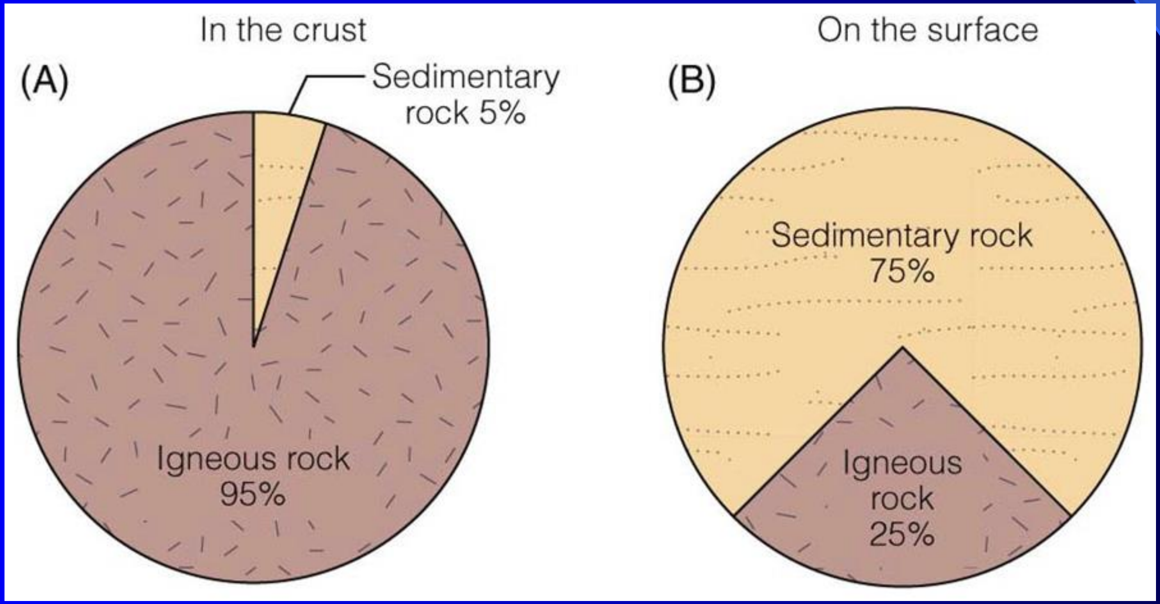
Sedimentary Rocks, Stratigraphy, and Geologic Time

A rock is any naturally formed, nonliving, coherent aggregate mass of solid matter that constitutes part of a planet, asteroid, moon, or other planetary object.

There are three families of rocks

- Igneous: formed from the cooling and consolidation of magma or lava
- Sedimentary: formed from either chemical precipitation of material or deposition of particles transported in suspension
- Metamorphic: formed from changing a rock as a result of high temperatures, high pressures, or both



The two main features that best classify rocks are

- Texture: the overall appearance of a rock, resulting from the size, shape, and arrangement of its mineral grains
- Mineral assemblage: the kinds and relative amounts of minerals present

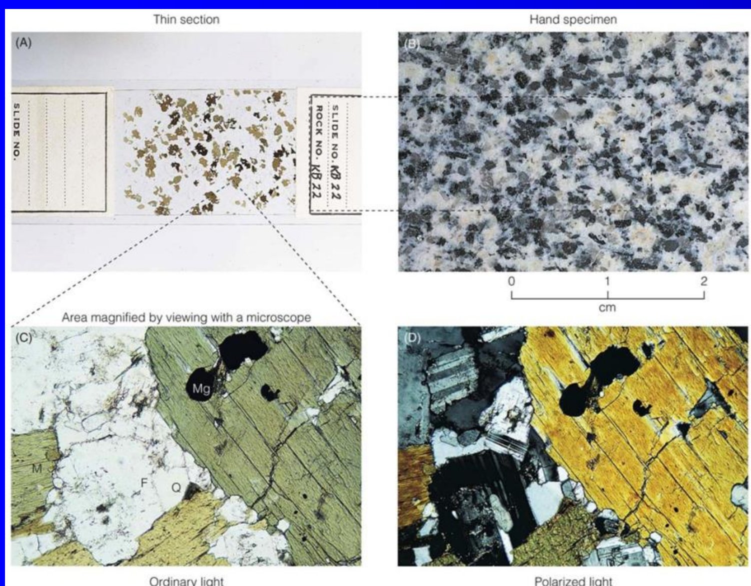
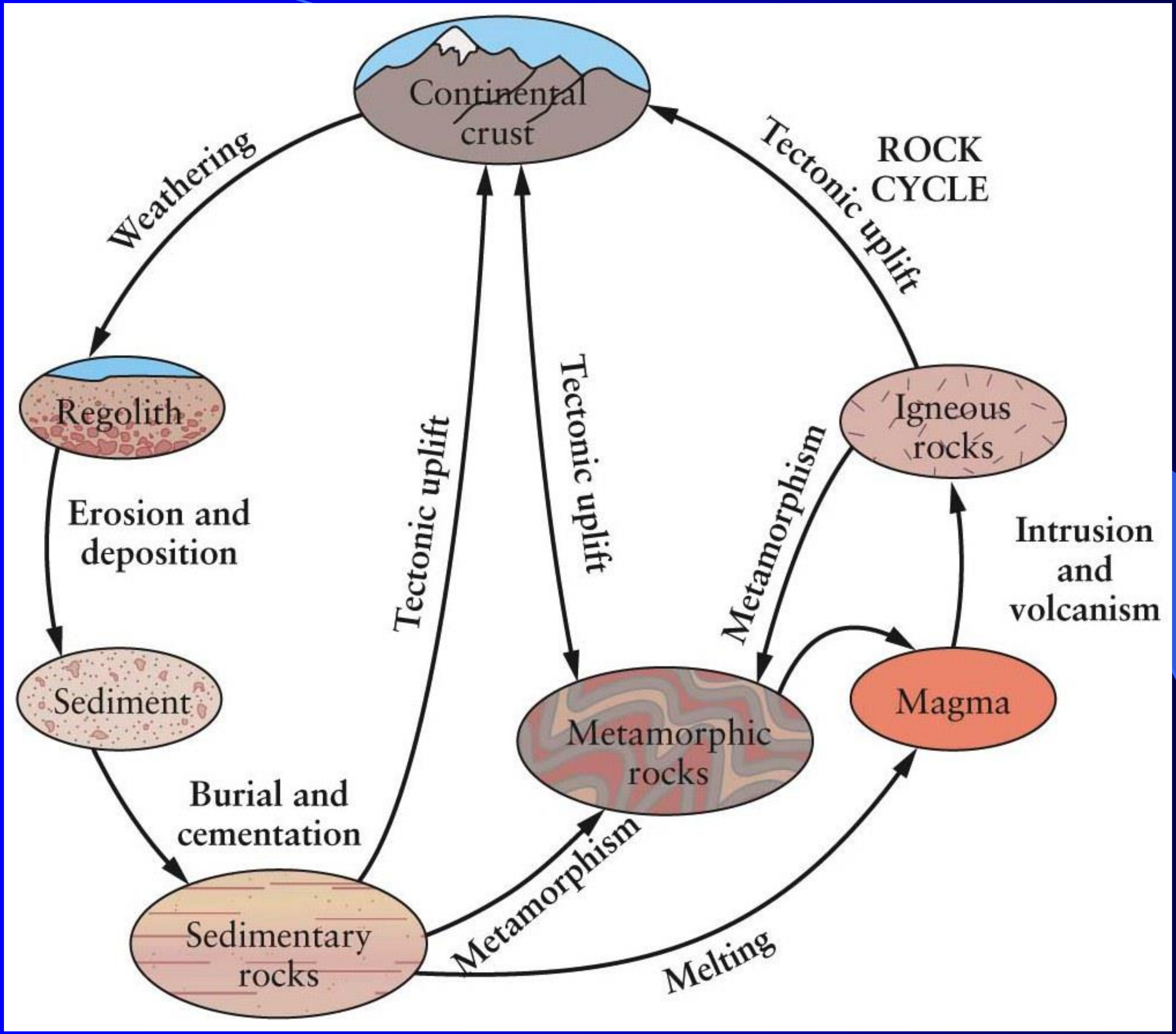


TABLE 3.2 Minerals Most Commonly Found in the Three Rock Families

Rock Family	Common Minerals
Igneous	Feldspar, quartz, olivine, amphibole, pyroxene, mica, magnetite
Sedimentary	Clay, chlorite, quartz, calcite, dolomite, gypsum, goethite, hematite
Metamorphic	Feldspar, quartz, mica, chlorite, garnet, amphibole, pyroxene, magnetite

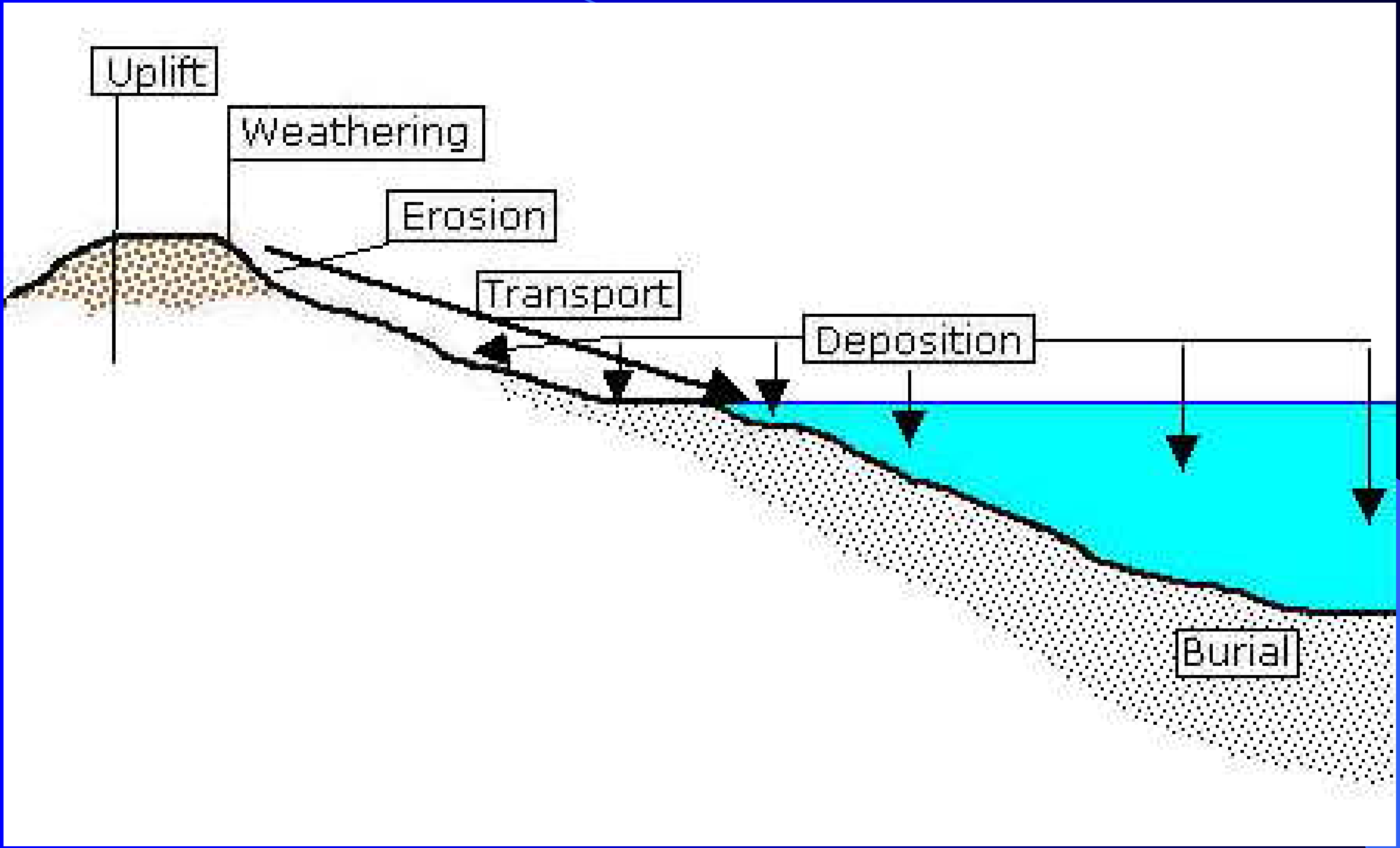


Continental crust
ROCK CYCLE
Weathering
Tectonic uplift
Regolith
Erosion and deposition
Tectonic uplift
Tectonic uplift
Metamorphism
Igneous rocks
Intrusion and volcanism
Sediment
Metamorphic rocks
Magma
Burial and cementation
Sedimentary rocks
Metamorphism
Melting

Sedimentary Rocks

1. Clastic - broken rock and minerals – conglomerate, sandstone, siltstone, shale
2. Chemical – precipitated from water – salt, gypsum
3. Biogenic - biochemical reactions in water – limestone, peat, coal

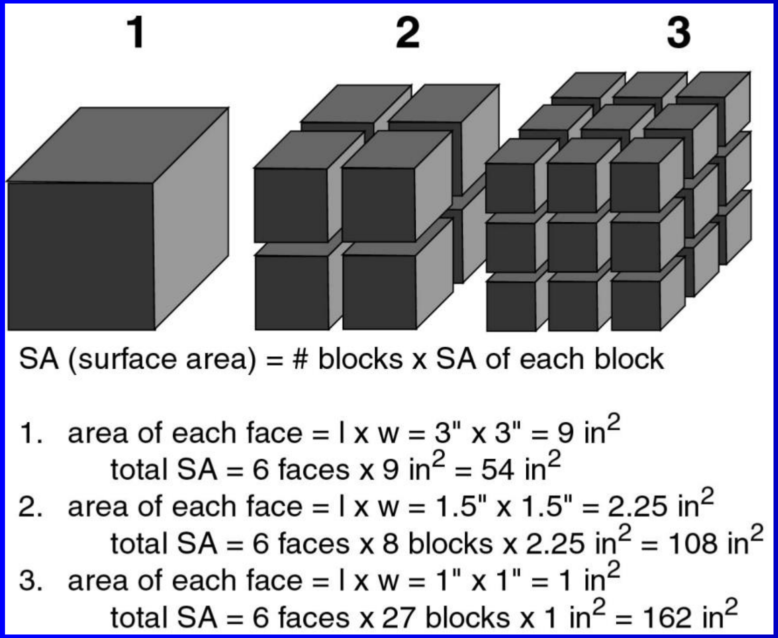
Sedimentary processes – Formation of sedimentary rocks

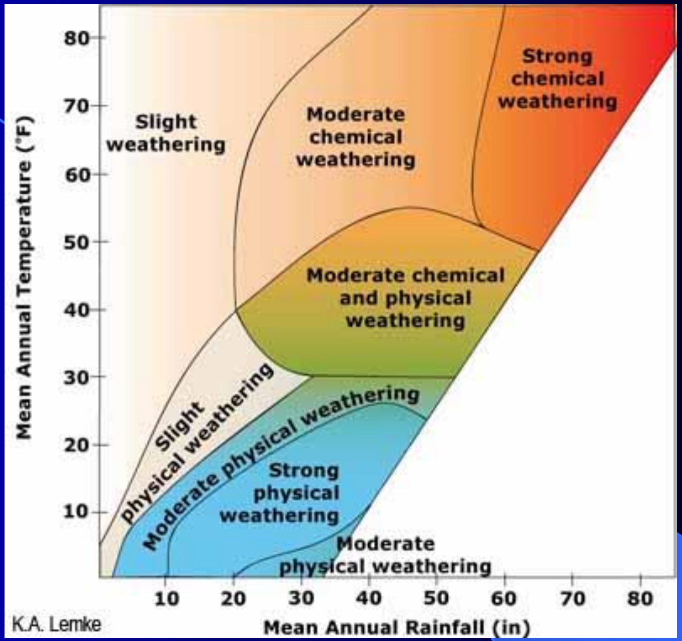


Weathering – Physical and Chemical

Physical weathering

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

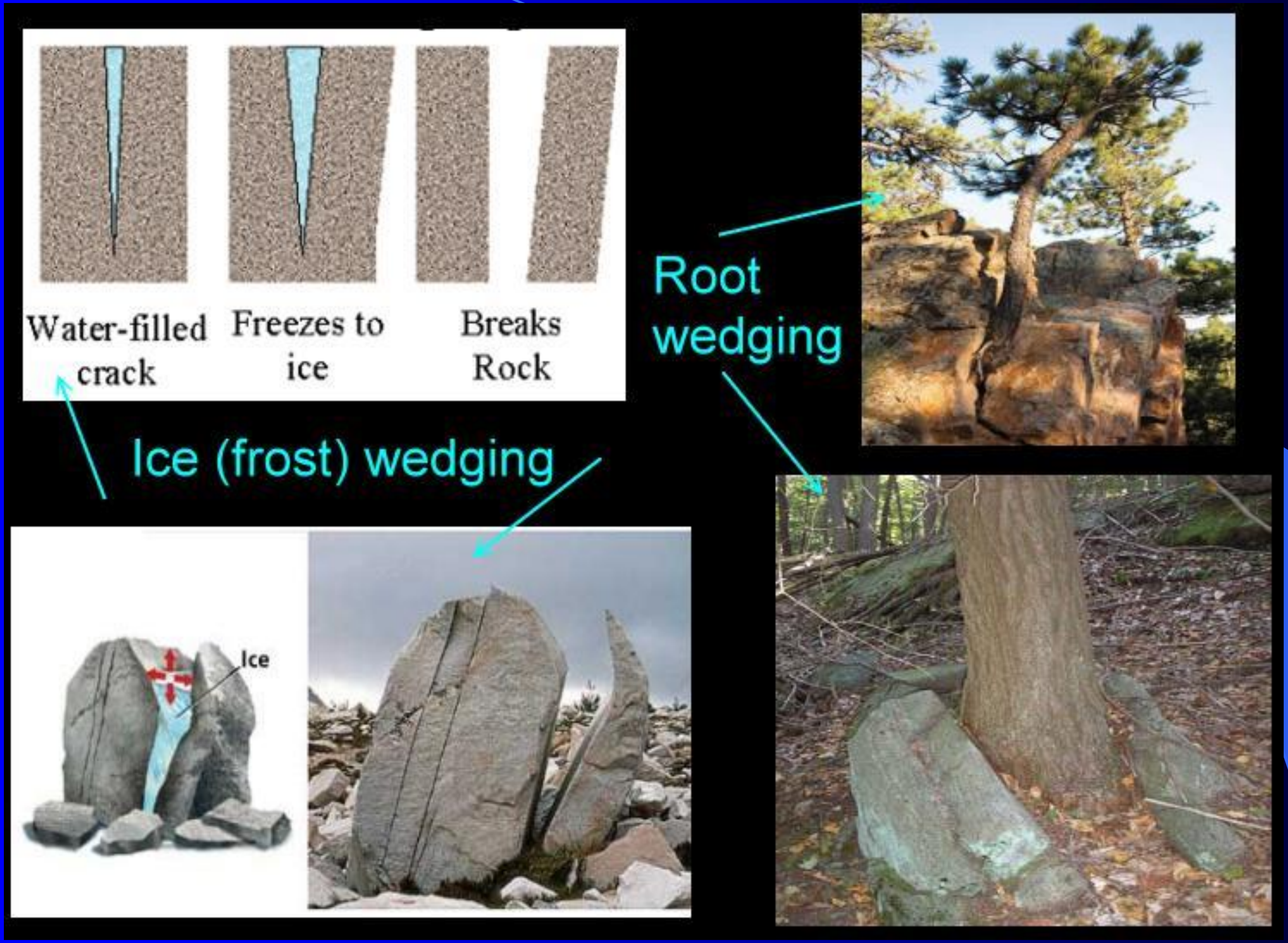




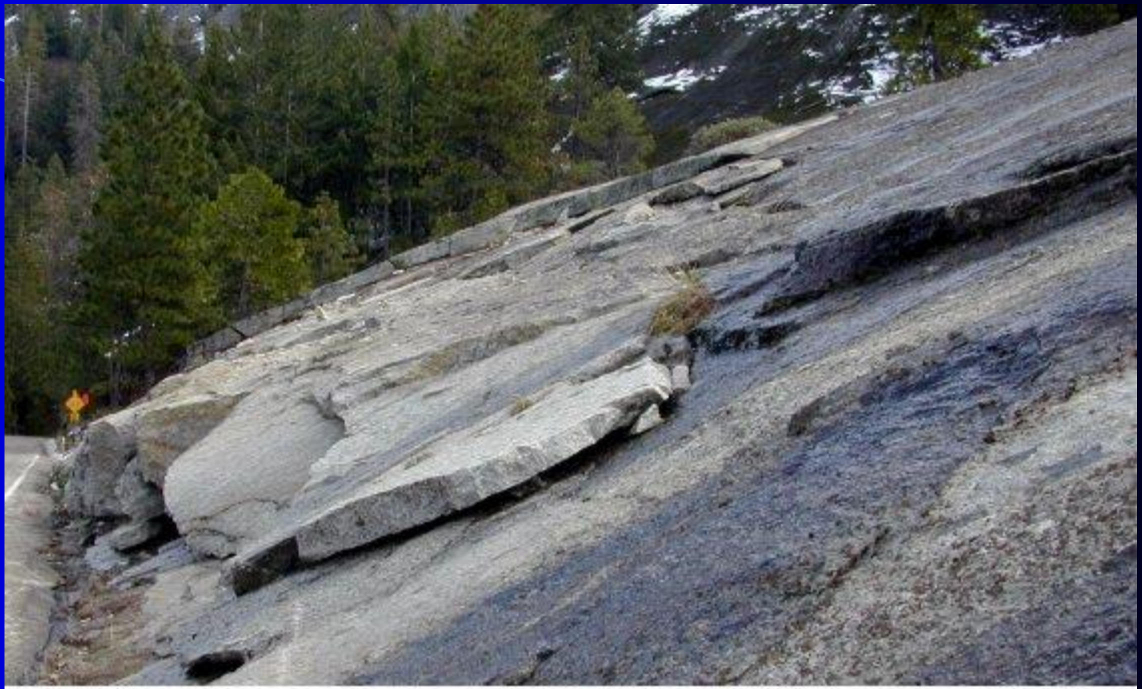
Chemical weathering

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

Physical Weathering



Physical Weathering



Exfoliation slabs, Yosemite National Park, California

Tarbuck & Lutgens

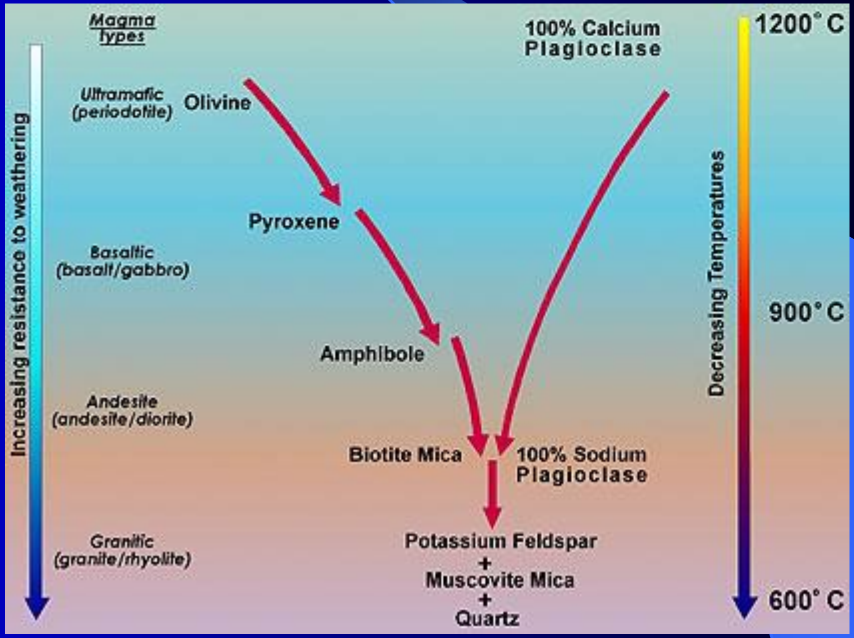
These rocks have been exposed to temperature extremes in desert surroundings which caused them to disintegrate.

Chemical Weathering Reactions

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

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

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

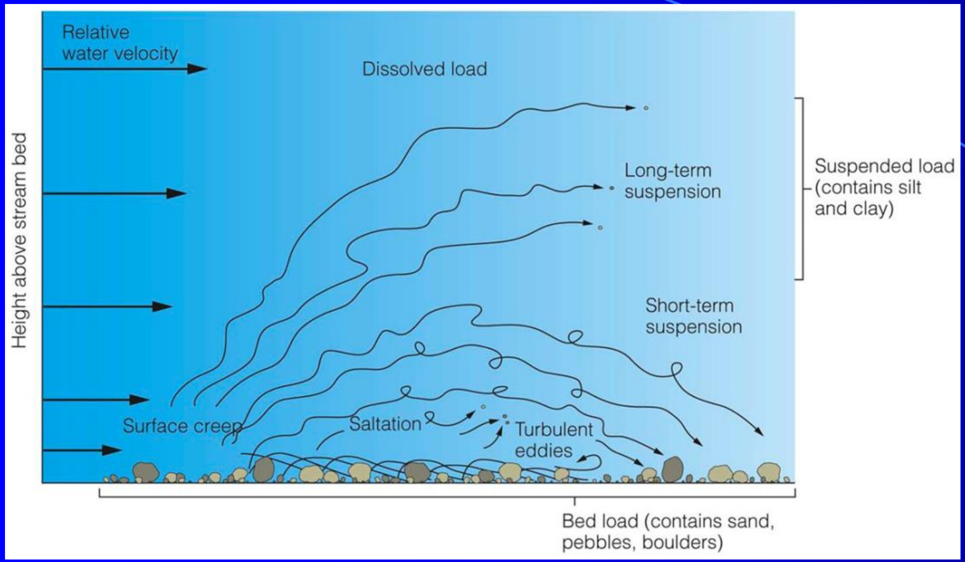


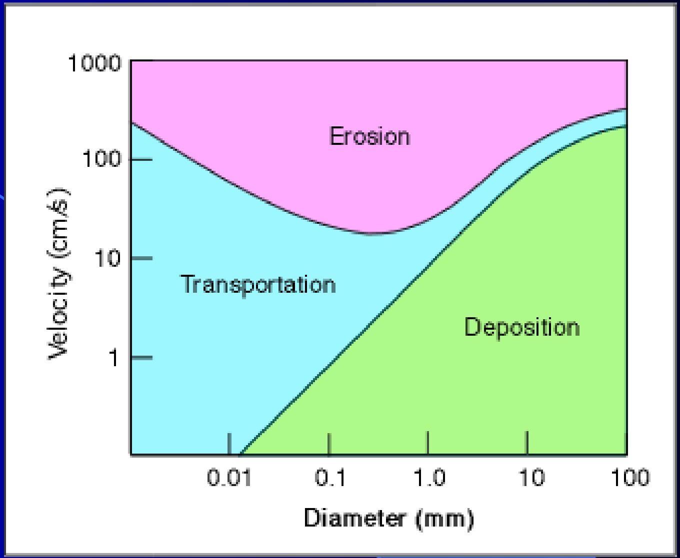
Regolith is the broken-up, disintegrated rock material found on the Earth's surface.

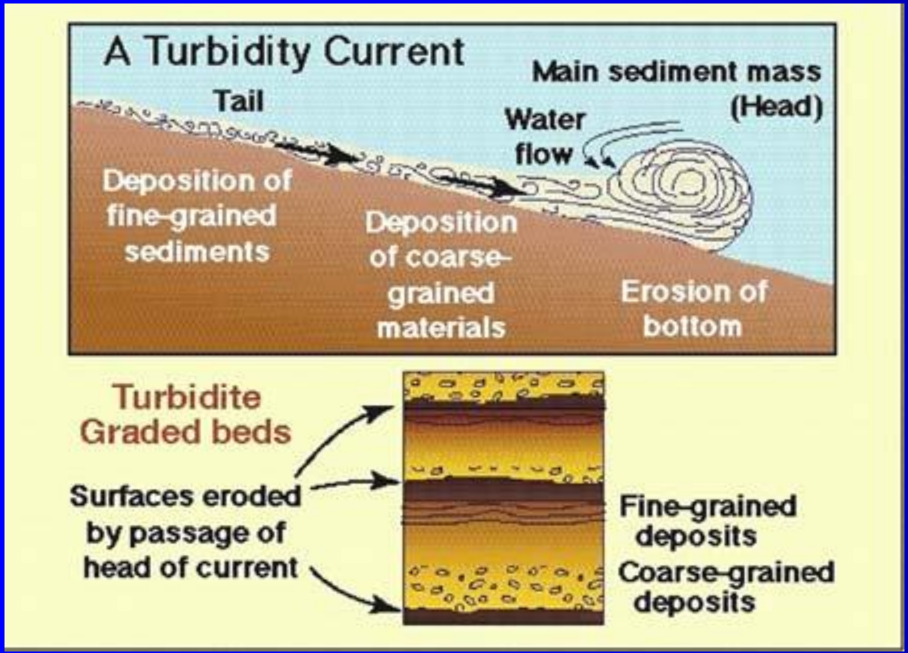
Three categories describe most of the various materials of the regolith

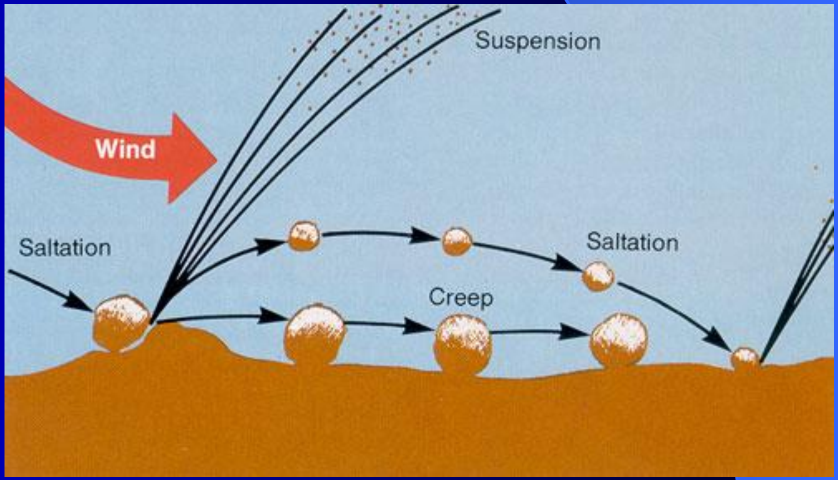
- Saprolite: rock that is weathered in situ
- Sediment: loose rock and mineral particles
  - Clastic sediment (broken particles)
  - Chemical sediment (dissolved material)
- Soil: contains organic matter mixed with minerals, can support rooted plants

Sediment transport

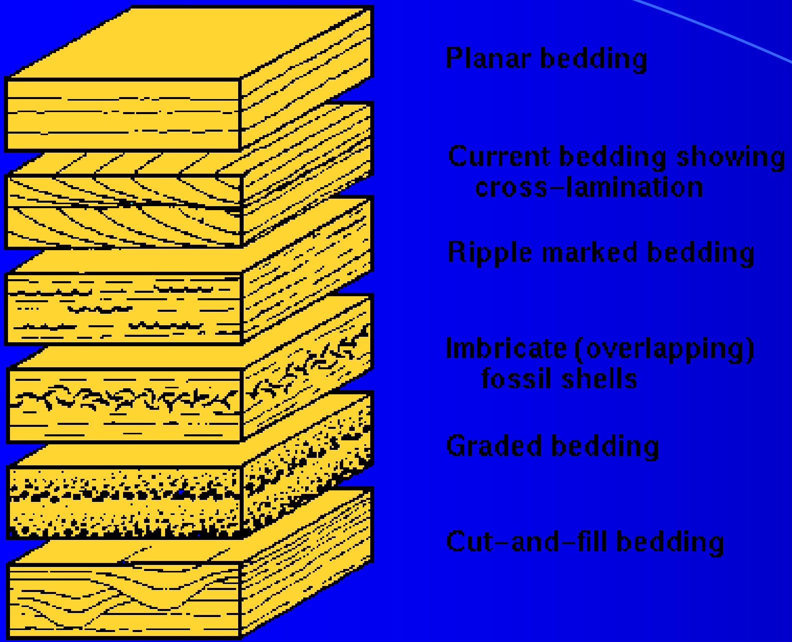


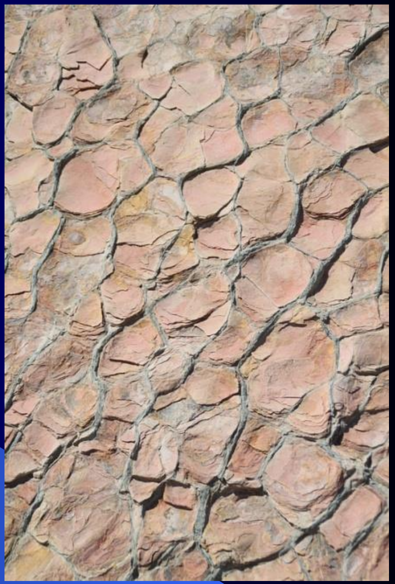


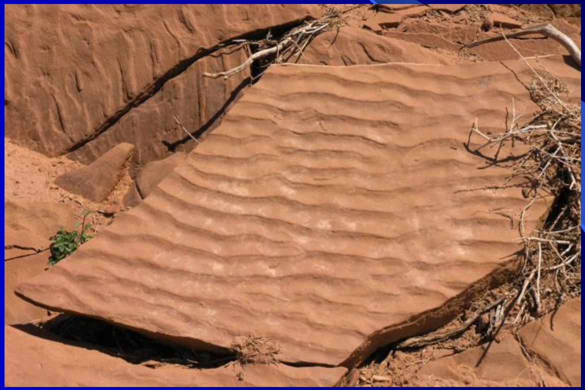




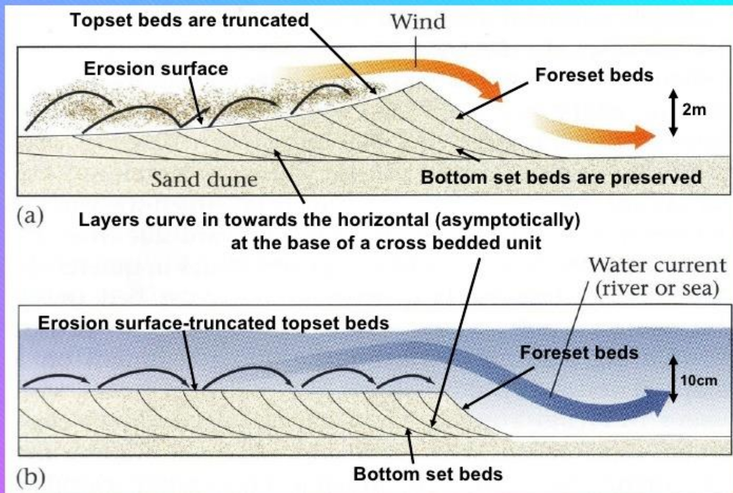
Sedimentary Structures





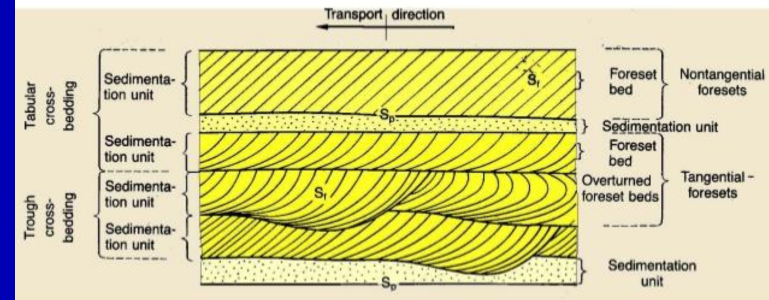


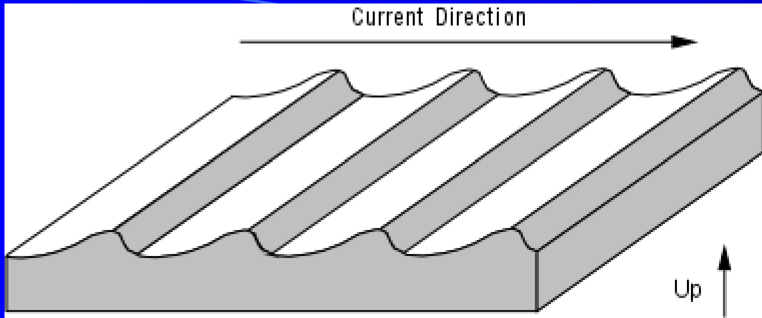
The Formation of Cross Bedding

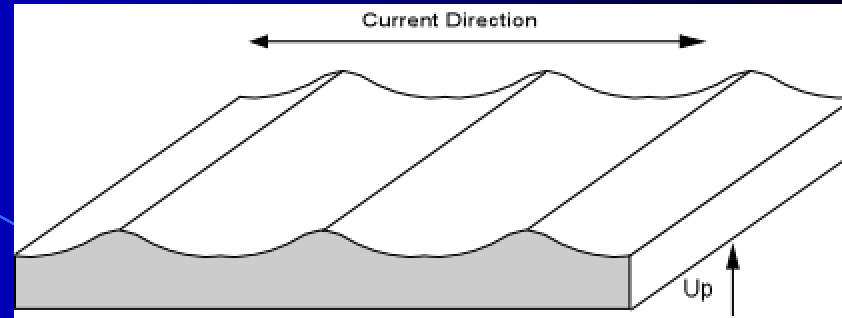


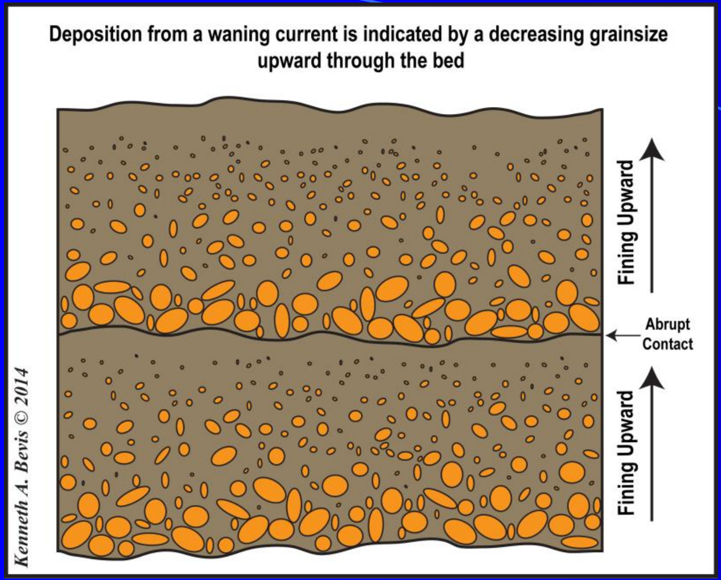
Cross-Bed Geometries

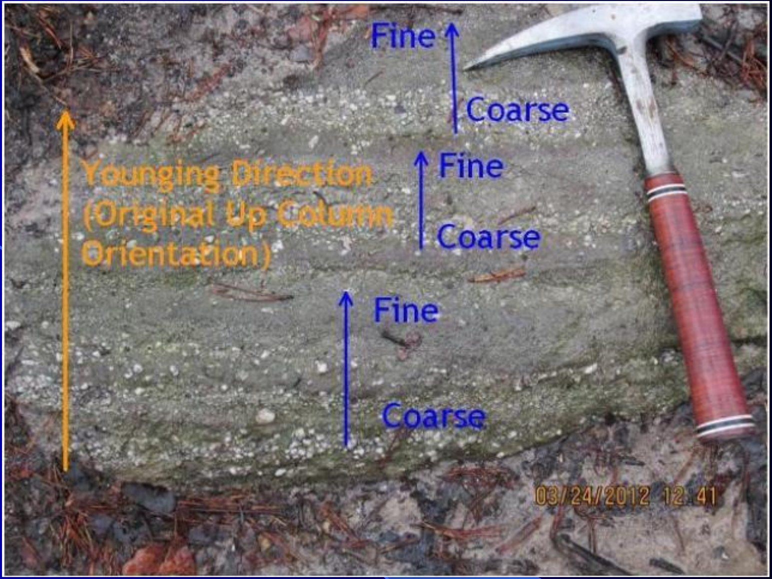
- McKee & Weir (1953) – Tabular & Trough Cross bedding
- Tabular Cross beds – units broad in lateral dimensions with respect to set thickness with planar bounding surfaces.
- Migration of large-scale ripples and dunes; lower flow regime
- Trough Cross beds – units whose bounding surfaces are curved, consist of elongate scour filled with curved laminae
- Migration of small-scale or large-scale ripples
- Paleocurrent measured in dip direction of foreset laminae

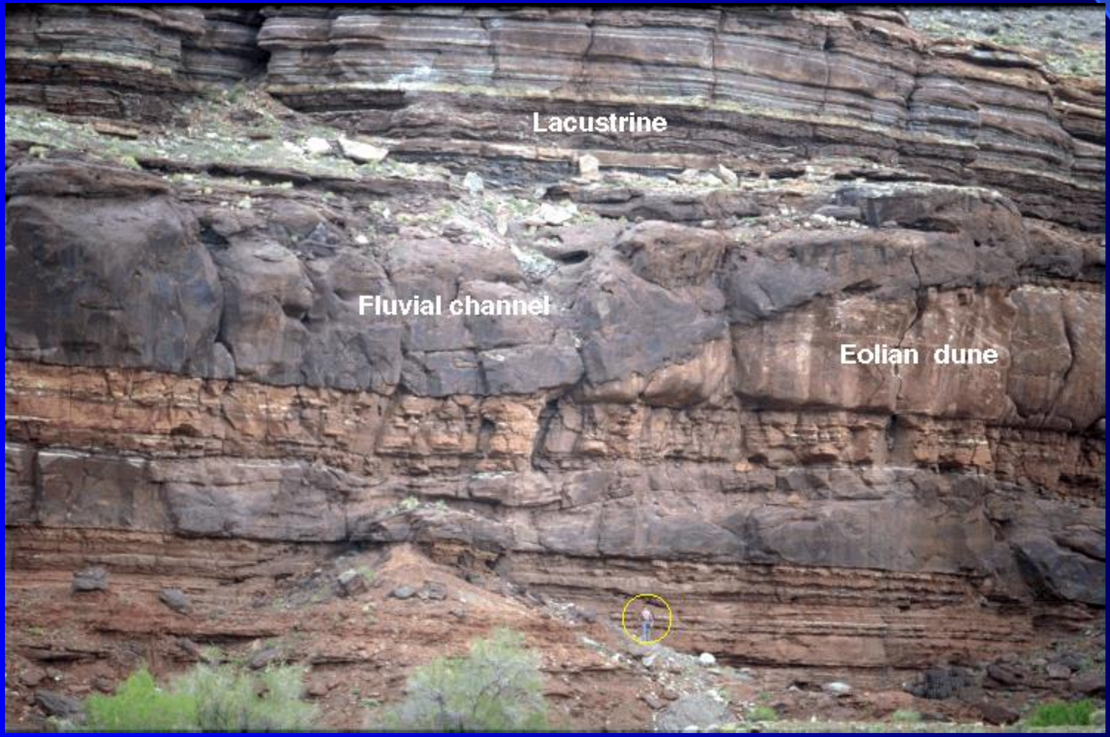



Current Direction
Up


Current Direction
Up


Deposition from a waning current is indicated by a decreasing grainsize upward through the bed
Fining Upward
Abrupt Contact
Fining Upward
Kenneth A. Bevis © 2014

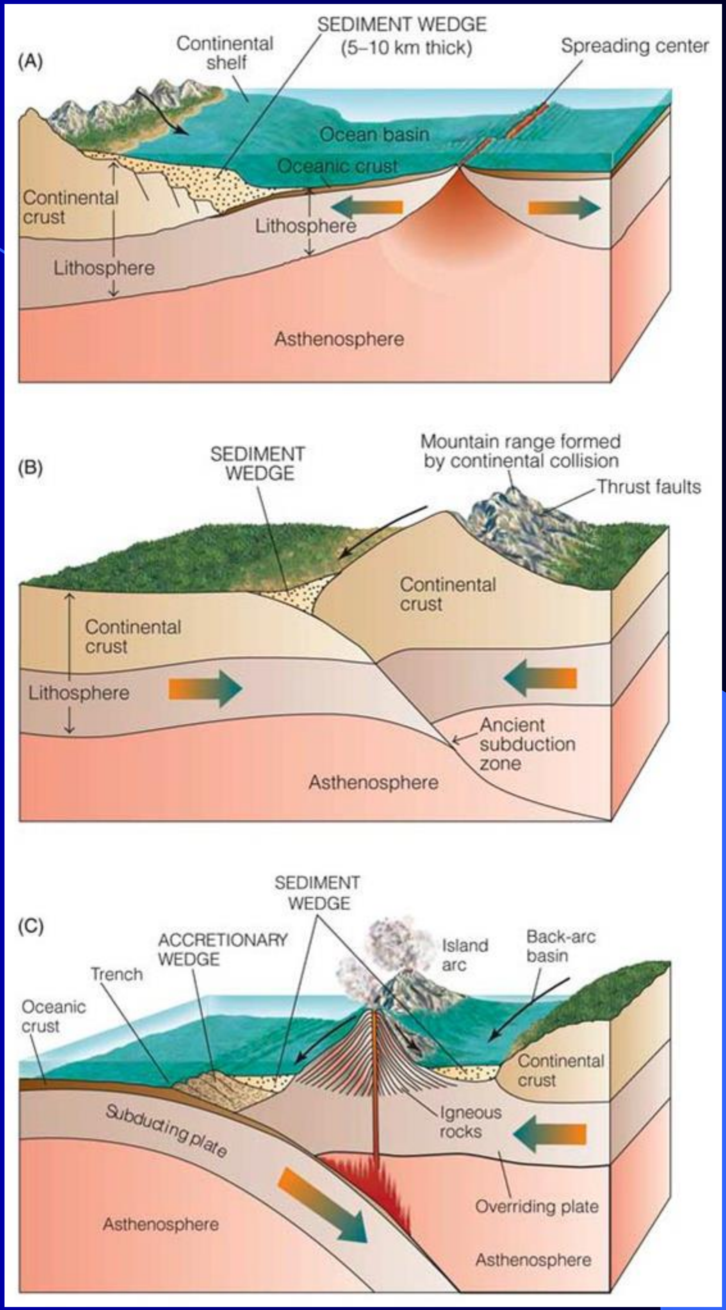

Fine
Coarse
Younging Direction (Original Up Column Orientation)
Fine
Coarse
Fine
Coarse
03/24/2012 12:41


Lacustrine
Fluvial channel
Eolian dune

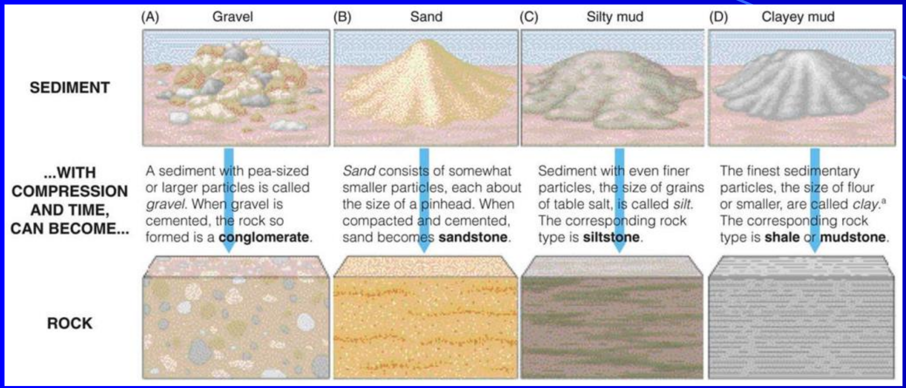
Clastic Sediments ⟶ Deposition

Locations where clastic sediment is deposited, low-lying areas, are largely controlled by plate tectonics

- Troughs
- Rift valleys
- Trenches and accretionary wedges
- Basins

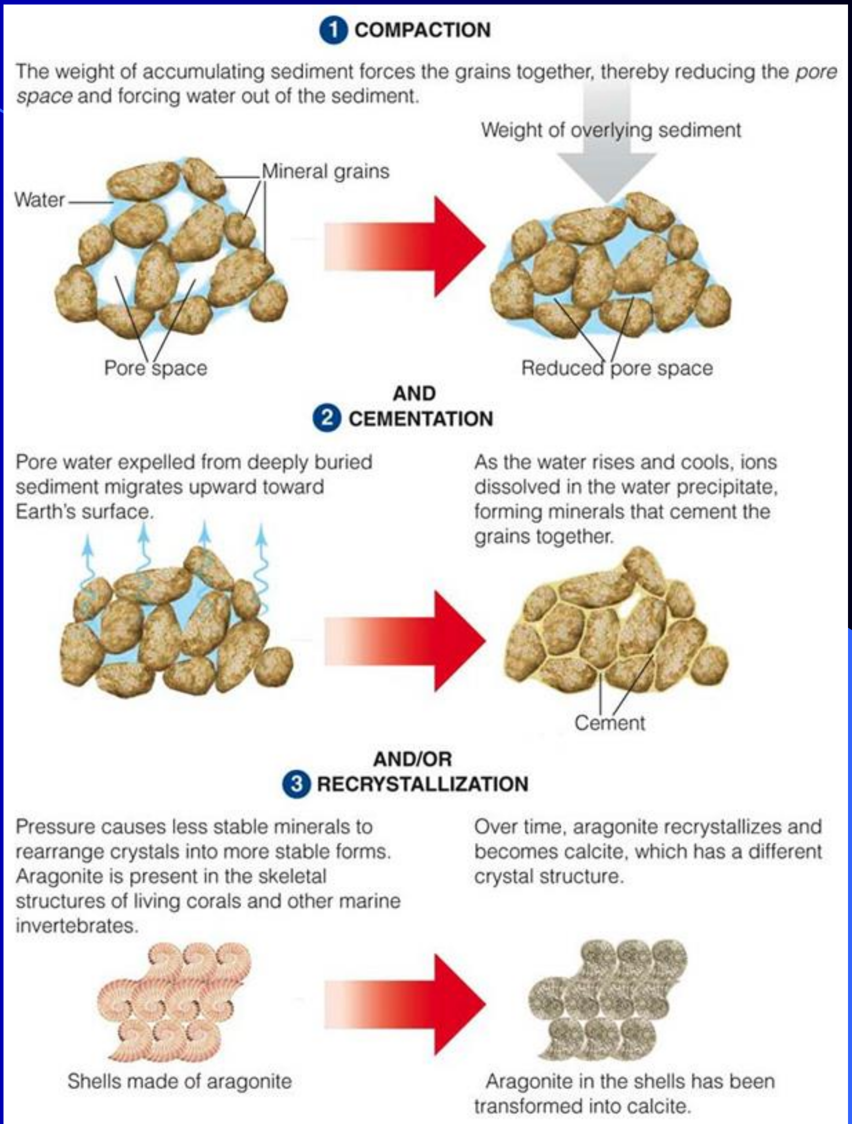


Clastic Sediments → Lithification



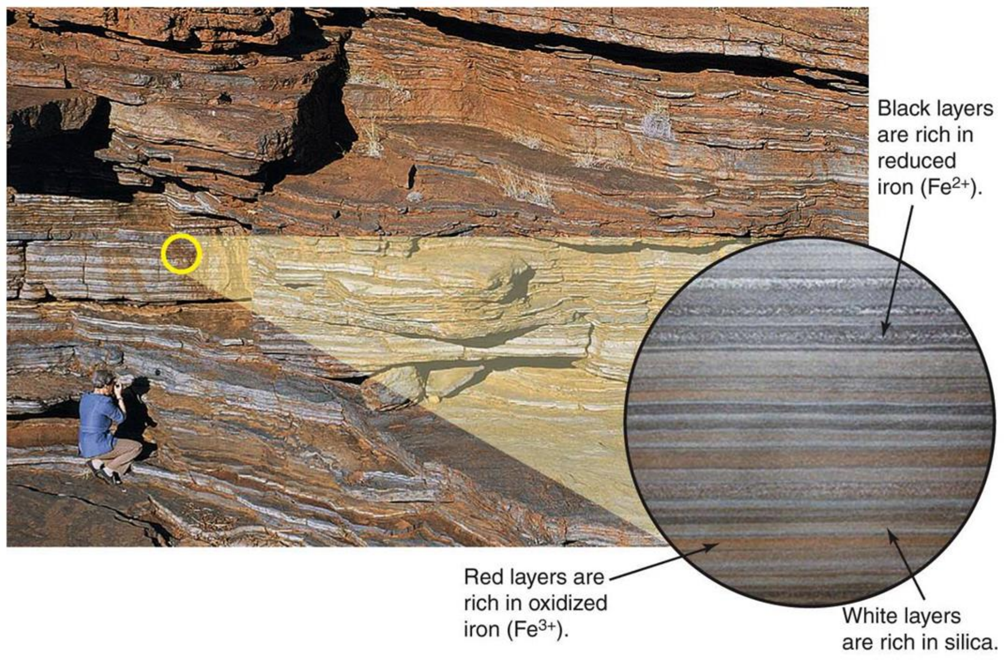
When clastic sediment is lithified, the result is clastic sedimentary rock

- Conglomerate: rounded clasts > 2 mm
- Breccia: angular clasts > 2 mm
- Sandstone: clasts 0.5 - 2 mm
- Siltstone: silt and clay-szied particles
- Shale: mostly clay-sized particles in a rock that easily splits into sheets
- Mudstone: shale that does not split



Chemical sedimentary rock results from lithification of chemical sediment formed by precipitation of minerals from water

- Evaporite: formed by evaporation
- Banded iron formation: formed during an atmospheric change from O_2-poor to O_2-rich
- Limestone: lithified shells and other skeletal material from marine organisms
- Chert: tiny particles of quartz from siliceous skeletons of microscopic sea creatures



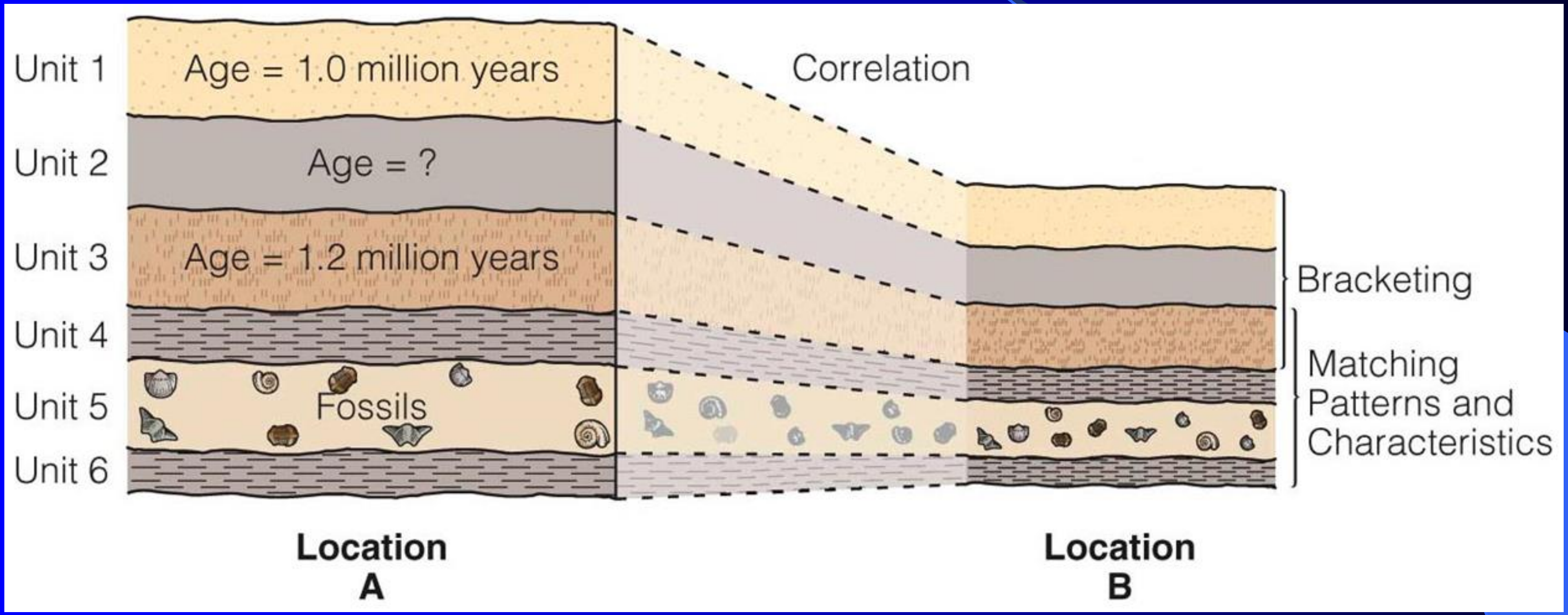
Close-up of layers in banded iron formation

Principles of Stratigraphy

Study of rock layers (strata) and layering (stratification)

1. The principle of original horizontality: states that sediment is deposited in a layer that is horizontal and parallel to Earth's surface.
2. The principle of stratigraphic superposition: states that in any sequence of strata, the order of deposition is from bottom to top.
3. The principle of lateral continuity: states that a layer of sediment will extend horizontally as far as it was carried, thinning laterally.

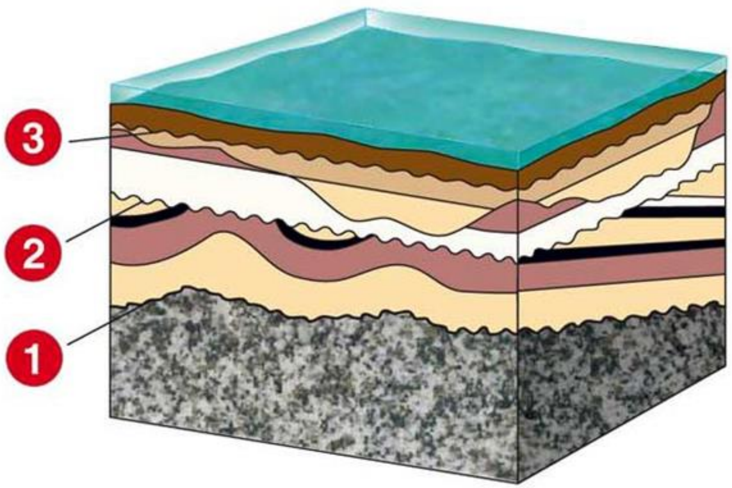
Stratigraphic correlation is the determination of equivalence in age of the succession of strata found in two or more different areas. This is accomplished by comparing fossils and other characteristics of sedimentary strata.



Law of faunal succession

A sequence of strata deposited without interruption is said to be conformable.

There are often breaks in a pile of strata that represent times of nondeposition or erosion, to which the term unconformity is applied.

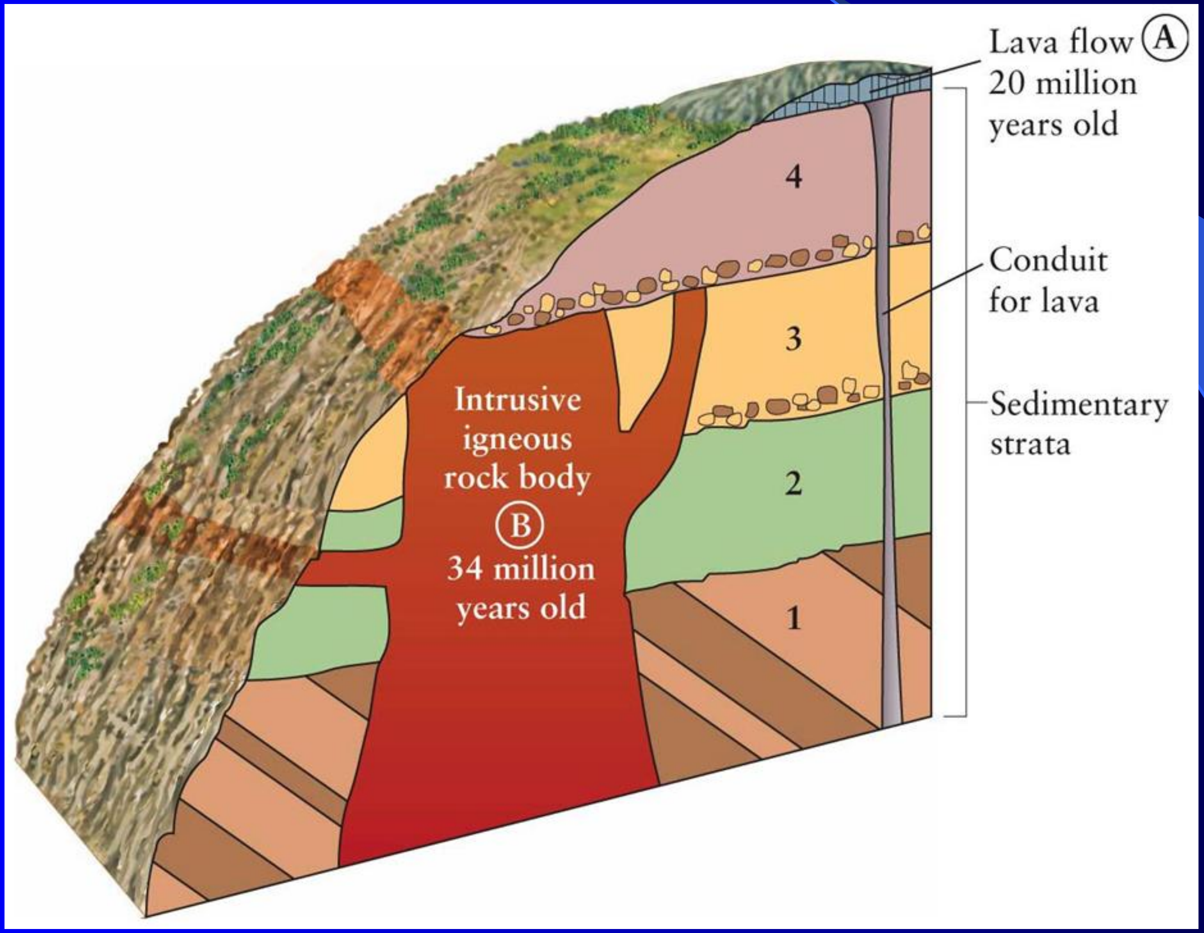


Type of Unconformity	Description/Cause
1 Nonconformity	A surface of erosion that separates younger sedimentary strata above from older igneous or metamorphic rocks below.
2 Angular unconformity	A surface of erosion between two groups of sedimentary rocks in which the orientation of older strata, below, are at an angle to younger strata, above.
3 Disconformity	A surface of erosion in which the orientation of older strata, below, are parallel to younger strata, above.

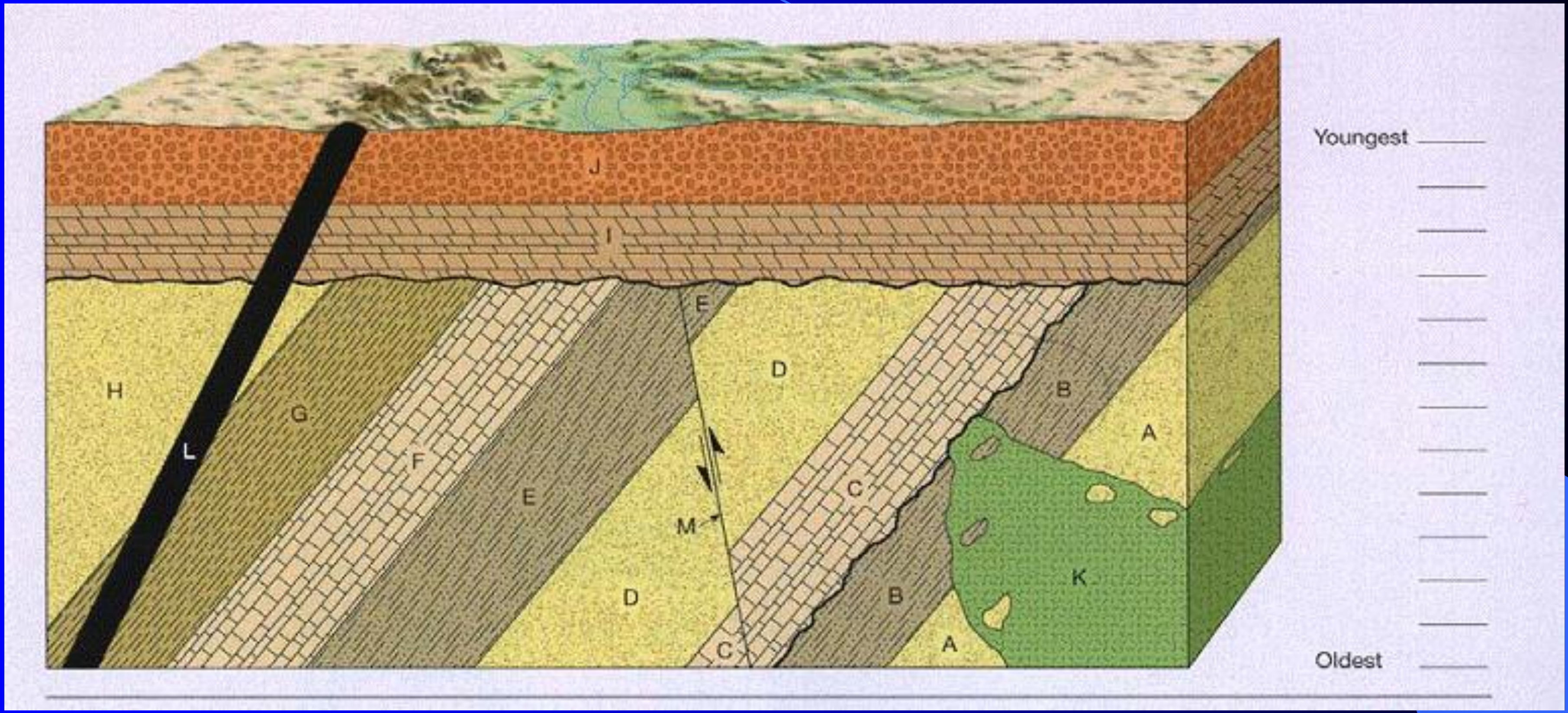
A fourth type of unconformity is called a paraconformity. Geologic time is missing from the section but there is no apparent erosional gap.

The principle of cross-cutting relationships: states that any geologic feature must be older than any feature that cuts it.

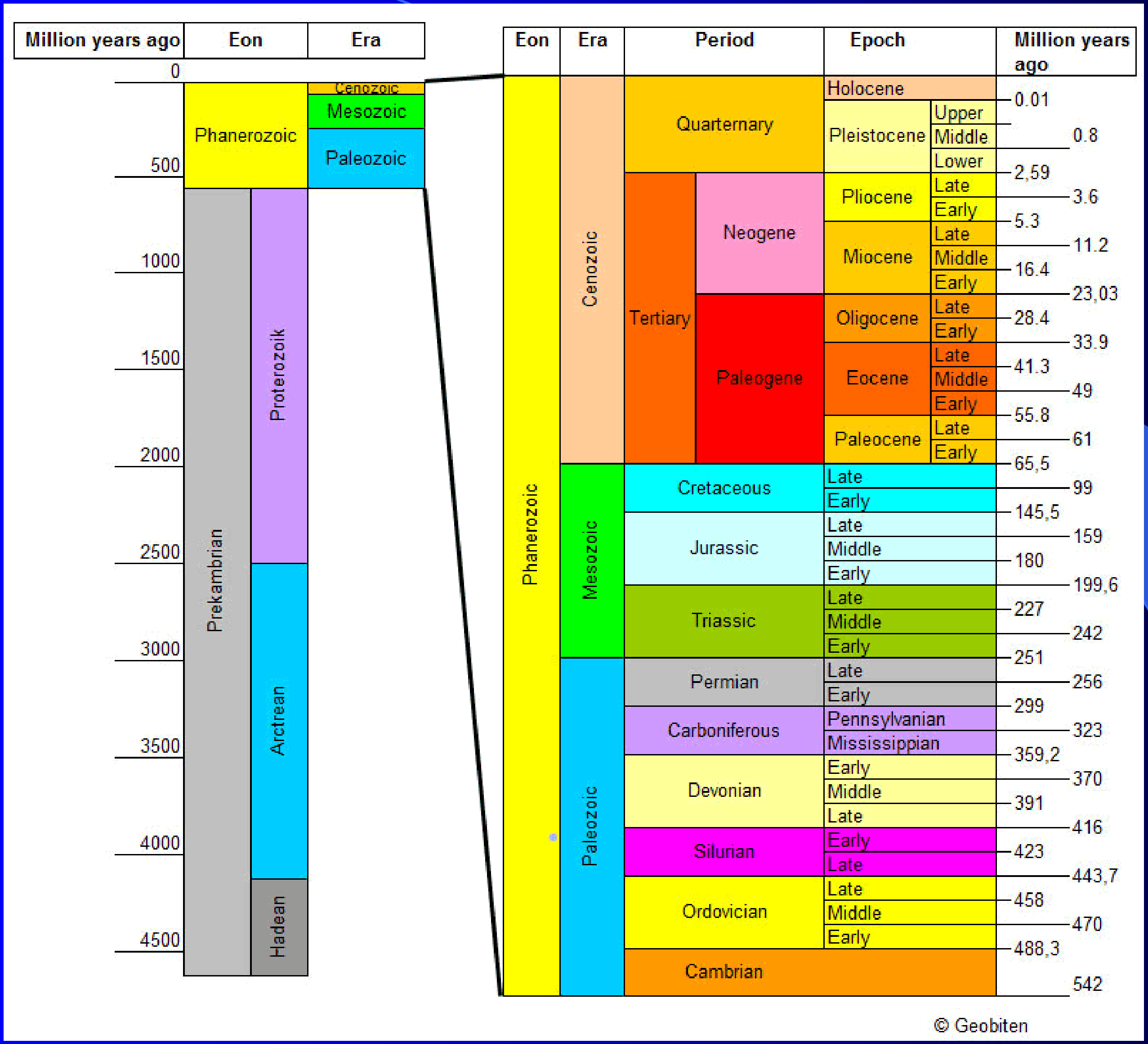
Similarly, a foreign rock that is encased within another rock unit must predate the rock that encloses it.



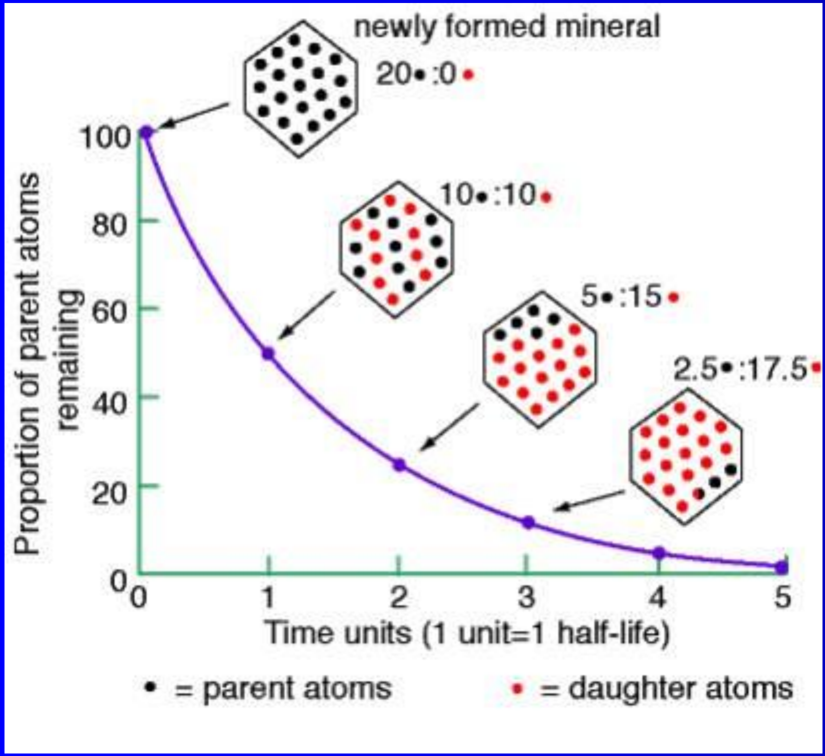
Relative Geologic Time – order of occurrence of geologic events



Geologic Time Scale



Determining Absolute Ages – Radioactive Decay



Parent	Half-life (10^9 yrs)	Daughter	Materials Dated
^{235}U	0.704	^{207}Pb	Zircon, uraninite, pitchblende
^{40}K	1.251	^{40}Ar	Muscovite, biotite, hornblende, volcanic rock, glauconite, K-feldspar
^{238}U	4.468	^{206}Pb	Zircon, uraninite, pitchblende
^{87}Rb	48.8	^{87}Sr	K-micas, K-feldspars, biotite, metamorphic rock, glauconite

The geologic time scale is based on sequence of events and the sedimentary rock record. Radiometric methods, except in rare instances, can only be used to date igneous and metamorphic rocks. So how do we put absolute ages on the geologic time scale?