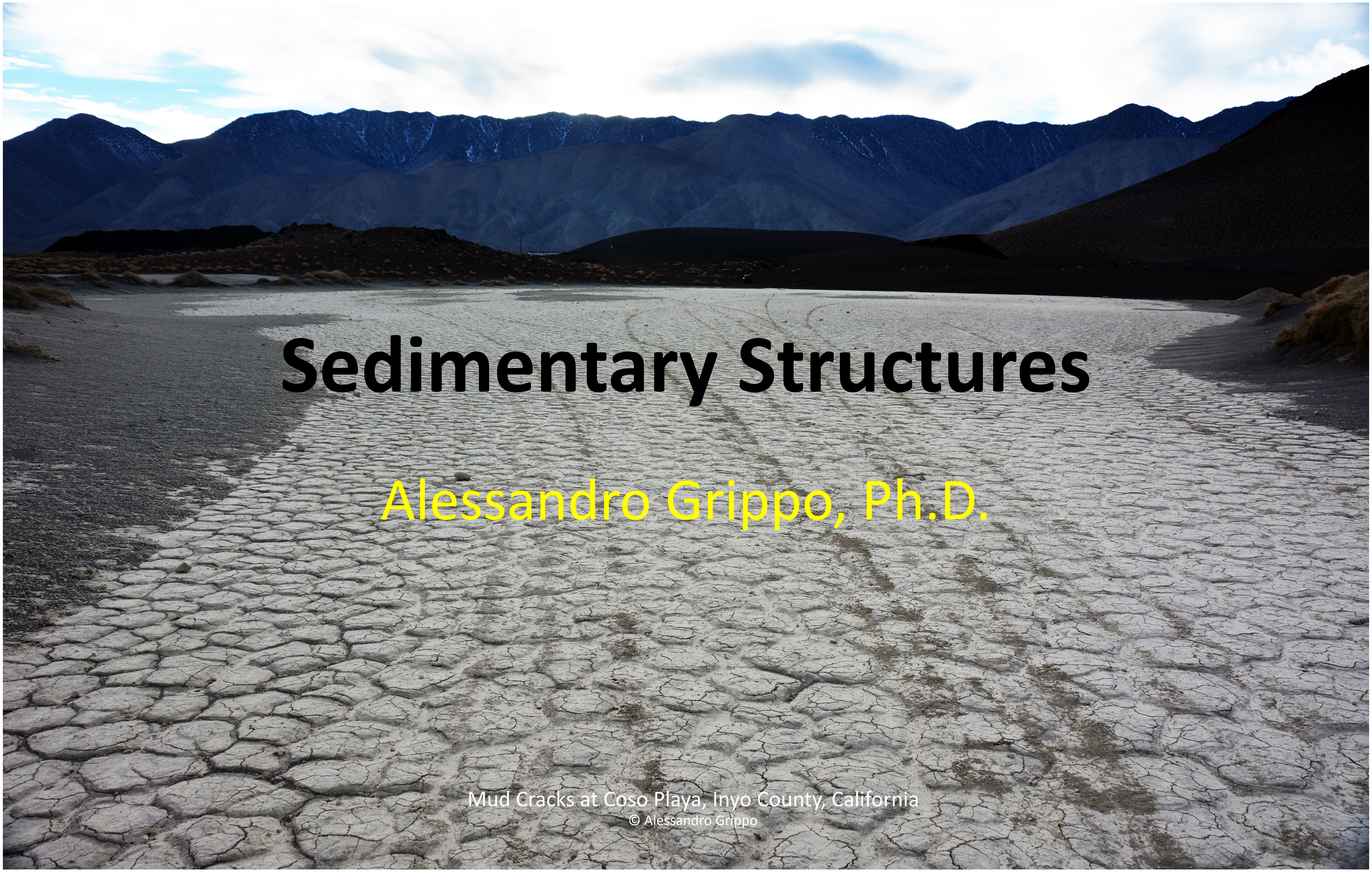
Sedimentary Structures

Alessandro Grippo, Ph.D.



Mud Cracks at Coso Playa, Inyo County, California

Sedimentary Structures

- Distinctive arrangement of grains

- Features that form in fresh sediment *before lithification*
  - at the moment of deposition
  - right after deposition

- As a consequence, they indicate the **environment of deposition**

What kind of Sedimentary Structures exist?

- Several kinds, but the most common are:
  - Horizontal bedding
  - Cross-Bedding
  - Graded bedding
  - Mud Cracks
  - Ripples
    - symmetrical
    - asymmetrical
  - Sole Marks
  - Way-up structures
    - include a variety of different types

Horizontal Bedding

Horizontal Bedding

- Most common sedimentary structure

- Occurs anytime a variation in sedimentation occurs
  - change in type of sediment (e.g. sand and mud)
  - change of dominant energy in the depositional environment
  - change in rate of sedimentation
  - interruption of sedimentation (unconformity)

- Layers are horizontal because most sedimentation occurs horizontally in water
  - exception: cross-beds in sands (sandstones)

- Steno's principles
  - original horizontality, lateral continuity, superposition

think: why do you see horizontal beds (or layers) in these images?

Cedar Breaks National Monument

Washington County, Utah

Capitol Reef National Park

Fruita, Wayne County, Utah

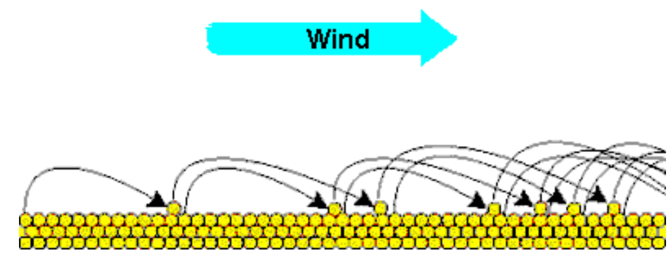
and what happened here?

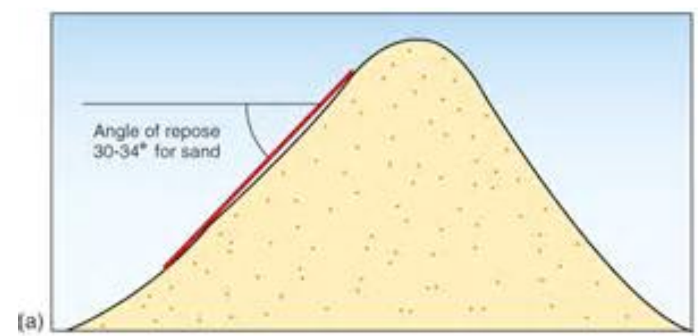
Venice Beach

Los Angeles, Los Angeles County, California

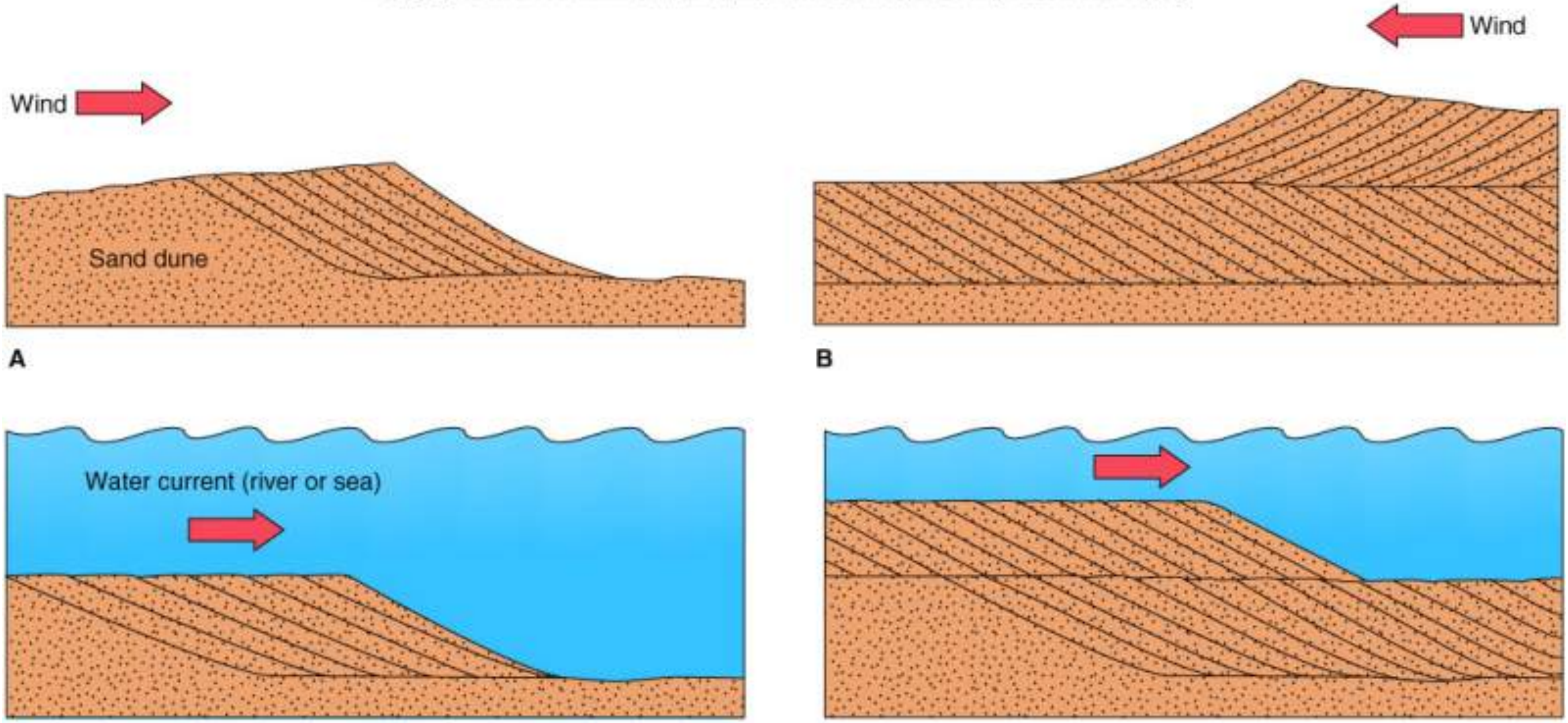
Cross-Bedding

- Cross-bedding originates from two facts
  - sands move by *saltation*, that is always in contact with the ground or bottom of a river or the ocean
  - when sand is falling naturally, it creates a small mound at an angle of approximately 34° (angle of natural repose)
- Cross-bedding is often developing within horizontal layers
- Cross-bedding is characteristic of sands and sandstones
- Typical of these sedimentary environments:
  - meandering rivers (in point bars)
  - river deltas
  - sand dunes





Cross-Bedding

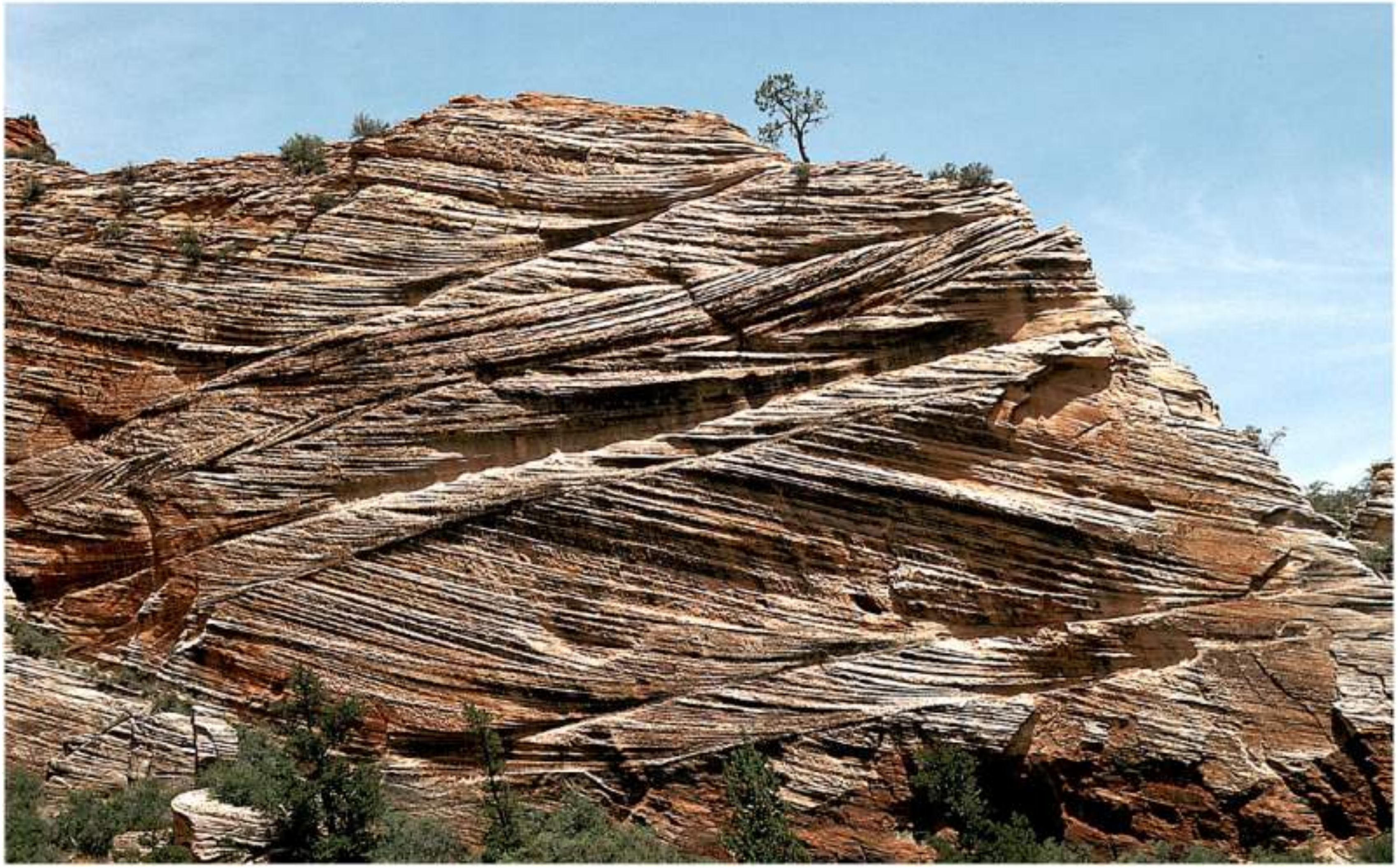


A

B

C

D



top

Checkerboard Mesa, Zion National Park

Kane County, Utah

right

The Wave at the Vermillion Cliffs

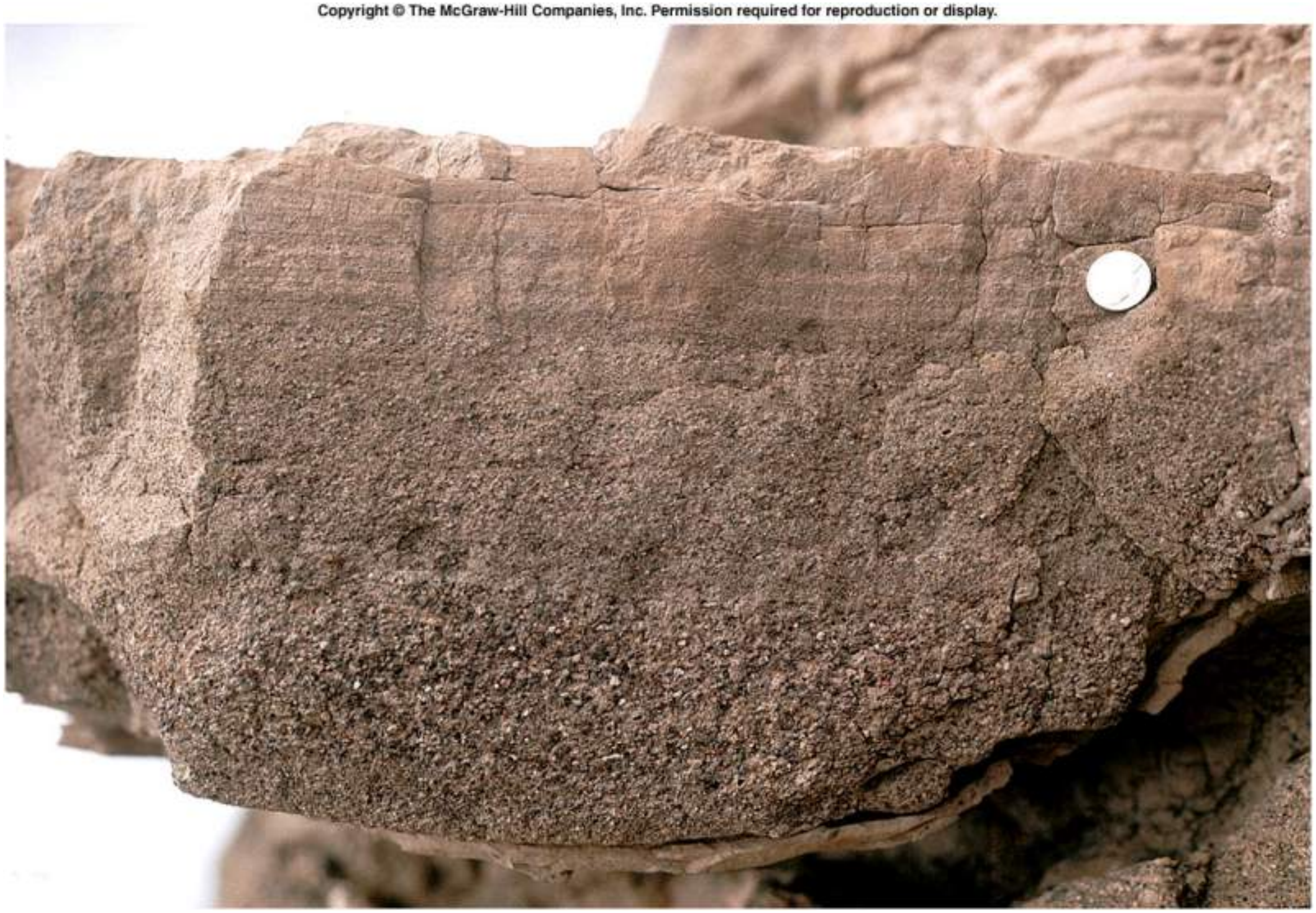
Coconino County, Arizona

top: Capitol Reef National Park, Kane County, Utah
bottom: Mojave Desert, Cadiz, San Bernardino County, California

top: Mojave Desert, Cadiz, San Bernardino County, California
bottom: Northern Apennines, Palazzuolo sul Senio, Firenze, Italy

Graded Bedding

- characterized by a progressive change in size from bottom to top of a layer

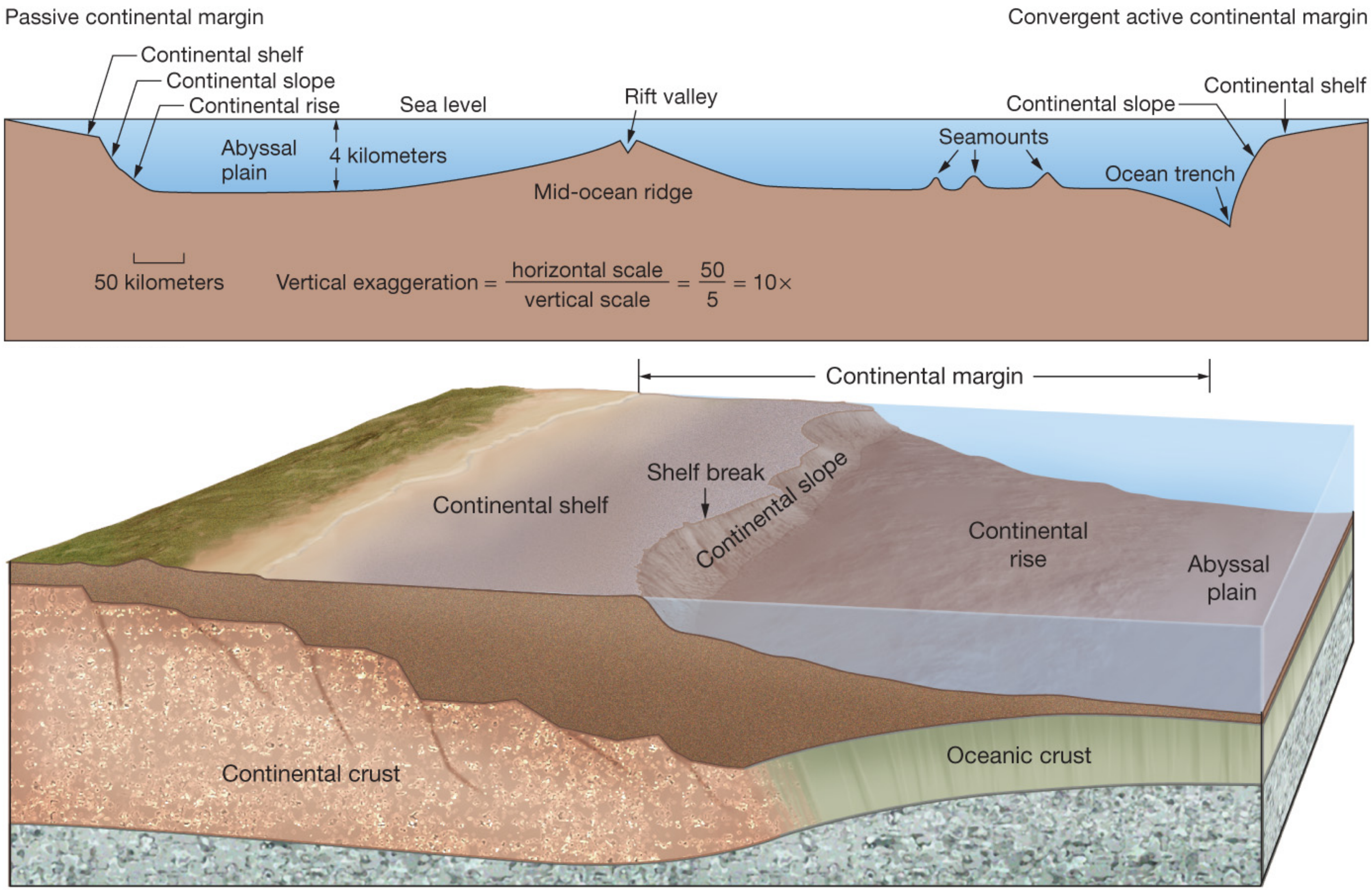


Graded Bedding:

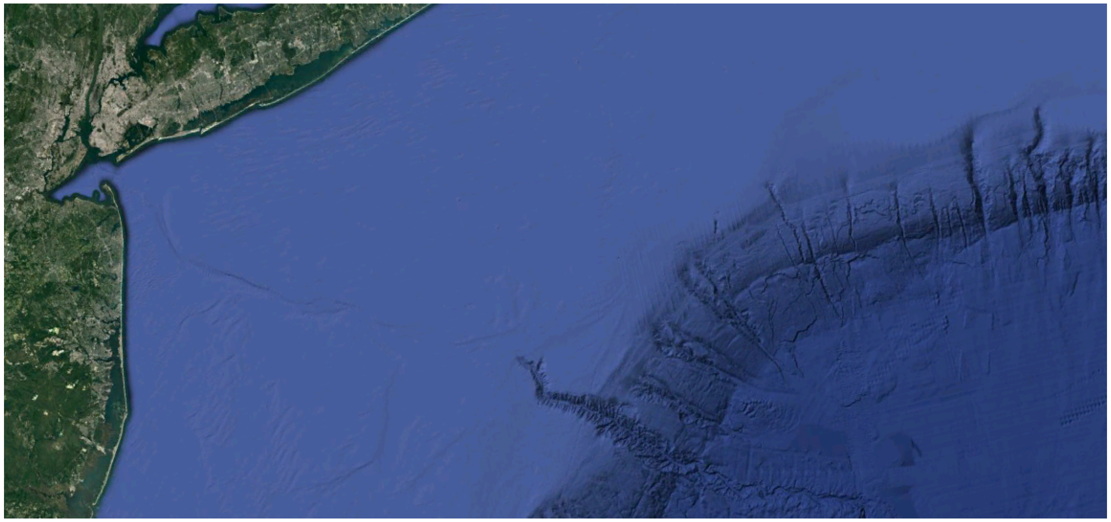
turbidity currents, submarine canyons, submarine fans

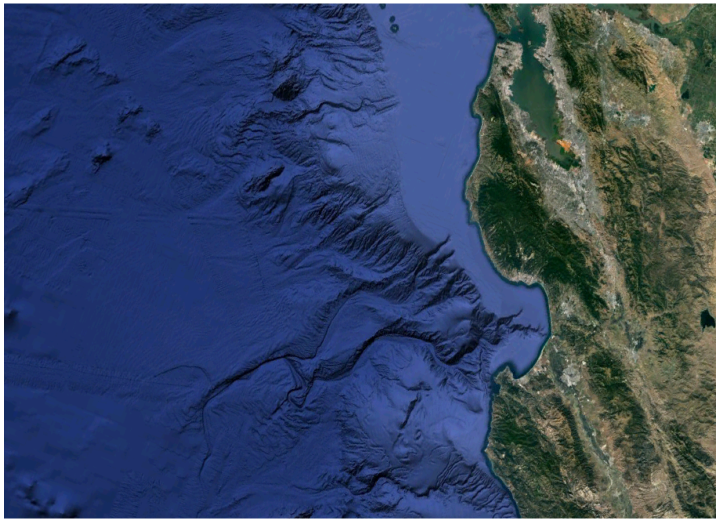
- Graded bedding forms as a consequence of turbidity currents
- Turbidity currents are density currents that move through submarine canyons carved along the continental slope
- Sediment is deposited at the base of the slope in a submarine fan
- Coalescing submarine fans form the continental rise

review: Continental Margins



Hueneme, Santa Monica and Redondo submarine canyons in Santa Monica Bay



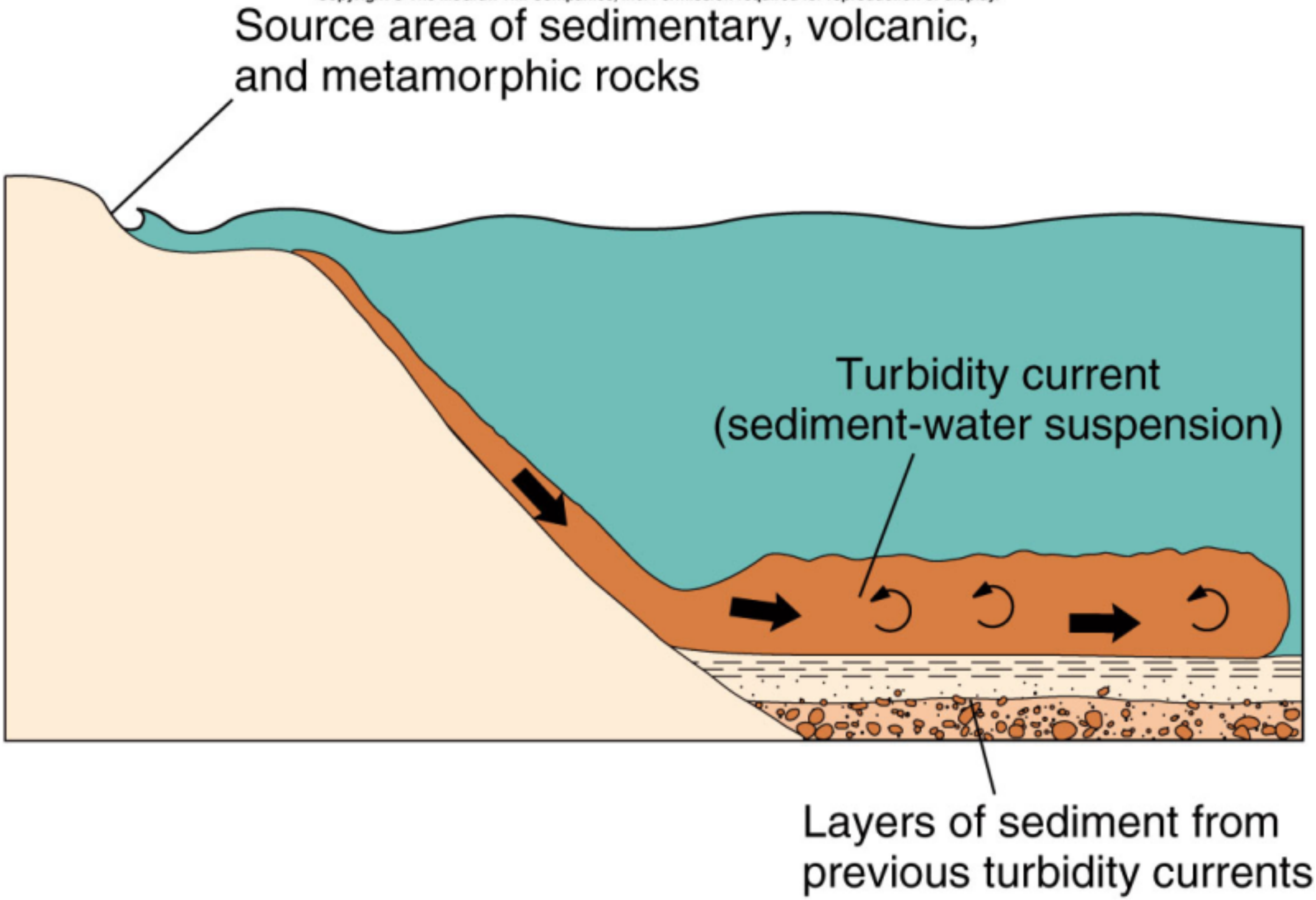


Left: submarine canyons along the eastern passive margin of North America (by New York, NY)
Right: submarine canyons along the western active margin of North America (by San Francisco, CA)

Submarine Canyons

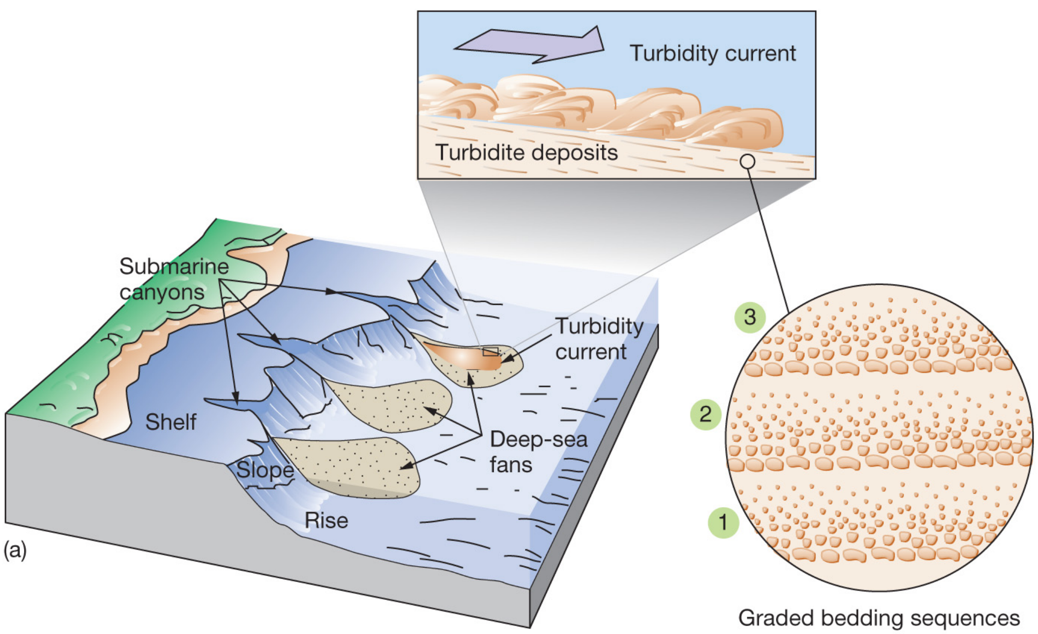
- Carved by turbidity currents (underwater density currents that carry sand and mud to the ocean bottom starting for the shelf)

- Sand and mud come form land, move on the shelf, and can be moved down the canyon by oversteepening, shaking by earthquakes, hurricanes, flooding from land

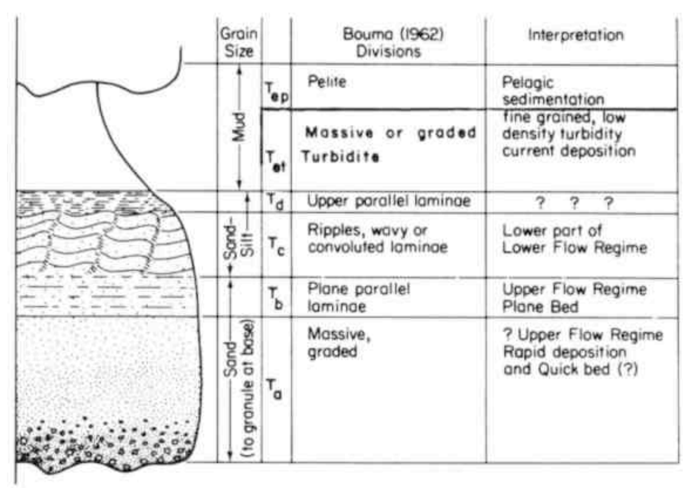

Source area of sedimentary, volcanic, and metamorphic rocks
Turbidity current (sediment-water suspension)
Layers of sediment from previous turbidity currents

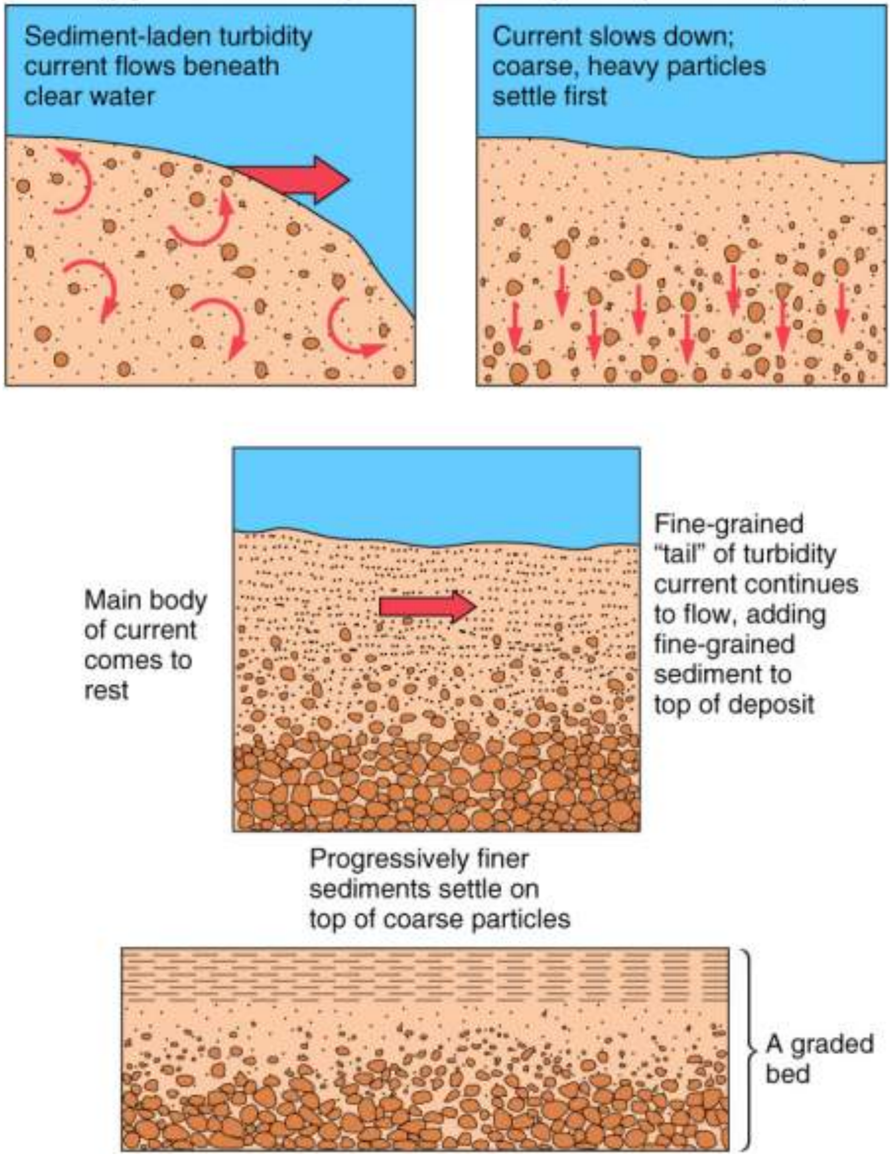
Turbidity Currents

- Currents deposit turbidites
  - graded beds
  - organized in a “Bouma Sequence”
  - graywacke sandstones



CLASSICAL TURBIDITE





Above: Bouma interval T_c

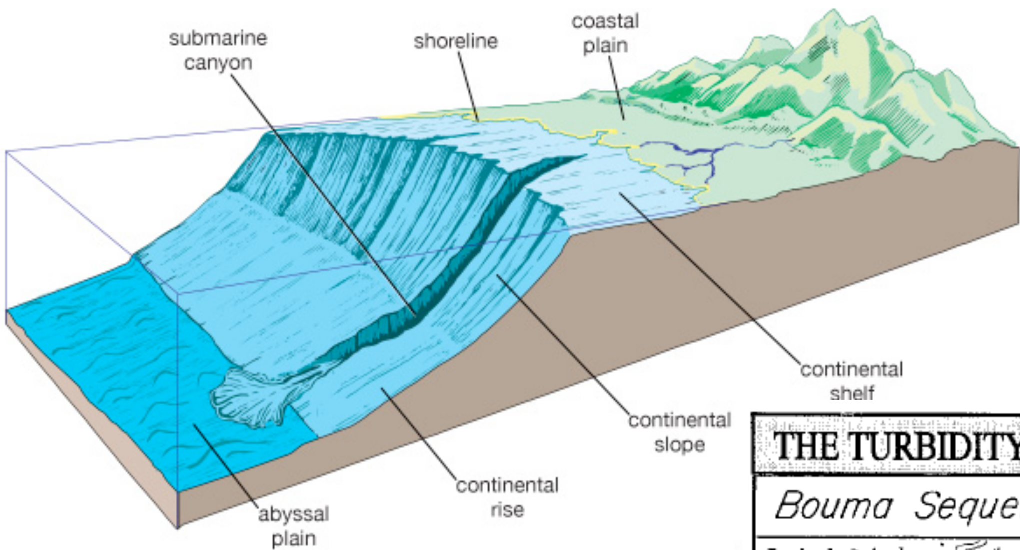
Below: Bouma intervals T_{b-c}

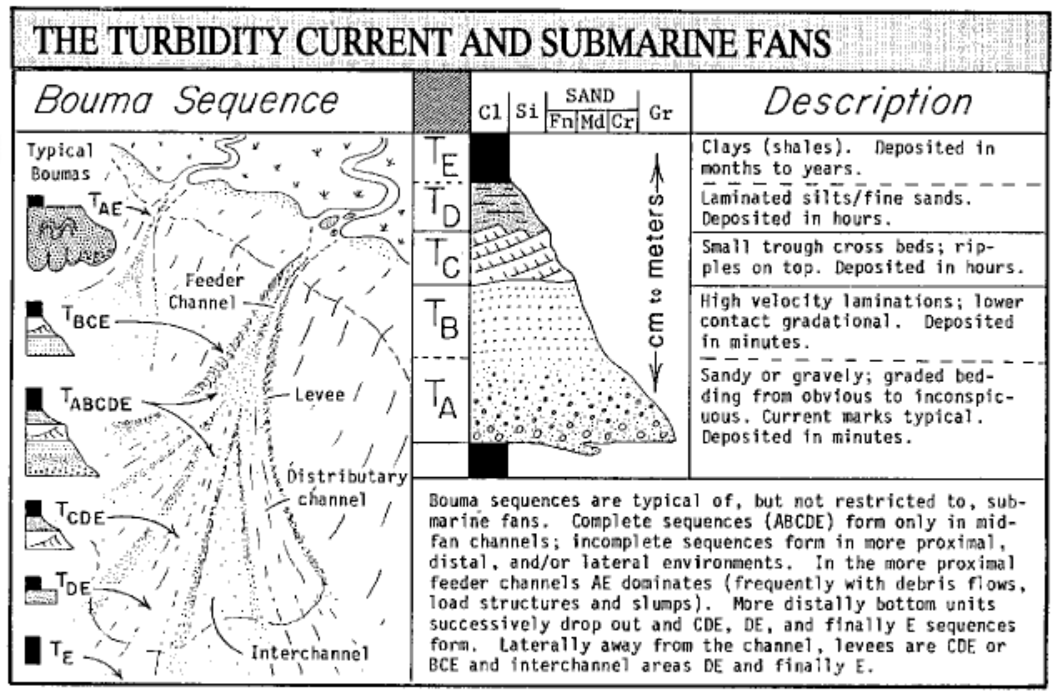
both images from the Miocene of the Northern Apennines

Palazzuolo sul Senio, Firenze, Italy

the Abyssal Fan and the Continental Rise:

morphology and Bouma Sequence structure





Deep-marine turbidite deposits from the Northern Apennines
Firenzuola, Firenze, Italy

Deep-marine turbidite deposits from the Santa Monica Mountains
Point Mugu, Ventura County, California

Mud Cracks

- Mud (silt and clay) expands when saturated
- When mud dries out polygonal cracks are formed
- In order for mud to dry, water has to evaporate
- Evaporation indicates a dry environment
- Mud cracks are not commonly preserved, but when they are, this sedimentary structure indicates an extremely dry environment, such as a desert

Mud Cracks at the desiccated bottom of Lake Powell. This are is usually under water (notice how the picnic area in the background stands at a higher elevation than the car)

Hite Crossing, Garfield County, Utah

Mud Cracks

top left:
Canyonlands National Park, Grand County, Utah

top right:
Coso Playa Lake, Inyo County, California

bottom left:
Mud Volcano in Nirano, Modena, Italy

all pictures © Alessandro Grippo

Mud Cracks

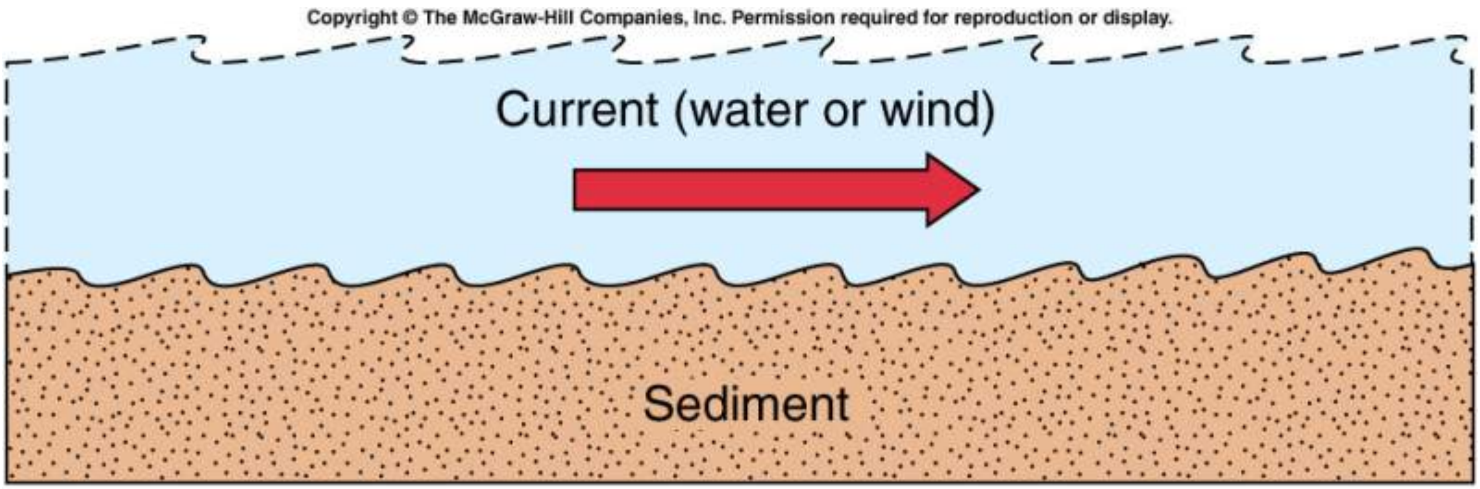
Mud Cracks preserved in rocks: after desiccation cracks were filled with sediment and lithified

Glacier National Park, Flathead County, Montana

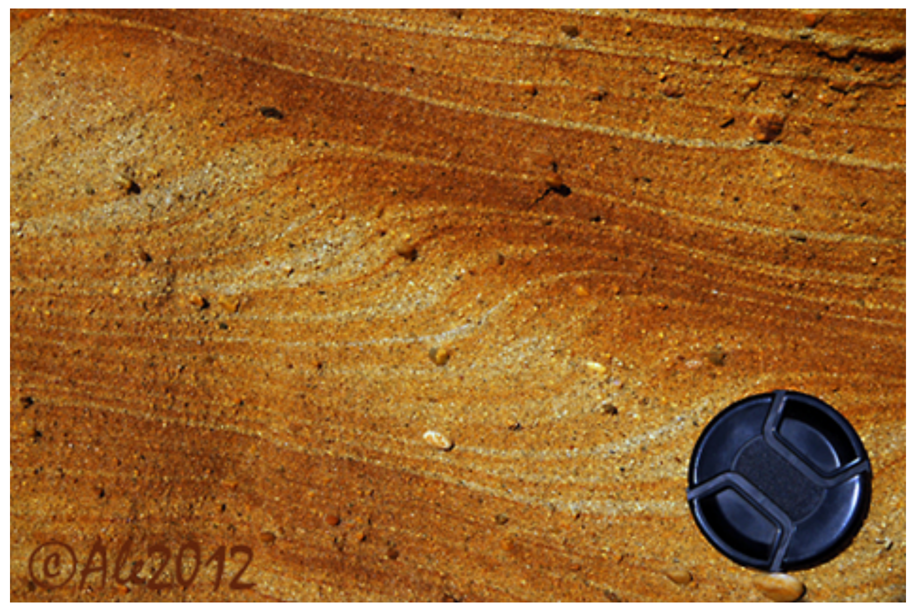
Ripples

- Ripples are simple ridges or wrinkles formed on surface of sediment layers
- Formed by friction between running water or wind and loose sediment
- Can be
  - asymmetrical (caused by unidirectional current)
    - rivers, tides, winds
  - symmetrical (caused by bidirectional current)
    - waves

Asymmetrical Ripples



San Rafael Desert, Green River, Utah
© Alessandro Grippo



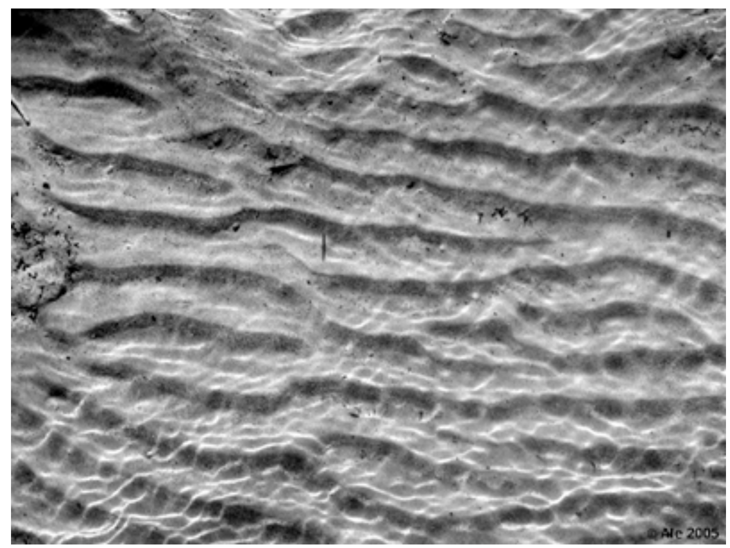
Santa Monica Mountains, Ventura County, California
© Alessandro Grippo

Asymmetrical Ripples

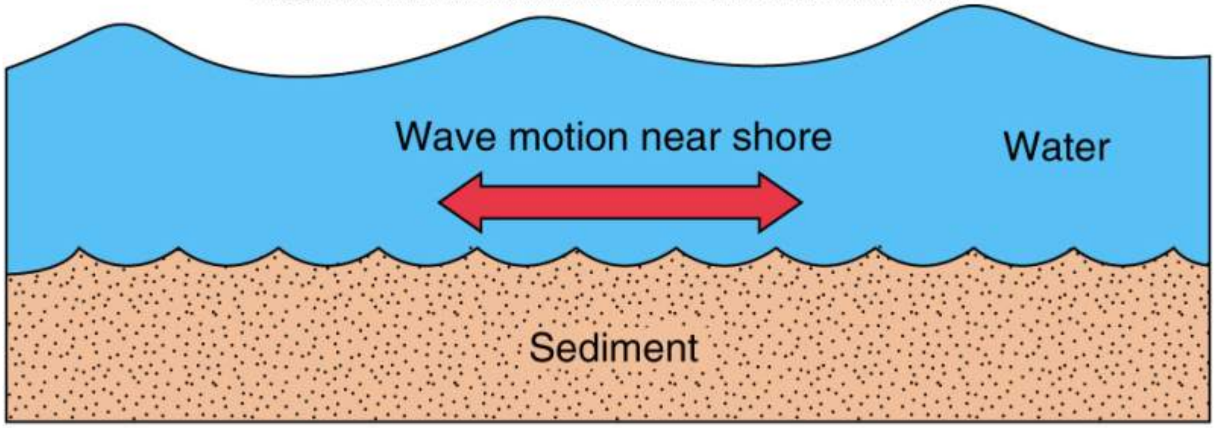
top left: Ripples formed by ebbing tide
Point Dume, Los Angeles County, California

bottom left: Ripples formed by ebbing tide
Bangladesh

bottom right: Ripples from by stream current
Alpine Junction, Lincoln County, Wyoming



Symmetrical Ripples

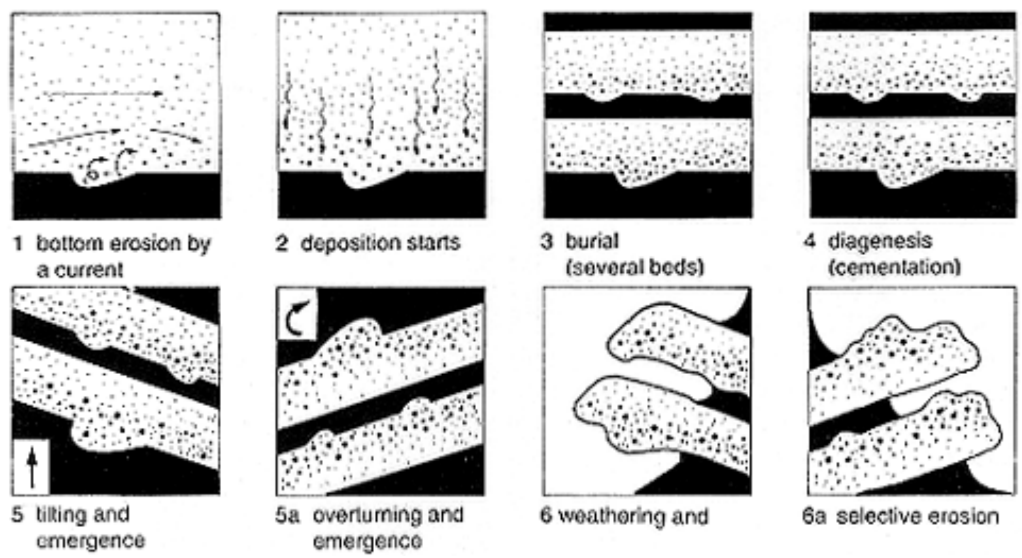


Nassau, Bahamas

Lower Cretaceous Dakota Sandstones, Littleton, Colorado

Sole Marks

- Sedimentary structures identified at the base of a layer
  - Marks and casts (from filling of marks)



From "Sedimentographica", © Franco Ricci Lucchi, Bologna, Italy, and New York, New York

Sole Marks and Casts

the Split Layer of the Moenave Formation

Marks (top) and casts (bottom) in the Moenave Split Layer
St. George Dinosaur Discovery Site at Johnson Farm
St. George, Washington County, Utah

Left:
Dinosaur Tracks casts

Bottom:
Dinosaur Tracks and mud cracks casts

St. George Dinosaur Discovery Site at Johnson Farm

St. George, Washington County, Utah

Way-Up Structures

- Structures that allow geologists to tell, in case there is doubt, which is the top (younger age) and which is the bottom (older age) of a sequence

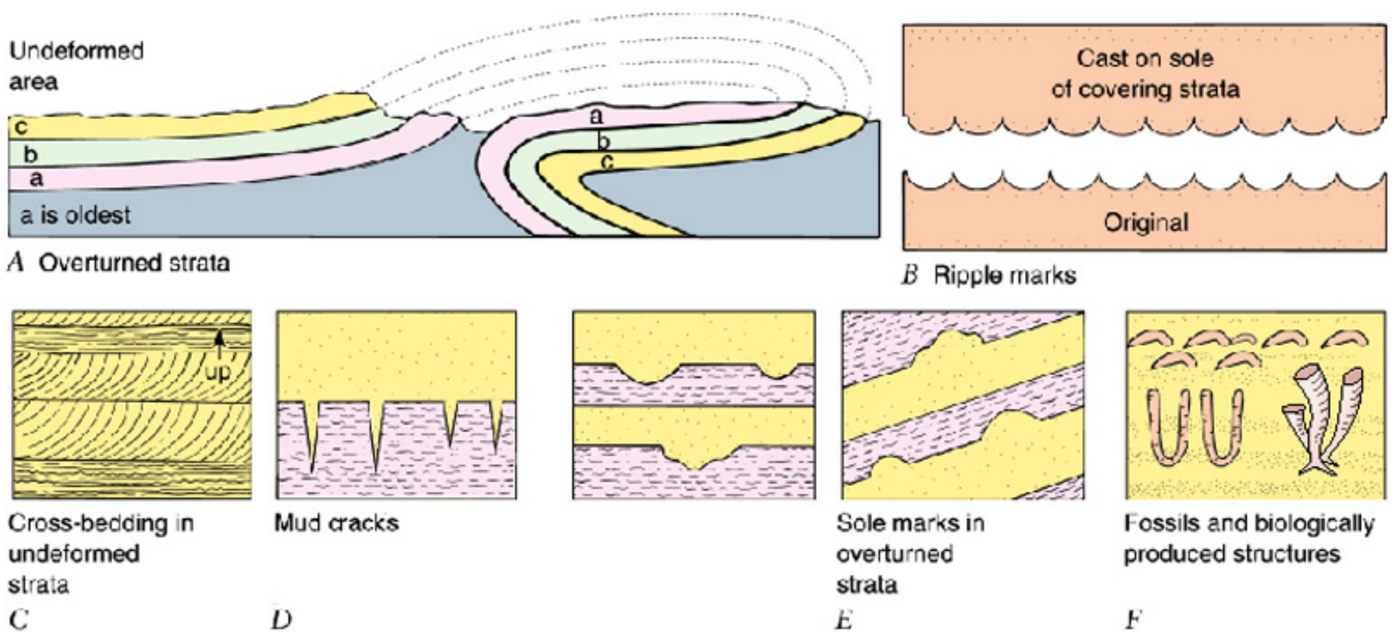
- Rocks can be overturned by tectonic forces

These layers have been folded and it might seem impossible to tell what is the top and what is the bottom of the sequence, unless you know the age of the sequence, find fossils, or use way-up structures

Cornwall, England

Way-Up Structures

- Graded beds, cross beds, mud cracks, flute marks, symmetrical ripples
- Stromatolites, burrows, tracks
- Fossils, if preserved in living position



stromatolites as way-up structures

Living Stromatolites
Hamelin Pool, Shark Bay, Australia

Fossil Stromatolites
Glacier National Park, Flathead County, Montana

Sedimentary Rocks Colors

- Useful in identification of:
  - environment of sedimentation
  - processes that followed lithification
- Cements can be stained, indicating post-depositional variations
  - examples from the Colorado Plateau sandstones
- Shales can be more diagnostic than sandstones or limestones
  - relation to lack of oxygen in the environment (anoxic, or euxinic conditions)

In this outcrop the horizontal beds retain the original red color (which is caused by hematite cement, and not by red grains of sand), while the cross beds have been "washed out" (the cement has been dissolved, removed, and replaced), and hence appear white.

San Juan County, Utah

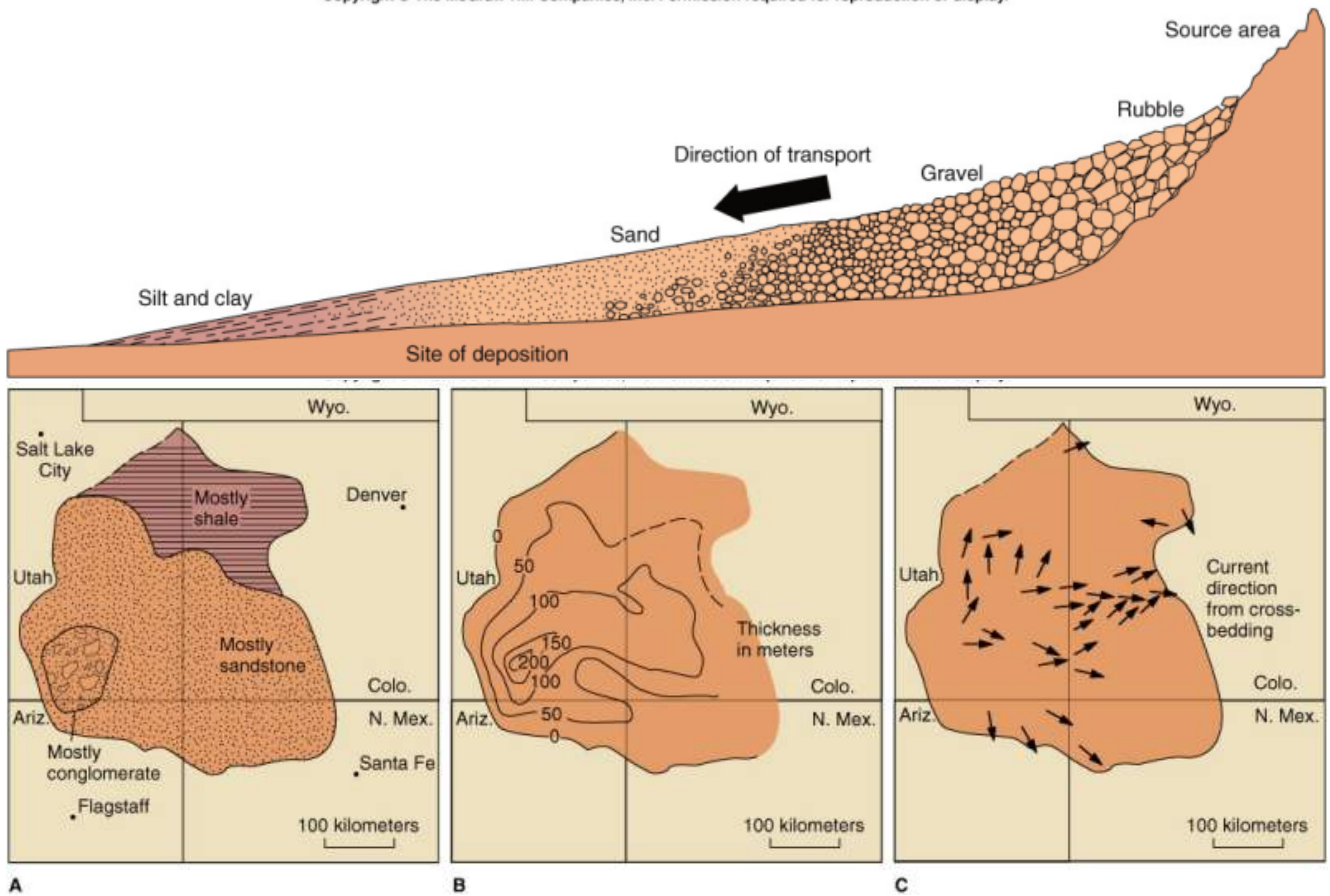
Sedimentary Rocks Colors:

general assumptions

Oxygen	Lack of Oxygen	
rock color: RED Iron rusts to Hematite	rock color: GREEN Iron does not rust. Pyrite (FeS_2) may form	Presence of Iron
rock color: WHITE or GRAY Organic Matter is recycled	rock color: BLACK Organic Matter is distilled into Carbon	Organic Matter

If Organic Matter and Iron are both present in the sediment and there is Oxygen, the Organic Matter is recycled and the rock is either white or red, depending on the amount of Iron. If there is no Oxygen, the rock is likely going to be black, and crystals of pyrite are also likely to form

Provenance of Sediment



Environments of Deposition