Indian Institute of Technology, Kanpur

Department of Earth Sciences

ESO213A: Fundamentals of Earth Sciences

Lecture 24. History of the Earth

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IITK Experimental Rock Deformation Laboratory

Aims of this lecture

- Methods of Studying the Past
- Reconstruction of history from stratigraphic records

Reading:
Marshak's Book (Part-IV)
Grotinger & Jordan's book (Chapter 8)
[*for the entire week*]

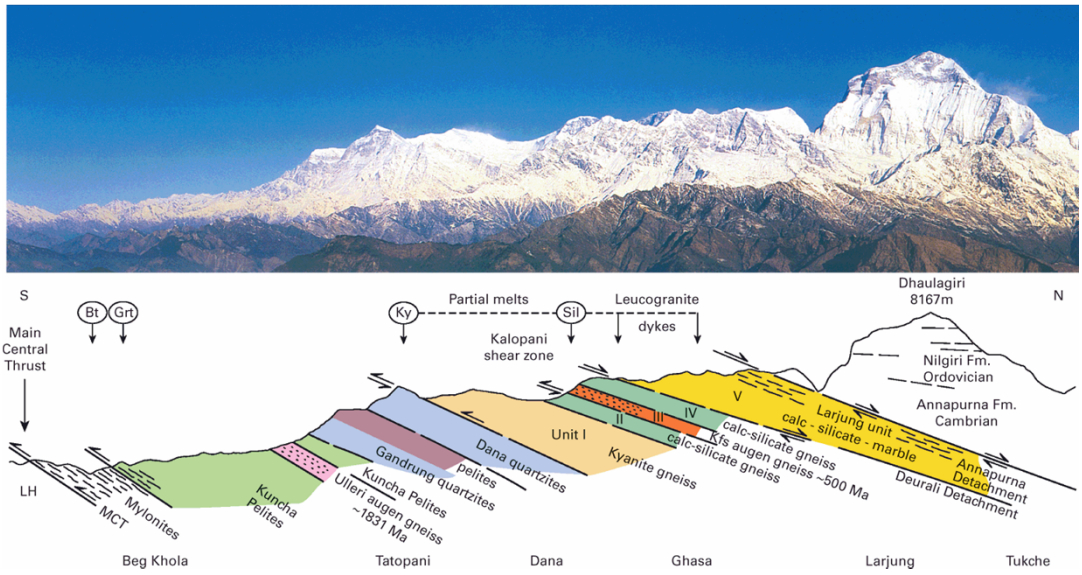
Earth has a History

- Geologic materials record enormous changes.
- Earth is a complex, evolving system.

- Physical and biological systems continuously interact.

- Earth constantly changes and has done so through time.
  - Species arise, flourish, and disappear forever.
  - Continents rift, drift, and collide.
  - Ocean basins open and close.
  - Sea level rises and falls.

Earth has a History



Searle, 2017

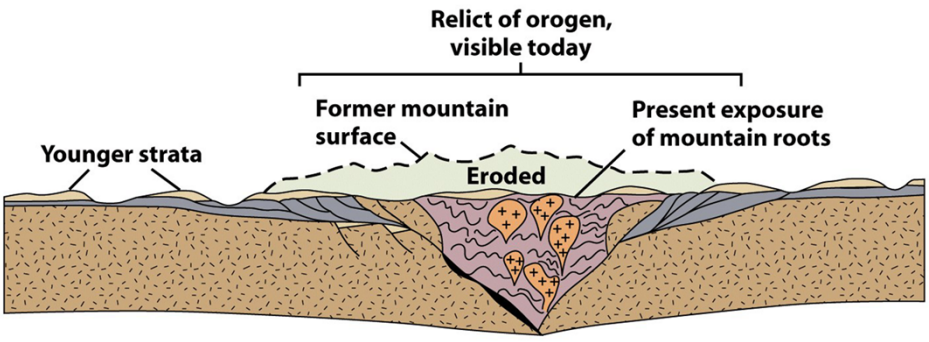
Methods of studying the past

- Historic Earth changes are measured by…
  - Orogenic events.
  - Sea level.
  - Climates.
  - Living organisms.
  - Continental positions.
  - Plate boundaries.
  - Chemistry.
    - Atmosphere.
    - Ocean.
  - Depositional environments.
- These changes are recorded in rocks.

Challenges:
- Discontinuous record
- Erosion
- Younger rocks are better preserved; older rocks less
- **There are still abundance of evidences**

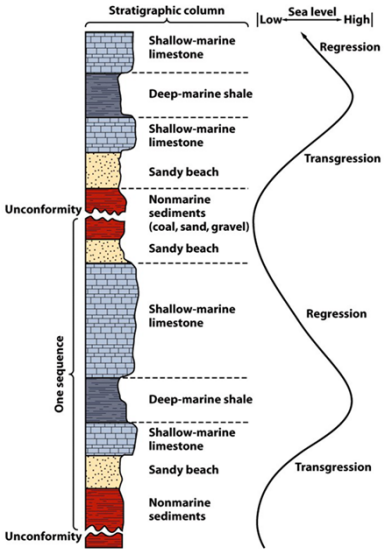
Ancient Orogens

- Ancient orogens – Former mountain belts.
  - Igneous activity, deformation, and metamorphism.
  - Thick sedimentary deposits filling foreland basins.
  - Ancient orogenic belts expose deeply buried rocks.

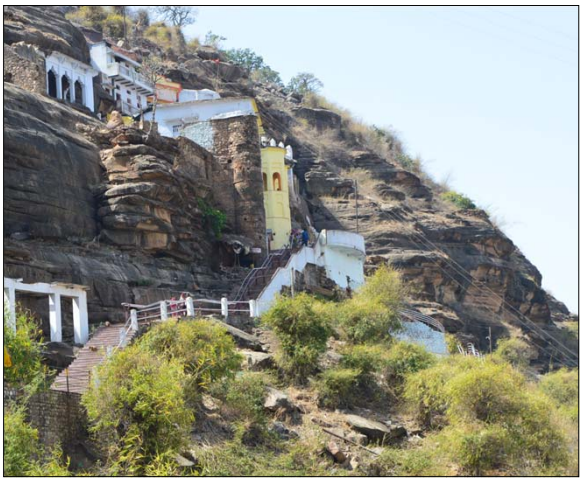


Depositional Environments

- Recognizing depositional environments.
  - Successions of strata record changes in depositional settings.
- Recognizing sea level changes.
  - Sediments record sea level flux.
  - Shallow and deep environments create distinctive sediments.

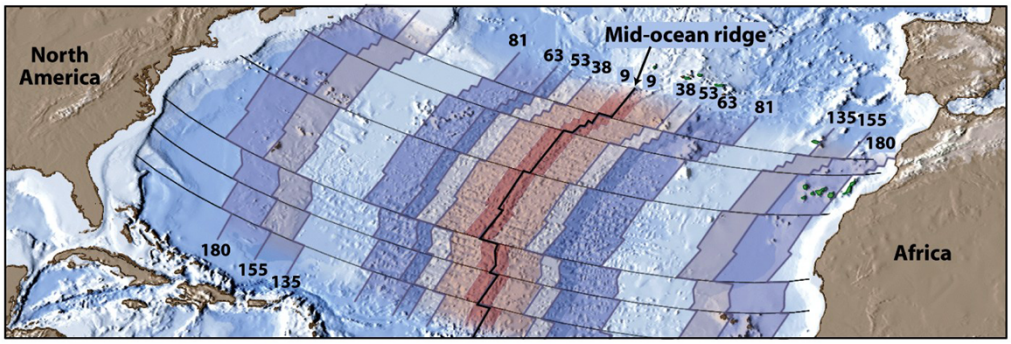


Depositional Environments



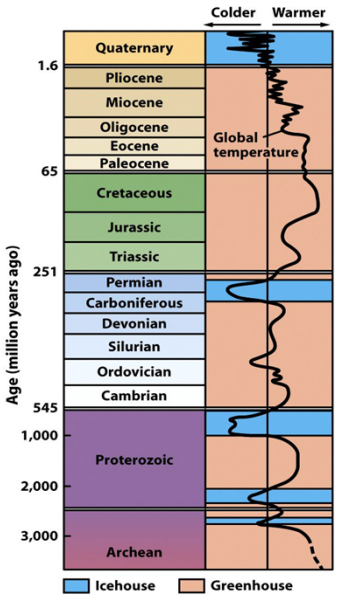
Changing Continental Positions

- Changing continental positions are preserved.
  - Paleomagnetism captures paleolatitude.
  - Ocean width changes by reversing sea-floor anomalies.
  - Rock and fossil distributions compare across oceans.



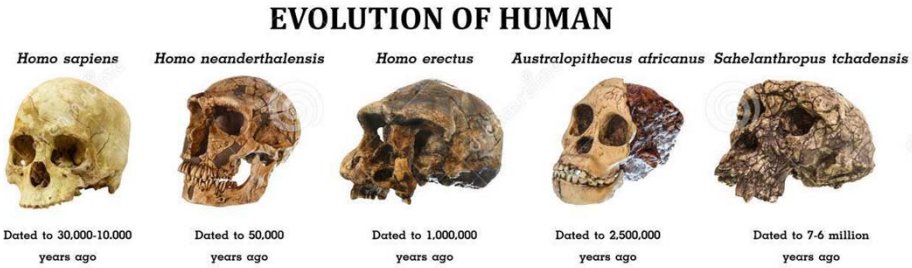
Palaeoclimate

- Paleoclimates – Rocks preserve ancient climates.
  - Tropical – Extensive coral reefs.
  - Subtropical – Extensive deserts.
  - Polar – Extensive glacial deposits.
- Climatic belts expand and contract.
  - Greenhouse Earth.
  - Snowball Earth.
- $^{18}O/^{16}O$ isotopic ratios preserve ancient temperatures

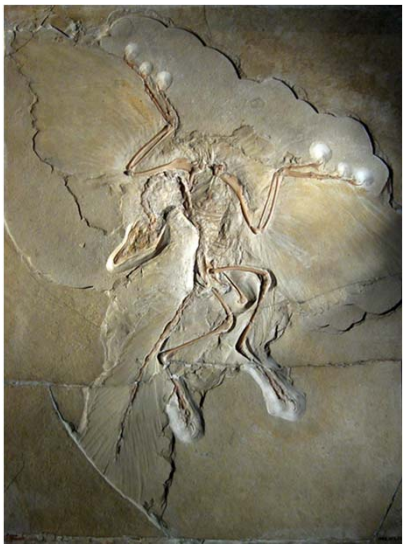


Evolution of Life

- Evolution – Fossils preserve changes in Earth's life.
  - Sedimentary rocks preserve fossil ecosystems.
  - Organisms inhabiting Earth have obviously changed.
    - Over geologic time, most species have exhibited both…
      - Trends toward specialization.
      - Catastrophic extinctions.



Evolution of Life



Archaeopteryx fossil

20,000-Year-Old Human Footprints

History from Stratigraphic Records

Stratigraphy is a branch of geology concerned with the study of rock layers (strata) and layering (stratification). It is primarily used in the study of sedimentary and layered volcanic rocks.

Original horizontality: all rock layers were originally horizontal (*Nicolaus Steno*).

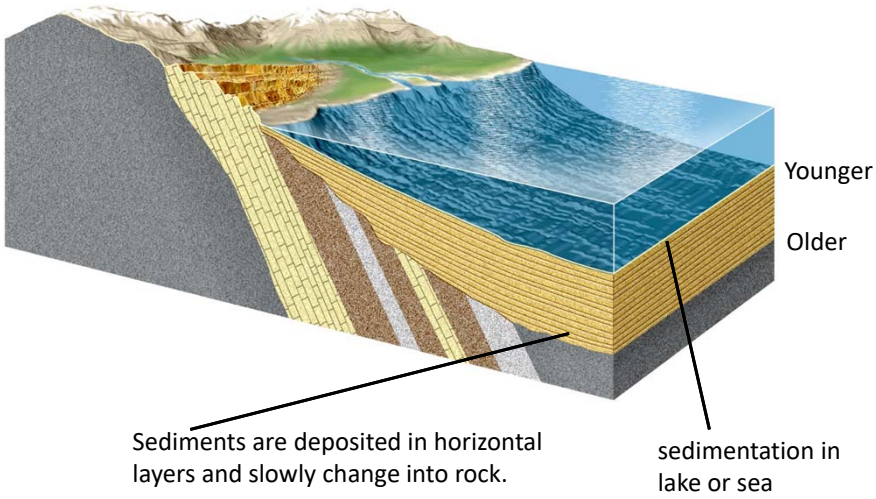
Superposition: in a sequence of sedimentary rock layers, each layer of rock is older than the layer above it and younger than the rock layer below it (*Nicolaus Steno*).

Faunal succession: fossils occur in a definite, invariable sequence in the geologic record (*William Smith*).

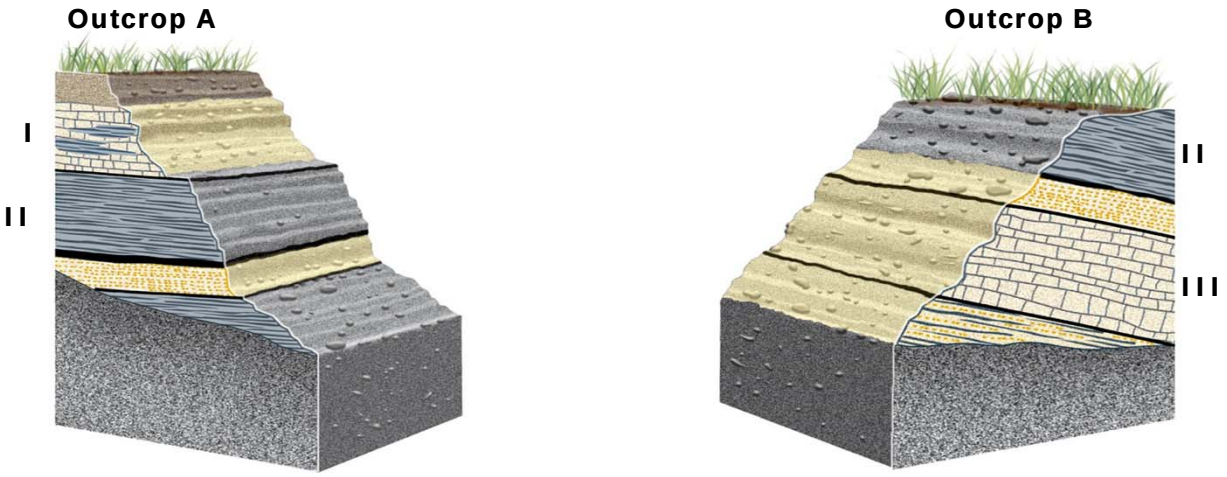
Cross-cutting relationship: if a fault or other body of rock cuts through another body of rock then it must be younger in age than the rock through which it cuts and displaces (*James Hutton*).

Laws of inclusions: if a rock body contained fragments of another rock body, it must be younger than the fragments of rock it contained. The intruding rock must have been there first to provide the fragments. (*James Hutton*).

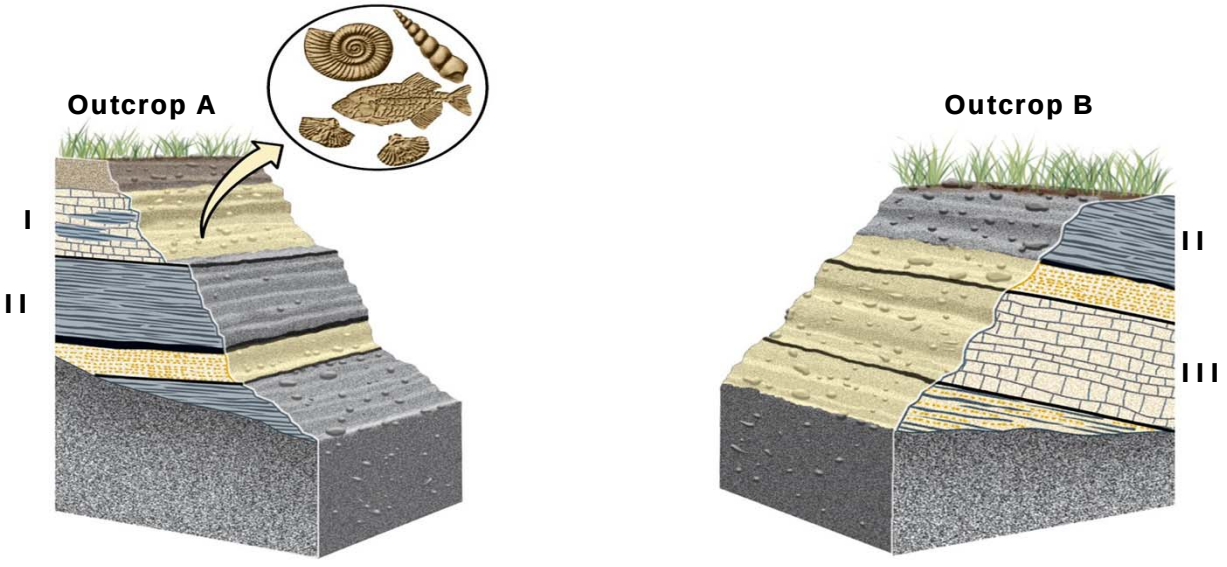
Original Horizontality and Superposition



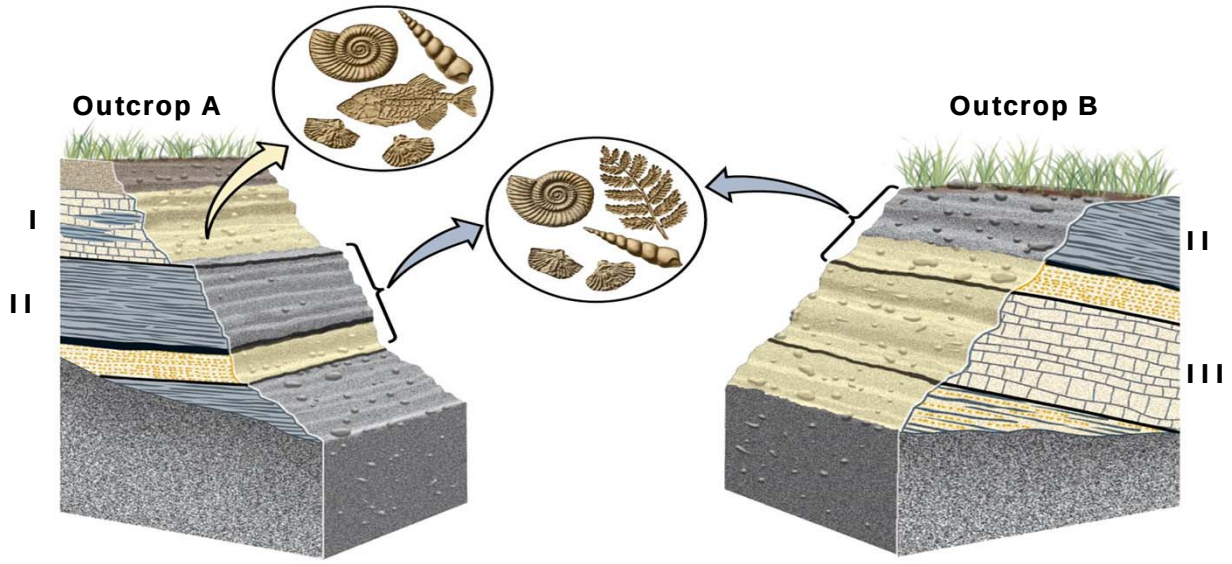
Faunal Succession



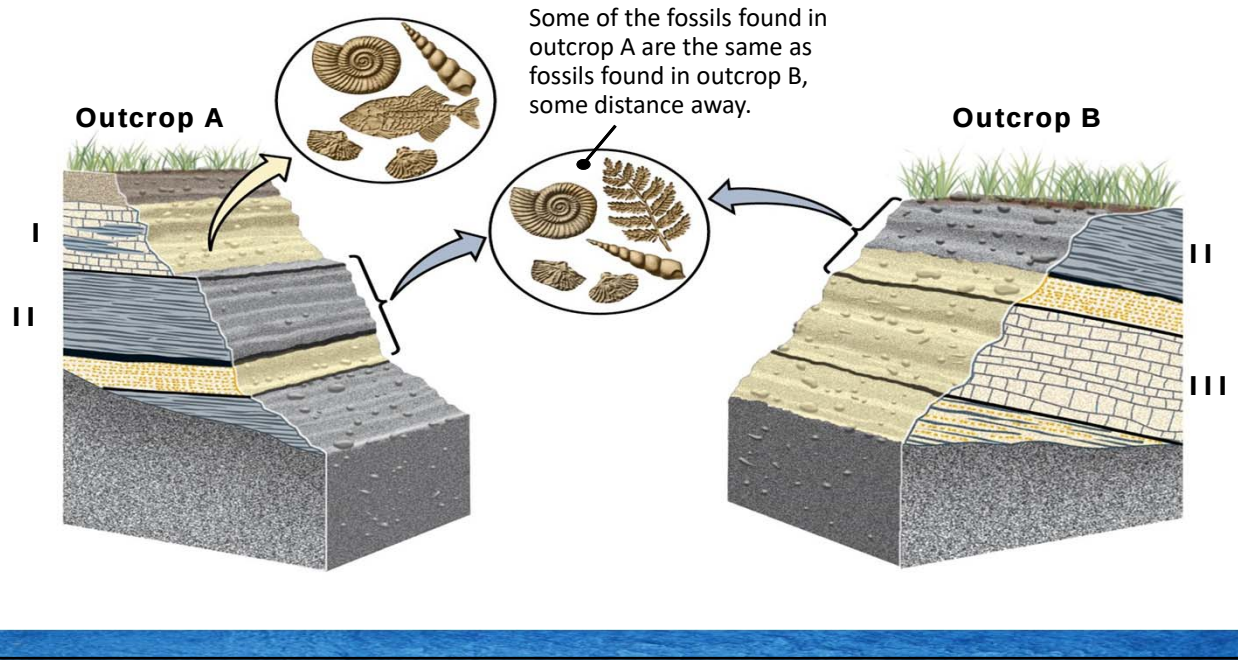
Faunal Succession



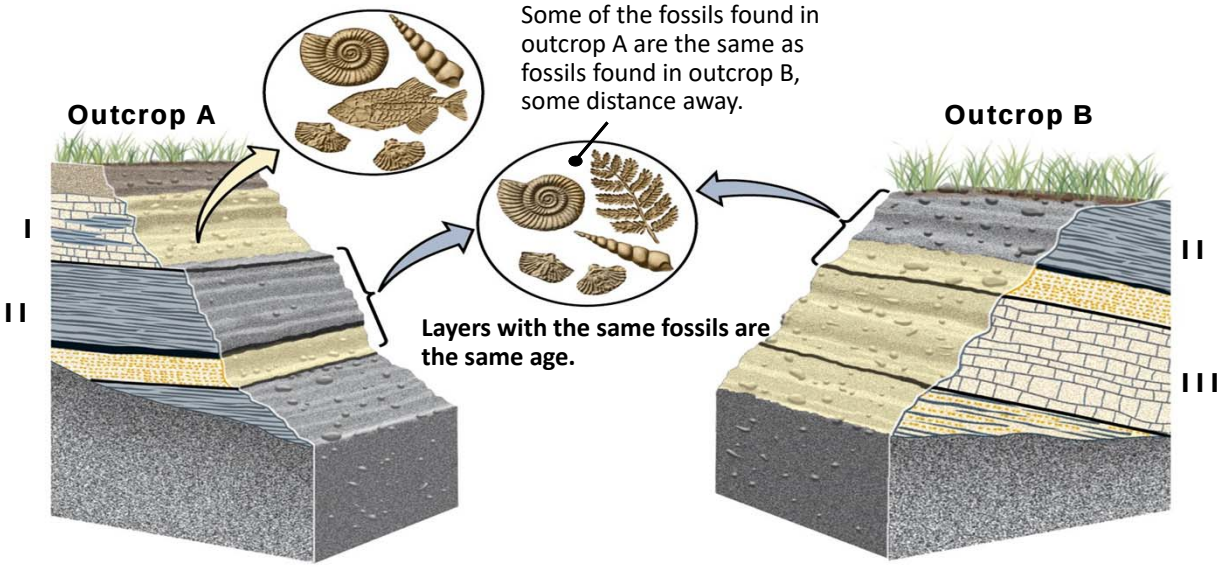
Faunal Succession



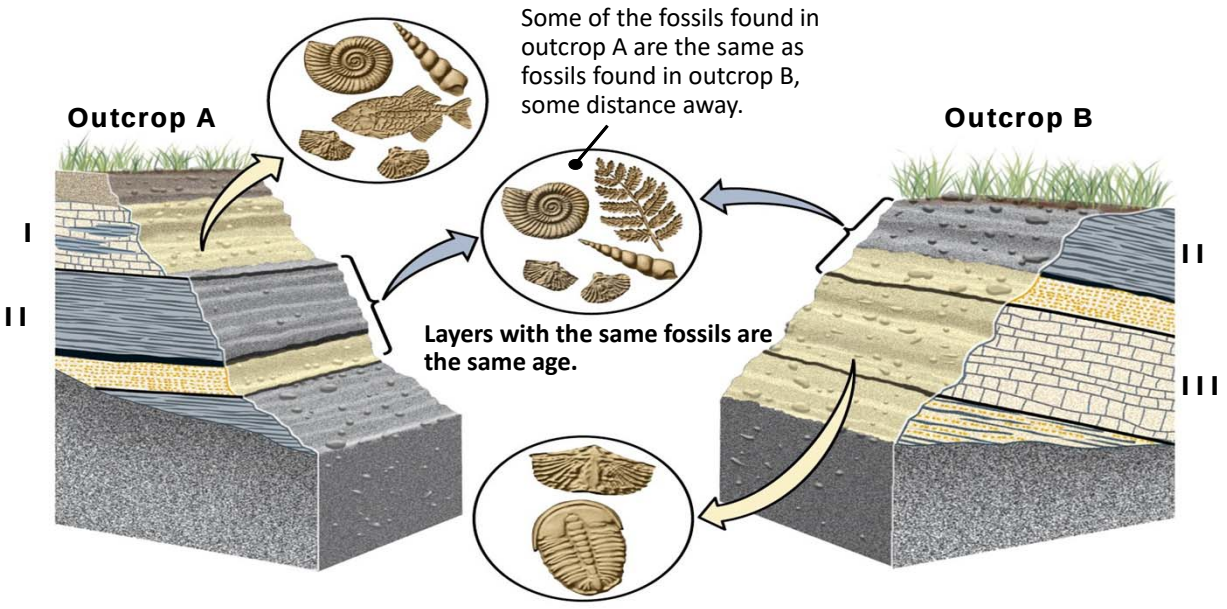
Faunal Succession



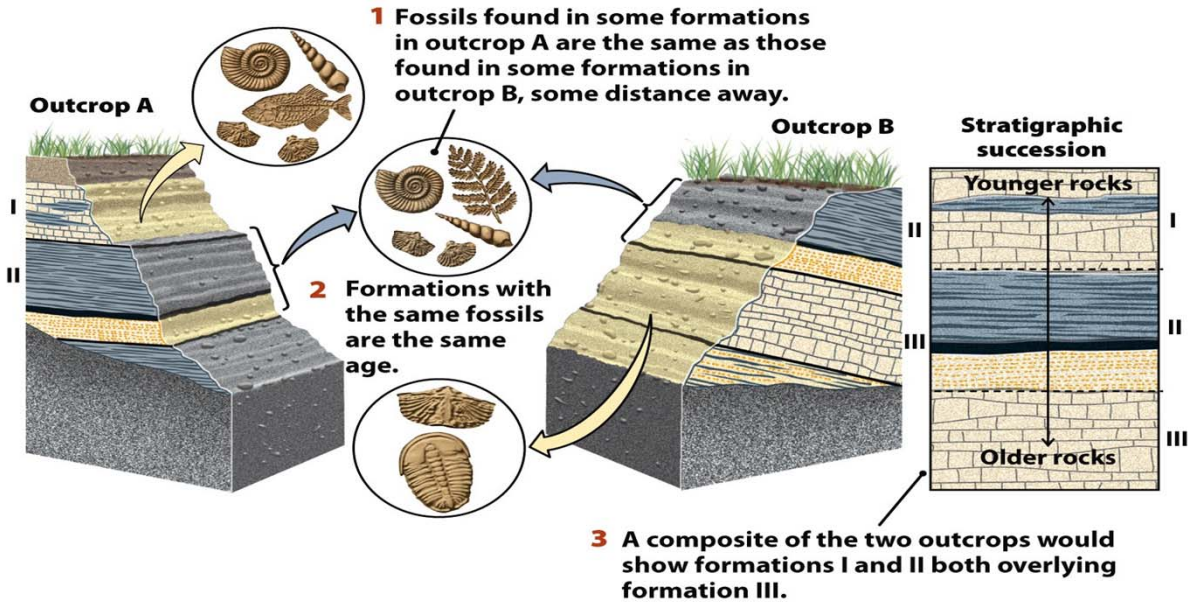
Faunal Succession



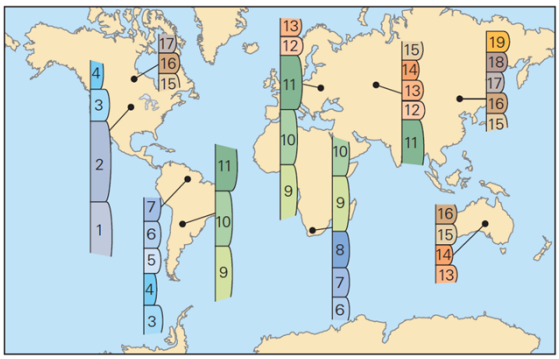
Faunal Succession



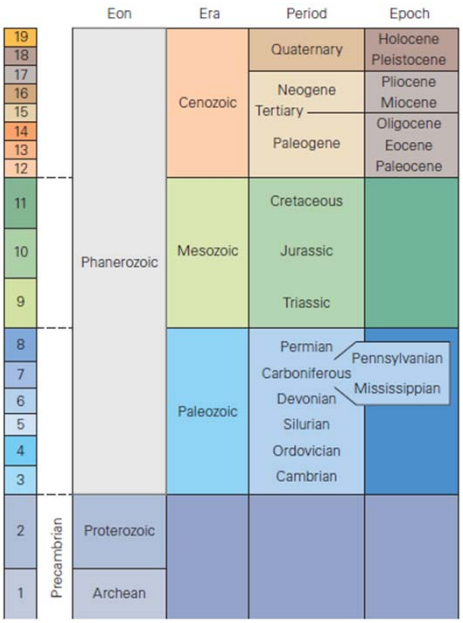
Faunal Succession



Faunal & Stratigraphic Succession



By correlation, the strata from localities around the world can be stacked in a chart representing geologic time to create the geologic column. Geologists assigned names to time intervals, but since the column was built without knowledge of numerical ages, it does not depict the duration of these intervals.



Stratigraphic Records

- Unconformities – gaps in the record

Disconformity: an unconformity between parallel layers of sedimentary rocks which represents a period of erosion or non-deposition. Disconformities are marked by features of subaerial erosion. This type of erosion can leave channels and paleosols in the rock record

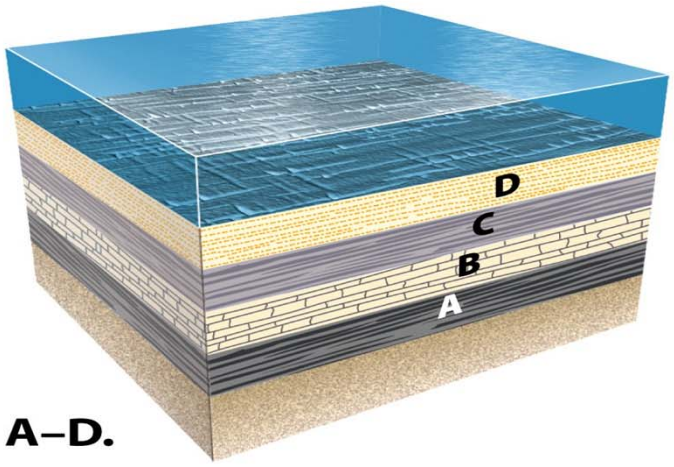
Nonconformity: A nonconformity exists between sedimentary rocks and metamorphic or igneous rocks when the sedimentary rock lies above and was deposited on the pre-existing and eroded metamorphic or igneous rock.

Angular Unconformity: an unconformity where horizontally parallel strata of sedimentary rock are deposited on tilted and eroded layers, producing an angular discordance with the overlying horizontal layers.

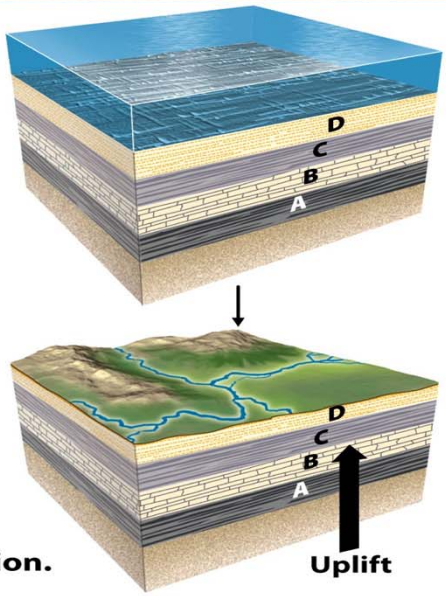
Paraconformity: a type of unconformity in which strata are parallel; there is no apparent erosion and the unconformity surface resembles a simple bedding plane. It is also called nondepositional unconformity or pseudoconformity. A paraconformity of shorter time period is known as Diastem.

Disconformity

TIME 1
Beneath the ocean, sedimentary beds accumulate in layers A–D.

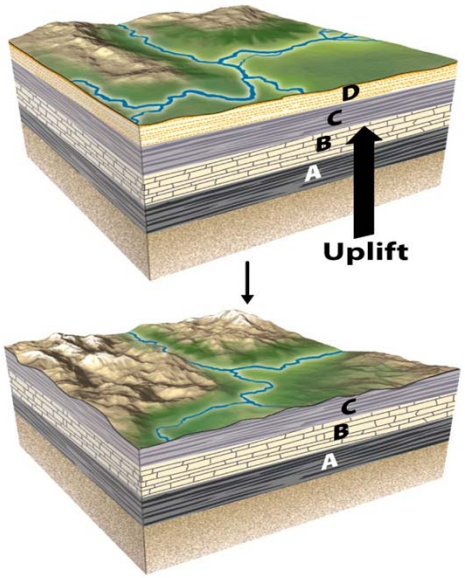


Disconformity



TIME 2
Later, tectonic forces cause uplift of the beds above sea level, exposing them to erosion.

Disconformity

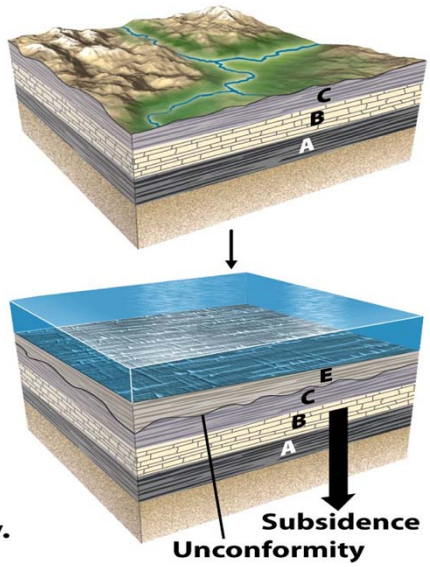


TIME 3
Erosion strips away layer D and part of C, leaving an irregular surface of hills and valleys.

Disconformity

TIME 3
Erosion strips away layer D and part of C, leaving an irregular surface of hills and valleys.

TIME 4
Subsidence below sea level allows a new layer, E, to be deposited over C. The irregular surface of C is preserved as an unconformity.



Disconformity

TIME 1
Beneath the ocean, sedimentary beds accumulate in layers A–D.

TIME 2
Later, tectonic forces cause uplift of the beds above sea level, exposing them to erosion.

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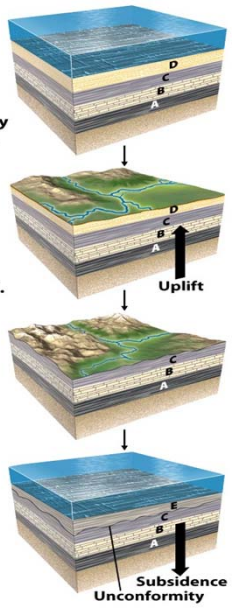
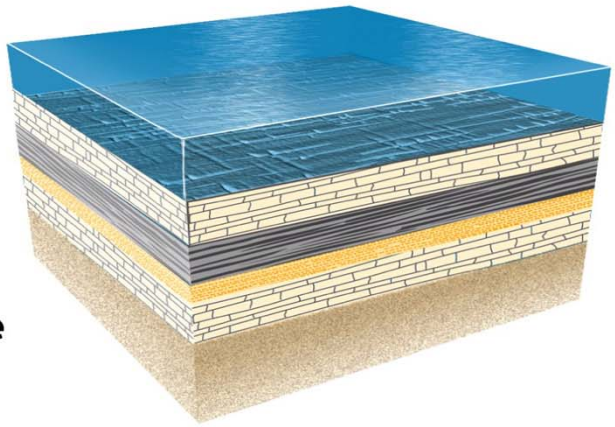
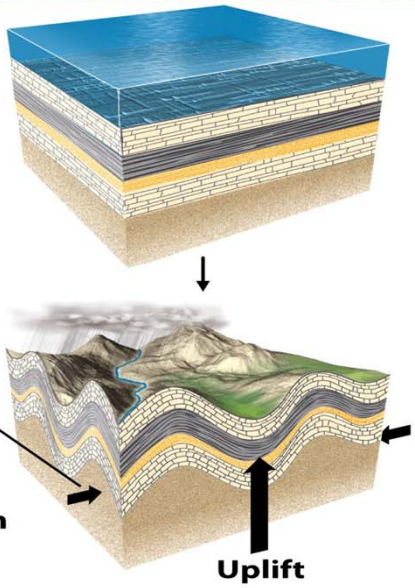


Angular Unconformity

TIME 1
Beneath the ocean, sediments accumulate in beds.

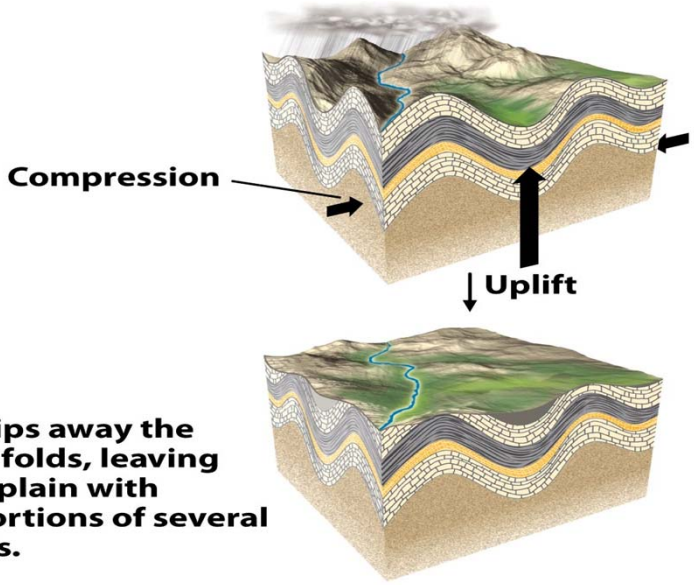


Angular Unconformity



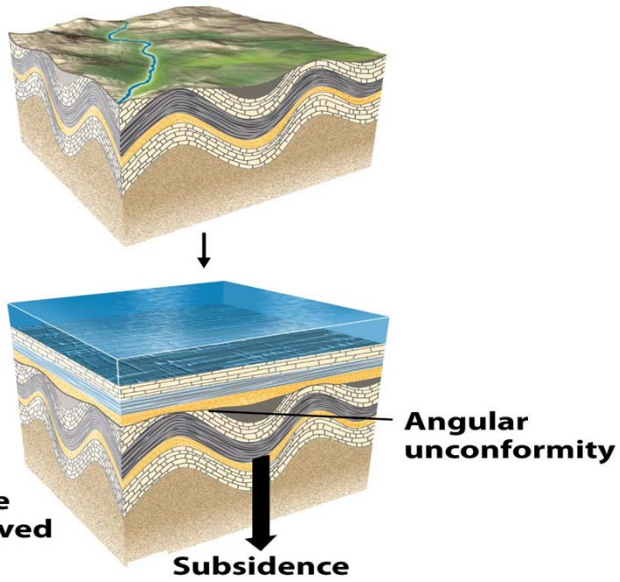
TIME 2
Later, tectonic forces cause uplift, folding, and deformation of the sedimentary beds.

Angular Unconformity



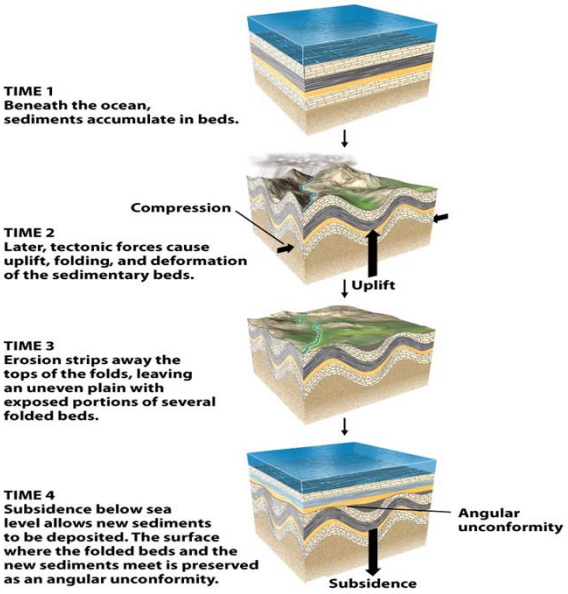
TIME 3
Erosion strips away the tops of the folds, leaving an uneven plain with exposed portions of several folded beds.

Angular Unconformity

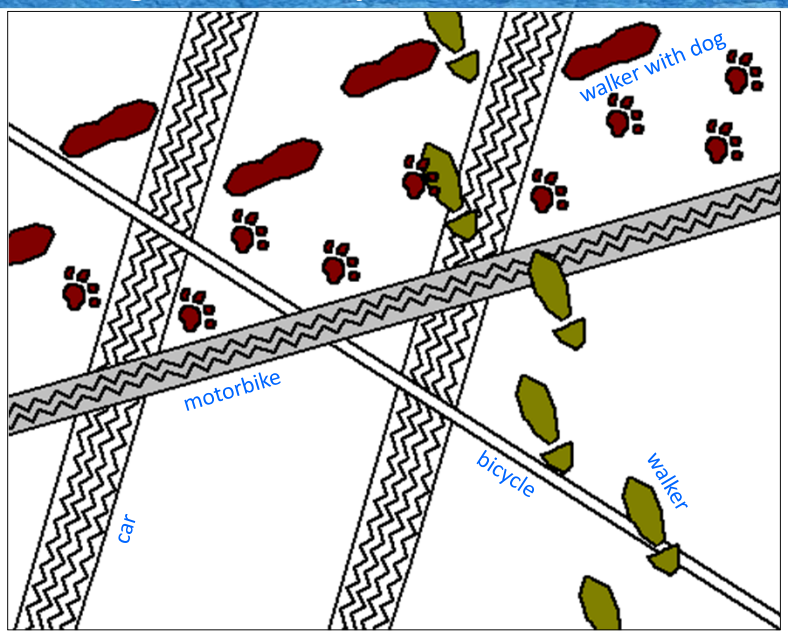


TIME 4
Subsidence below sea level allows new sediments to be deposited. The surface where the folded beds and the new sediments meet is preserved as an angular unconformity.

Angular Unconformity



Cross-Cutting Relationship



walker with dog

walker

motorbike

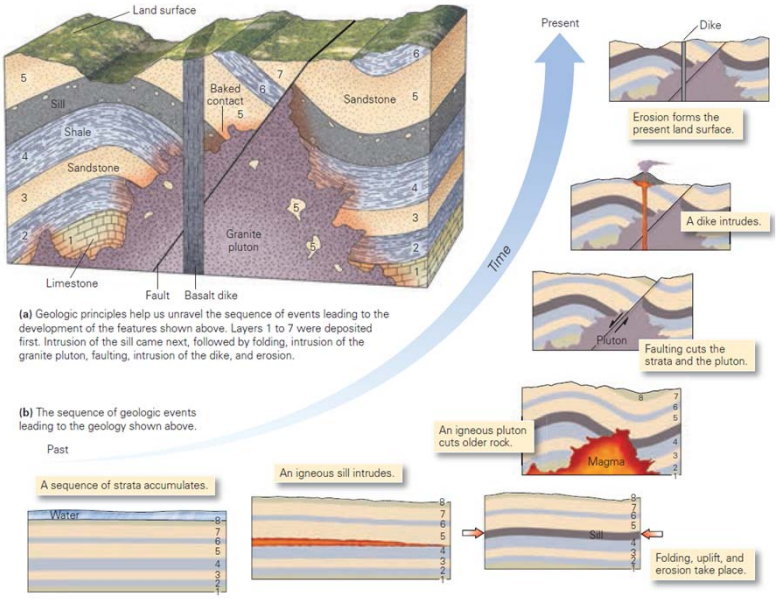
bicycle

car

Cross-Cutting Relationship

- The latest fracture movement should displace previous ones in a terrain with multiple generation of fractures.
- If the latest fracture involve shear component (Type -II), the previous fractures should slip accordingly along latest fracture.

Cross-Cutting Relationship



(a) Geologic principles help us unravel the sequence of events leading to the development of the features shown above. Layers 1 to 7 were deposited first. Intrusion of the sill came next, followed by folding, intrusion of the granite pluton, faulting, intrusion of the dike, and erosion.

(b) The sequence of geologic events leading to the geology shown above.

Next Lecture

Geological Time Scale (relative and absolute)