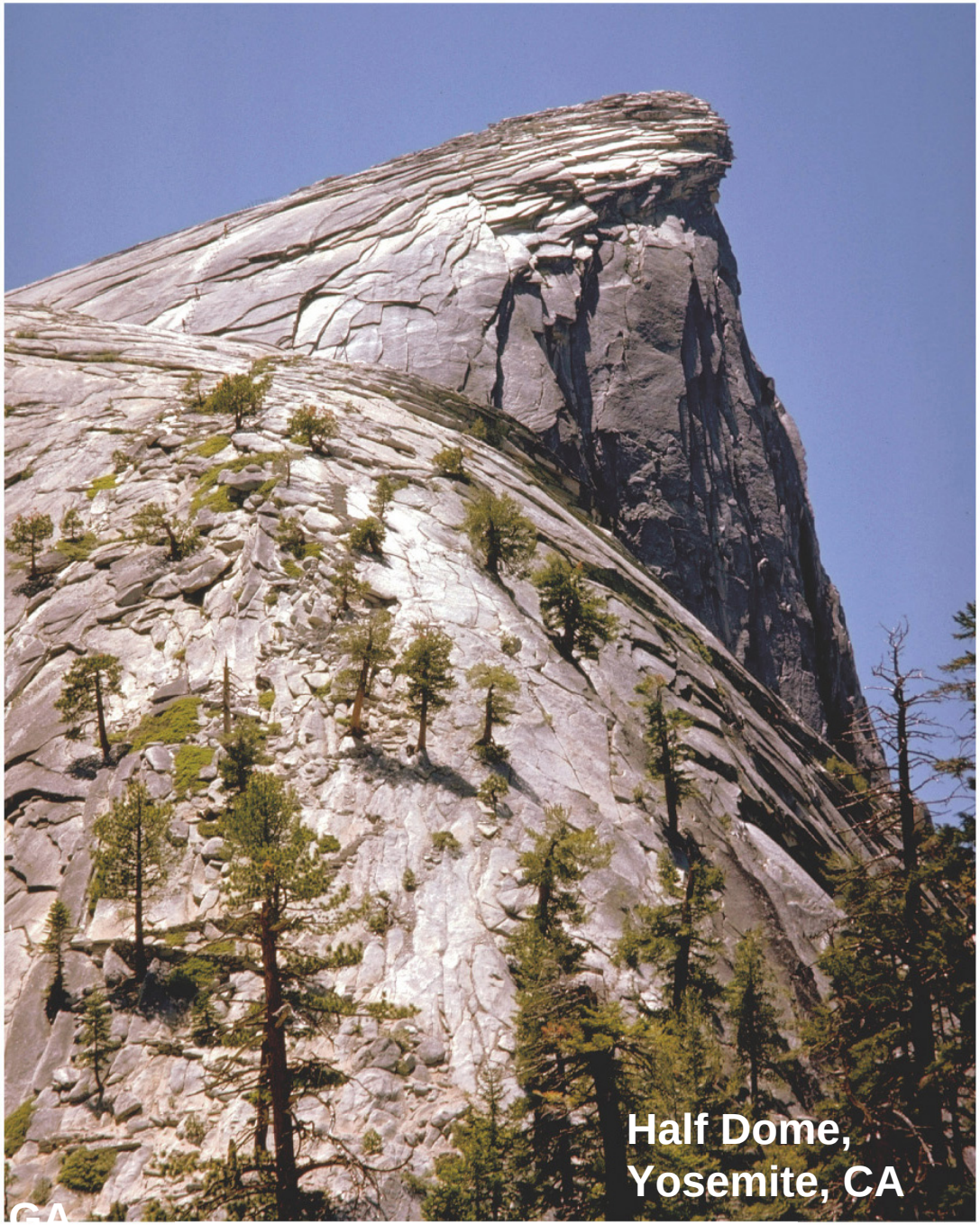
Exfoliation:
Rock breaks apart in layers that are parallel to the earth's surface; as rock is uncovered, it expands (due to the lower confining pressure) resulting in exfoliation.

Mechanical Weathering





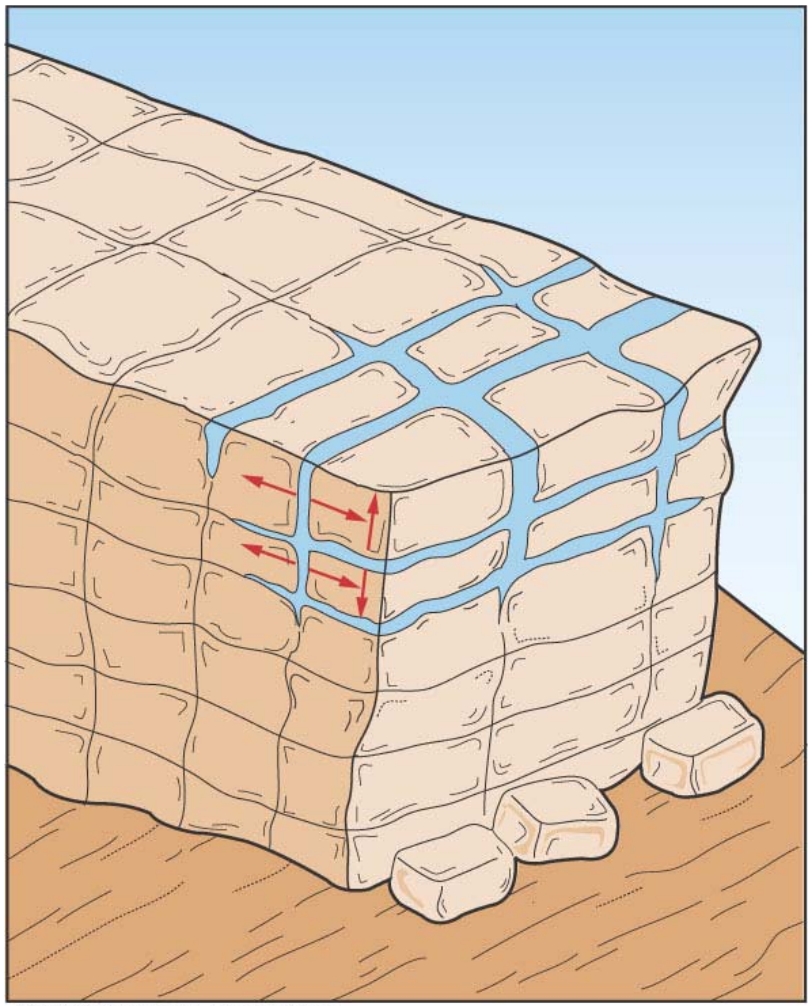
Sheet Joints (Exfoliation)


Half Dome,
Yosemite, CA

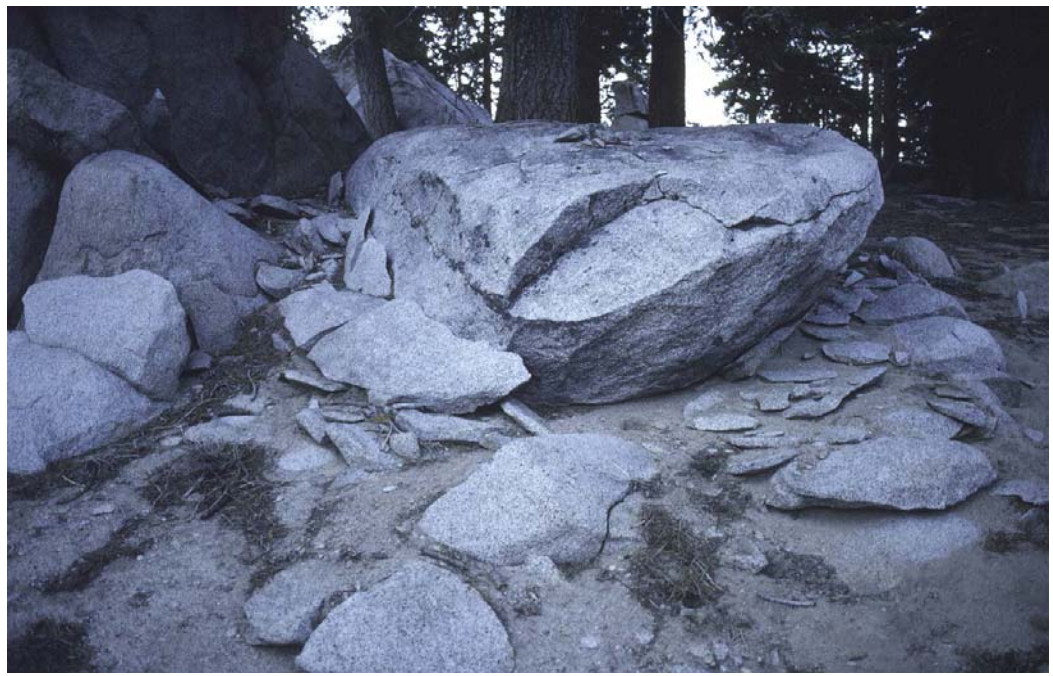
Exfoliated Domes, Yosemite

Stone Mountain, Georgia, showing the product of exfoliation due to unloading

Frost Wedging: rock breakdown caused by expansion of ice in cracks and joints



Shattered rocks are common in cold and alpine environments where repeated freeze-thaw cycles gradually pry rocks apart.



Thermal expansion due to the extreme range of temperatures can shatter rocks in desert environments.

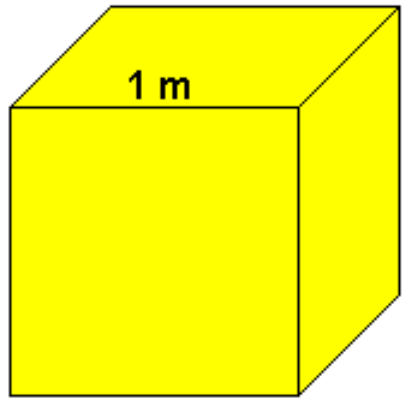
Repeated swelling and shrinking of minerals with different expansion rates will also shatter rocks.

Role of Physical Weathering

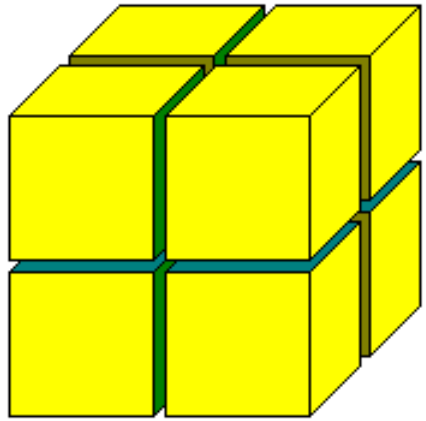
1) Reduces rock material to smaller fragments that are easier to transport

2) Increases the exposed surface area of rock, making it more vulnerable to further physical and chemical weathering

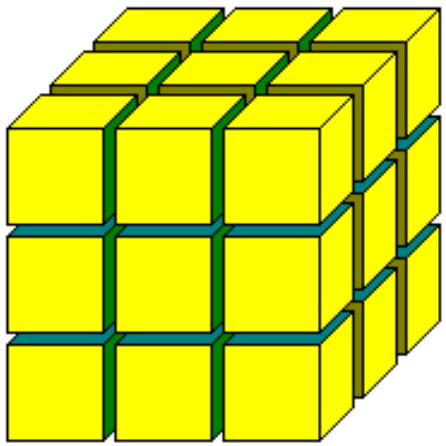
Surface Area and Weathering



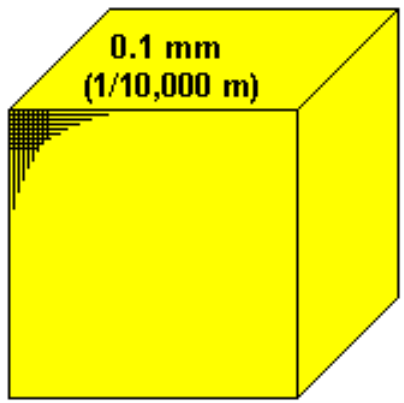
Area = 6 x $1m^2$ = 6 m^2



Area = 6 x $(1/2m)^2$ x 8 = 12 m^2



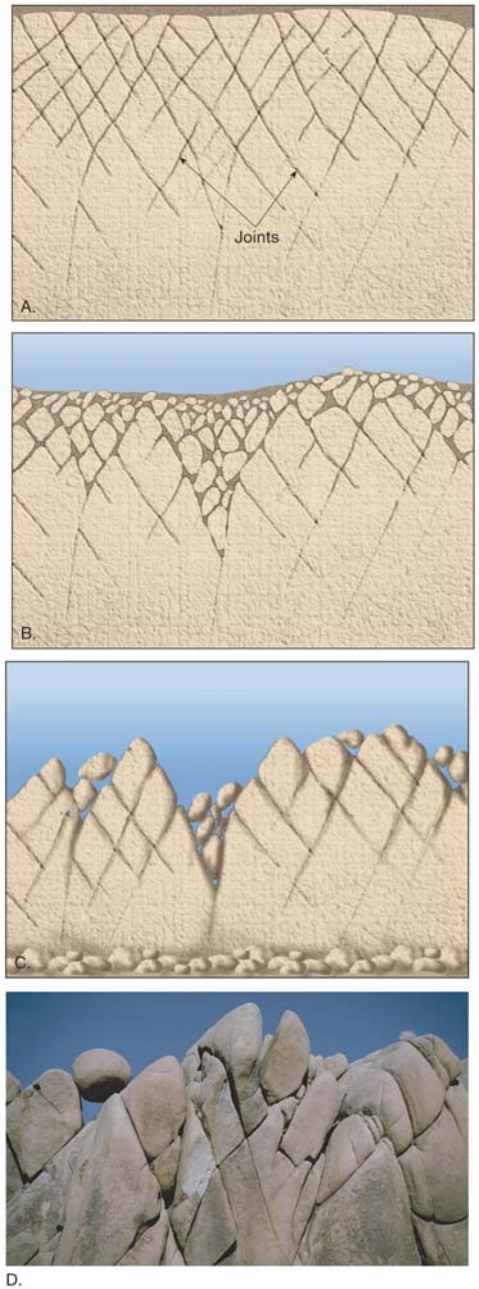
Area = 6 x $(1/3m)^2$ x 27=18 m^2



Area = 6 x $(1/10,000m)^2$ x 10^8 = 10^4 m^2 = 2.5 acres

Rates of weathering

Joints in a rock are a pathway for water – they can enhance mechanical weathering



Chemical Weathering

Definition: transformation/decomposition of one mineral into another

Mineral breakdown

- carbonate dissolves
- primary minerals --> secondary minerals (mostly clays)

Net loss of elements retained in the soil.

Chemical Weathering

- Water is the main operator:
  - Dissolution
    - Many ionic and organic compounds dissolve in water
      - Silica, K, Na, Mg, Ca, Cl, CO_3, SO_4
  - Acid Reactions
    - Water + carbon dioxide <---> carbonic acid
    - Water + sulfur <---> sulfuric acid
    - H^+ effective at breaking down minerals

Dissolution

$H_2O + CO_2 + CaCO_3 \rightarrow Ca^{+2} + 2HCO_3^-$

water + carbon dioxide + calcite dissolve into calcium ion and bicarbonate ion

Biological activity in soils generates substantial CO_2

Bicarbonate is the dominant ion in surface runoff.

Chemical Weathering

- Oxidation
  - Oxygen dissolved in water promotes oxidation of sulfides, ferrous oxides, native metals
- Organic Activity
  - Plant material makes H^+ ions available

Chemical Weathering

- *Hydration*: attachment of water molecules to crystalline structure of a rock, causing expansion and weakness

- *Hydrolysis*: combination of hydrogen and oxygen in water with rock to form new substances

Chemical Weathering

Solution: process by which rock is dissolved in water

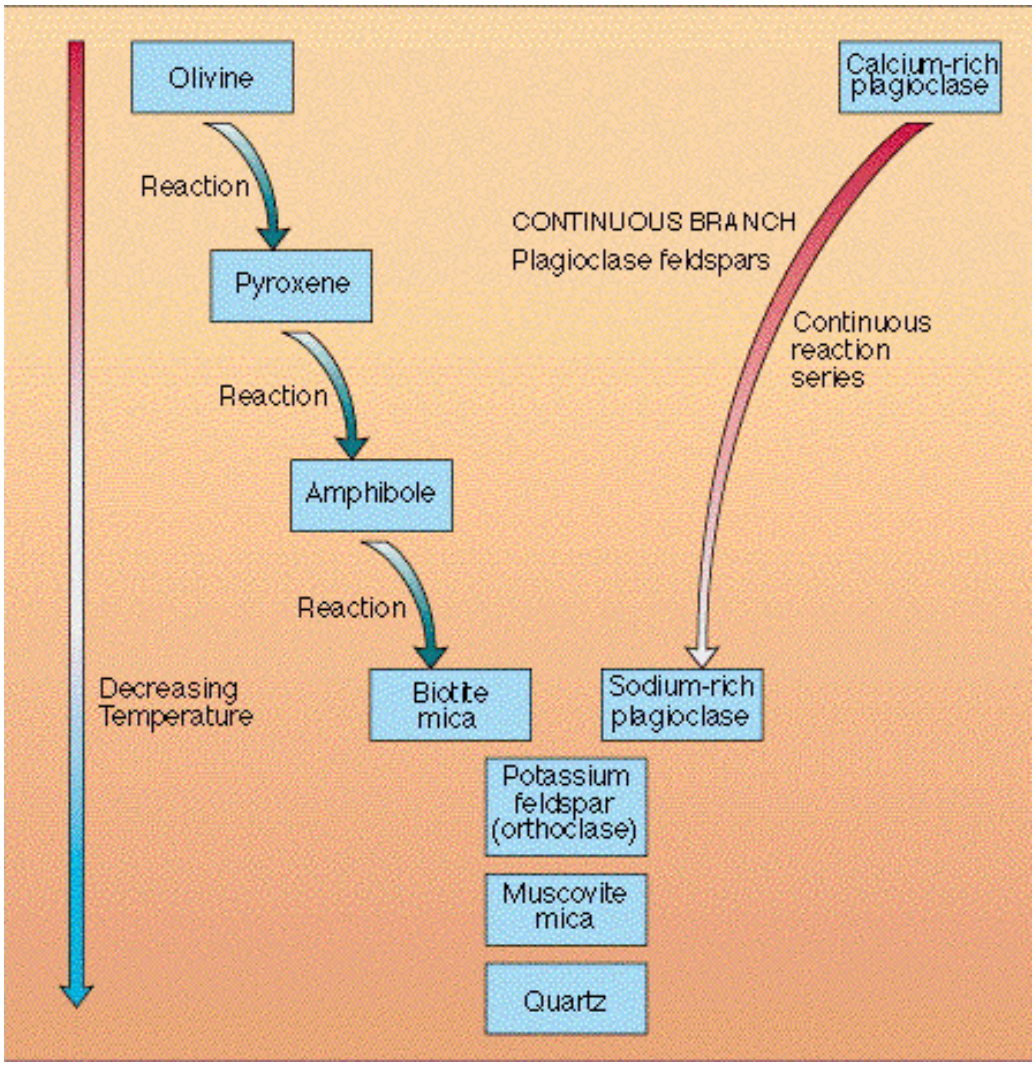
- Is strongly influenced by pH and temperature
- When water becomes saturated, chemicals may precipitate out forming *evaporite* deposits.
- Calcium carbonate (calcite, limestone), sodium chloride (salt), and calcium sulfate (gypsum) are particularly vulnerable to solution weathering.

Resistance to Weathering

First to Crystallize

Bowen's Reaction Series

Last to Crystallize



Fast Weathering

Goldrich Stability Series

Slow Weathering

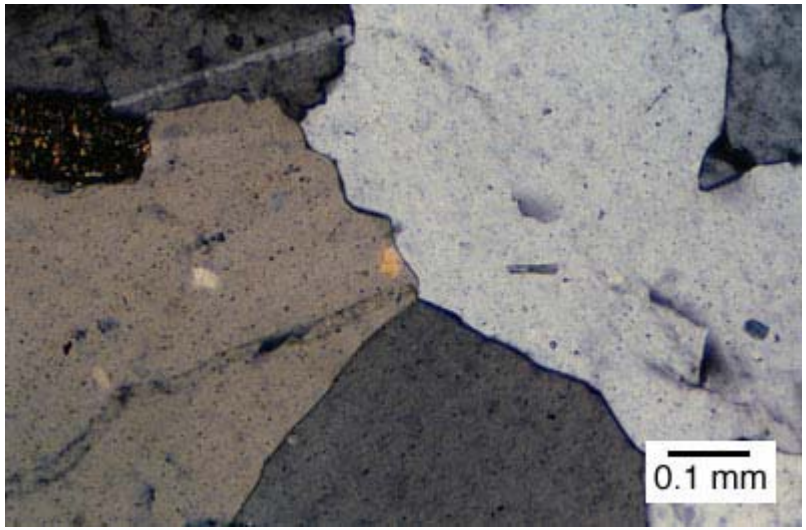
Olivine/pyroxene to clay

+ H_2CO_3 (acid)

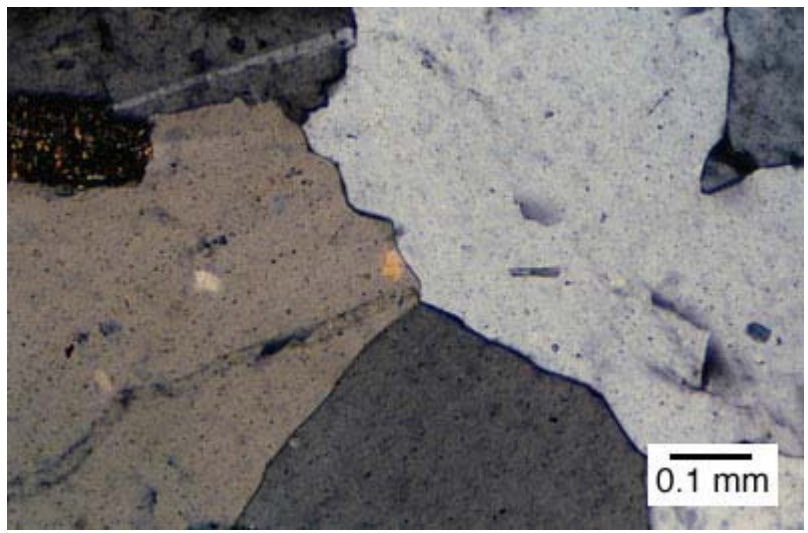
Feldspars to clay

+ H_2CO_3 (acid)

Quartz to quartz (!)



+ anything



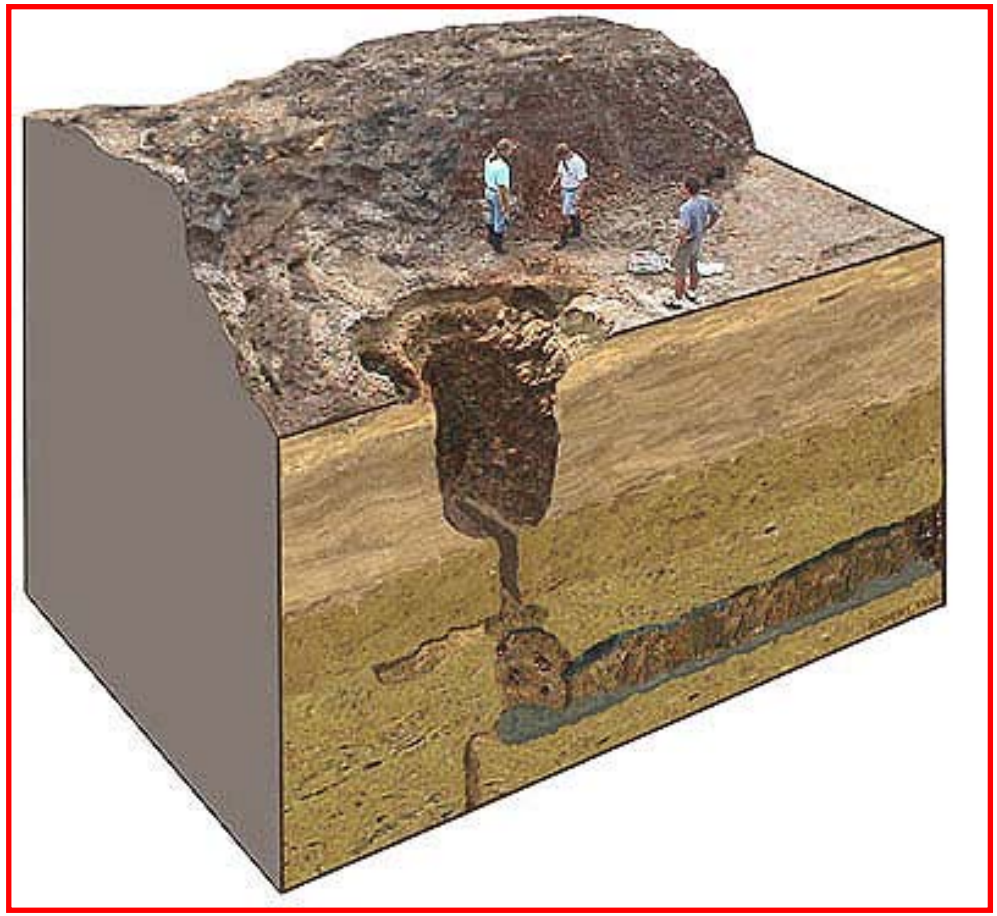
Calcite to …….

+ anything

↓

nothing

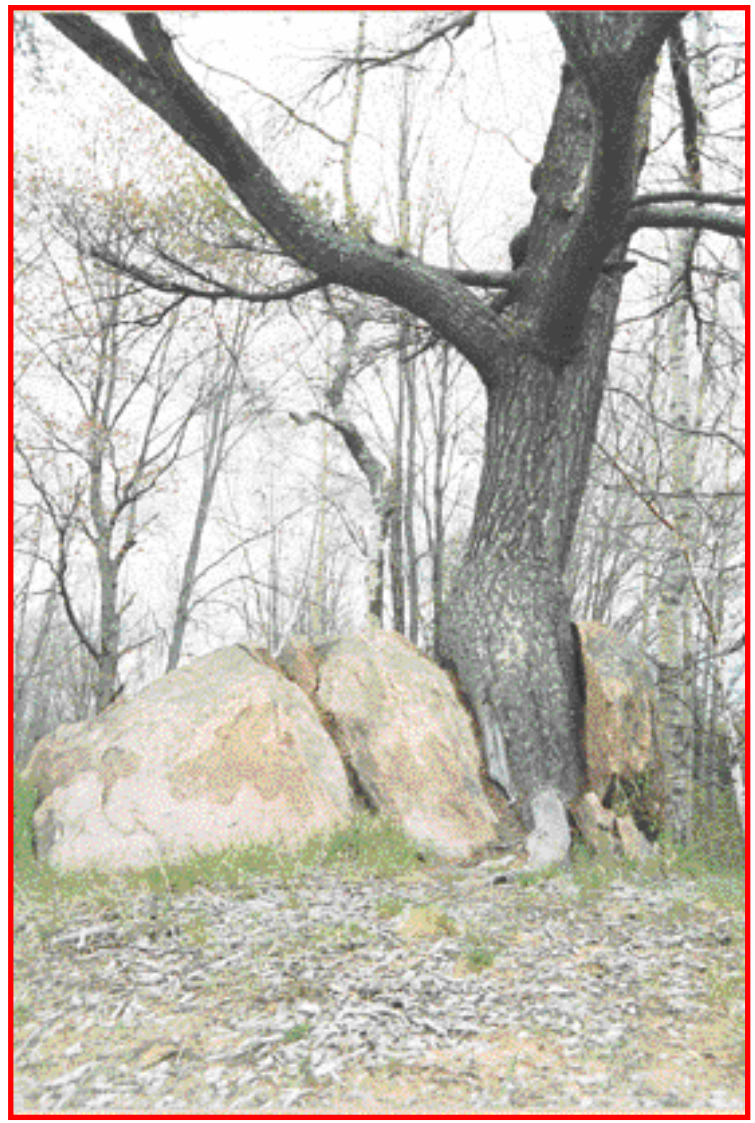
'Karst' landforms develop in areas underlain with limestone



Biological Weathering

Can be both chemical and mechanical in nature.

- roots split rocks apart
- roots produce acids that dissolve rocks.
- tree throw
- burrowing animals



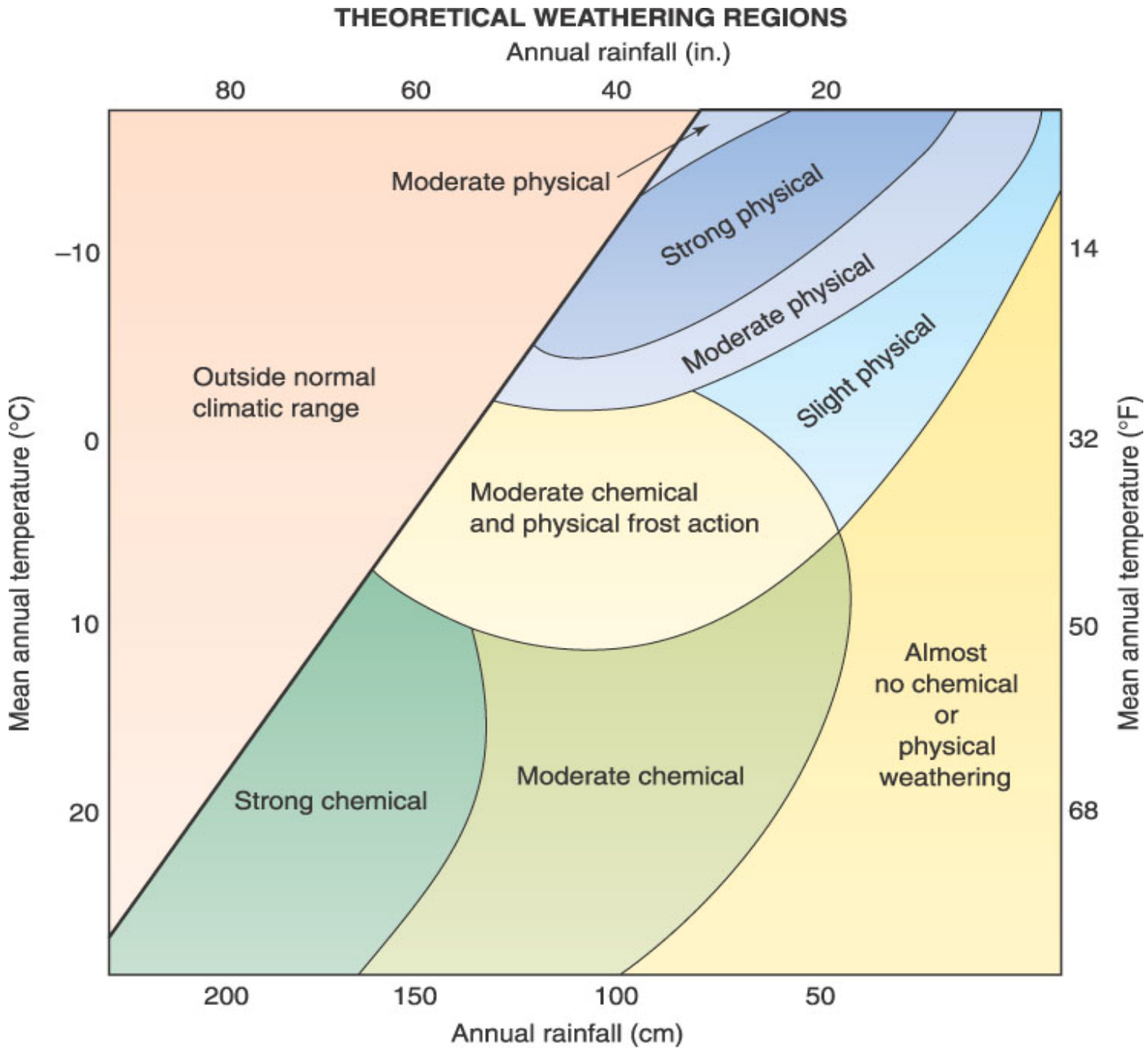
Weathering

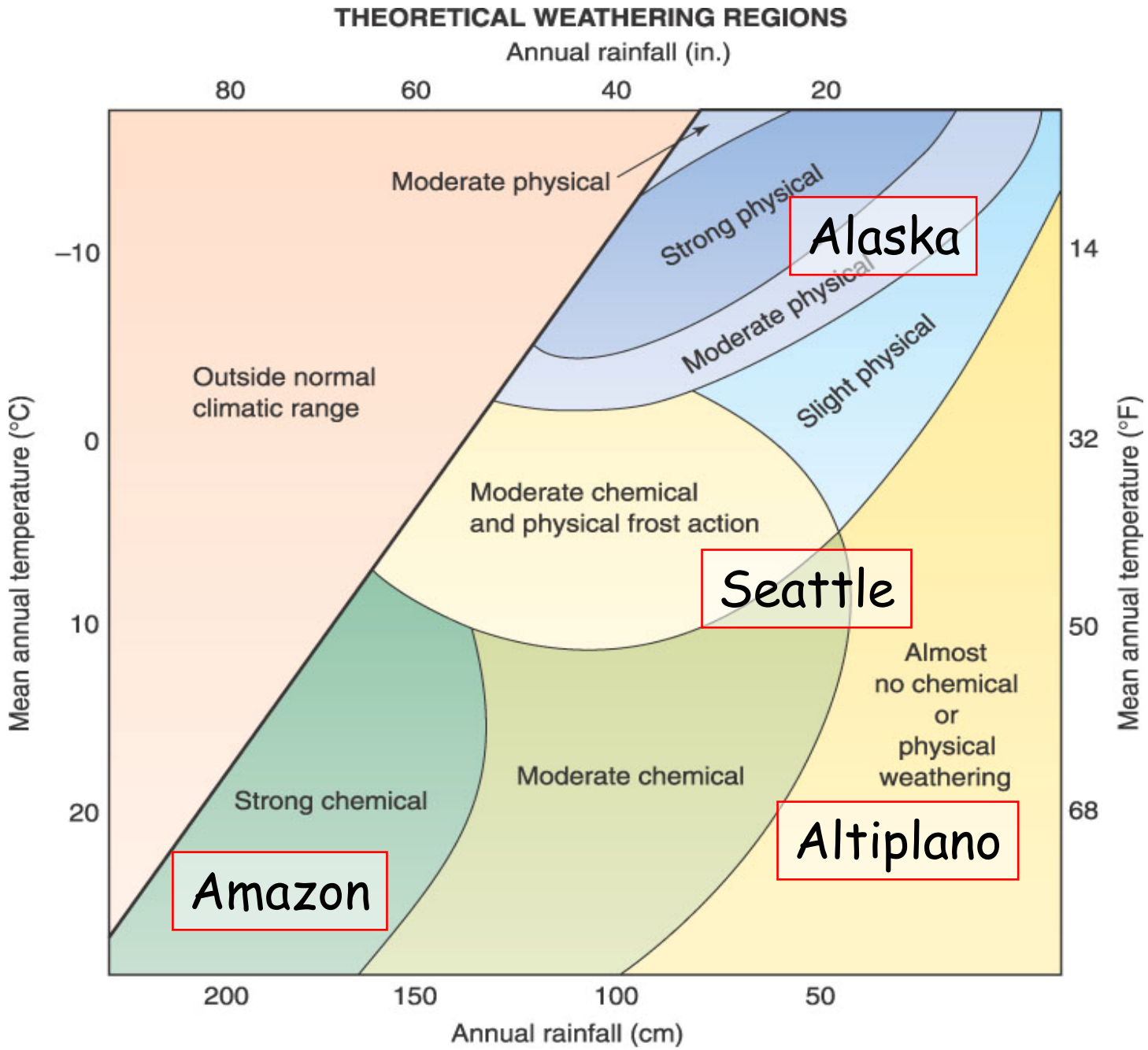
- Climate
  - Temperature and moisture characteristics
  - Chemical weathering
    - Most effective in areas of warm, moist climates – decaying vegetation creates acids that enhance weathering
    - Least effective in polar regions (water is locked up as ice) and arid regions (little water)
  - Mechanical weathering
    - Enhanced where there are frequent freeze-thaw cycles

Mechanical and Chemical Weathering

- Fracturing, disintegration caused by mechanical weathering exposes more surface area.

- Greater surface area, means more places for chemical action to occur.


THEORETICAL WEATHERING REGIONS
Annual rainfall (in.)
80
60
40
20
Moderate physical
Strong physical
Moderate physical
Slight physical
Outside normal climatic range
Moderate chemical and physical frost action
Almost no chemical or physical weathering
Moderate chemical
Strong chemical
–10
0
10
20
14
32
50
68
Mean annual temperature (°C)
Mean annual temperature (°F)
200
150
100
50
Annual rainfall (cm)


THEORETICAL WEATHERING REGIONS
Annual rainfall (in.)
80
60
40
20
Moderate physical
Strong physical
Alaska
Moderate physical
Slight physical
Outside normal climatic range
Moderate chemical and physical frost action
Seattle
Almost no chemical or physical weathering
Moderate chemical
Strong chemical
Amazon
Altiplano
−10
0
10
20
Mean annual temperature (°C)
14
32
50
68
Mean annual temperature (°F)
200
150
100
50
Annual rainfall (cm)