GEOLOGIC TIME
part III

lateral relationships, facies, sea-level change

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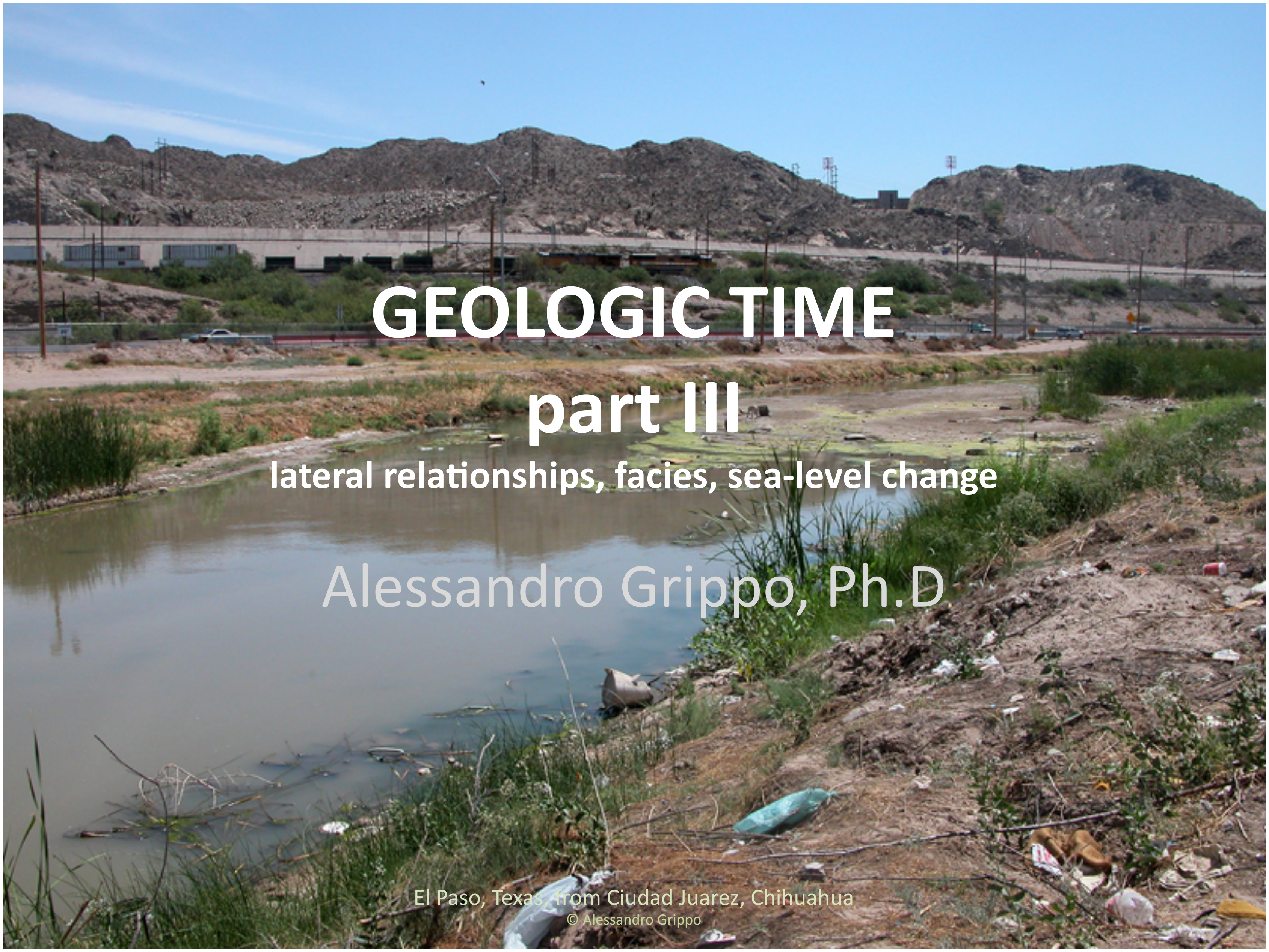


El Paso, Texas, from Ciudad Juarez, Chihuahua

a review

- Relative Time methods
  - Stratigraphy
  - Outcrops
  - Layers (strata) and contacts (bedding planes)
  - Steno's principles
  - Inclusion and Cross-Cutting Relationships
  - Unconformities
  - Correlation
  - Significance of Fossils

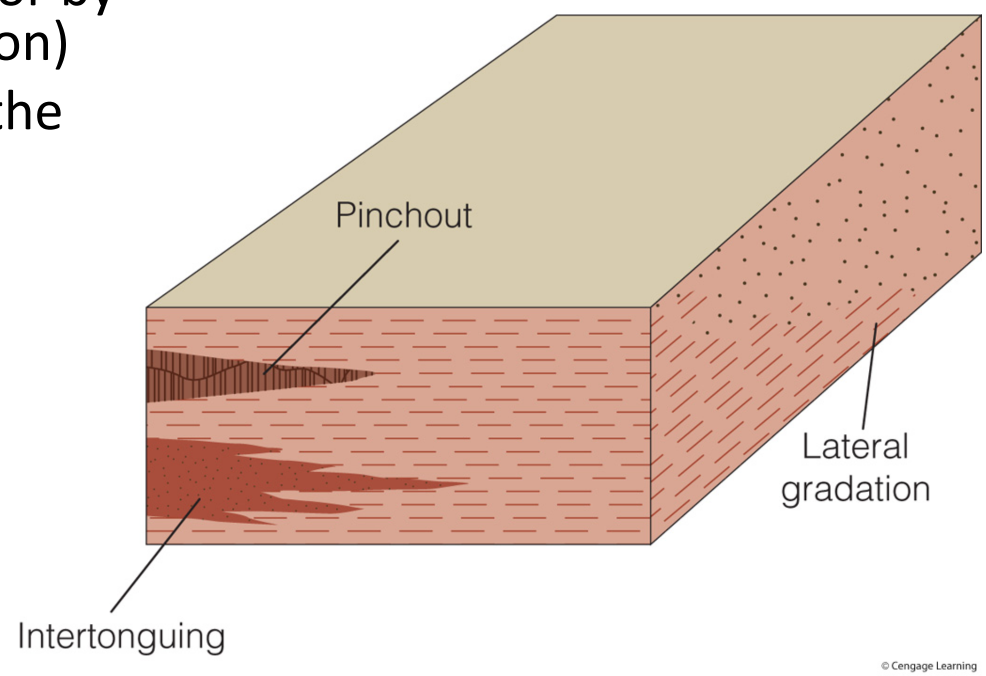
- Numerical Time methods
  - Radioactive methods (including ^{14}C)
  - Fission Tracks
  - Tree Rings
  - Varves

Layers and their Contacts, Steno's principles, Cross-Cutting Relationships and Correlation at work

Normal faulting, House Rock Junction, Arizona

Lateral Relationships

- Lateral Continuity (Steno's)
  - Layers may terminate laterally because:
    - they are cut by a fault or by erosion (after deposition)
    - they are deposited at the end of a basin
    - they *pinch* out
    - they *intertongue* with adjacent rocks
    - they change by lateral gradation



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Why would layers change laterally?

- Sedimentary rocks reflect the environment of deposition
- If environments are found side by side, then sedimentary rocks also change side by side
- Sediments then would have distinctive, different characteristics, in every single environments

Facies

- By studying today's environment, we understand why and how sedimentary rocks change laterally
- We then apply what we learn from today's environment to environments of the past (Uniformitarianism)
- A Sedimentary Facies is a body of sediment with distinctive characteristics, and that points to a specific sedimentary environment

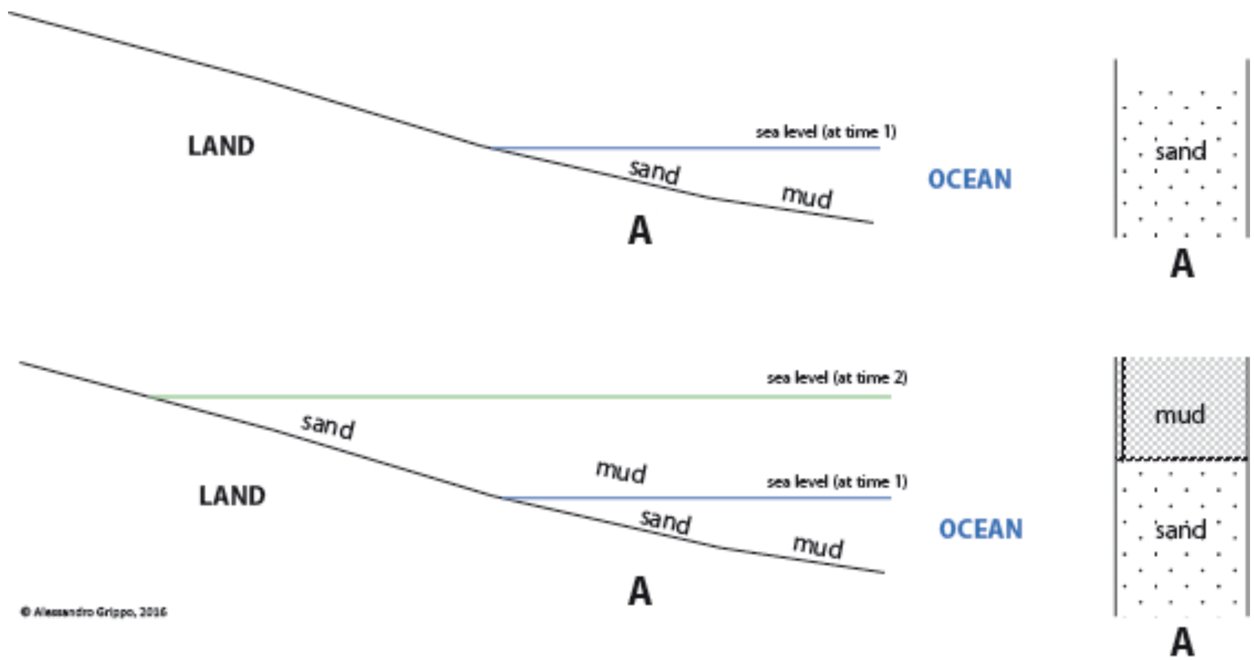
Facies

- A facies can be broad in its meaning
  - for instance, a “deep-marine facies”
- A facies can be narrowed down to a very small environmental niche
  - for instance, a “low-energy, intertidal temperate facies”
- In general, a facies is based on how a rock association “looks”, and it indicates an environment of deposition

Environmental Change and Facies Migration

- Environments are not fixed (in place or in time)
- When an environment changes, so do the rocks that are deposited in that environment
- So, at the same location you might have different environments
- And at the same time your original environment migrates, or moves, somewhere else

Facies changes



This area was affected by a rise in sea level, caused by climate change. At time 1, location A was a coastal beach area, and as such, sand was deposited. At time 2, sea level rose and sand deposition moved away from A (sand can only be a coastal beach sediment): the facies moved, or change laterally.

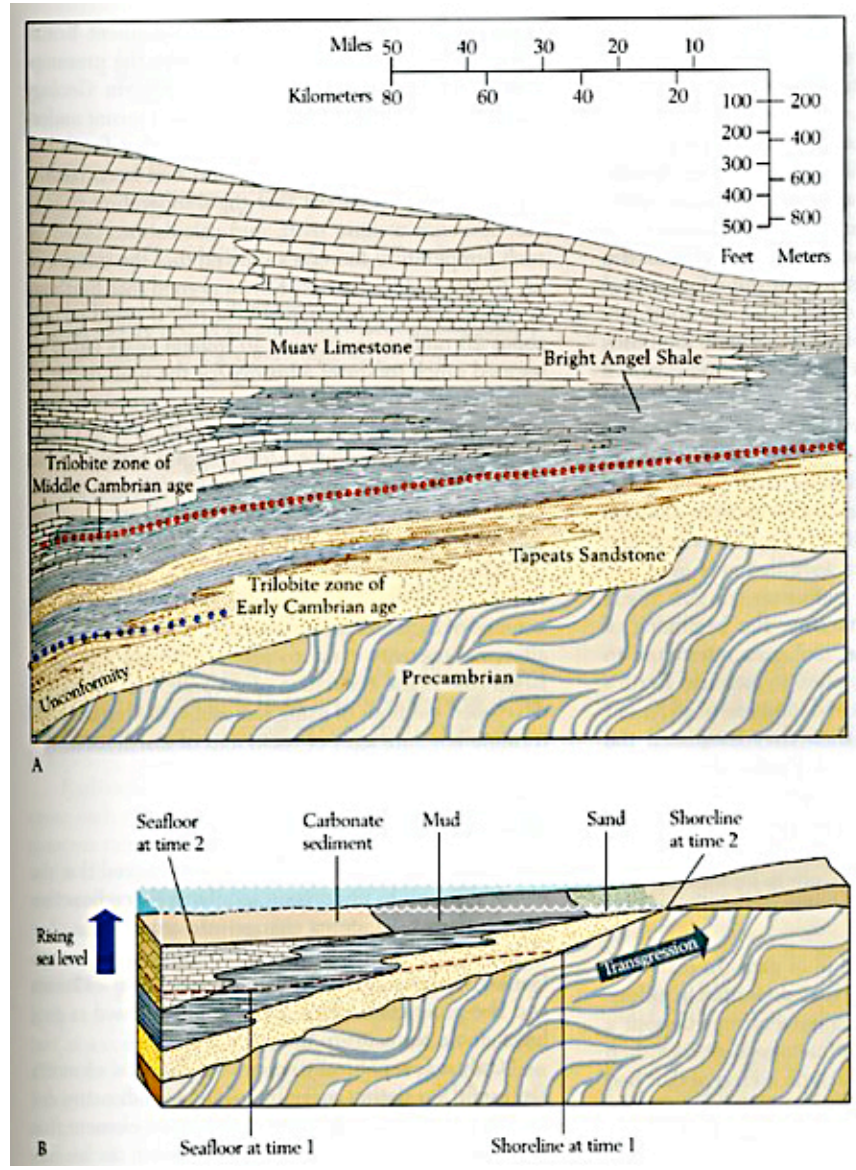
What happened at location A? It was originally a coastal shallow water area, it is now a deeper marine area, where the only sediment can be mud. Mud is then deposited on top of sand

Lessons learned

- Facies migrate laterally in time
  - Lateral continuity exists, but rocks might change
- Facies migrate vertically in time
  - That is why we have different layers on top of each other: at that location, the environment has changed
- The same facies (e.g. the sand) might be continuous as a layer, but does was not deposited at the same time (rock units do not represent time, but just the environment)
- Knowing the horizontal and vertical sequence of rocks (facies) allows us to know about climate change
  - If mud is on top of sand at location A, then sea level rose
  - If we were to find sand on top of mud, then sea level fell at that location
- The lateral distribution of facies is equivalent to the vertical distribution. This is called **Walther's Law** (from Johannes Walther)

An example from the Grand Canyon, Arizona

- In here you can see:
  - lateral facies change
  - vertical facies change
  - intertonguing of facies
  - lack of time significance of rock units
  - Walther's Law
  - evidence of Transgression



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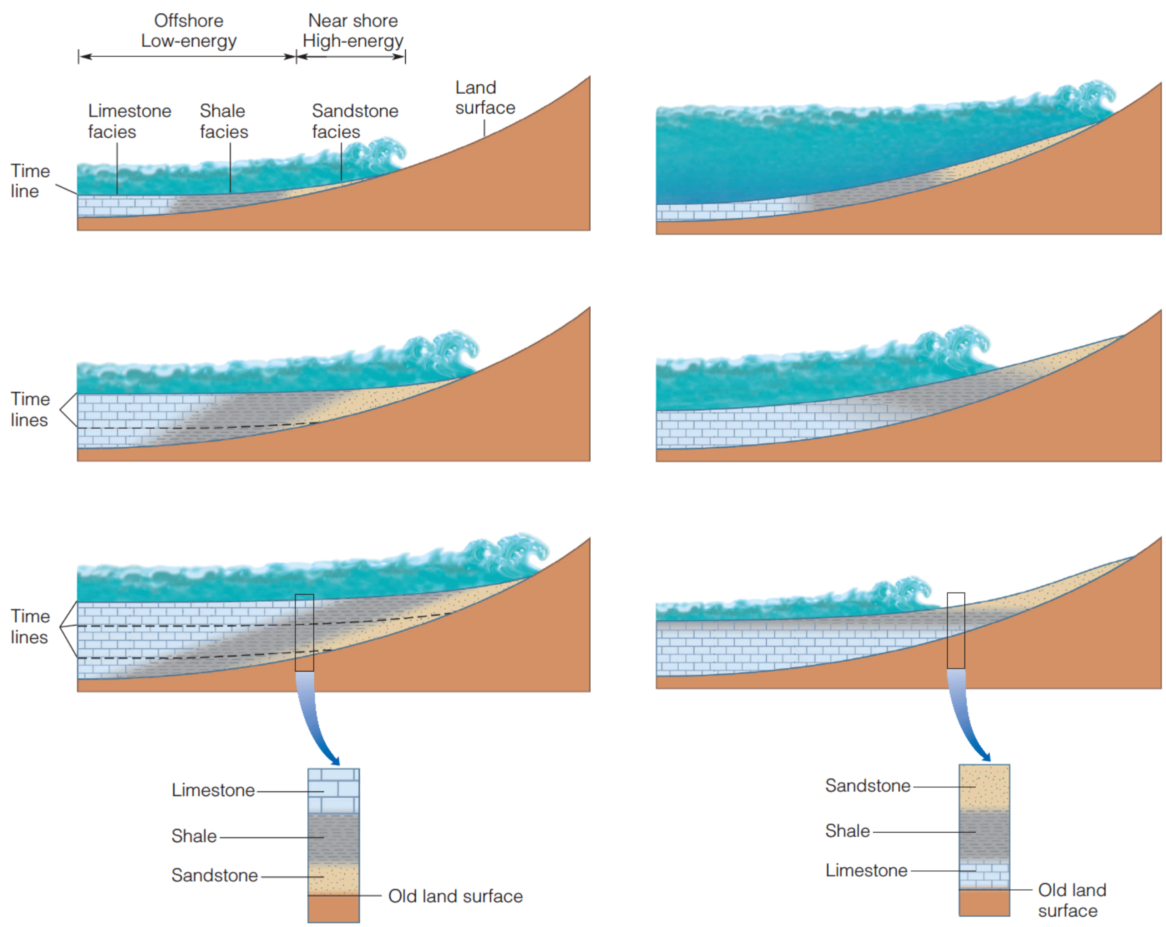
Transgression and Regression

- A transgression is a *relative* rise in sea level
- A regression is a *relative* sea level fall, or drop
- They can be identified in the field by looking at sedimentary sequences:
  - fining-upward: transgression
  - coarsening upward: regression



fining upward sequence

coarsening upward sequence

A Marine Transgression as seen in the rock record

Cadiz, San Bernardino county, California

What are high-energy and low-energy environments?

- High-energy environments:
  - those where the velocity of the transportation agent is high enough that coarse sediments (gravel and sand) can be deposited
    - mountain streams, stream beds, alluvial fans, sand dunes, channels of submarine fans
    - beaches, proximal parts of continental shelves

- Low-energy environments:
  - those where the velocity of the transportation agent is low enough that only fine sediments like mud (silt and clay) and salts * can be deposited
    - swamps, lagoons, marshes, lakes, floodplains
    - distal parts of continental shelves
    - deep oceans, close to land (muds), submarine fans
    - deep oceans, away from land (carbonates)

* under certain conditions, salts can be deposited also in agitated waters

Why does sea-level change?

- There could be more or less water in the oceans
- There could be more or less space where the water could go
- The same amount of water can expands or shrinks with changing water temperatures

More or less water in the oceans?

- During Greenhouse Times, there is no ice at sea level
  - Ice melts and flows into the ocean
  - Sea level rises (transgression)

- During Icehouse Times, there is ice at sea level
  - Snow does not melt and turns into ice, preventing water from going back into the ocean
  - Sea level drops (regression)

Isn't the space at the ocean bottom always the same?

- No, it depends on expansion rates at mid-ocean ridges
- A fast spreading ridge produces a lot of oceanic crust in a short amount of time
  - That would cause more oceanic crust to be at high temperature, that would be expand and be more buoyant
  - There would be less space for water, which would flood continents (transgression)
  - example: North America in the mid-Cretaceous

- A slow spreading rate would see a quickly cooling oceanic crust around mid-ocean ridges
  - The crust would then sink, or stay at a lower level
  - This would generate more space for the water, that would retreat from continents (regression)
  - example: North America in the Pleistocene

past North America

peak Greenhouse: Cretaceous

peak Icehouse: Pleistocene