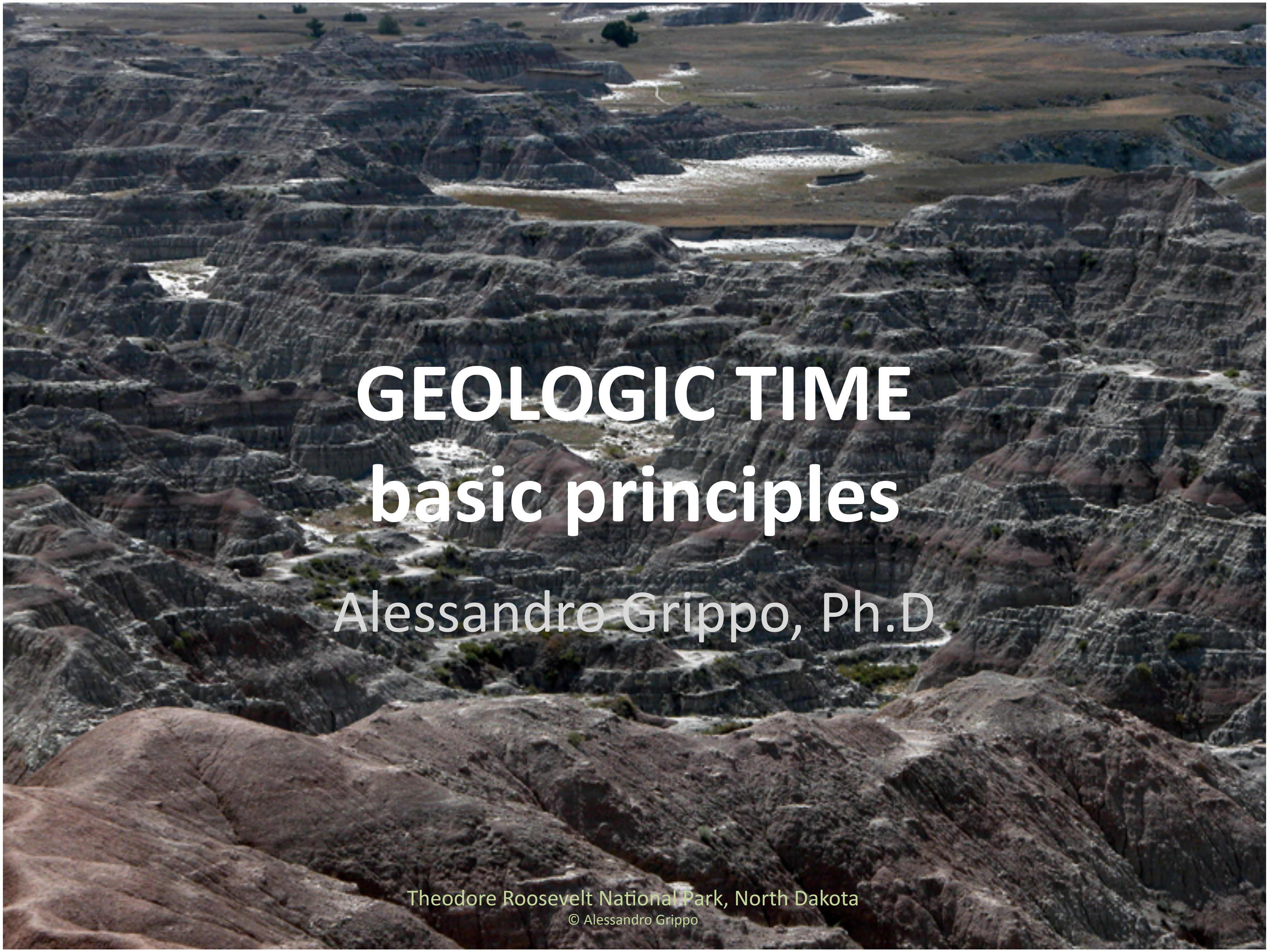


GEOLOGIC TIME
basic principles

Alessandro Grippo, Ph.D

Theodore Roosevelt National Park, North Dakota

Relative Time

- In order to establish a sequence of events in time (relative time) we use five different principles

- Three of them are known as Steno's Principles (from Nicolaus Steno): superposition, original horizontality, and lateral continuity
- Two more were added later: the principle of cross-cutting relationships and the principle of inclusions

Steno's principles
1. **Superposition**

- In an undisturbed succession of sedimentary rocks layers:
  - the oldest layer is at the bottom
  - the youngest layer is at the top
- Or, the sequence gets younger from the bottom to the top

Scotts Bluff National Monument, Nebraska

Steno's principles
2. **Original Horizontality**

- Because of the influence of gravity, sediment is deposited in horizontal layers (there are some exceptions)
  - So, when you see sequences where layers are not horizontal, those sequences have been tectonically deformed

Horizontal layers
Tectonic deformation is minimal or absent

Moenkopi Formation
at the Grand Falls of the Little Colorado River
Navajo Nation at Leupp, Arizona

Tilted layers

These layers were originally horizontal, and subsequently deformed

Valencia, Los Angeles County, California

Vertical layers, as seen at the core of a thrust fault.
These layers were originally horizontal.

Firenzuola, Firenze, Italy

How do horizontal layers get tilted?

In this example we see five different stages of deformation:

A – undisturbed horizontal layers

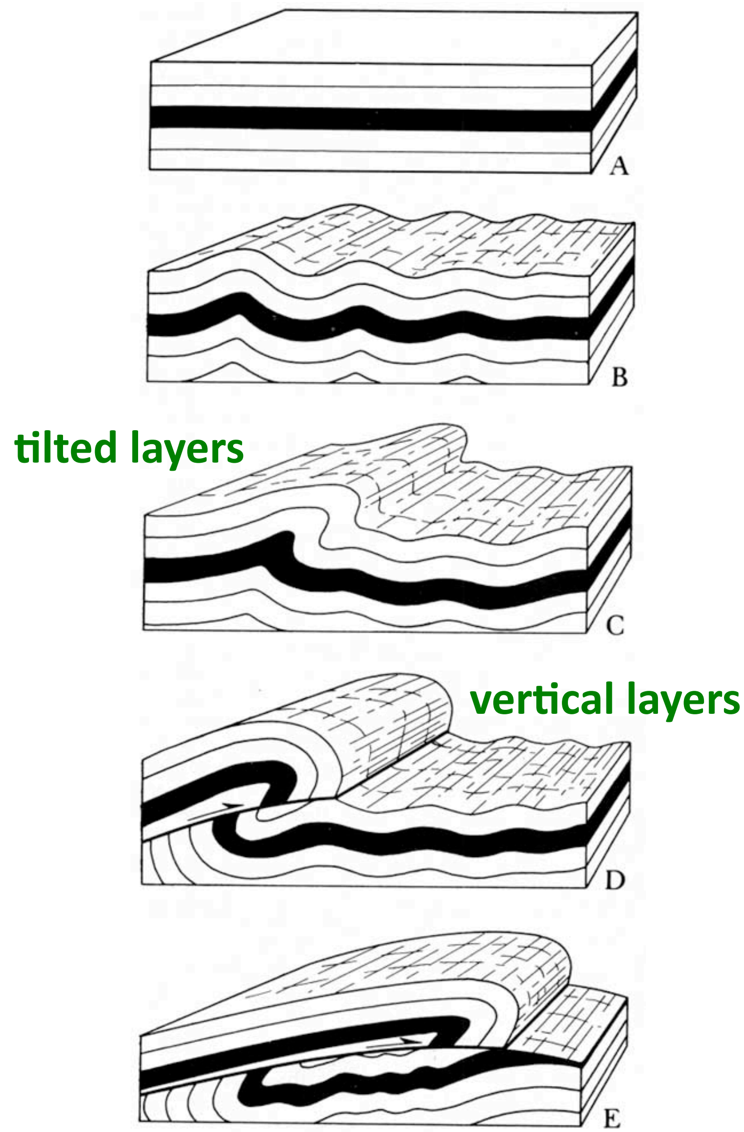
B – lateral compression causes mild folding (structures called synclines and anticlines)

C – compression continues and causes a fold to develop a steep tilted side (limb) and a vertical side

D – a rupture occurs (a thrust fault*)

E – continued compression at this point causes almost horizontal sliding of one block over the other

* a fault is a fracture along which movement occurs
when the fault surface is nearly horizontal and allows for very old rocks to overlie very young rocks, it is called a thrust fault)



Modified from "The Big Bend of the Rio Grande: A Guide to the Rocks, Geologic History, and Settlers of the Area of Big Bend National Park", Texas Bureau of Economic Geology, 1987.

Steno’s principles

3. **Lateral Continuity**

- Sediment extends laterally, in all directions until it thins and pinches out, or terminates against the edge of the depositional basin

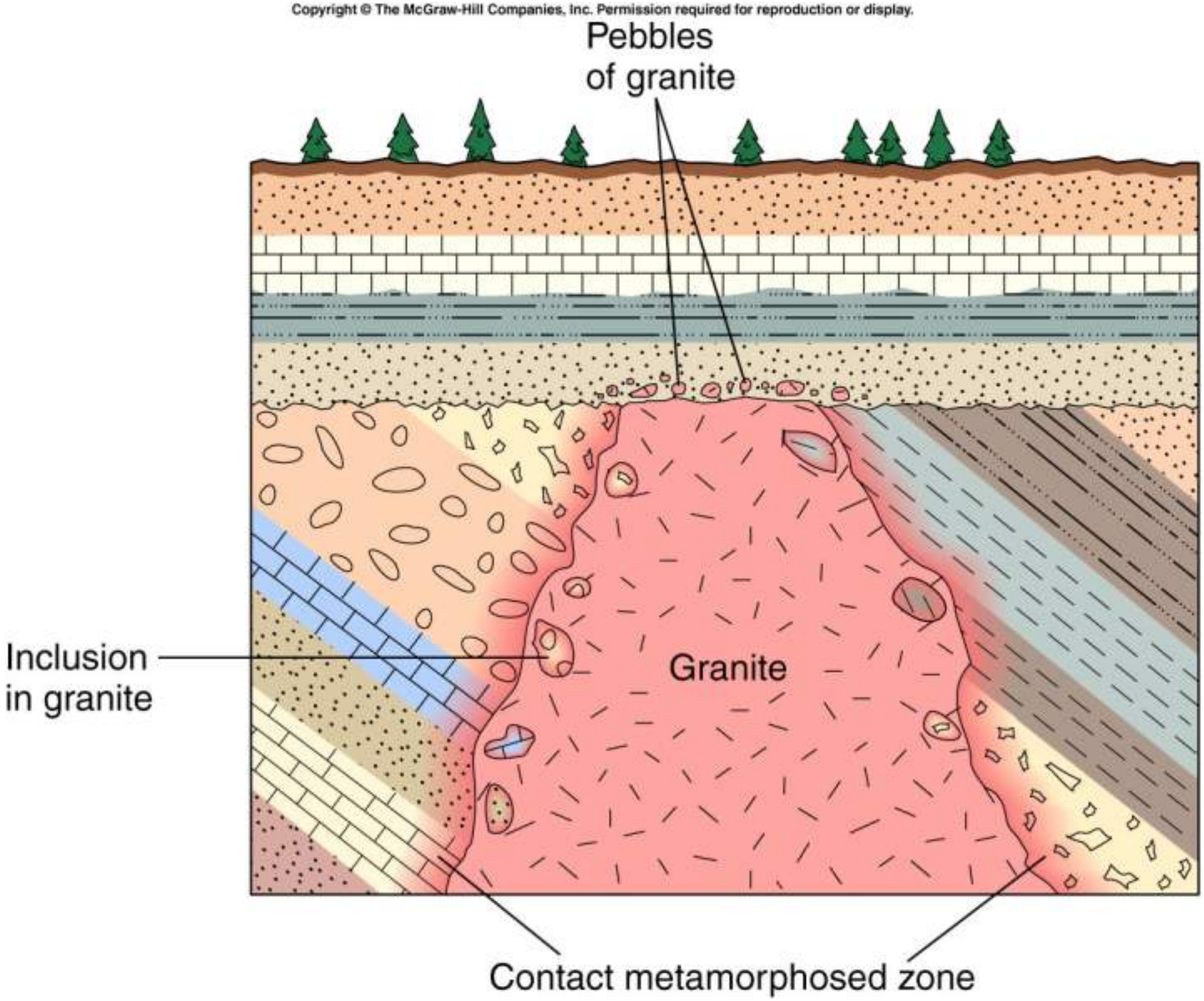
Bryce Canyon National Park, Utah

other principles

4. **Cross-Cutting Relationships**
5. **Inclusions**

- What cuts, is younger than what has been cut
- An igneous intrusion (a pluton or a dike), or a fault (a fracture along which motion occurs) must be younger than the rocks it intrudes or displaces

- An inclusion (or fragment) inside a body of rock is always older than the rock itself


Pebbles
of granite
Inclusion
in granite
Granite
Contact metamorphosed zone

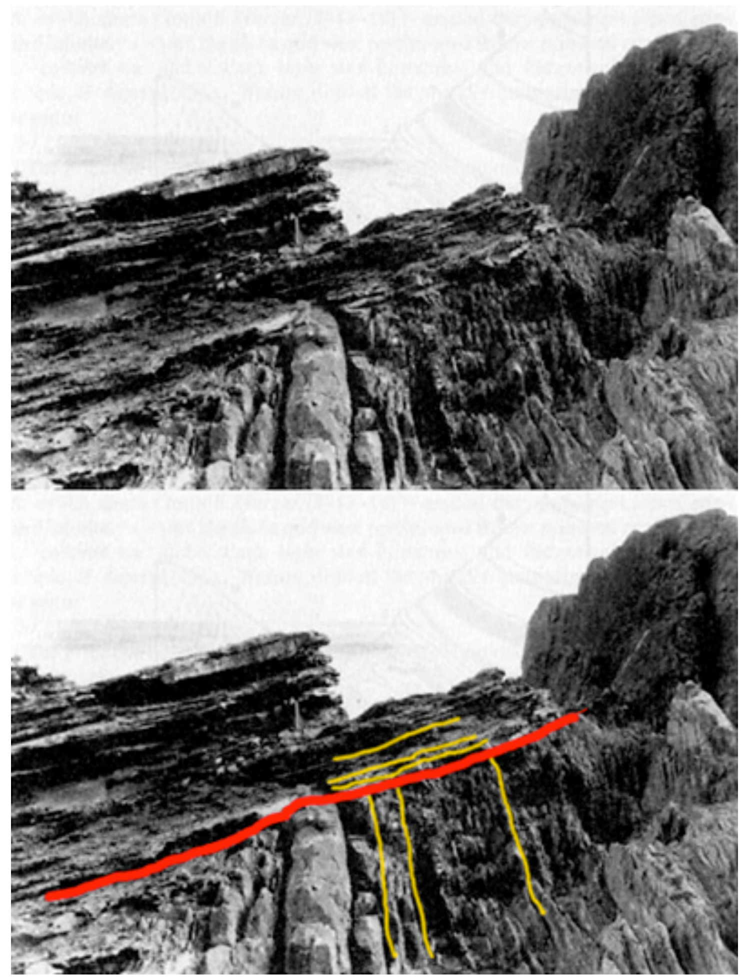
At this location lava flowed over sedimentary rocks, melting and truncating the original layers. The lava cooled into a dark extrusive igneous rock (basalt) interrupting the original lateral continuity of the light colored sandstone layers of the Moenkopi Formation. As such, the black rock is younger than the reddish sandstones (it interrupts their pattern)

Moenkopi Formation
at the Grand Falls of the Little Colorado River
Navajo Nation at Leupp, Arizona

A normal fault: the left block (hanging wall) moved downward in respect to the right block (foot wall). The layers were continuous (correlation is not immediate but note the kinked bed edges along the fault) but have been cut by the fault.
Hence, the fault is younger than the layers (it occurred after the layers had formed)
House Rock Junction, Arizona

Unconformities

- Gaps in the rock record
- Gaps occur for two reasons:
  - non-deposition
  - erosion (which also implies non-deposition)
- First recognized by James Hutton at Siccar Point



Siccar Point, Berwickshire, Scotland

Unconformities

- At unconformities, time is not recorded, and the geologic record is incomplete
- The gap could be short (less than 1 million years) or very long (hundreds of millions to billions of years)
- Unconformities are surfaces, and not layers
- The geologic time not represented at an unconformity is defined as a hiatus

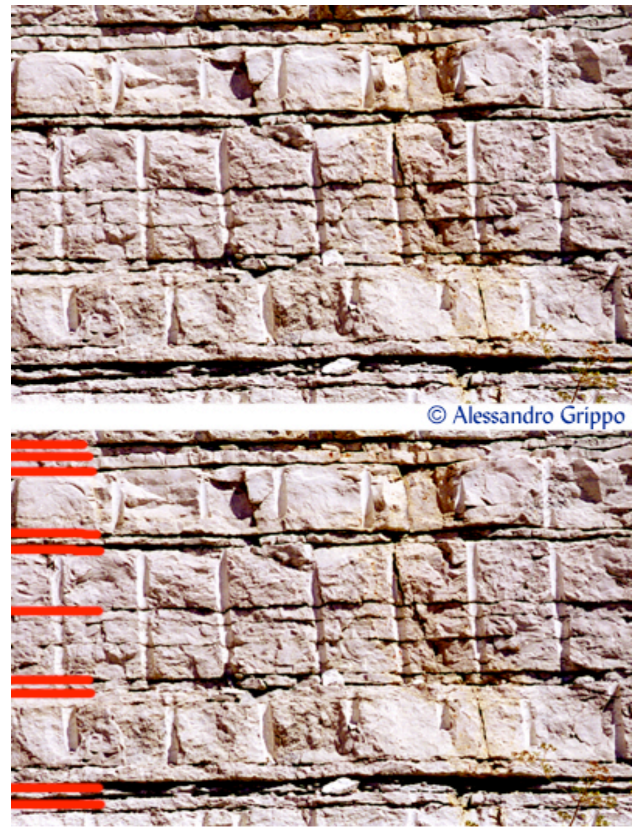
Unconformities

- Unconformities are of four different types:
  - Paraconformities
    - The sequences of strata above and below the unconformity are parallel, and there was no erosion, just non-deposition
  - Disconformities
    - The sequences of strata above and below the unconformity are parallel, and there was erosion
  - Angular Unconformities
    - The sequences of strata above and below the unconformity are at an angle
  - Nonconformities
    - Sedimentary rocks covering eroded plutonic and/or metamorphic rocks

Unconformities

1. **Paraconformity**

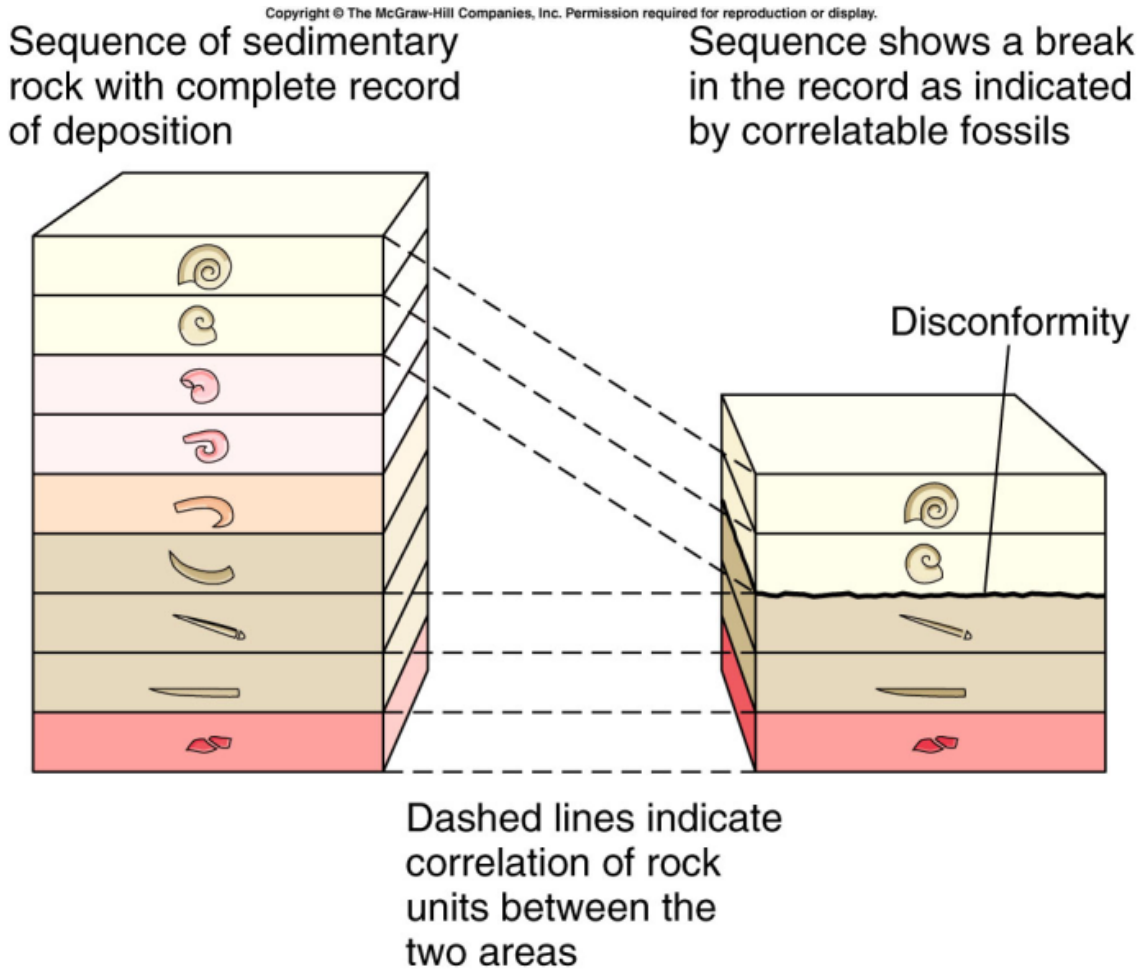
- Paraconformities and disconformities are often difficult to tell one from the other
- Time is missing because rocks were never deposited during that time, but there is no erosion
- Clues can be found in fossils, hardened surfaces, bioturbation, etc.



Paraconformity or Disconformity?
What seems like a continuous section is in reality deposited as a "stop and go" sequence. This is a submarine high that shows a "condensed" section
Pesaro e Urbino, Italy
© Alessandro Grippo

Unconformities

2. **Disconformity**

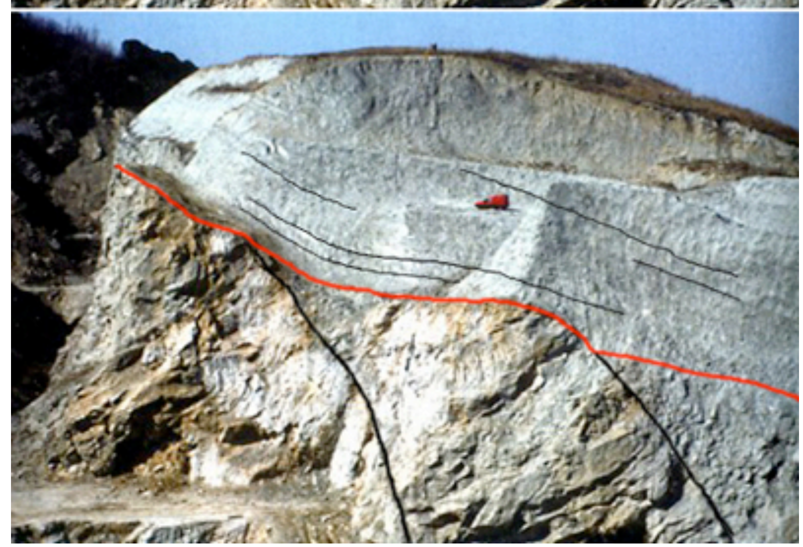


Unconformities

3. **Angular Unconformity**

In this image from a quarry, we see thick, tilted banks of gypsum overlain by horizontal, thin layers of bluish shales

Their contact is an angular unconformity



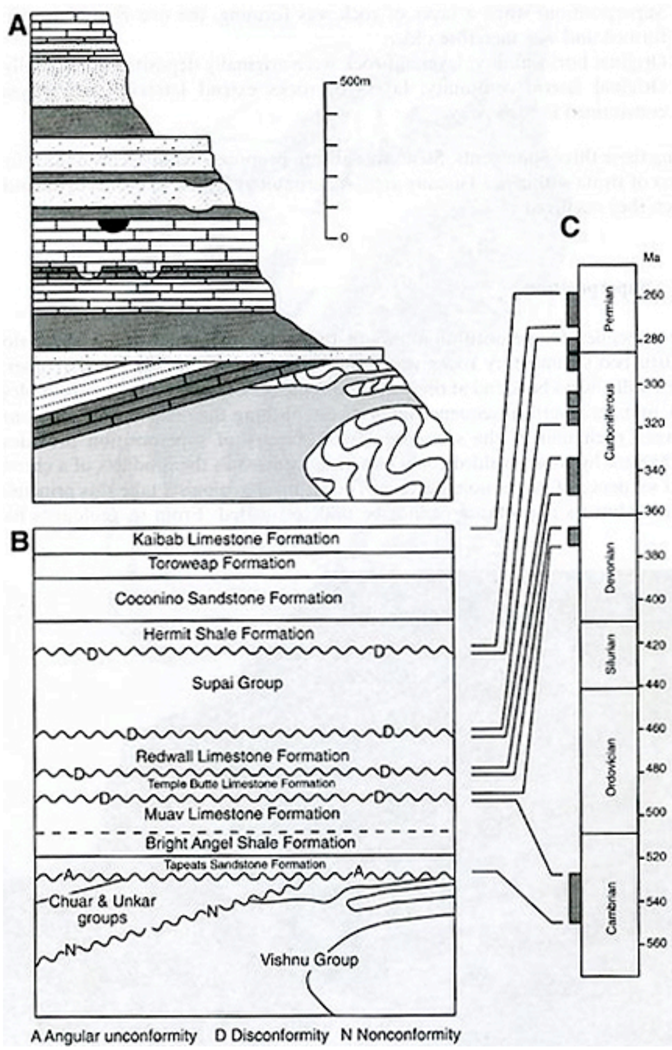
Bologna, Italy

Unconformities

4. **Nonconformity**

G

An example from the Grand Canyon, Arizona



The image to the left, taken from Doyle et al. (2001) shows:

A - a vertical profile of the Grand Canyon section

B - a stratigraphic sketch of the Units and Formations present in the area, including their name, which also shows the three different kinds of Unconformities, labeled as A, D, and N

C - part of the Geologic Time Scale covering the Paleozoic Era, showing the age of the rock units, or Formations

Correlation

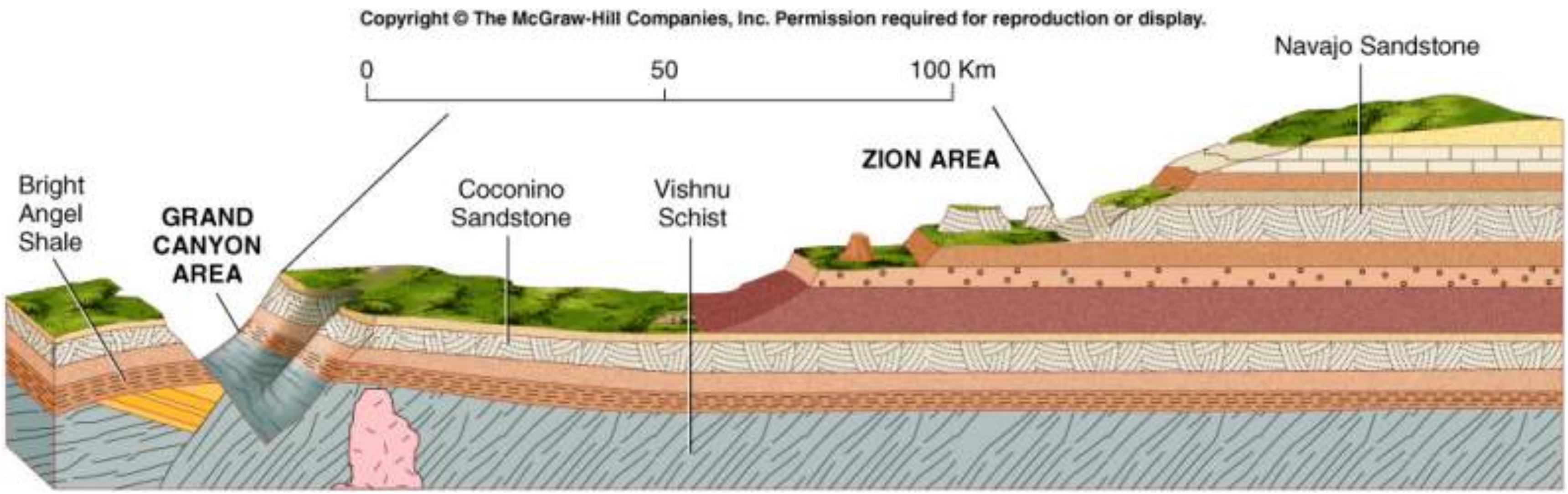
- To correlate means to establish equivalency in time
- Correlation can also be pursued between rocks, but it will likely lose its temporal meaning
- There are three main ways to correlate between rock sequences:
  - By physical continuity: you can see or trace your layers directly. It is usually limited to small areas
  - By similarity of rock types: this is tricky and you should be absolutely certain that your are looking at the same rock
  - By use of fossils
    - Principle of Fossil Succession
    - Concept of Index Fossil
    - Concept of Fossil Assemblage (remember Albert Oppel's zones)

Correlation

1. **Physical Continuity**

Correlation

2. **Similarity of Rock Type**



Correlation
3. **Fossils**

- Fossils are remnants of ancient forms of life, or of their activity

- Since fossils change (evolve) in time according to a known and predictable order, they can be used as a correlation tool

Significance of Fossils

- Fossil give us two lines of information:
    - the Environment of Deposition
        - the physical place where organisms lived
    - Relative Time (because of William Smith's Principle of Fossil Succession: faunas and flora follow each other in time according to a known and predictable order)
        - the time interval when said organisms lived

Basic use of Fossils for Correlation

- Finding one single fossil *per se* is not enough
  - if an organism lived for a very long time, it might not be very useful for correlation

Nautilus is considered to be a "living fossil," as the species has undergone little change in the last 400 million years. The nautilus first appeared about 265 million years before the first dinosaurs.

because of this, a Nautilus fossil will not be very indicative of any time period in Earth History

Index Fossils

- An **Index Fossil** is the fossil of a species which:
  - lived for a very short amount of time
  - was widespread
  - lived in different environments
  - it is easy to find in the fossil record

Mucrospirifer mucronatus, a Middle Devonian brachiopod index fossil from Lebanon, New York

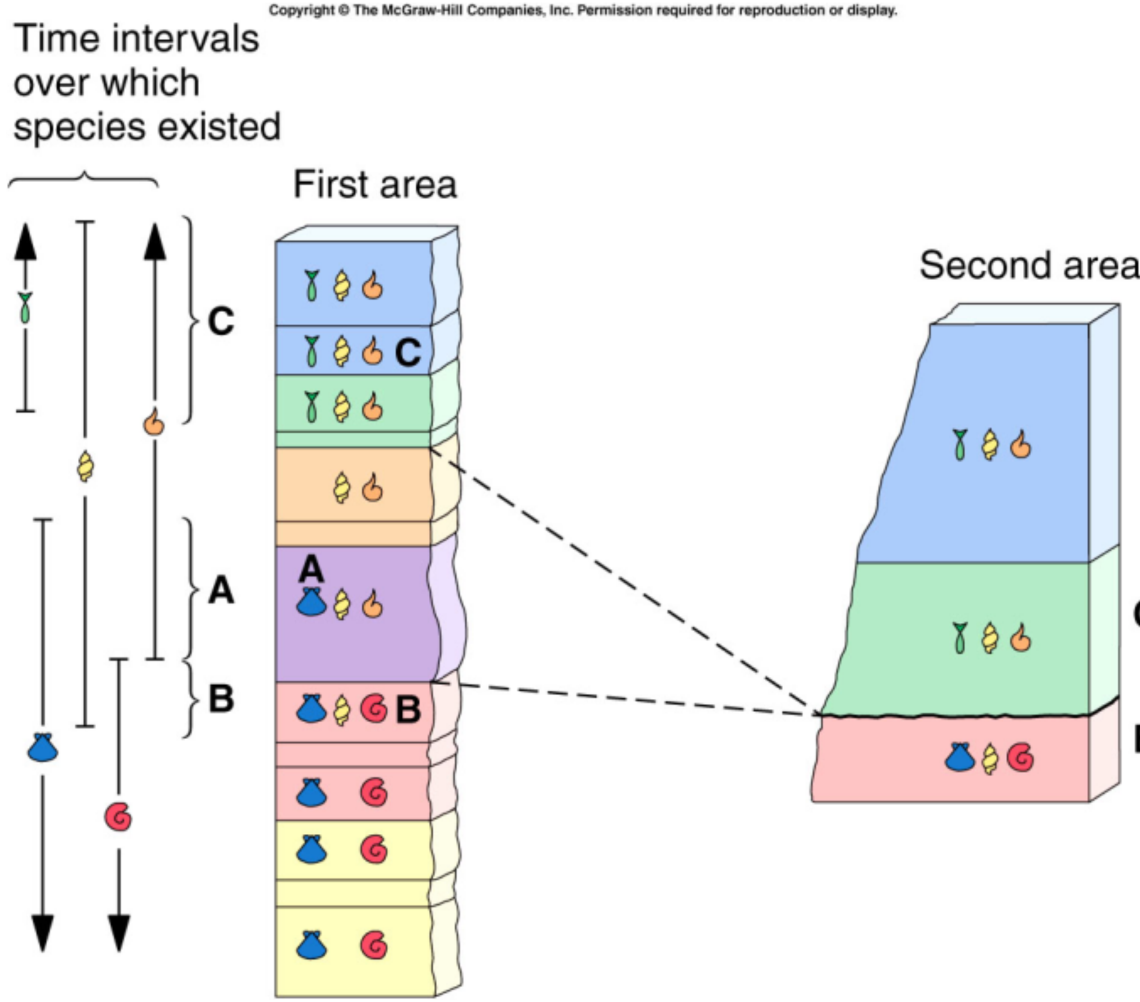
from:
http://www.thefossilforum.com/index.php?/gallery/image/38004-mucrospirifer-mucronatus-from-madison-co-ny/

- Index Fossils, unfortunately, are rare

Fossil Assemblages

- Often, we have to resort to the use of Fossil Assemblages, association of fossils with different **ranges**

- A range is the vertical distribution of a fossil species in rocks, from the moment of its first occurrence (FO) to the moment of its last occurrence (LO)


Time intervals
over which
species existed
First area
Second area
C
A
B
C
A
B
C
B

STRATIGRAPHY

end of part 2