Clastic Sedimentary Rocks

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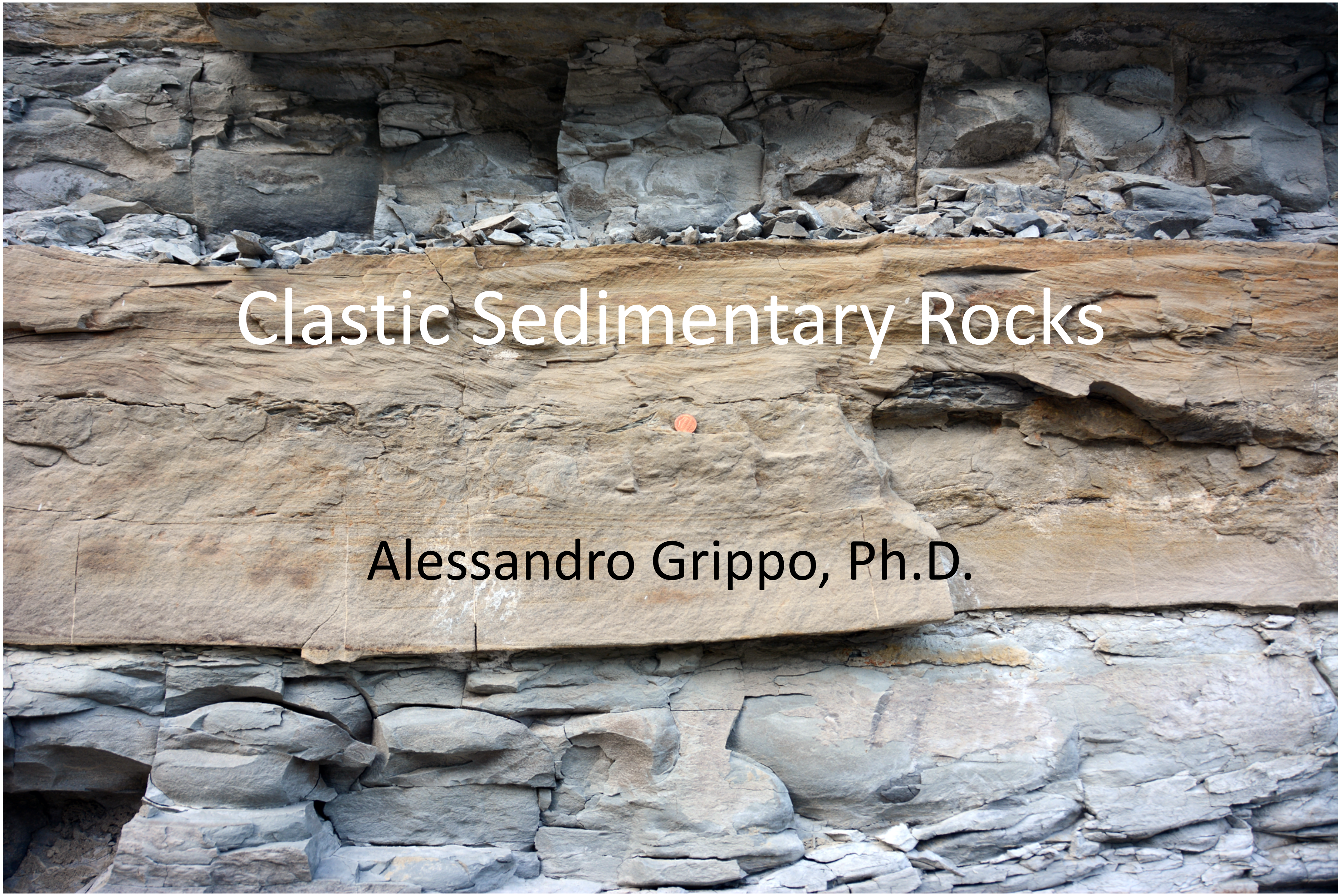


Alternating sandstones and mudstones in Miocene turbidites
Camaggiore di Firenzuola, Firenze, Italy

review

- Mechanical weathering creates
  - Gravel, sand, silt, clay particles
- Chemical weathering creates
  - Quartz, clay minerals, ions in solution

- Particles are eroded, transported, deposited, lithified
  - During these processes, particles become rounded and sorted

- A mature sediment is one where particles are rounded, sorted, and mostly composed of quartz

- Lithification implies that a clastic sediment is turned into a clastic sedimentary rock

What rocks do we get from clasts cementation?

- Gravel
  - Breccia
  - Conglomerate
- Sand
  - **Sandstone**
    - Quartz sandstone
    - Arkose sandstone
    - Graywacke sandstone
- Silt
- Clay
  - Mudstone
  - Claystone
  - **Shale**

Breccia

(*pronounce* Bretsch-chah)

- Clastic sedimentary rock, formed by cemented angular grains of gravel

- Because of the lack of rounding and sorting of its component grains, a breccia indicates no transportation
  - Or, the source of sediment (where the sediment originates from) is (or was) nearby

- Usually found in mountain areas, or along faults

Breccia

Conglomerate

- Clastic sedimentary rock, formed by cemented rounded grains of gravel
- While still immature (no sorting, no quartz), the roundness of grains indicates transportation
- As a regular process, only a strong water current can carry grains the size of gravel
  - A conglomerate indicates a fluvial environment

Conglomerate

Sandstone

- Clastic sedimentary rock, formed by cemented grains of sand

- A sandstone indicates a high-energy environment, where water or wind move swiftly
  - Beaches, rivers, alluvial fans, some tidal flats
  - Sand dunes
  - Submarine fans (continental rise)

- The texture of a sandstone can be studied for roundness, sorting, and compositional maturity

- The color of a sandstone depends on its constituent minerals, but can also be function of its cement

Quartz Sandstone

- A quartz sandstone is mature
  - Grains are rounded, sorted, and mostly quartz
- Such a sandstone indicates long distance traveled and long periods of erosion, transportation, deposition
  - Beaches of passive continental margins
  - Sand dunes (coastal or in desert areas)

Quartz Sandstone

A

Quartz Sandstone

Very mature modern quartz sand
“Sugar” beach in Carrabelle, Apalachicola Bay, Florida

Very mature Jurassic sandstone
Navajo Formation, Paria River at U.S. 89
Grand Staircase – Escalante National Monument, Utah

Arkose Sandstone

- An arkose sandstone is immature
  - Can be subangular to subrounded
  - Can contain some gravel
  - Mostly, it is not just made of quartz but among its constituent grains it is possible to find K-feldspar
    - K-feldspar was the example used in the discussion on chemical weathering
    - K-feldspar is one of the first minerals to weather. If you can still find K-feldspar in a sand, it means that sand has not traveled very far from its source

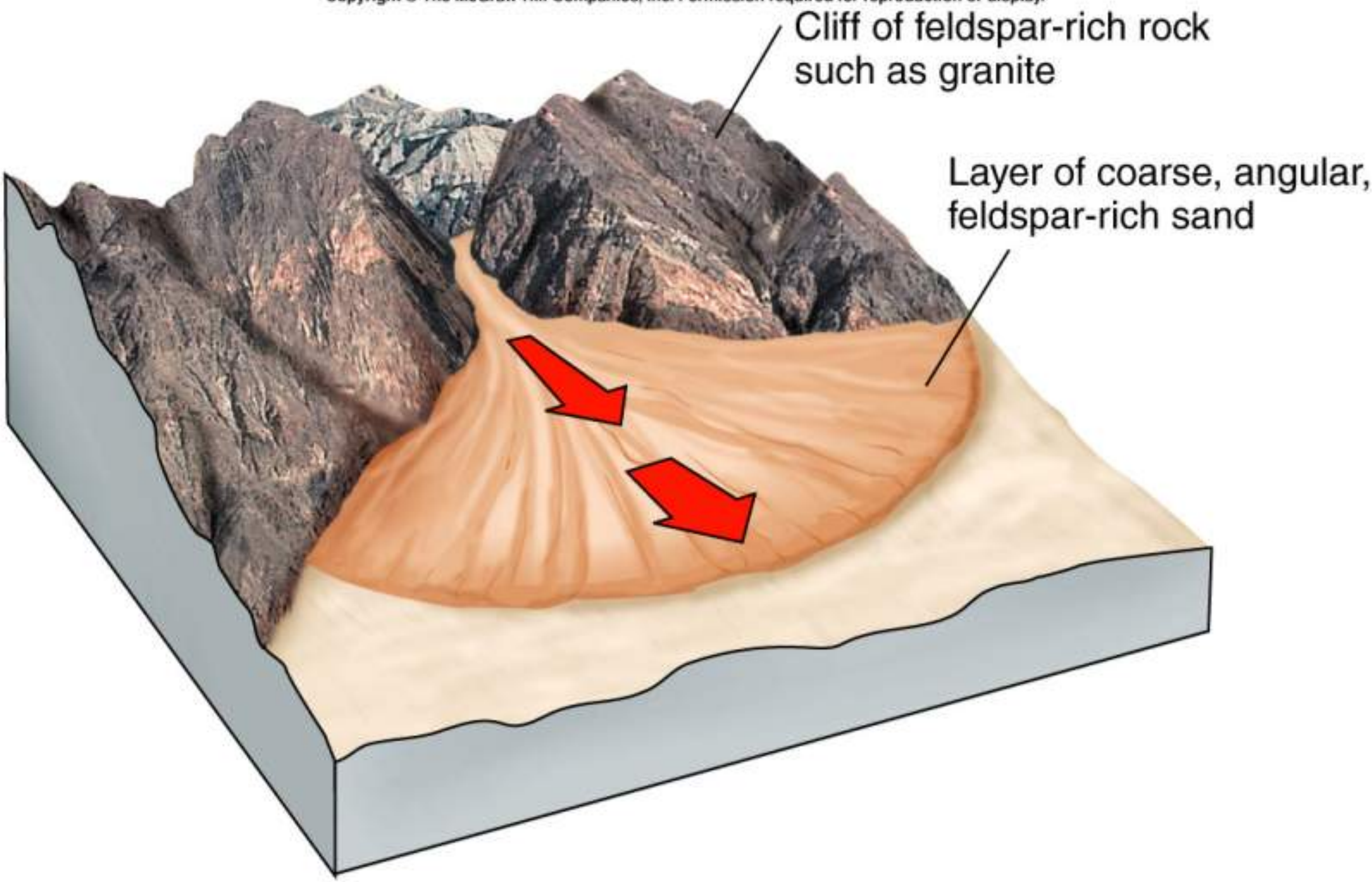
  - The presence of K-feldspar indicates limited transportation
  - An arkose is usually found at the base of a (granitic) mountain chain, very close to the sediment source, in a body called alluvial fan

Arkose Sandstone

B

Fig. 6.10b2

Arkose Sandstone


Cliff of feldspar-rich rock
such as granite
Layer of coarse, angular,
feldspar-rich sand

Alluvial Fans

Alluvial Fans at Badwater, Death Valley National Park

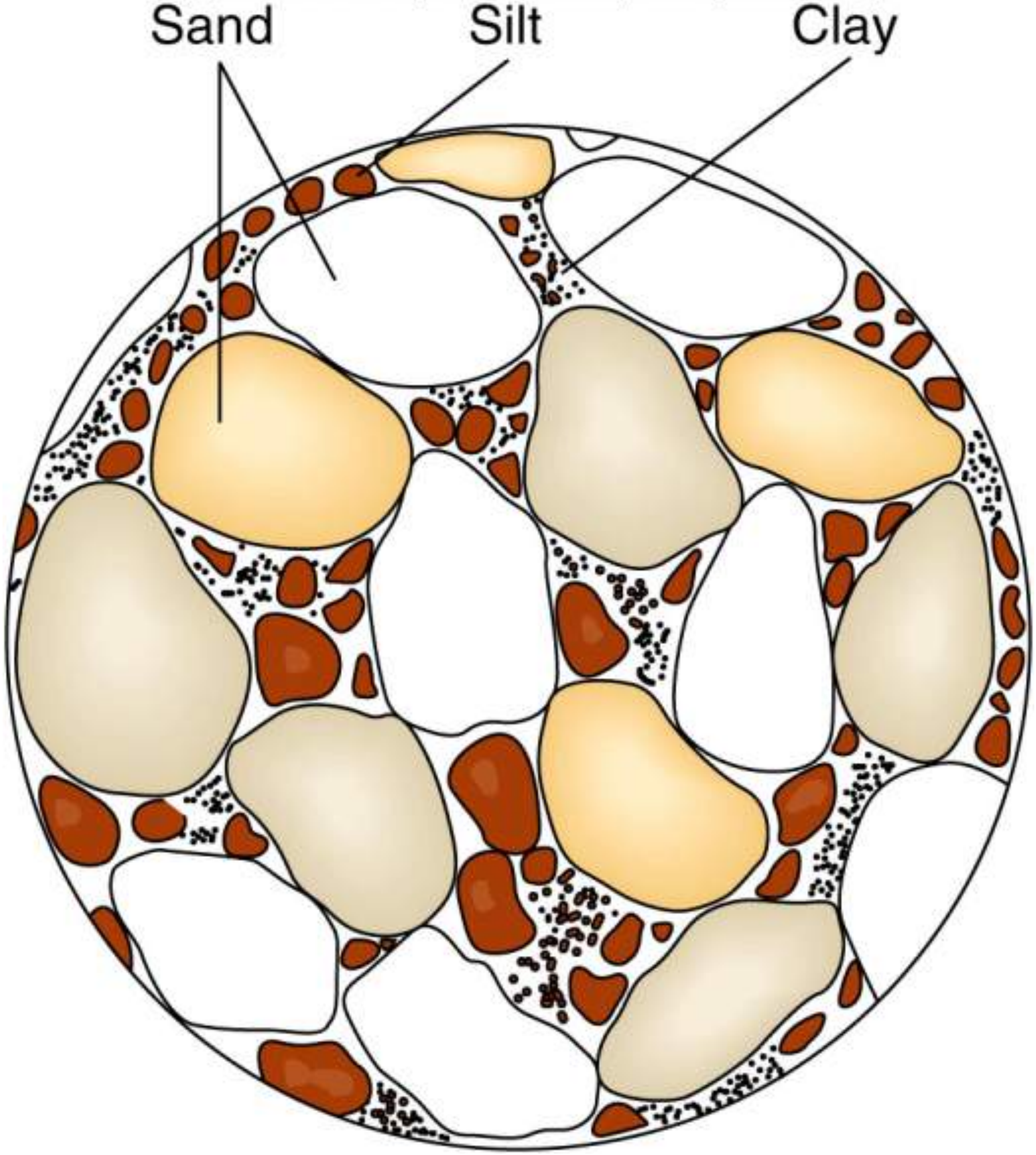
Graywacke Sandstone

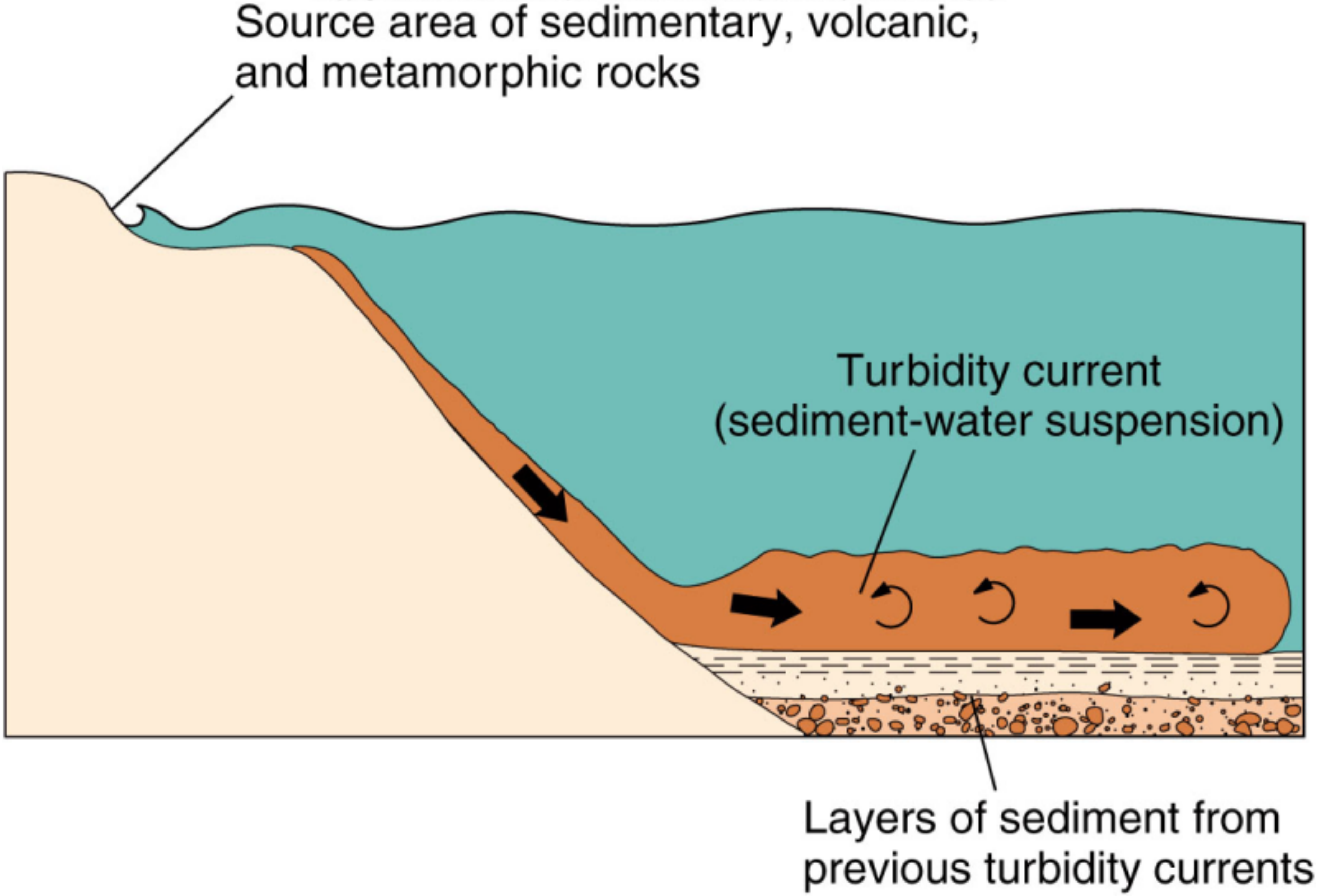
- A Graywacke Sandstone is immature
  - It contains sand and mud, hence it is a sandstone with a matrix
  - It is organized in a “graded bed” sequence, also known as Bouma's Sequence
  - It is usually dark in color because of its high content of carbonized organic matter attached to clay minerals
  - It forms because of the mixing of previously separated (sorted) bodies of sand and mud
  - Turbidity currents move sand and mud down submarine canyons, incised on the continental slope

Graywacke Sandstone

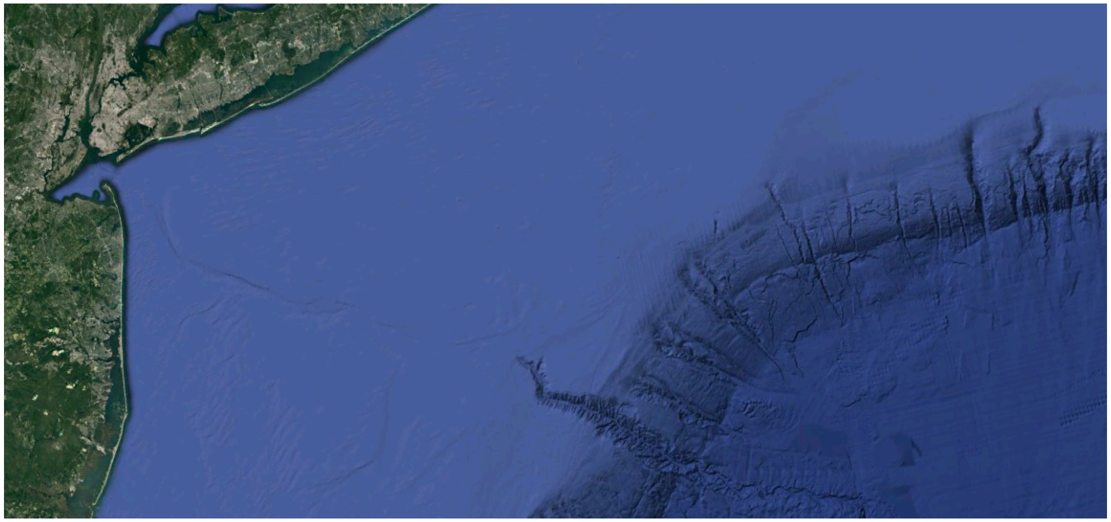
c

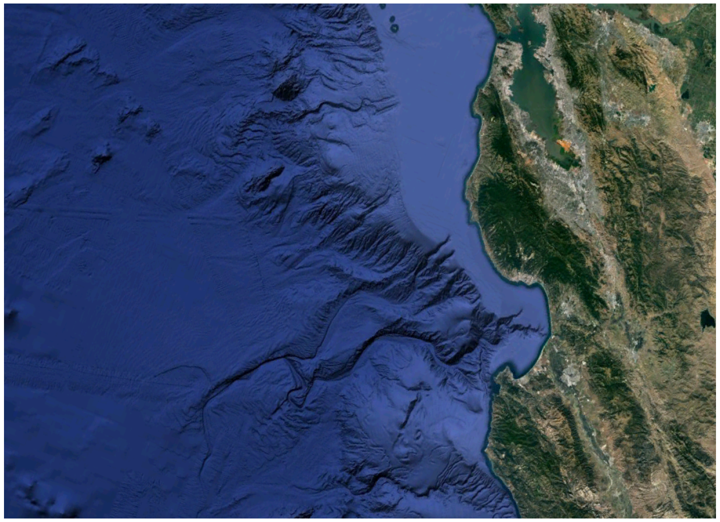
Graywacke Sandstone


Sand
Silt
Clay


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

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)

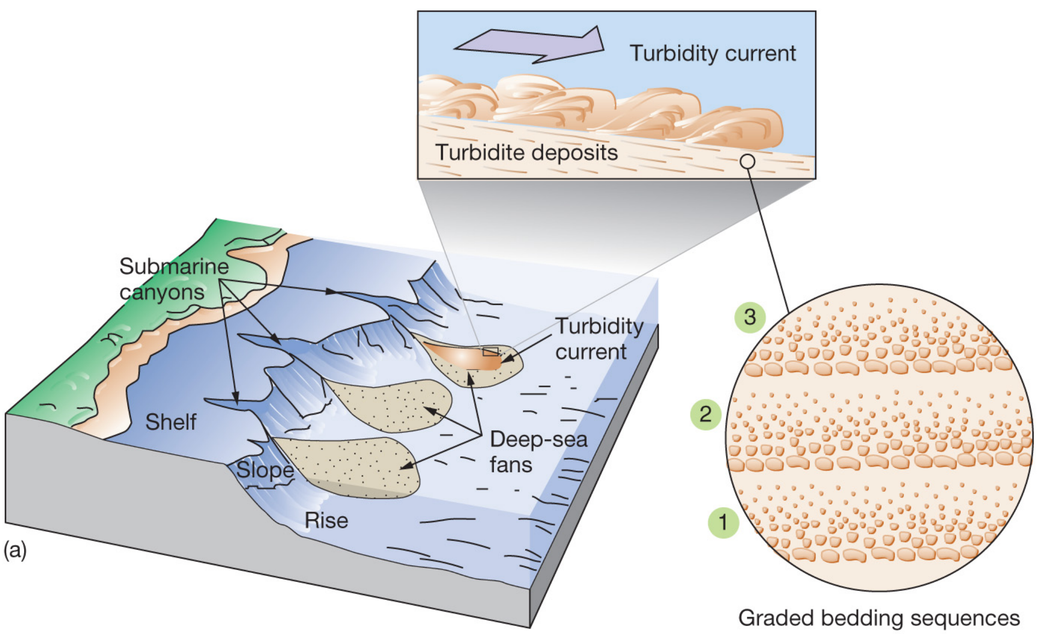
Submarine Canyons

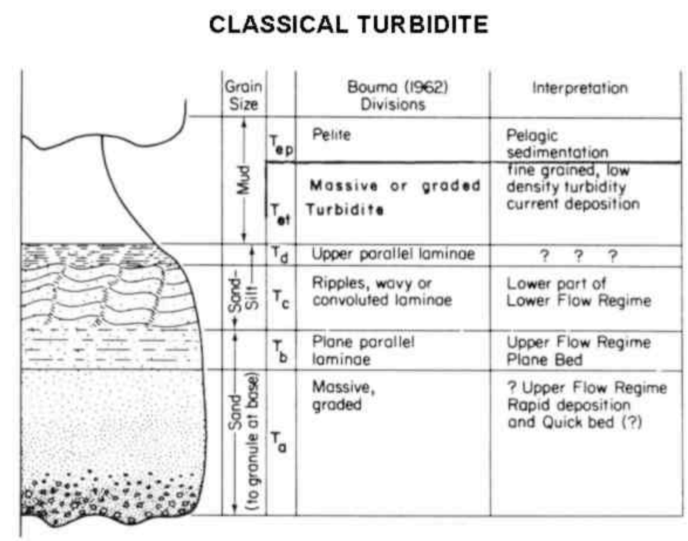
- Carved by turbidity currents (underwater density currents that carry sand and mud to the ocean bottom starting from the shelf)

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

Turbidity Currents

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



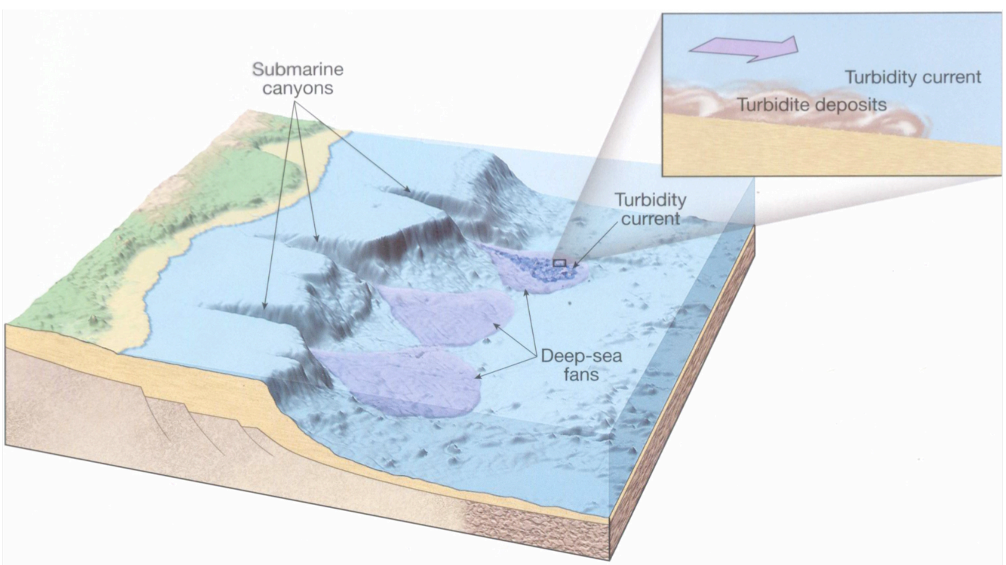


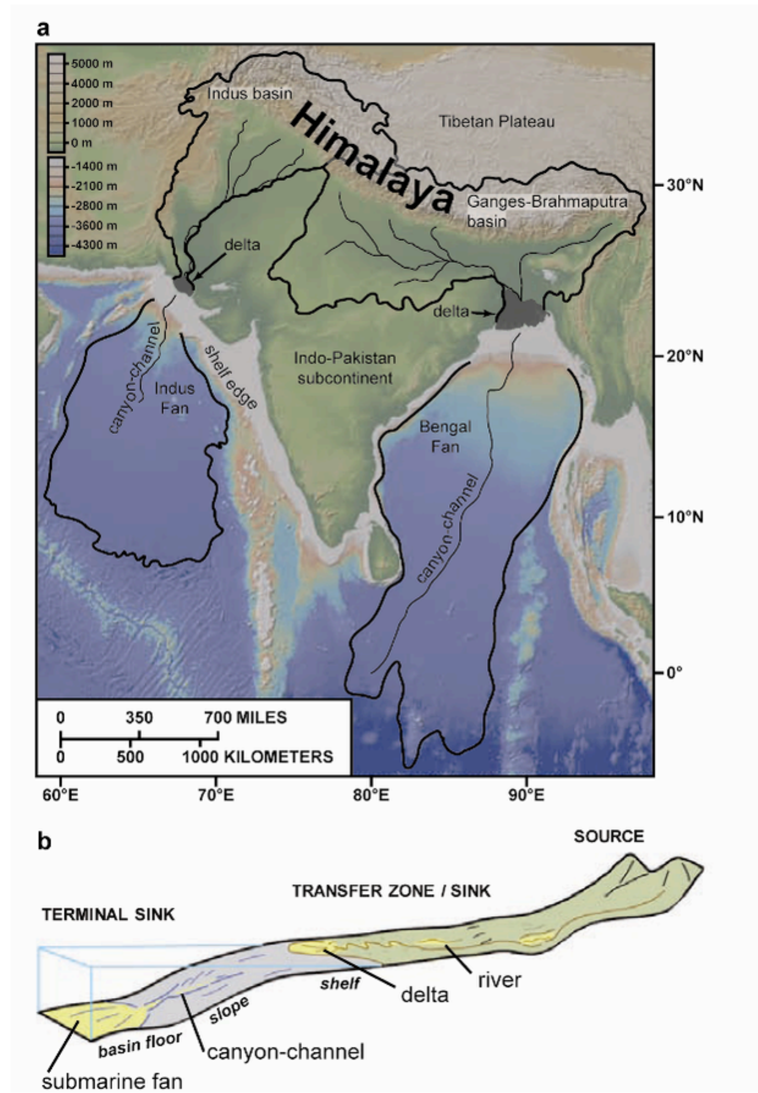
Turbidites

Deep-marine turbidite deposits from the Northern Apennines of Italy

Continental Rise

- Turbidites leaving submarine canyons are deposited at the base of the continental slope
- They form abyssal fans, which would coalesce into the continental rise
- The continental rise marks the transition between the slope and the abyssal plain of the deep ocean

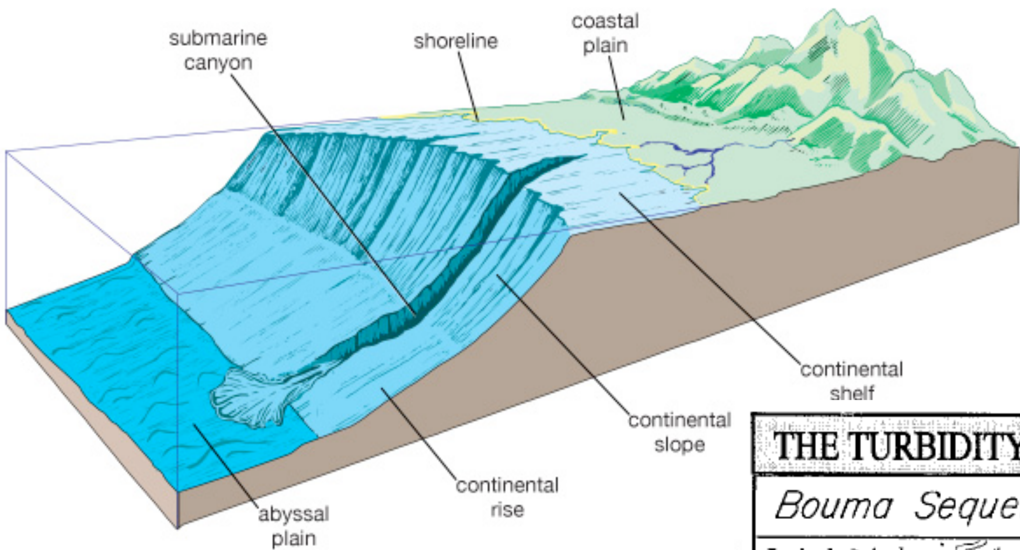


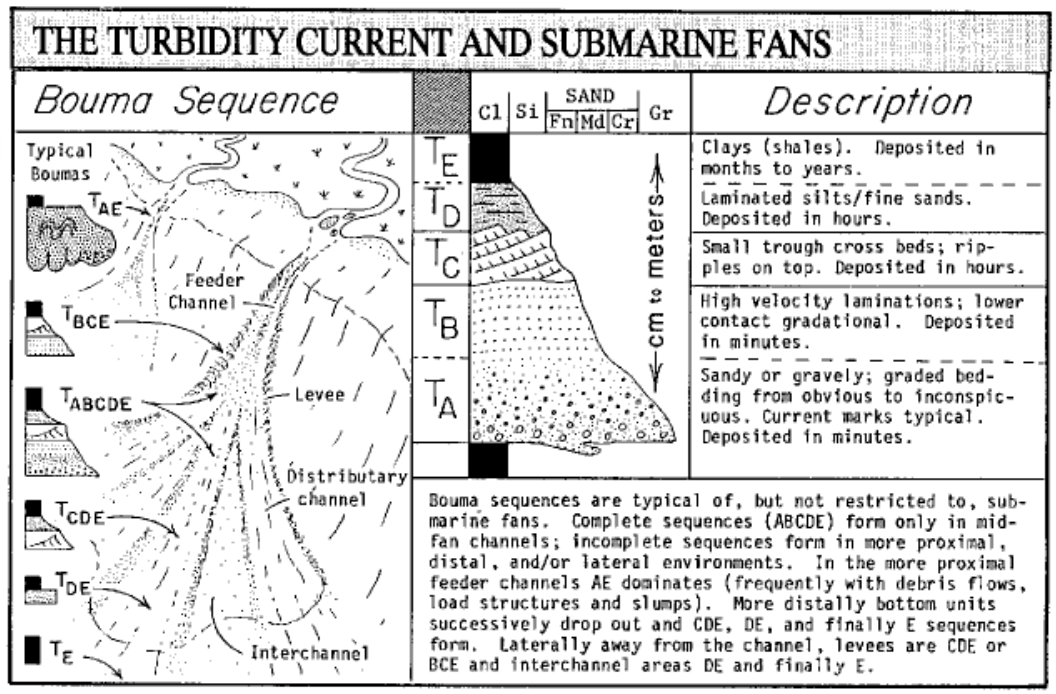


The biggest submarine fans of the world: the Indus and the Bengal fans, in the Indian Ocean

the Abyssal Fan and the Continental Rise:

morphology and Bouma Sequence structure





Deep marine sediments on land: turned into rocks, and brought above sea level by plate tectonics

These are turbidites from the Great Falls of the Missouri, by the city of Great Falls, Montana

(at this location the explorer Lewis and Clark could not proceed any further on the river, and had to start their portage on the Great Plains)

Siltstone

- Siltstone is a clastic sedimentary rock formed by cemented grains of silt
  - Silt is a fine size sediment usually derived from further abrasion on sand, which implies that silt composition is most often quartz, and the grains are rounded and sorted
  - Silt can end up with clay minerals to form mud
  - Silt is commonly find in low-energy environments, such as oxbow lakes, lakes, lagoons, swamps, marshes

Mudstone and Claystone

- Mudstone is a clastic sedimentary rock formed by cemented grains of silt and clay (mud)
- Claystone is a clastic sedimentary rock formed by cemented grains of clay only
- Both rocks indicate very quiet environments of deposition
  - These rock are relatively uncommon because their flat clay minerals have not been subjected to compaction (as it happens instead in **shales**
  - As such, they retain a random crystal orientation even upon cementation, that gives the rock a dull, anonymous aspect

Desiccated mud draping silt

Mudstone (with mud cracks) draping ripples formed in silt to fine sand sediment
Colorado Plateau, Emery County, Utah

Shale

- Shale is a clastic sedimentary rock formed by cemented grains of clay only

- Because of compaction during lithification, the flat crystals of clay acquire a preferential orientation perpendicular to the direction of compression

- This results in a characteristic alignment of the grains that is visible at the macroscopic scale, and is called **fissility** (which means that a shale can be split along flat surfaces, or that is **fissile**)

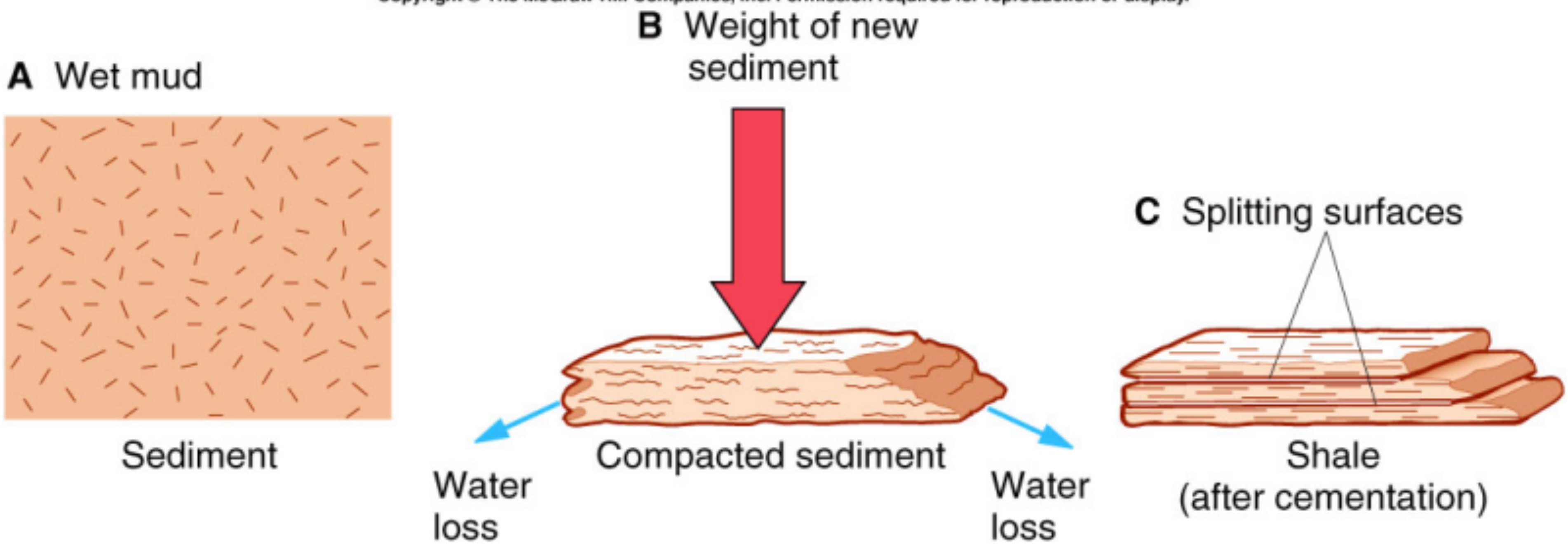
Shale

A

Shale

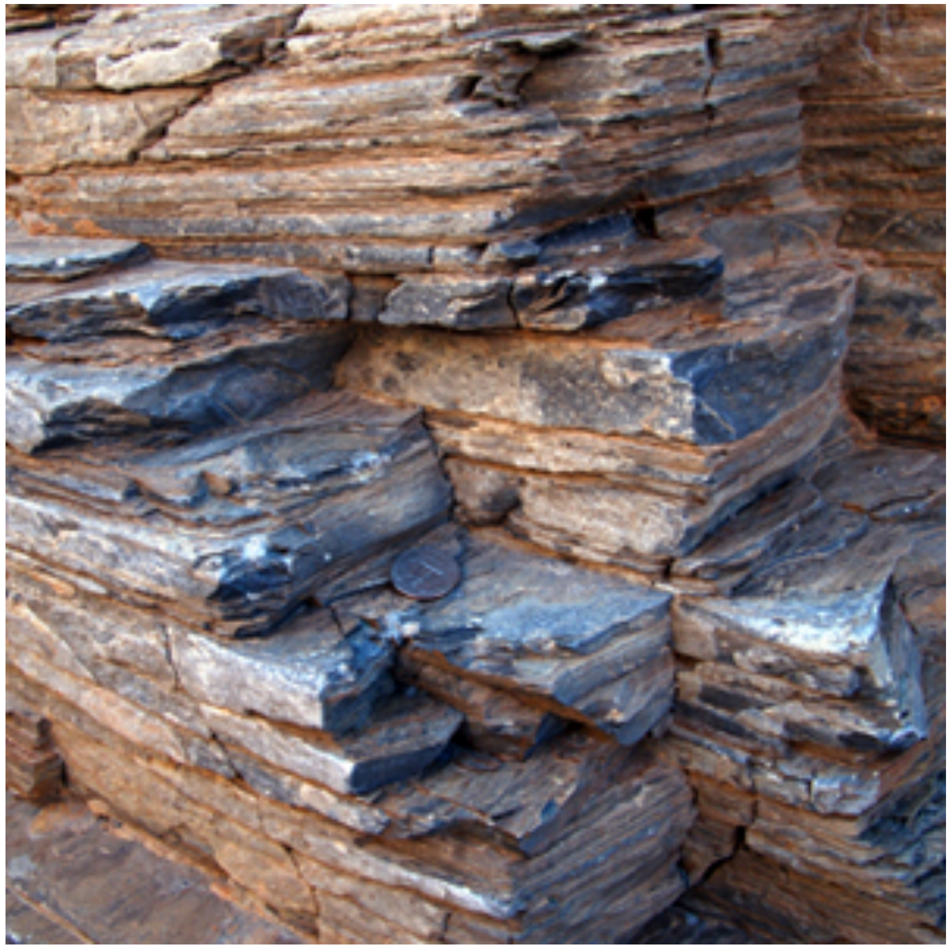
B

Shale



A Wet mud
Sediment
B Weight of new sediment
Compacted sediment
Water loss
Water loss
C Splitting surfaces
Shale (after cementation)

Shales



Shales from Mosaic Canyon
Death Valley National Park, California

Shales

- Shales indicate very quite environments
  - On land, lakes, swamps, lagoons, marshes
  - In the ocean, deep waters close to continents (off the continental rise) or more distal (at great depths in the ocean) if no other chemical sediment, such as limestone or chert, is found
- Shales are usually dark because of their high content in organic matter
  - During the course Earth history, intervals when the ocean bottom was affected by widespread anoxia (lack of oxygen) see the deposition of **black shales**

Black Shales

This sequence represents deep marine sedimentation in the now vanished Tethys Ocean during the Cretaceous Period. The Cretaceous was a greenhouse time and its oceans were much warmer then ours of today. One consequence of higher water temperatures is a low level of oxygen at the ocean bottom, sometime culminating in total anoxia. When that happens, regular sedimentation (the white limestones of the image) can be interrupted by the deposition of dark to black mud sediments that are eventually cemented into black shales. The shales are effectively black for their high content of carbonized organic matter, that could not be decomposed in absence of oxygen at the ocean bottom

Vispi quarry, Bottaccione Gorge, in Gubbio, Perugia, Italy

What is next?

- This ends our discussion on clastic sedimentary rocks
- The next class will be about chemical sedimentary rocks