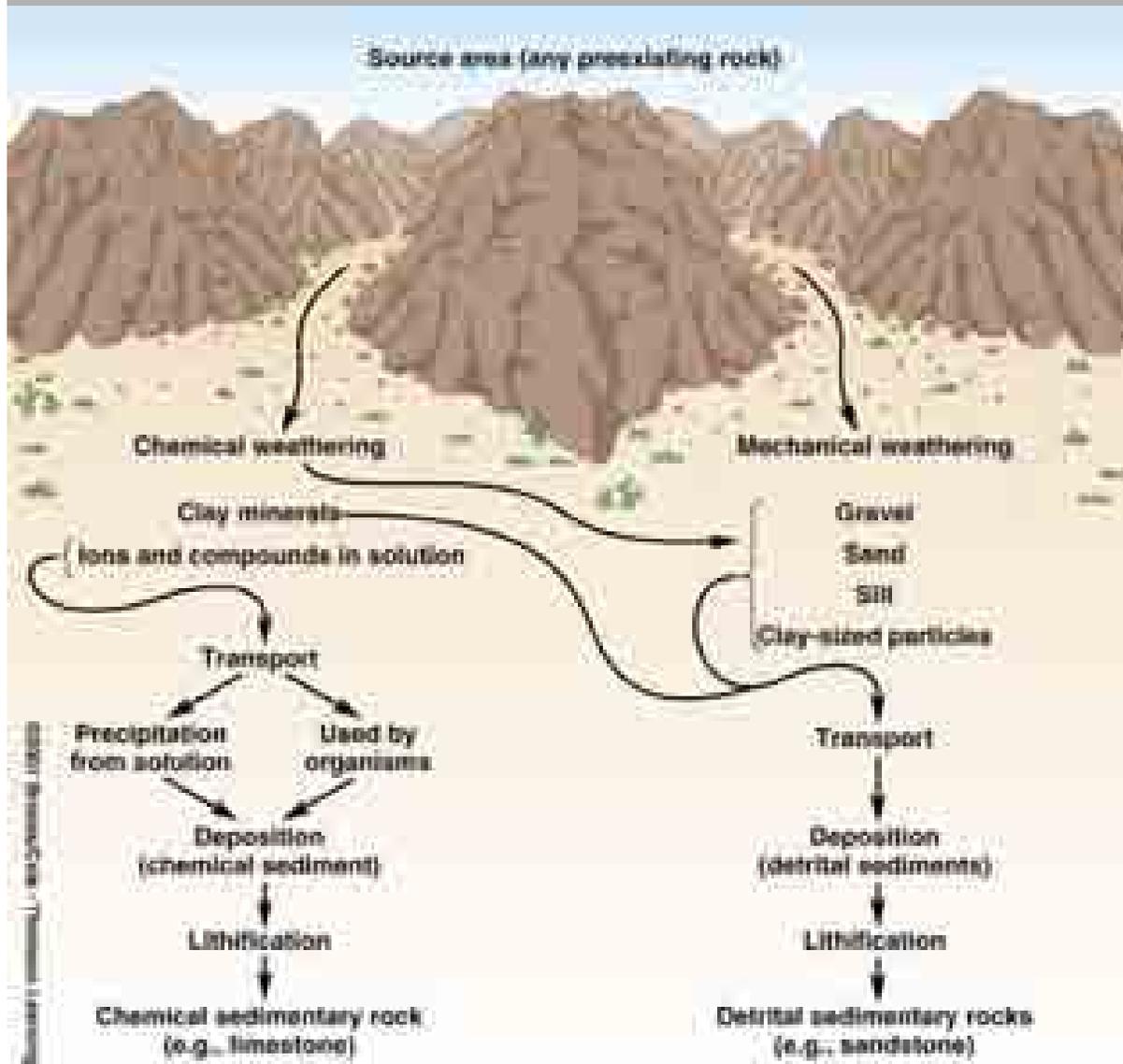


Sedimentary Rocks and their processes

The story behind the rock

Sedimentary Rocks (aka: Soft rock)



Sedimentary rocks are composed of sediment, all solid particles derived by mechanical and chemical weathering as well as minerals precipitated from solution by chemical or biochemical processes.

Introduction

- Chemical and biochemical sediments respectively consist of minerals precipitated from solution by the inorganic chemical processes or the activities of organisms.
- Detrital sediments are solid particles derived by weathering. Particle size is particularly important for classifying this type of sediment.

Size	Sediment Name
>2 mm	gravel
1/16-2 mm	sand
1/256-1/16 mm	silt
<1/256 mm	clay
	} mud

Why Study Sedimentary Rocks?

- Sediments and sedimentary rocks are the most commonly encountered Earth materials. They cover 75% of the continents and nearly all of the ocean floor except at ocean ridges.
- Features preserved in sedimentary rocks record the environmental conditions at the time the sediment was originally deposited. Therefore sedimentary rocks are especially important for deciphering Earth history.
- Much of our knowledge of the evolution of life on Earth derives from fossils preserved in sedimentary rocks.
- Some sediments and sedimentary rocks are resources in their own right, or contain resources.

What are sediments?

- Sediments are particulate matter derived from physical or chemical weathering of the earth's crust which are subsequently transported by wind, water or ice.



Marshak (2003)



Marshak (2003)

Talus



www.geoberg.de/text/geology/08061004.jpg

- large rock fragments
- weathering of rocks in mountainous regions
- your text page 154

Sediment transport & deposition

- Sediment is transported by wind, water and ice. Ice is a solid and so can carry sediment particles of any size, but wind transports only sand and smaller particles. The most prolific transport agent is running water. The larger the particle size, the more vigorous the current required for transport.
- Whether transported by water, wind, or ice, sediment eventually accumulates in a geographic area known as a depositional environment.

Sediment transport & deposition

- Abrasion during transport reduces particle size and smooths sharp corners, a process known as rounding.
- Transport & depositional processes influence sorting, which refers to the variety of particle sizes present in a sediment or sedimentary rock. Sorting and rounding provide information that can help decipher the history of a sedimentary deposit.

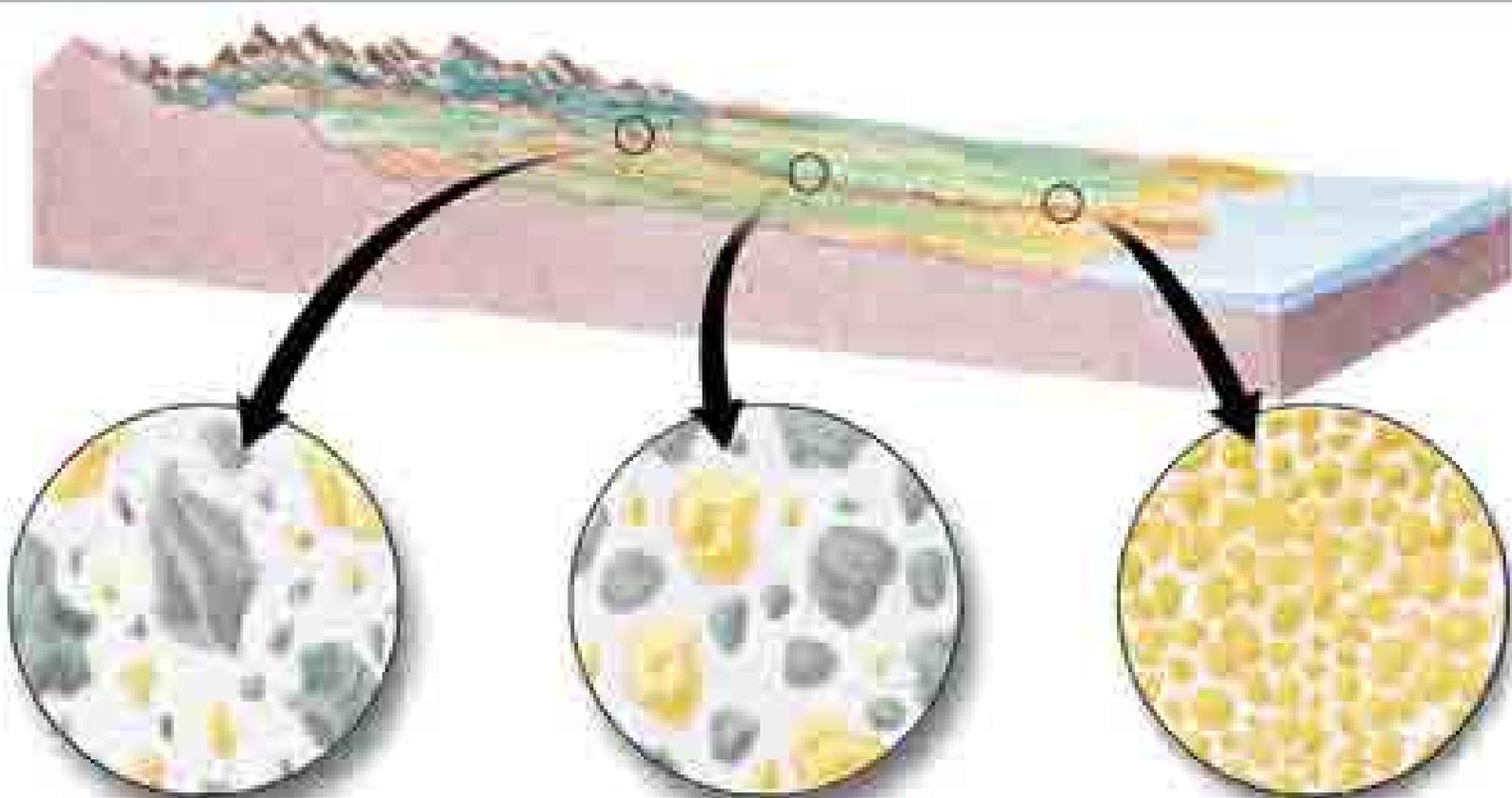


Important factors of depositional environments

(Table 5.1 page 155 text)

- Type of transporting agent (water, wind, ice)
- Flow characteristics of depositing fluid (velocity or variation in velocity)
- Size, shape, and depth of body of water, and circulation of water
- Geochemical parameters (T, P, O content, and pH)
- Types and abundances of organisms present
- Types and composition of sediments entering environment

Stream sediment

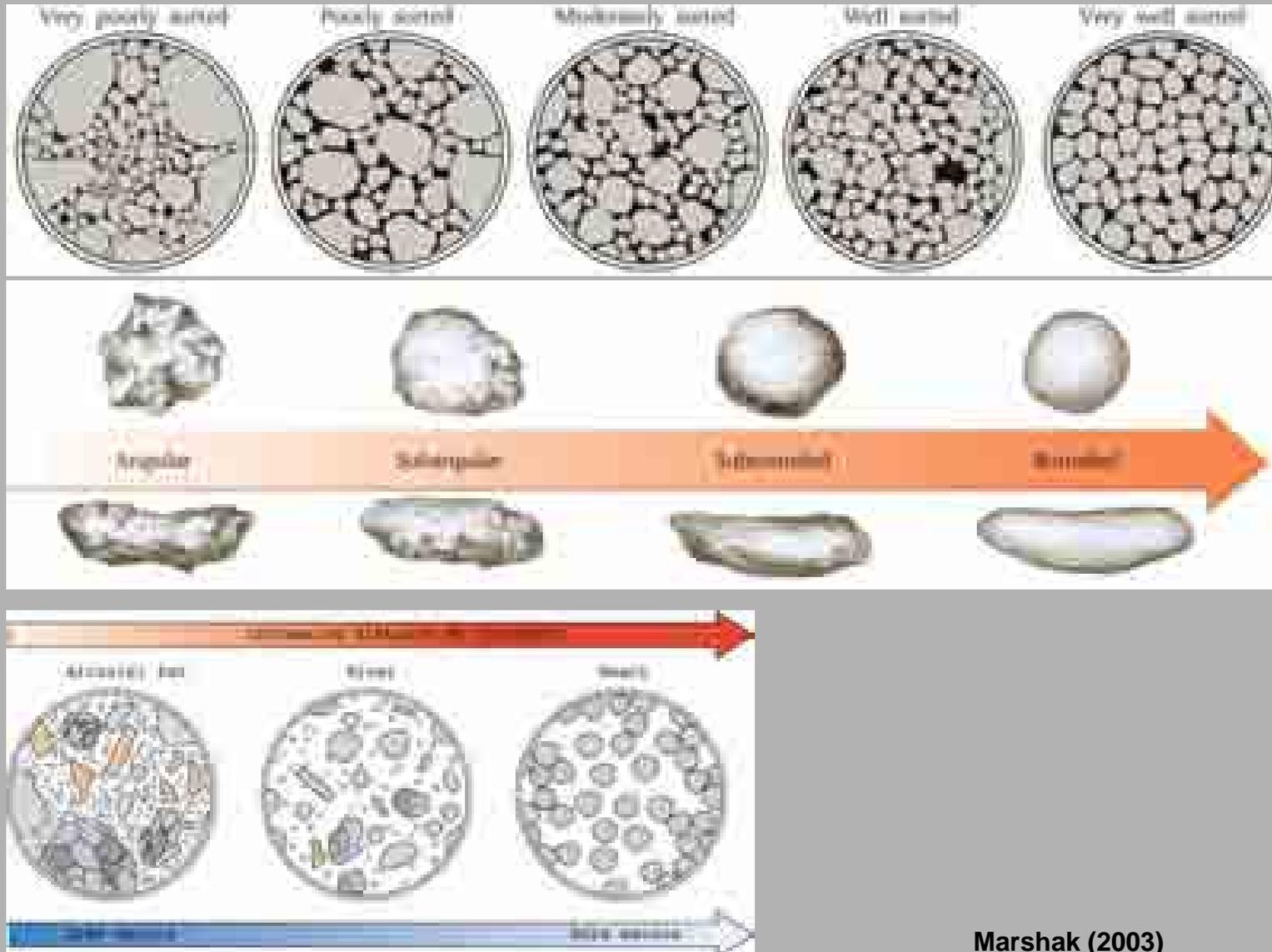


1 Particles are large and irregular, and consist of a variety of minerals, including some that weather easily

2 Particles are mid-sized and more rounded, and include fewer minerals that weather easily

3 Particles are small and rounded, and consist mainly of minerals that resist weathering, such as quartz

Describing sediments

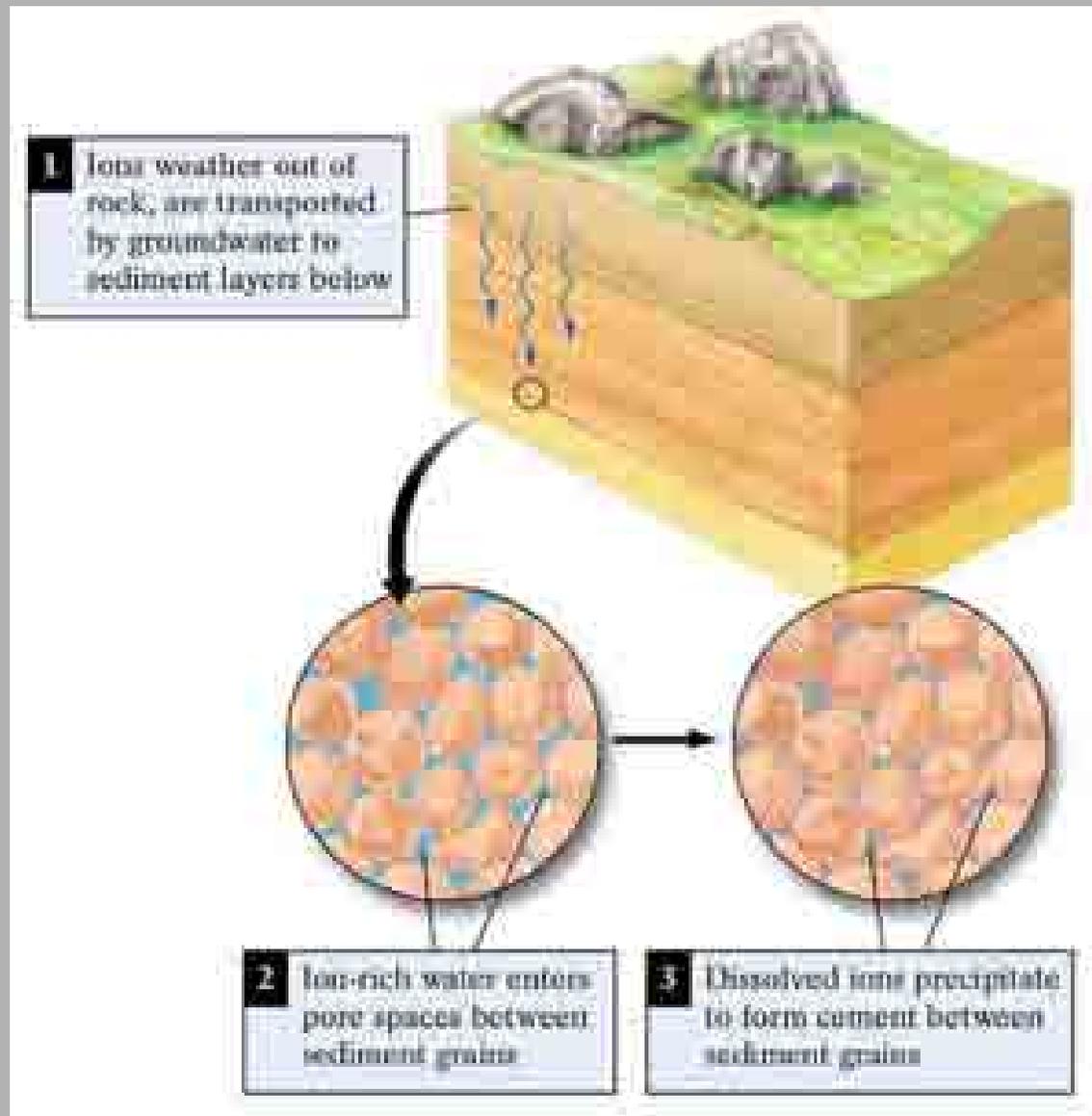


Marshak (2003)

Terminology

- Lithification, which involves compaction and cementation, converts sediments to sedimentary rocks.
- Compaction, driven by the weight of sediment overlying a deeper layer, reduces the volume of a deposit as particles pack more closely and pore space is reduced.
- Cementation binds one particle to another by chemical precipitation of minerals in sediment pore space. Common cements include quartz, calcite, and hematite.
- Lithification of gravel, sand, and mud requires both compaction and cementation, but compaction alone is sufficient to lithify mud.

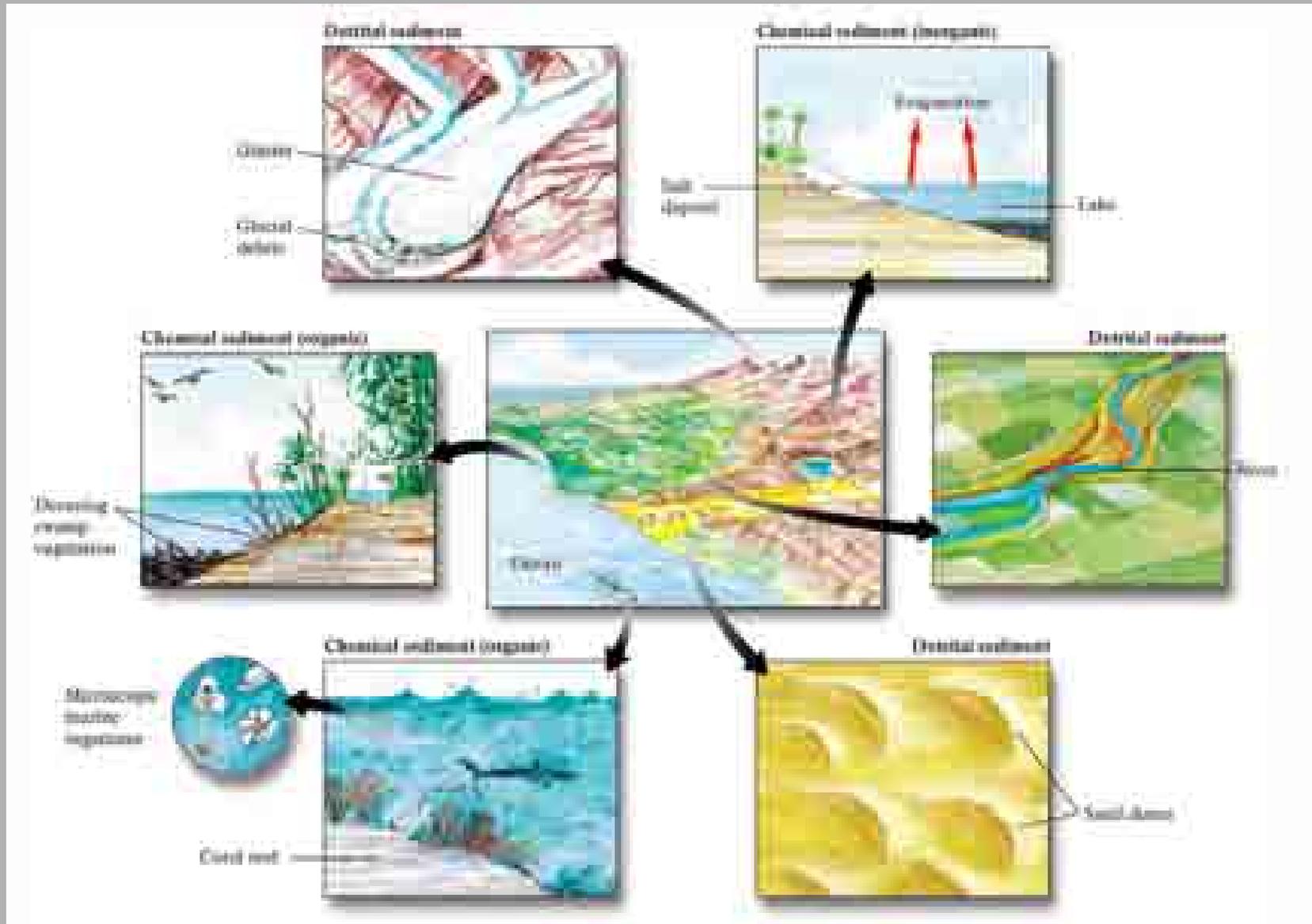
Lithification of sediment



Sedimentary rocks

- Clastic sedimentary rocks are formed from the mechanical break up of other rocks and are classified based on the particle size, e.g. sandstone. Closer to the source the grains will tend to be larger and more angular
- Chemical sedimentary rocks are formed from the precipitation of minerals from solution, e.g. limestone formed from the calcium carbonate or halite formed from the drying up of an inland sea.
- Biogenic sedimentary rocks are produced directly from biological activity, e.g., coal, chalk and chert

Types of sediment



Clastic or Detrital rocks

Detrital sedimentary rocks are formed of solid particles such as sand & gravel derived by weathering. These rocks are classified by the size of their constituent particles

Sediment Name & Size	Description	Rock Name
gravel (>2 mm)	rounded gravel	conglomerate
	angular gravel	breccia
sand (1/16-2 mm)	mostly quartz	qtz sandstone
	>25% feldspar	arkose
silt (1/16-1/256 mm)	mostly silt	siltstone
clay (<1/256 mm)	mostly clay	*claystone
		} mudstone

* fissile claystone is called shale

Your text: pg 158!!

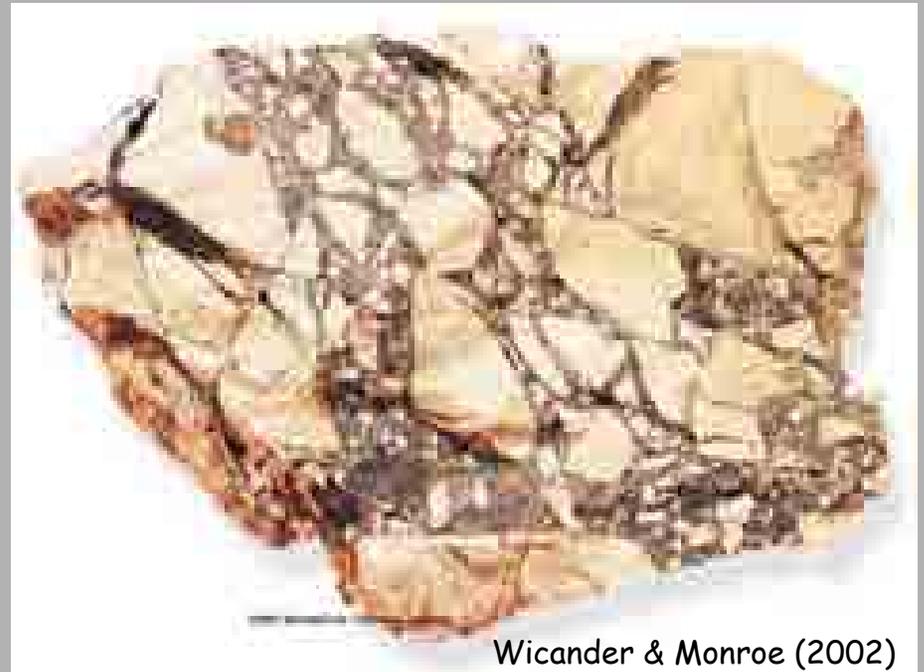
Clastic sedimentary rocks

Conglomerate and breccia are composed of round and angular gravel, respectively.

Your text: pg 160!



Wicander & Monroe (2002)



Wicander & Monroe (2002)

Clastic Sedimentary Rocks

quartz sandstone



- Sandstone is composed of sand-size (1/16-2 mm) particles. Several types of sandstone are recognized based on the mineralogy of the sand particles.
- Quartz sandstone is the most common and made up largely of quartz grains.

Wicander & Monroe (2002)

Clastic sedimentary rocks



shale

Wicander & Monroe (2002)

Mudrock is detrital rock made of any combination of silt and clay. Siltstone and claystone are varieties of mudrock.

Shale is a fissile (splits along many closely spaced planes) mudstone or claystone.

Mudrocks are the most common type of sedimentary rocks and form from sediment deposited in quiet-water environments.

Chemical sedimentary rocks

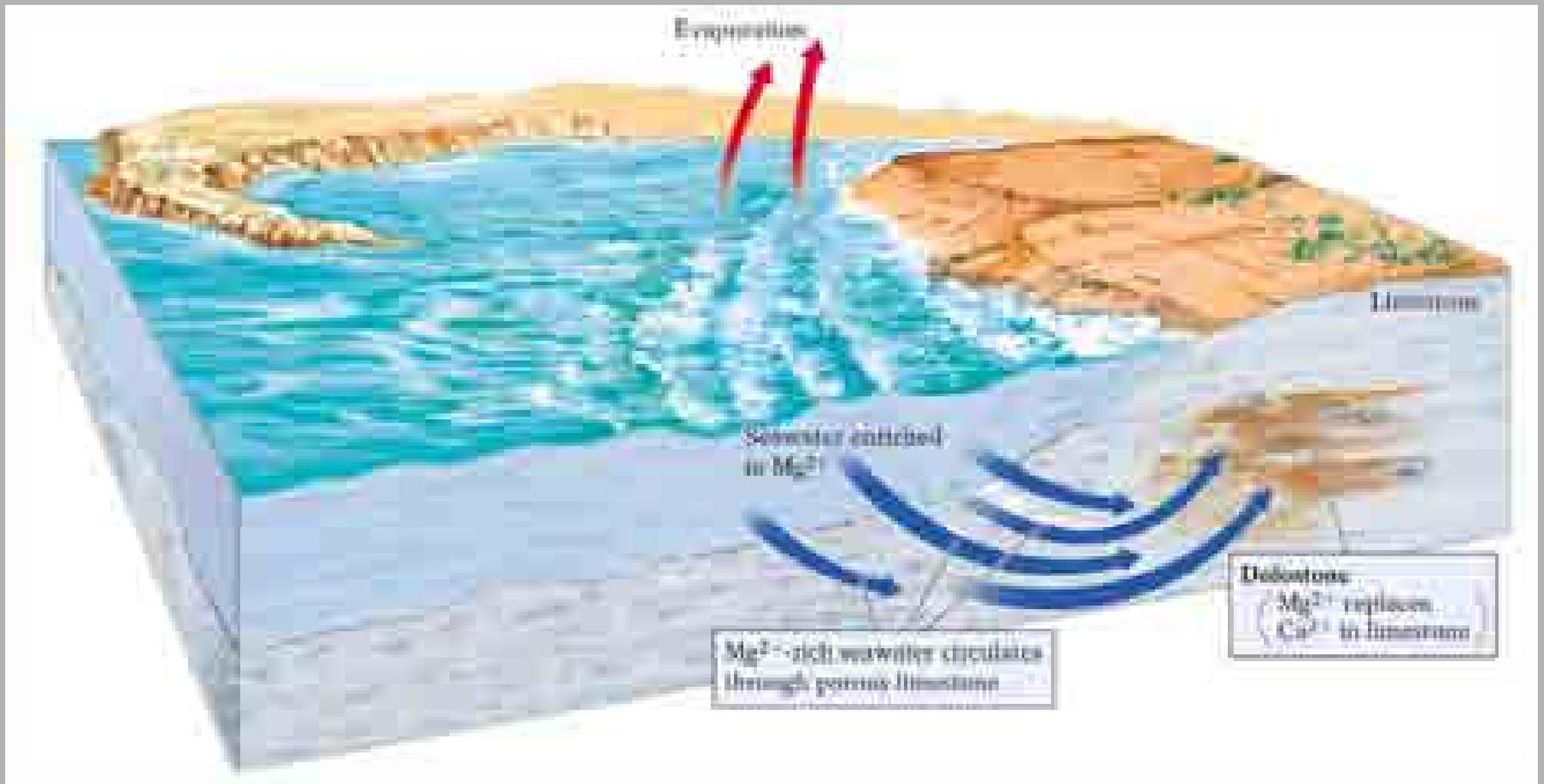
Chemical sedimentary rocks are formed of ions taken into solution by chemical weathering of parent material. Many have crystalline texture of interlocking mineral grains. These rocks are classified based on their mineral composition.

Texture	Compostion	Rock Name
varies	calcite (CaCO_3)	*limestone
varies	dolomite [$\text{CaMg}(\text{CO}_3)_2$]	**dolostone
crystalline	gypsum ($\text{CaSo}_4 \cdot 2\text{H}_2\text{O}$)	rock gypsum
crystalline	halite (NaCl)	rock salt

** most limestone is biochemical*

*** dolostone is chemically altered limestone*

Formation of dolostone



Chemical sedimentary rocks

Rock salt



Wicander & Monroe (2002)

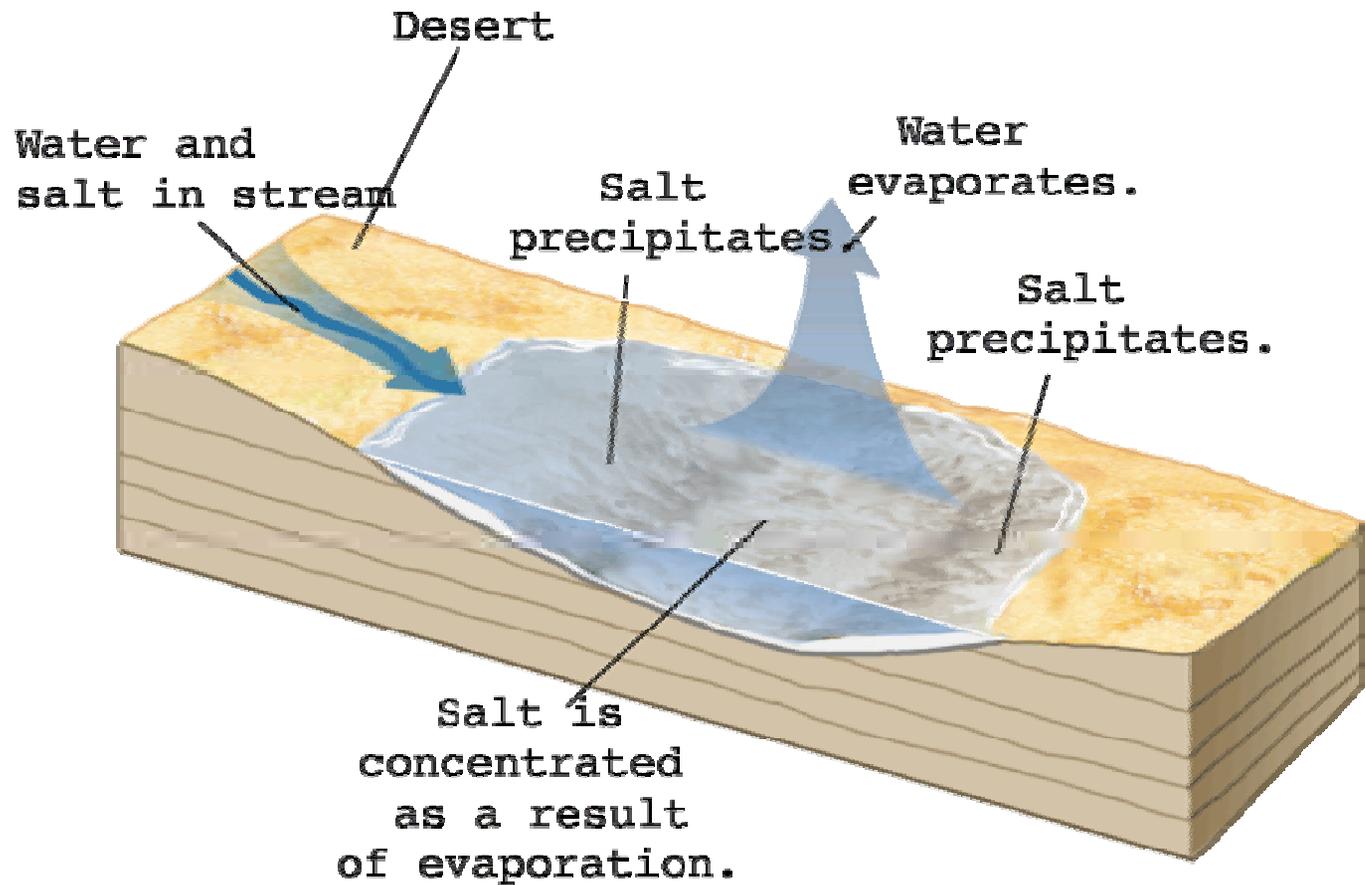
Evaporites are chemical sedimentary rocks formed by precipitation of minerals from evaporating water. Rock salt and rock gypsum are most common and are important resources, forming large deposits in Michigan, Ohio, New York, and the Gulf Coast region.



Gypsum

Wicander & Monroe (2002)

Evaporite formation



Marshak (2003)

Locations of subsurface evaporite



Chernicoff &
Whitney (2002)

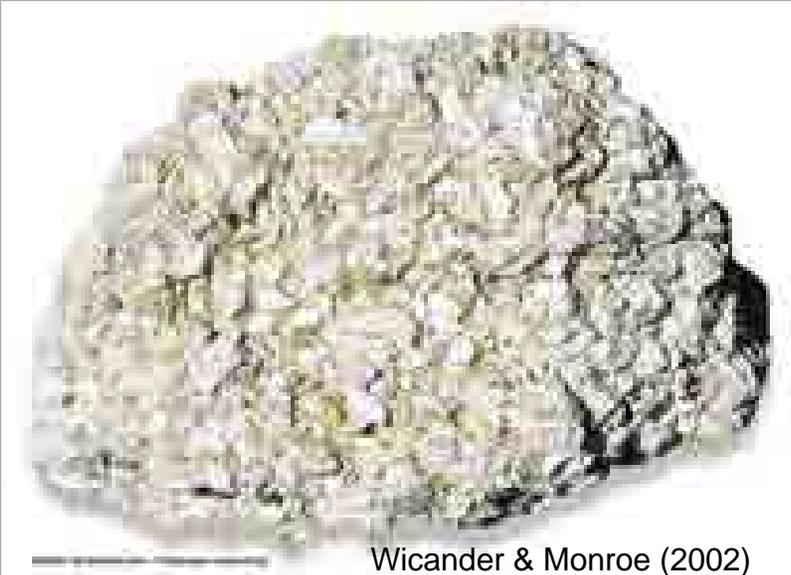
Biochemical sedimentary rocks

Biochemical sedimentary rocks are formed of ions taken into solution by chemical weathering of parent material, as are chemical sedimentary rocks. Organisms aid in the precipitation of biochemical sedimentary rocks

Texture	Composition	Rock Name
*clastic	calcite (CaCO₃) shells, etc.	limestone
crystalline	altered microscopic shells of qtz	chert
	carbon from altered plant remains	coal

*** composed of individual particles or grains, fragments of shells or similar grains in the case of biochemical limestone**

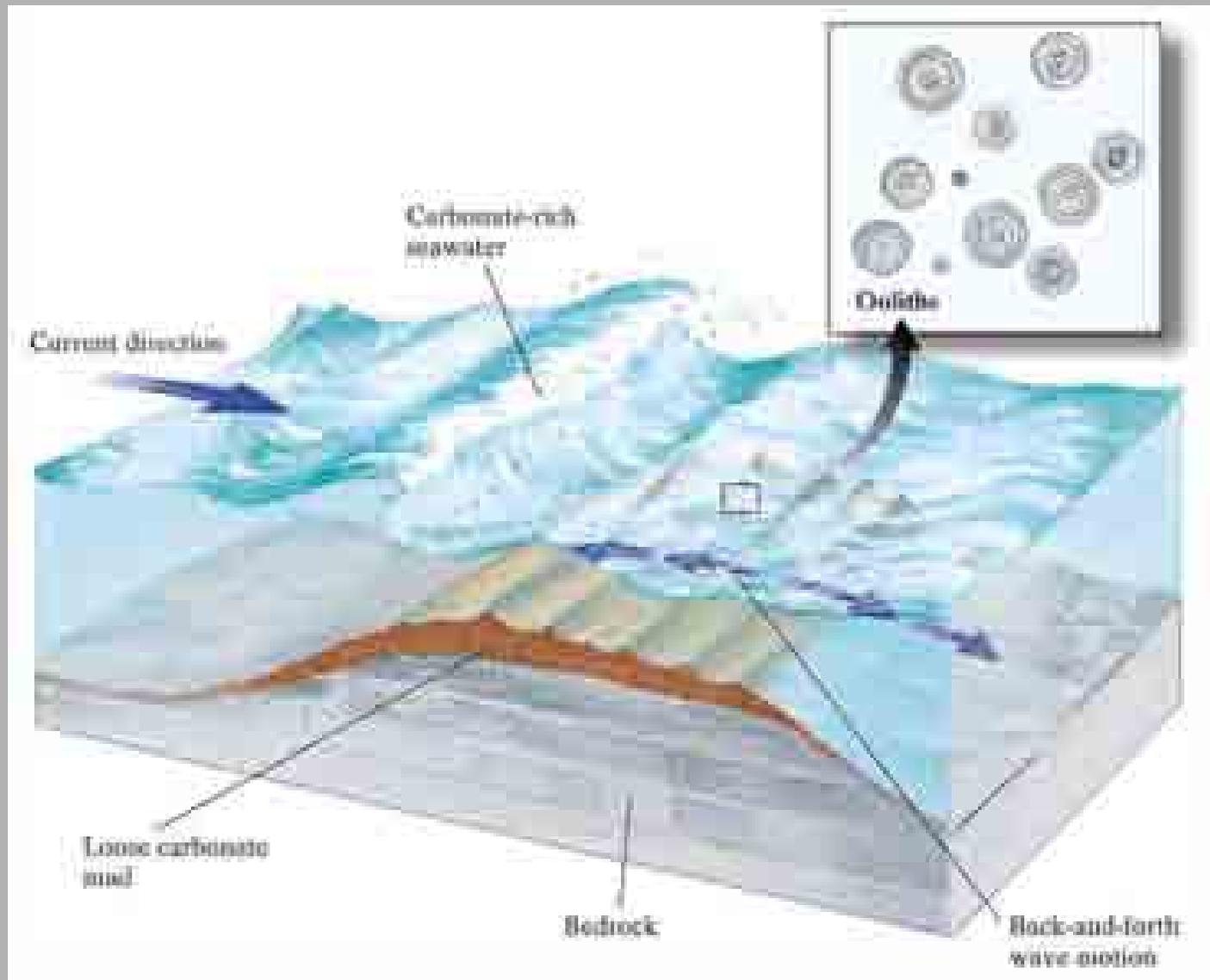
Biochemical sedimentary rocks



Limestone derived from bio-chemical processes is much more common than that formed by inorganic processes. Limestone composed of skeletal fragments of marine invertebrates is quite common. Both coquina and fossiliferous limestone contain abundant skeletal material. Coquina, however, contains much pore space, but pores of fossiliferous limestone are filled with cement and mud.

Formation of oolites

Text: pg 163



Microfossils



Marshak (2003)

Biochemical Sedimentary Rocks

Chert is composed of quartz and is found as nodules in limestone, or in distinct layers where it is composed of the microscopic shells of tiny marine organisms. Coal consists of the compressed, altered remains of land plants that occupied swamps and bogs.

Chert



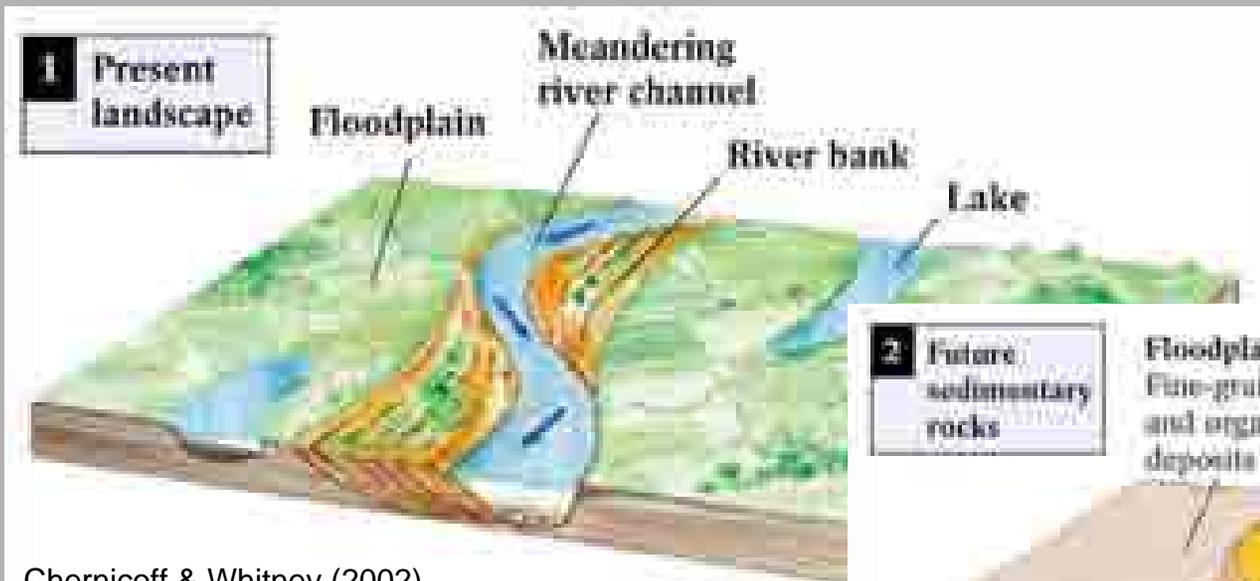
Wicander & Monroe (2002)

Coal



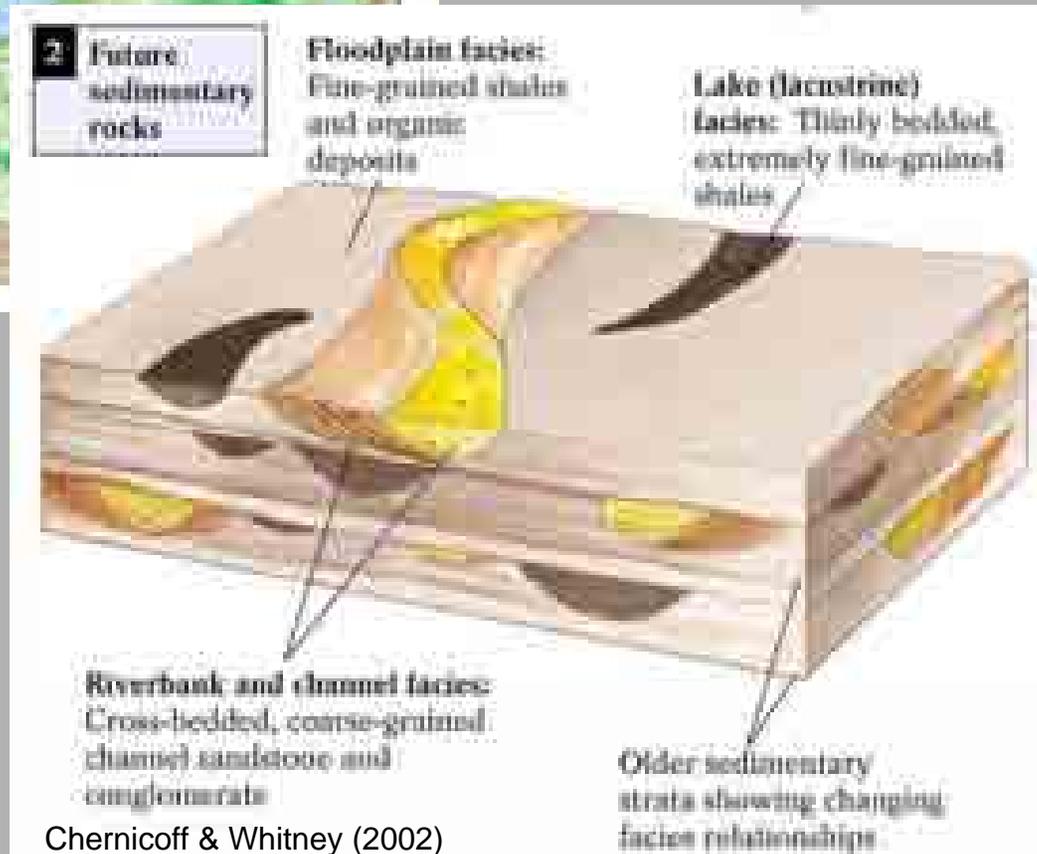
Wicander & Monroe (2002)

Sedimentary facies formation



Chernicoff & Whitney (2002)

Sedimentary facies are bodies of sediment or sedimentary rock containing distinct chemical, physical, and biological attributes imparted by their environments of deposition.

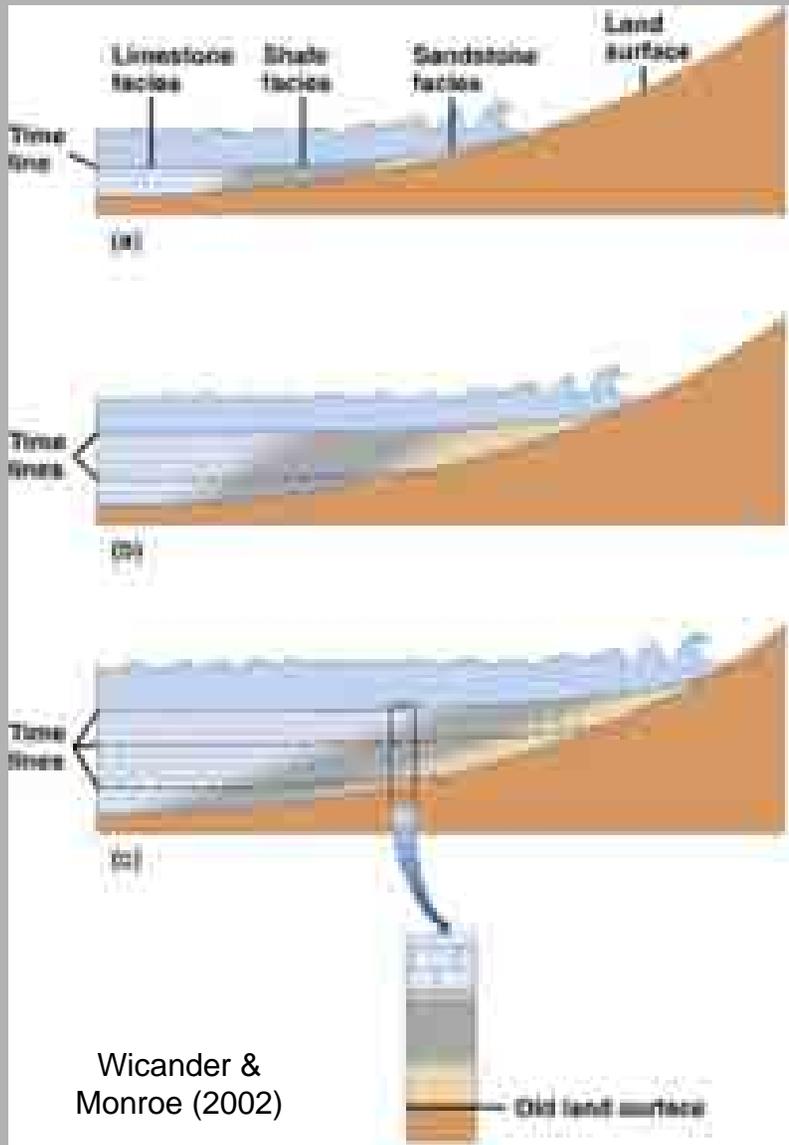


Chernicoff & Whitney (2002)

Sedimentary facies

- In marine coastal areas for example, several facies accumulate simultaneously on various areas of the seafloor. Each area is characterized by a distinct set of environmental conditions which influences sediment type.
- The stacking arrangement of sedimentary rocks records the lateral relationships between facies/environments at the time of sediment deposition.
- In coastal areas, the stacking of sediment layers deposited in laterally adjacent environments results from movement of the shoreline with relative changes in sea level.

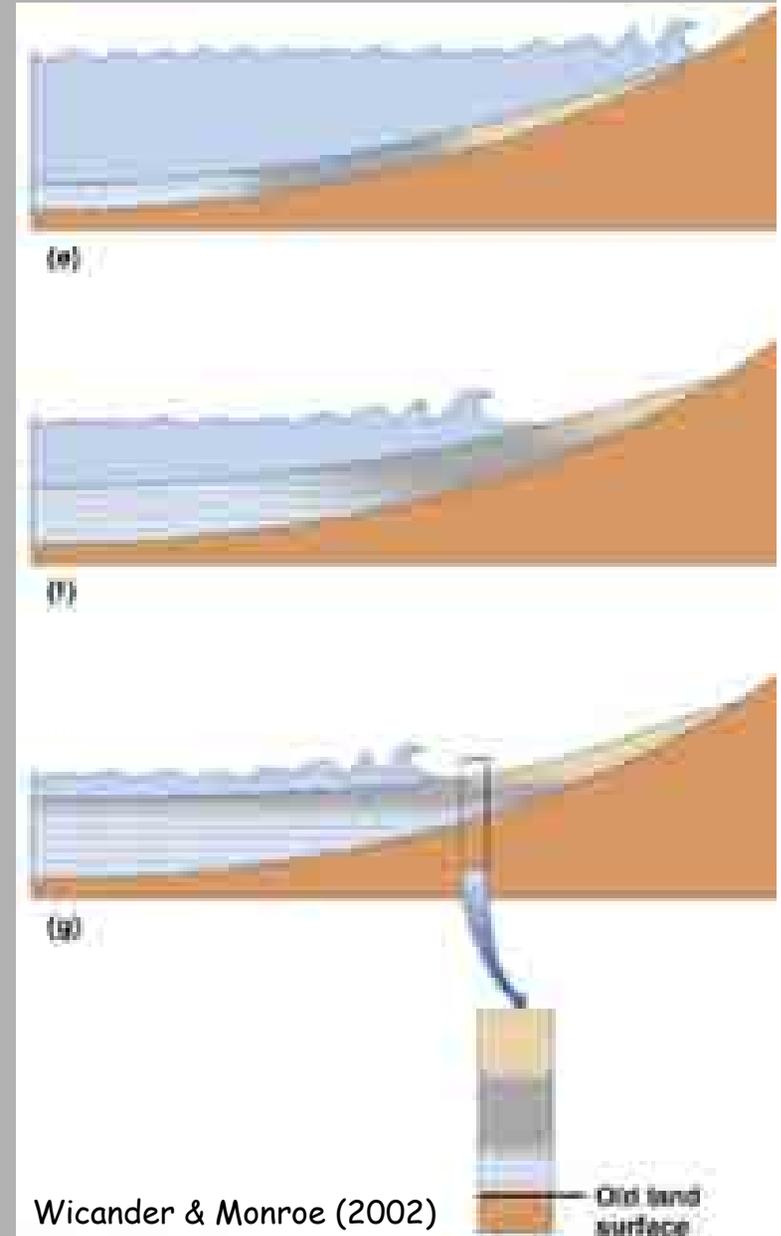
Marine transgression



As shorelines move, depositional environments and the sediments accumulating in them follow. A landward shift in the shoreline gives rise to a marine transgression (relative rise in sea level). As facies shift landward with the shoreline, nearshore sediments come to overlie old land surfaces, and offshore sediments are stacked atop those of the nearshore. Transgressions produce a distinctive vertical arrangement of facies, with offshore deposits atop the stack.

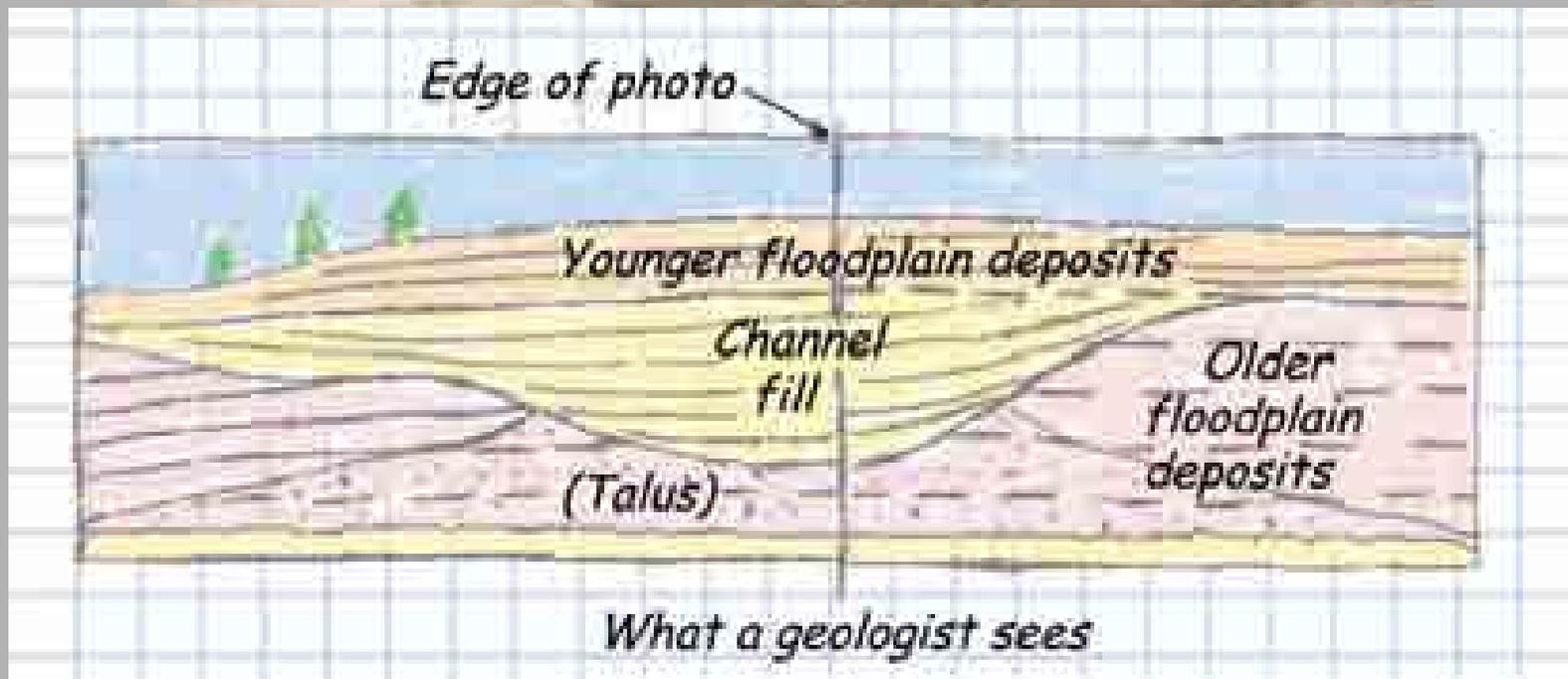
Sedimentary Facies

Marine regressions are seaward shifts in the shoreline. They produce a facies stacking arrangement, wherein nearshore deposits overlie offshore deposits. This facies arrangement records the relative drop in sea level that accompanies a regression. Many of the sedimentary rocks at the interiors of continents were deposited as shallow seas repeatedly flooded and withdrew from broad areas.



The story in sedimentary rocks

- Sedimentary rocks contain clues that can be used for interpreting a deposit's depositional history.
- Reconstructing the depositional environment of a deposit is of practical importance. For example, knowing the depositional environment of sedimentary rocks containing petroleum and natural gas is critical for siting exploration and exploitational wells.
- Sedimentary textural characteristics like rounding and sorting are clues to depositional environments. For example, desert sand dune deposits are well sorted and well rounded, whereas glacial deposits are poorly sorted.
- Sedimentary structures and fossils also are useful for interpreting depositional history.



Sedimentary Structures

Sedimentary structures are features formed in sediment by physical or biological processes at the time of, or shortly after deposition. Strata or beds are layers that differ in color, texture, and composition from rock layers above and below. Crossbedding refers to inclined layers within a given bed. Formed by wind or water, this feature slopes downward in the direction of flow.



Wicander & Monroe (2002)

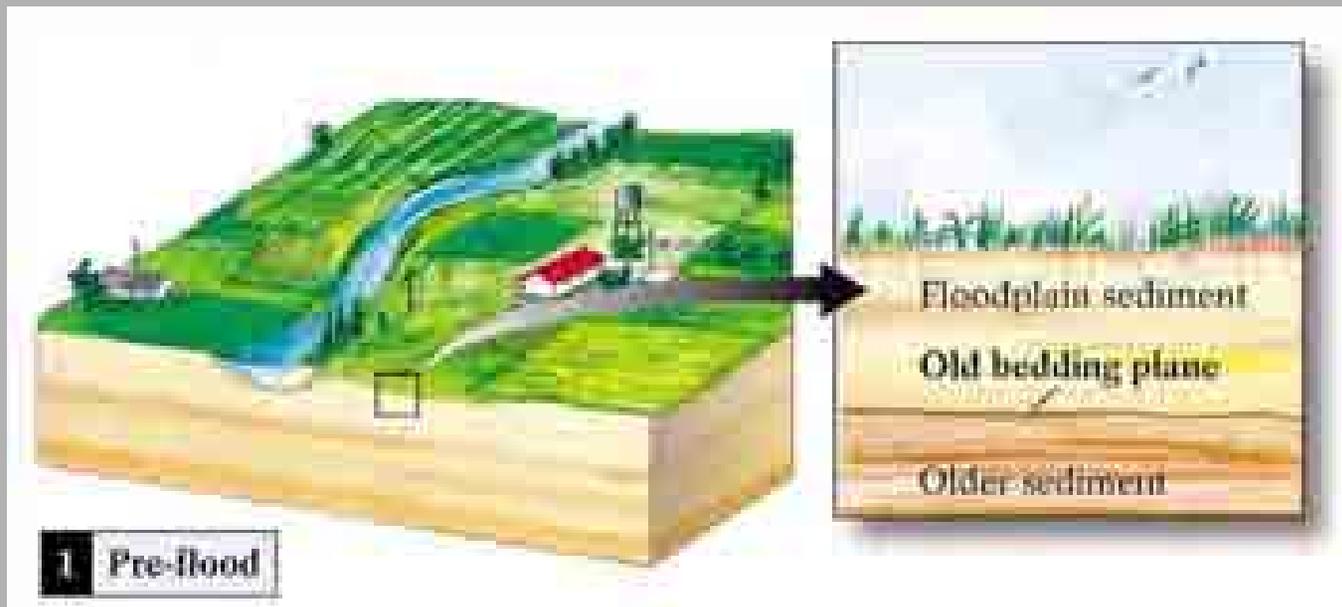


Wicander & Monroe (2002)

The 3 types of bedding

- Parallel, cross-bedding and graded bedding
- Pages 168-171 text, very nice pics and diagrams

Development of a bedding plane



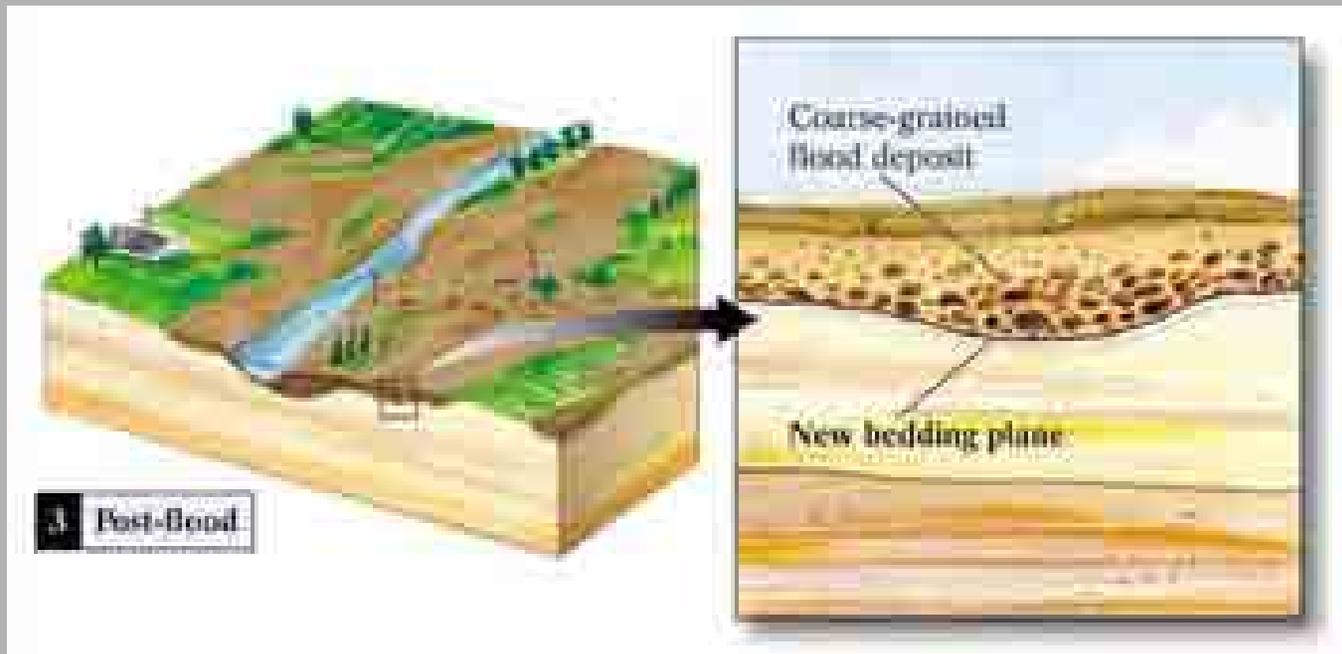
Chernicoff & Whitney (2002)

Development of a bedding plane



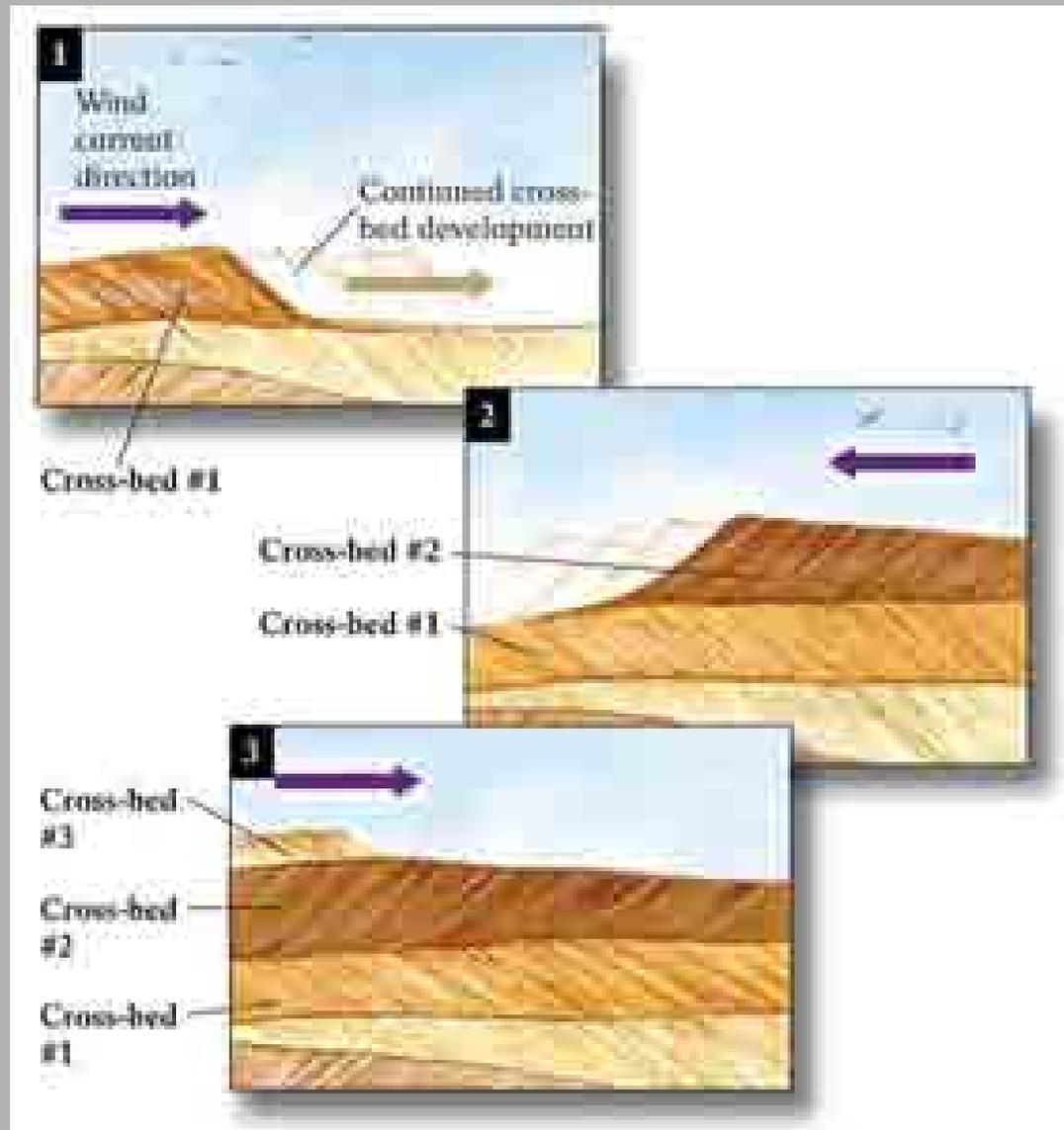
Chernicoff & Whitney (2002)

Development of a bedding plane



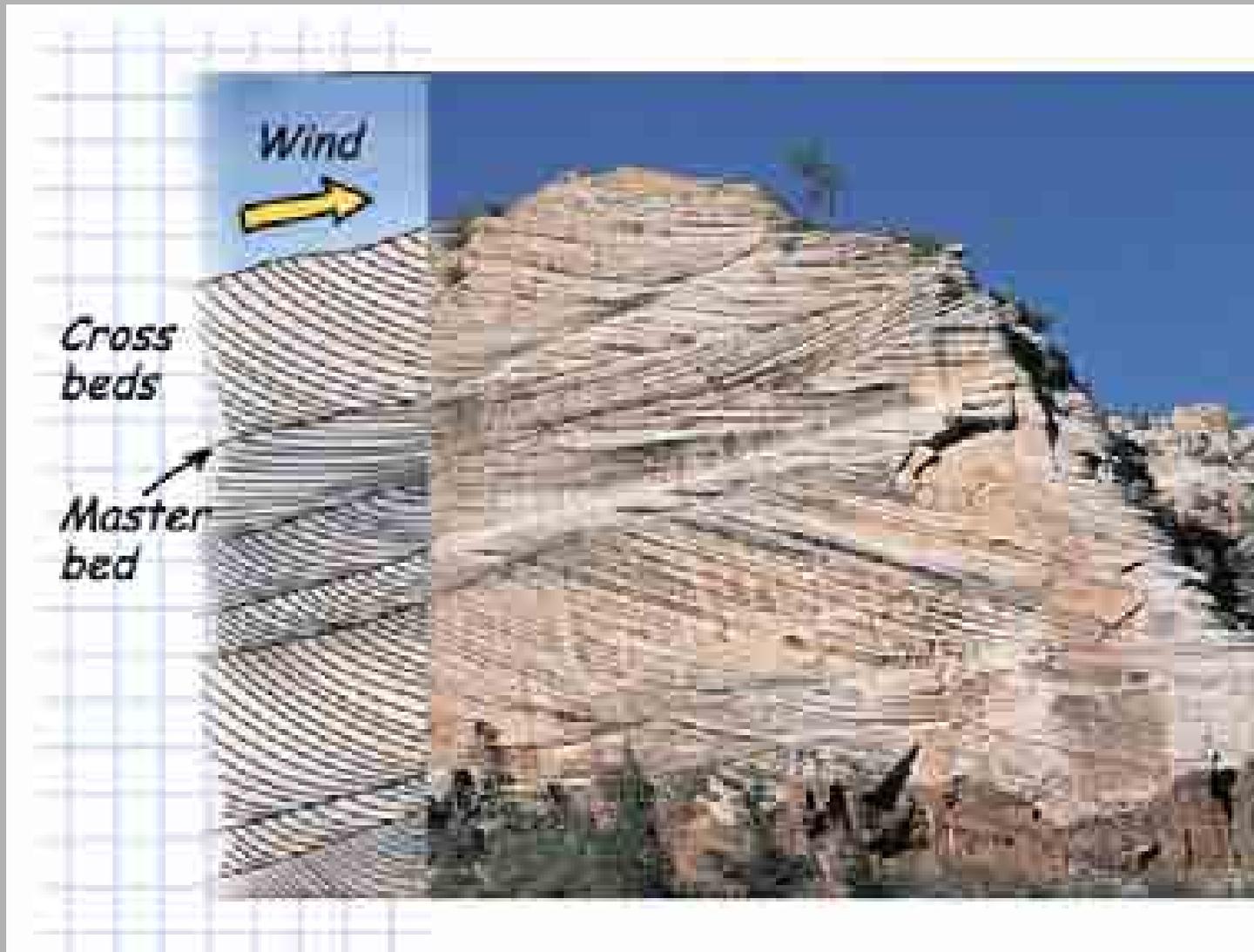
Chernicoff & Whitney (2002)

Development of cross-bedding



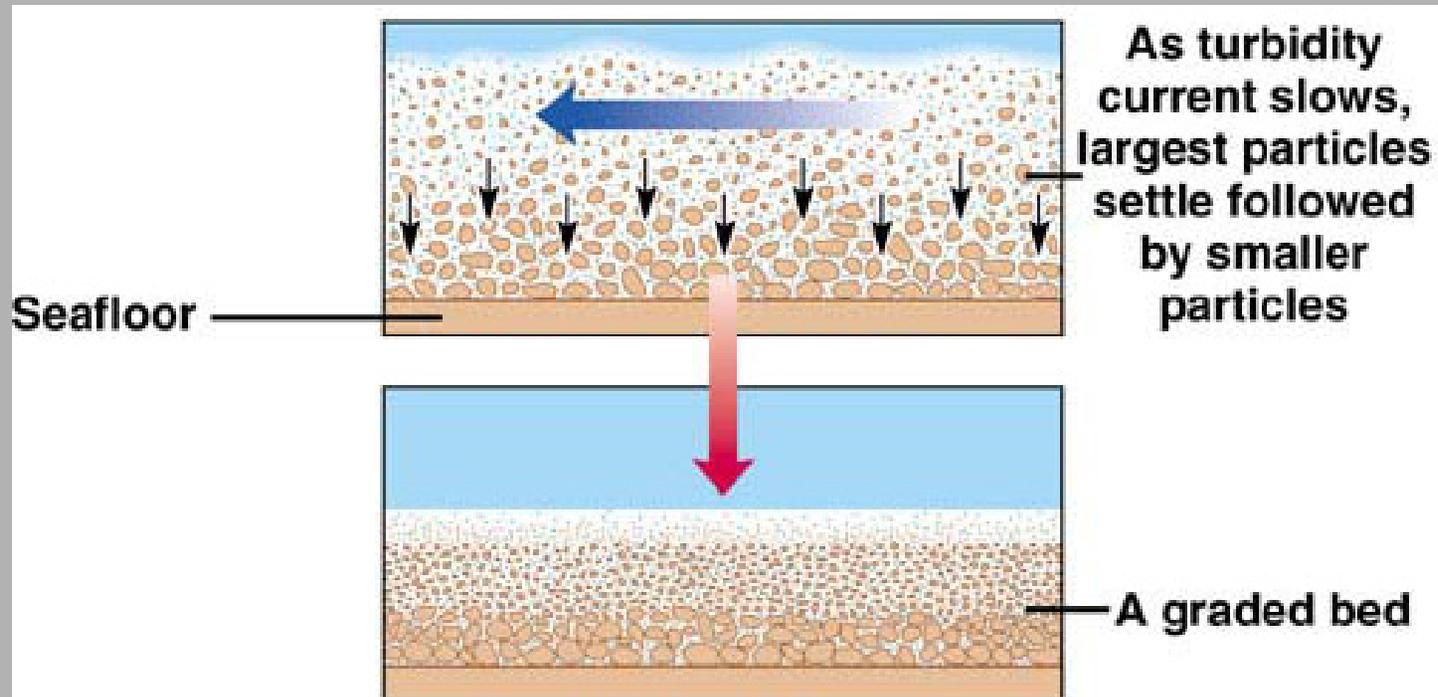
Chernicoff & Whitney
(2002)

Cross bedding

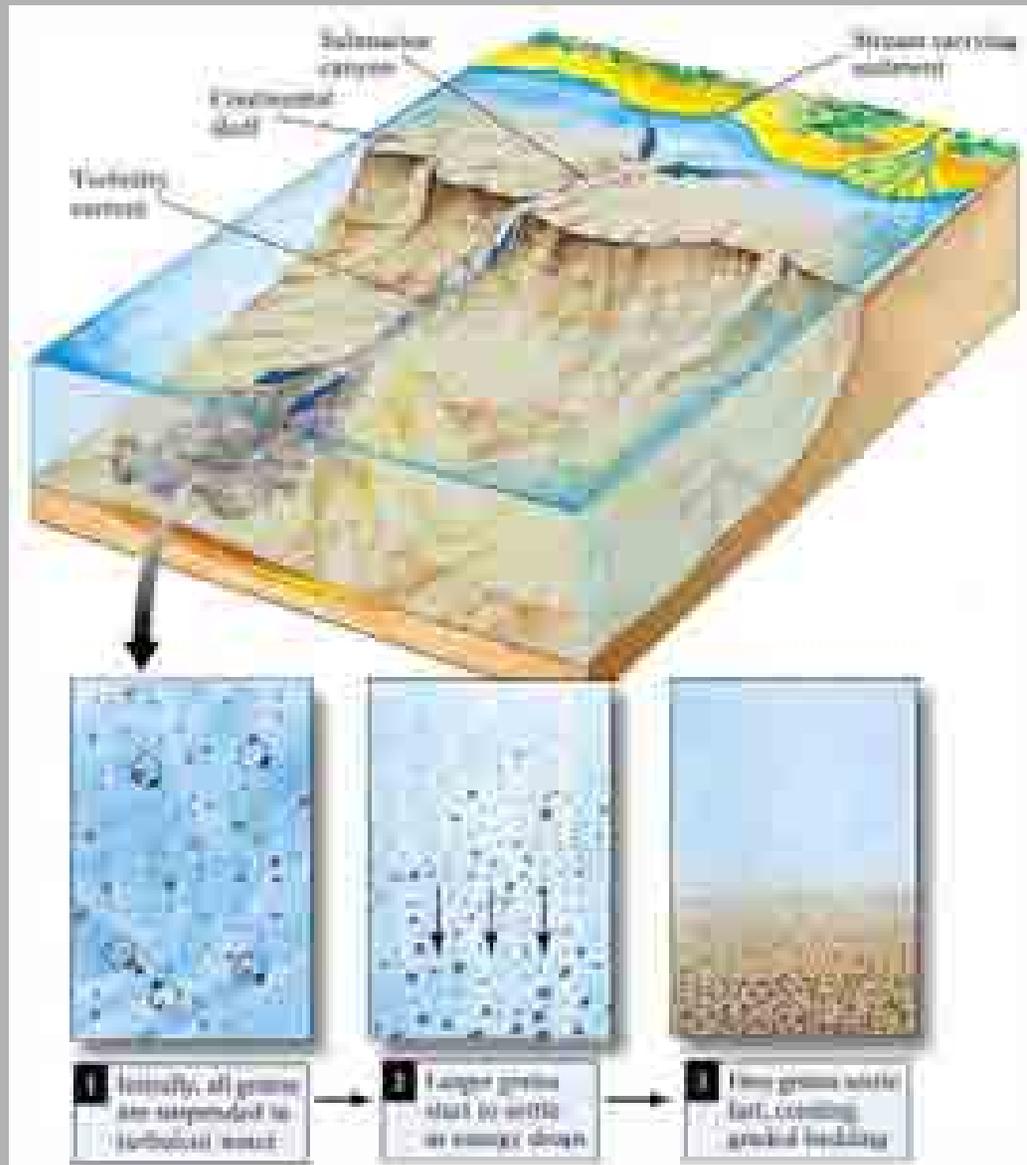


Graded bedding

Graded bedding refers to an upward decrease in grain size within an individual bed. It is often found in the deposits of turbidity currents, high density submarine flows. As turbidity currents slow, larger particles are deposited first and progressively smaller ones deposited as flow continues to weaken.

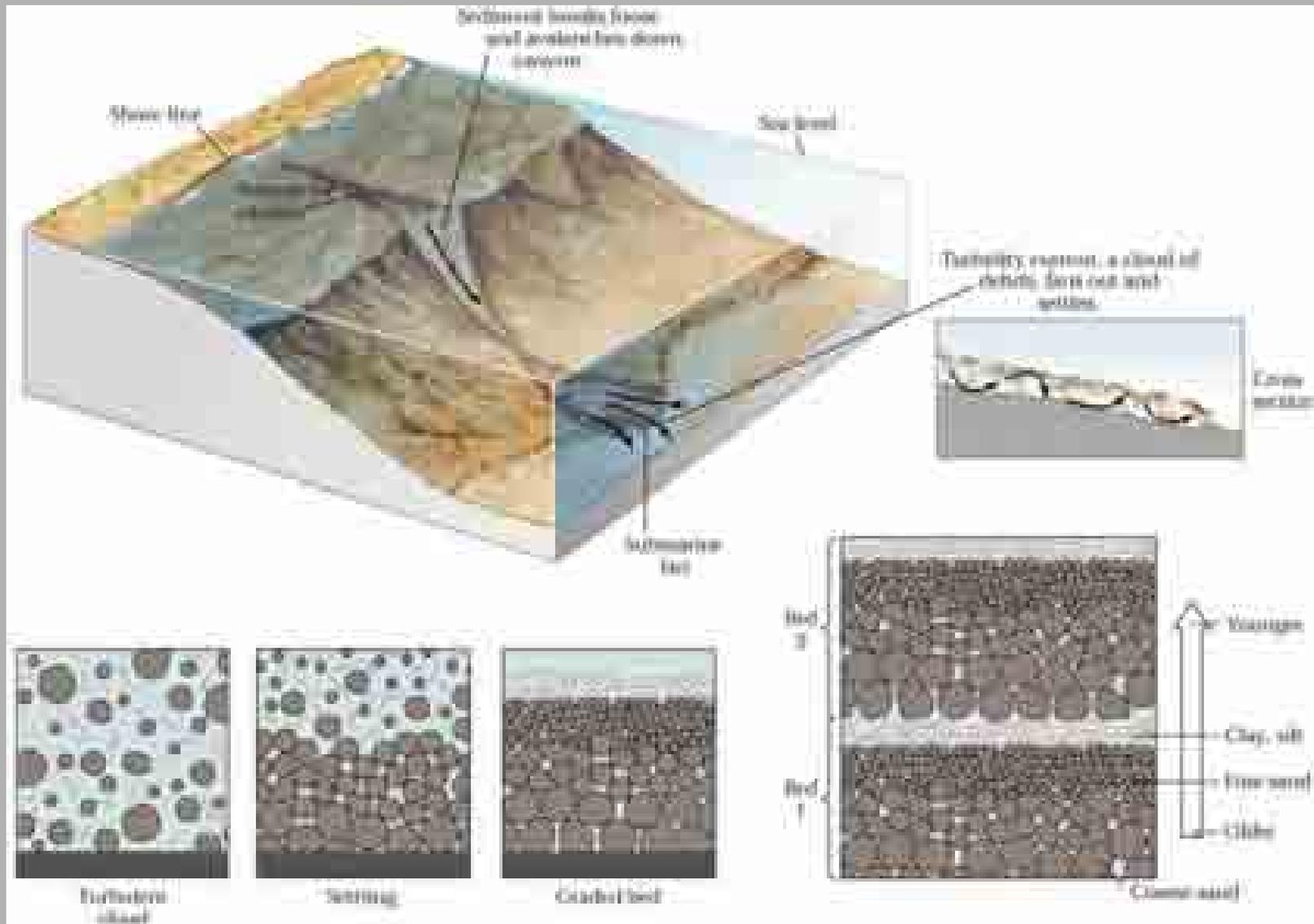


Graded bedding of sediment



Chernicoff &
Whitney (2002)

Graded bedding



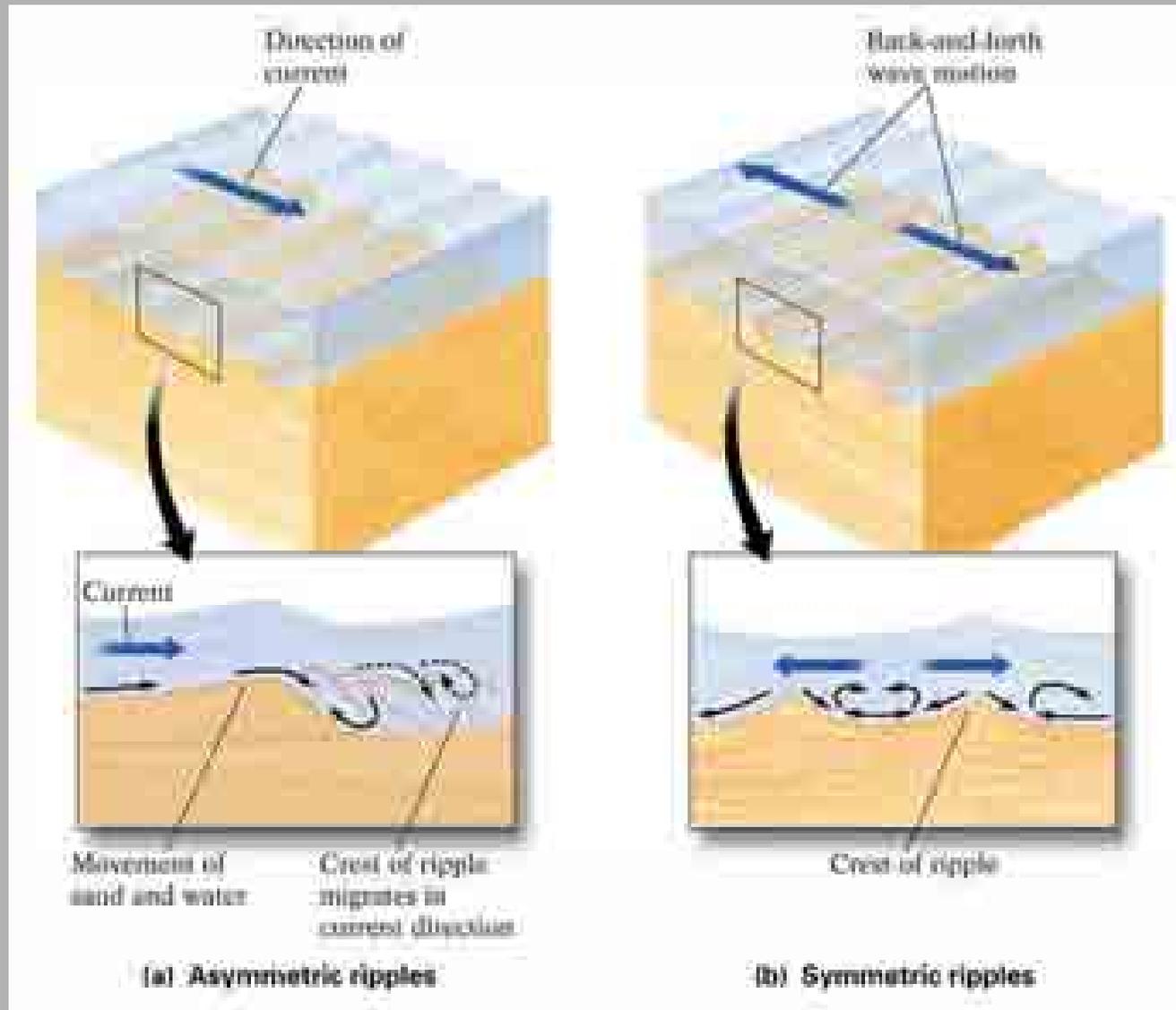
Sedimentary structures

Ripple marks, small ridges separated by intervening troughs, form on sand deposits and are often preserved in the rock that forms from these deposits.

Current ripple marks have asymmetric cross-sections and record flow in one direction as in streams. Wave-formed ripple marks have symmetric cross-sections generated by the back-and-forth motion of waves.



Asymmetric and symmetric ripples.



Chernicoff &
Whitney (2002)

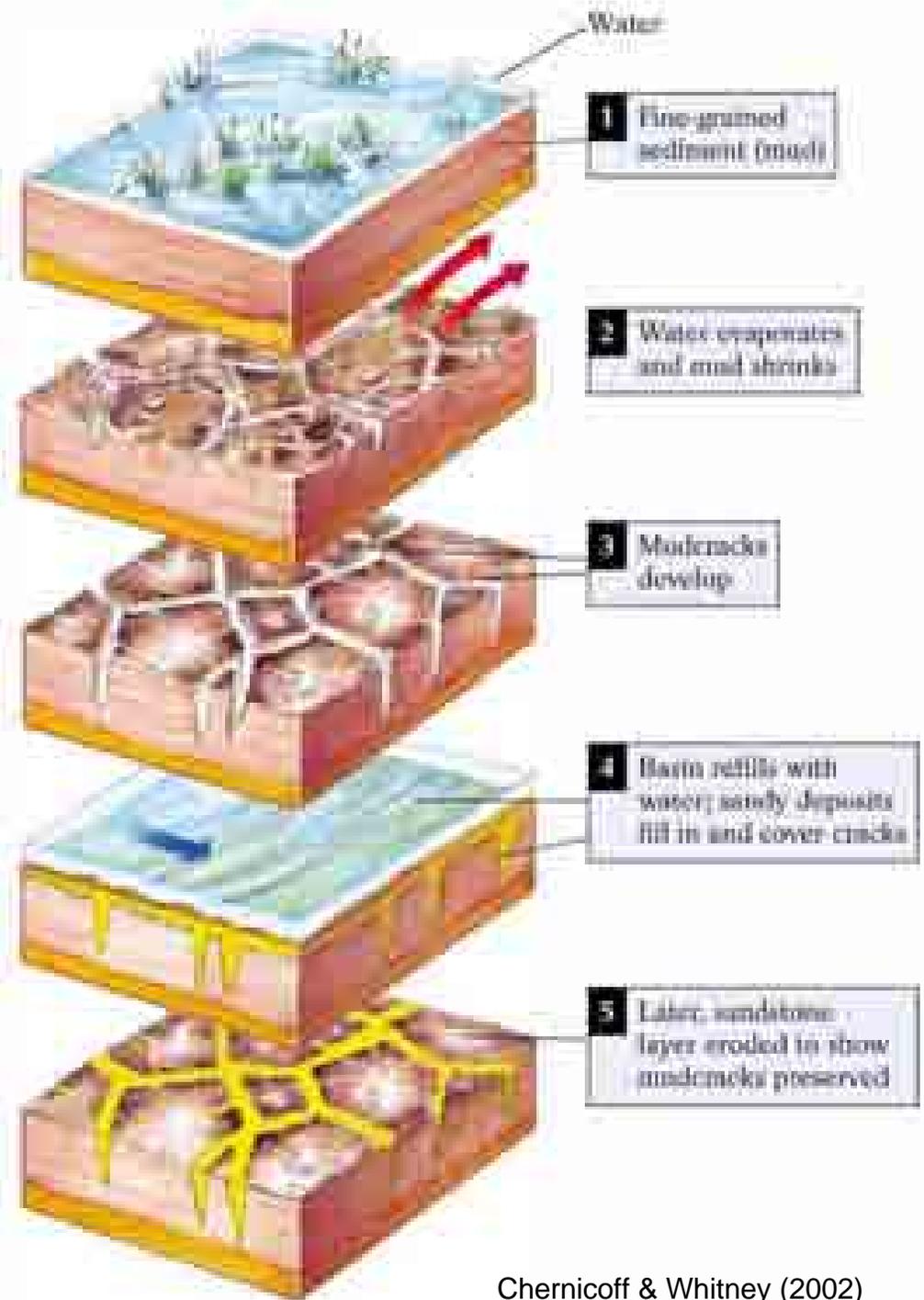
Sedimentary structures

Mud cracks are shrinkage cracks that form polygonal patterns of intersecting fractures. They form when clay-rich sediment dries. Mud cracks are preserved in sedimentary rocks and indicate that the depositional environment was one where periodic drying occurred, such as on a river floodplain, a lake shore, or tidal flat.



Wicander & Monroe (2002)

Mud cracks...



Fossils



Wicander & Monroe (2002)

Fossils are the remains or traces of ancient organisms. They provide insight for prehistoric life, but also are useful for reconstructing depositional environments. The morphology of an ancient organism or its life habits reveal important information about the environment in which the organism lived. For example, heavy-shelled clams lived in shallow-water, turbulent conditions, whereas clams from quite low-energy settings have thin, fragile shells. Filter-feeding organisms like corals require clear seawater because suspended sediment clogs their feeding organs.

Index Fossils

<http://pubs.usgs.gov/gip/geotime/fossils.html>

CENOZOIC ERA (Age of Recent Life)	Quaternary Period	<i>Fossil globos</i>		<i>Nautilus tabularis</i>	
	Tertiary Period	<i>Calyptrogonia varietus</i>		<i>Yuccosella prostrata</i>	
	Cretaceous Period	<i>Nautilus sigillatus</i>		<i>Urosalpinx tabularis</i>	
MESOZOIC ERA (Age of Reptiles)	Jurassic Period	<i>Perisphinctes turati</i>		<i>Murchisonia turonensis</i>	
	Tertiary Period	<i>Trochites subrotunda</i>		<i>Murchisonia turonensis</i>	
	Triassic Period	<i>Lophospira alternata</i>		<i>Paraspirifer bosei</i>	
PALEOZOIC ERA (Age of Ancient Life)	Permian Period	<i>Orthis planumbona</i>		<i>Leptopyllidium profferum</i>	
	Carboniferous Period	<i>Cardium multibrachiatum</i>		<i>Proserpinca girtyi</i>	
	Devonian Period	<i>Neurospirifer mucronatus</i>		<i>Palaeospira mucronata</i>	
	Silurian Period	<i>Cyrtospira nigrescens</i>		<i>Neurospira turati</i>	
	Ordovician Period	<i>Bathyspira esteri</i>		<i>Favosites frutescens</i>	
	Cambrian Period	<i>Paraspirifer zoeus</i>		<i>Strophomena carrolli</i>	
PRECAMBRIAN					

Depositional environment



Wicander & Monroe (2002)

Texture, sedimentary structures, & fossils are especially important for interpreting depositional environment. Interpretations are largely based on uniformitarianism which assumes that cross-beds, mud cracks, etc., formed in the past by the same processes and under the same conditions as they do today. The Navajo Sst has structures similar to those found in modern sand dunes and is interpreted to have formed in a similar manner.

Depositional Environments

- Continental:
 - Fluvial: Alluvial Fan, Braided Stream, Meandering Stream
 - Desert
 - Glacial
 - Deltaic: delta plain, delta front, prodelta
- Marginal marine:
 - Beach
 - Lagoon
 - Tidal Flat
 - Neritic: Continental shelf, organic reef
- Marine:
 - Oceanic: Continental slope

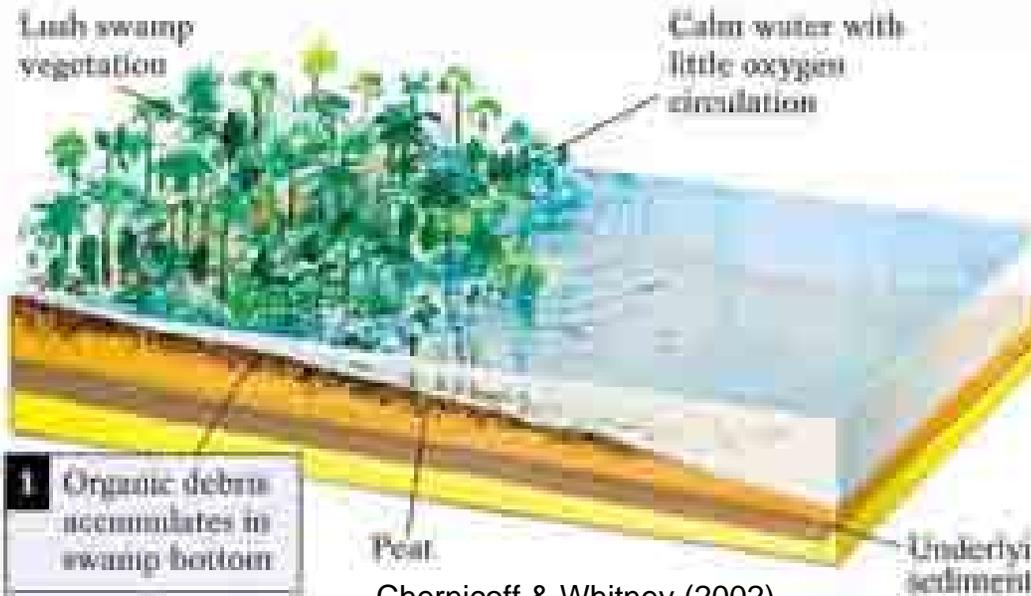
Resources in Sedimentary rocks

- Sand and gravel for building and road construction.
- Limestone for manufacture of cement.
- Gypsum for manufacture of wallboard.
- Phosphate-bearing sedimentary rock for fertilizer.
- Quartz sand for manufacture of glass.
- Carnotite, a uranium-bearing mineral mined to fuel nuclear reactors, is found associated with plant remains in sandstones formed in ancient stream channels.
- Uranium – Canada is the worlds largest producer. Derived from sedimentary rocks. Uraninite is easily oxidized and dissolved in groundwater but equally easily reduced and precipitated in the presence of organic matter

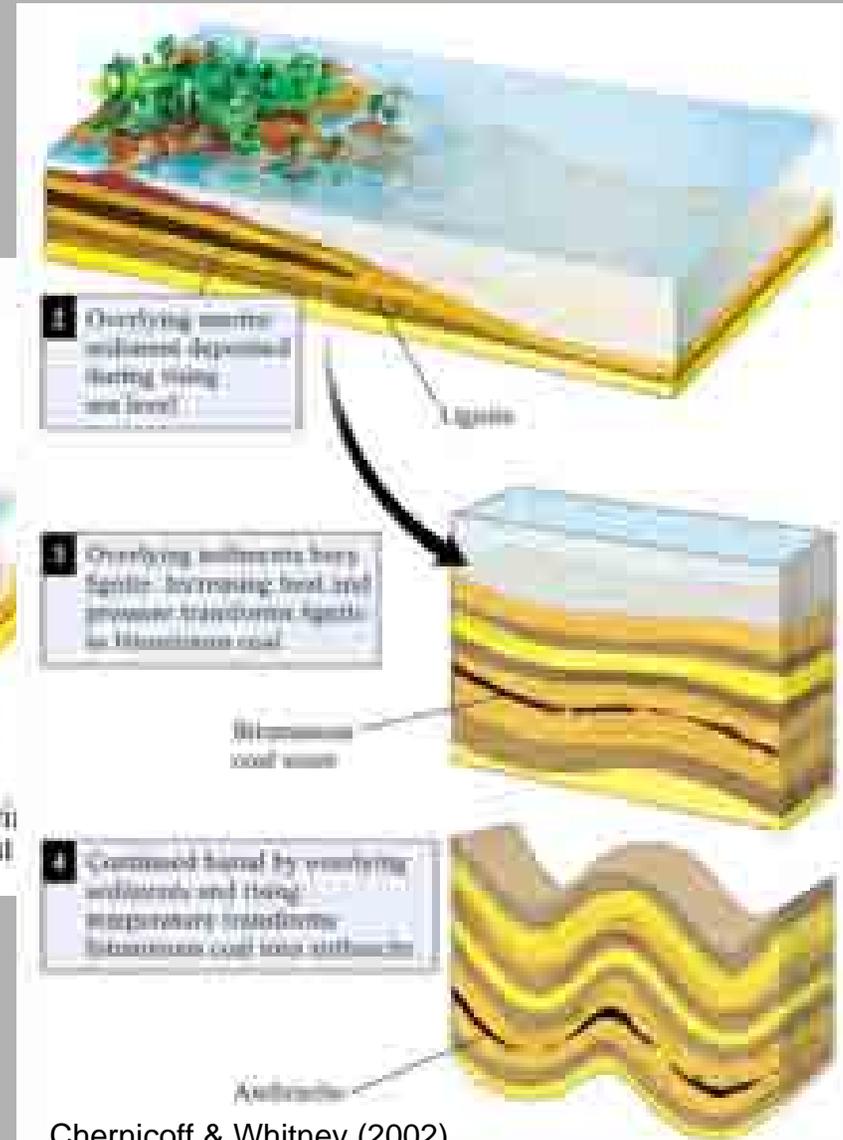
Resources in Sedimentary rocks

- Hematite & magnetite, iron ore minerals, are found in chemical sedimentary rocks known as BIFs
- Bauxite – major source of Al
- Placer deposits - gold, tin and diamonds
- Fossil fuels – coal, oil and natural gas

Formation of coal in swamps



Chernicoff & Whitney (2002)



Chernicoff & Whitney (2002)

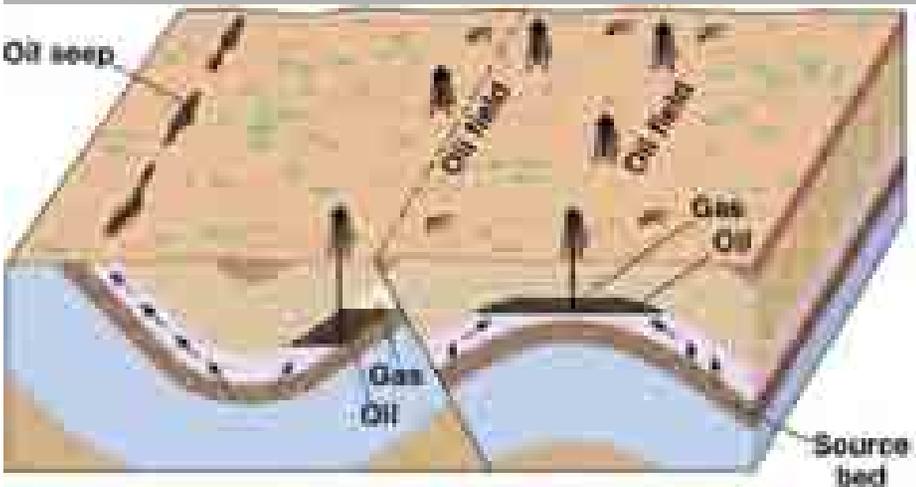
Petroleum and Natural Gas

- Referred to as hydrocarbons, because they consist of hydrogen and carbon, petroleum and natural gas are extracted from sedimentary rocks.
- Buried and heated, the remains of microscopic marine organisms are converted to hydrocarbons.
- Once formed in an organic-rich source rock, hydrocarbons migrate to and accumulate in reservoir rocks. For the hydrocarbons to accumulate, the reservoir rock must be overlain by a cap rock that limits further migration.
- Reservoir rocks must have considerable pore space to store the hydrocarbons, and permeability to allow hydrocarbons to flow from the rock during extraction.

Petroleum and Natural Gas

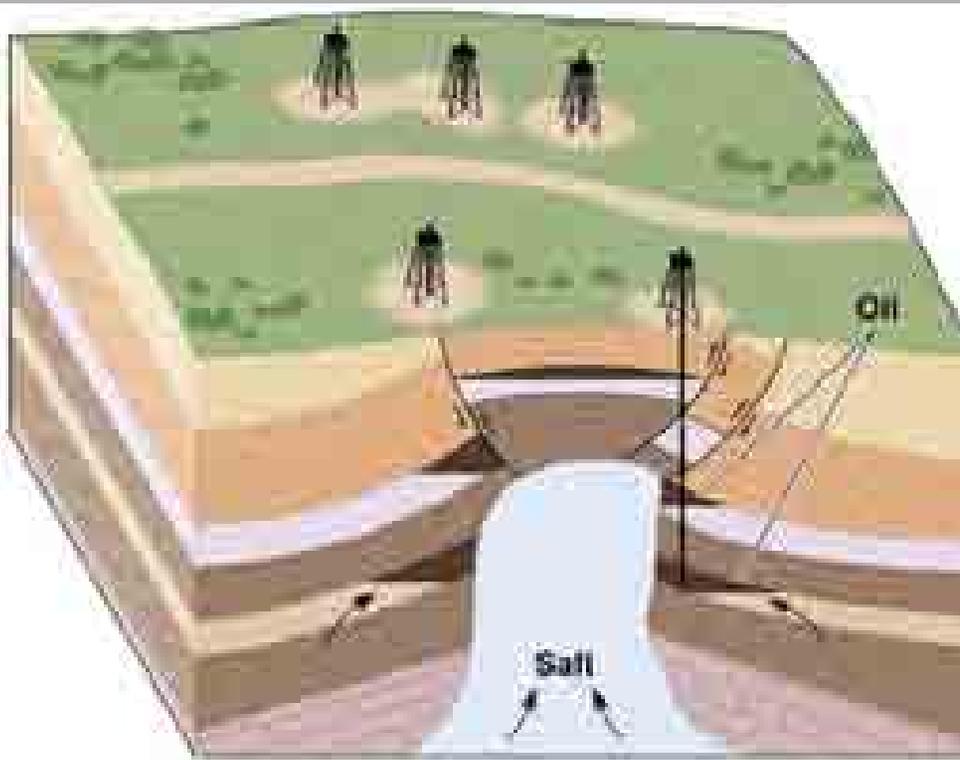


Stratigraphic traps owe their existence to variations in strata, such as with coral reefs and near-shore marine sandstones.



Structural traps result when rocks are deformed by folding, faulting, or both.

Petroleum and Natural Gas



Wicander & Monroe (2002)

- In the Gulf Coast region of the U.S., hydrocarbons are trapped in structures adjacent to salt domes, large mushroom-shaped pillars of rock salt.
- Salt domes form when thick layers of rock salt are deeply buried beneath other deposits. Weight of the overlying deposits causes the rock salt to deform plastically

http://www.ags.gov.ab.ca/energy/oilsands/alberta_oil_sands.html



Location of the Athabasca, Cold Lake, and Peace River oil sands in Alberta with regulatory boundaries.

Alberta Oil Sands

- Deposits of Bitumen- a molasses-like viscous oil
- Contained in 140, 200 km² of NE Alberta (twice the size of NB.....)
- Only 2% of the initial established resource has been produced to date
- Large trucks and shovels dig it out, process it and ship the sand back to the pit
- Occur in Cretaceous (~100 Ma) fluvial-estuarine deposits of NE Alberta
- An **estuary** is a semi-enclosed **coastal** body of **water** with one or more **rivers** or **streams** flowing into it, and with a free connection to the open **sea**.
- Lesser Devonian (~400 Ma) carbonates
- Poor diamonds.....

CBM of Alberta

- Coalbed Methane: a natural gas found in coal
- CH₄ (methane), minor N, CO₂
- a byproduct of geological processes
- the coal is both the source and the storage!

Drill rig involved in CBM exploration of Horseshoe Canyon Formation coals, Alberta Plains.



<http://www.ag.gov.ab.ca/energy/cbm/photos/index.html>

Cleat in coal – well-developed cleat (blocky fractures) at the Coalspur Coal Zone, Coal Valley mine, Alberta Foothills.



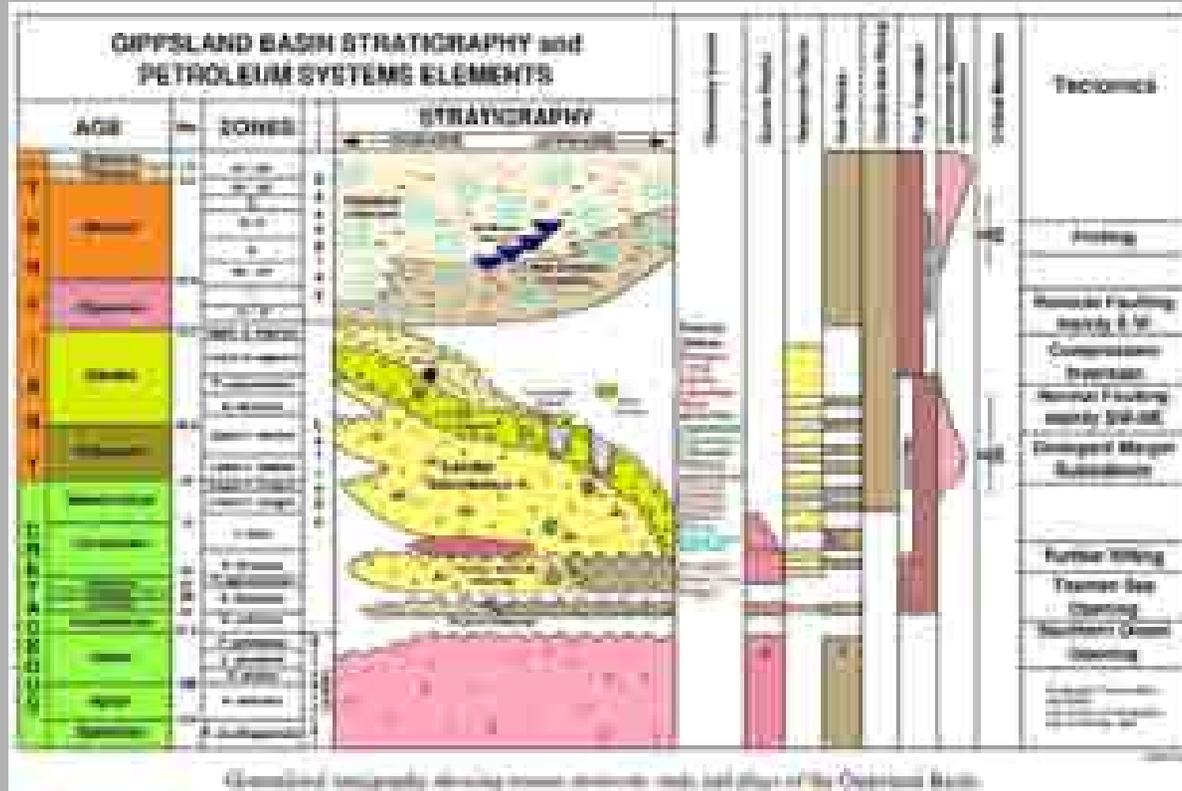
<http://www.ags.gov.ab.ca/energy/cbm/photos/index.html>

Cardinal River Mine

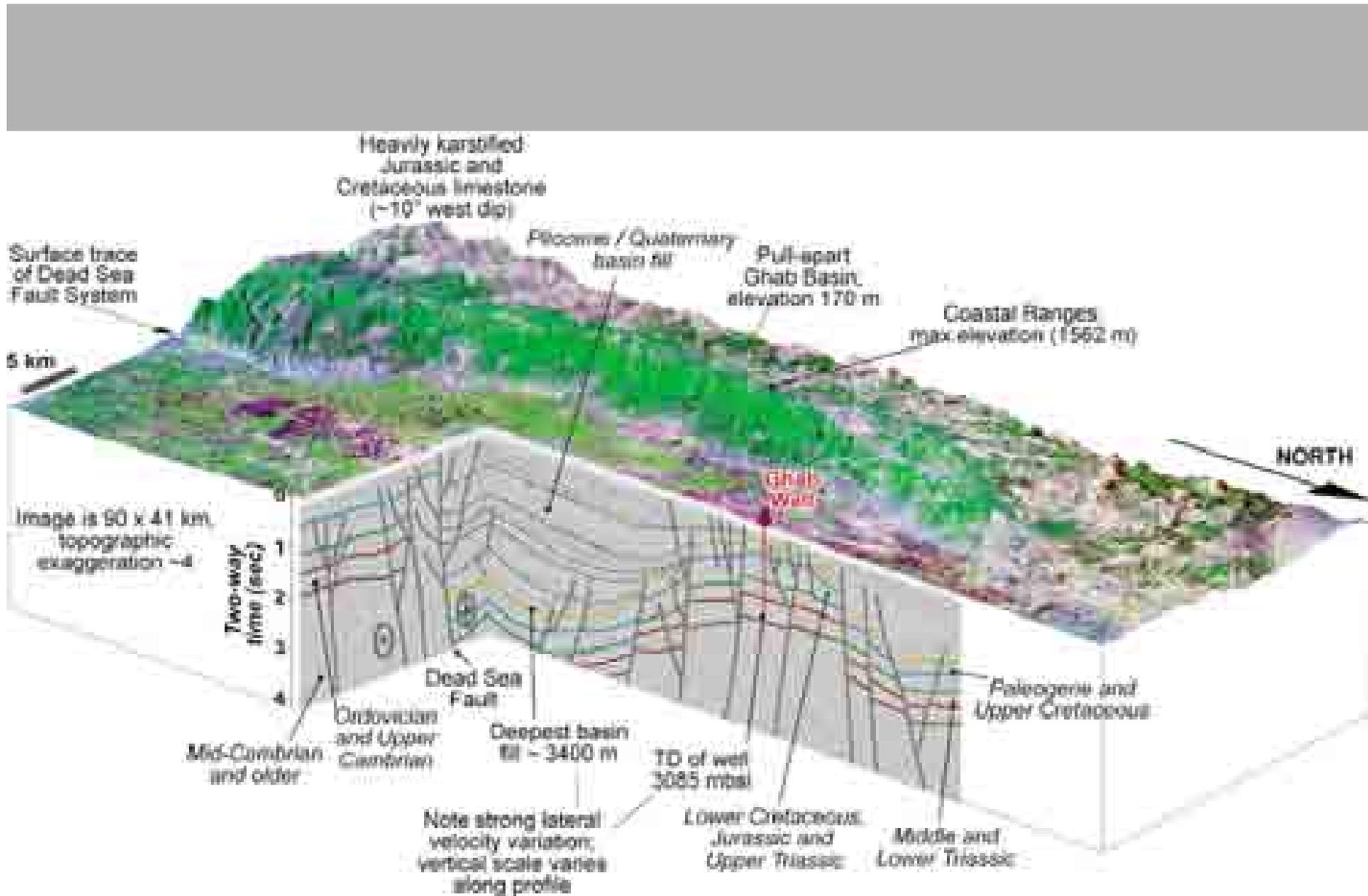


<http://www.ags.gov.ab.ca/energy/cbm/photos/index.html>

Examples:

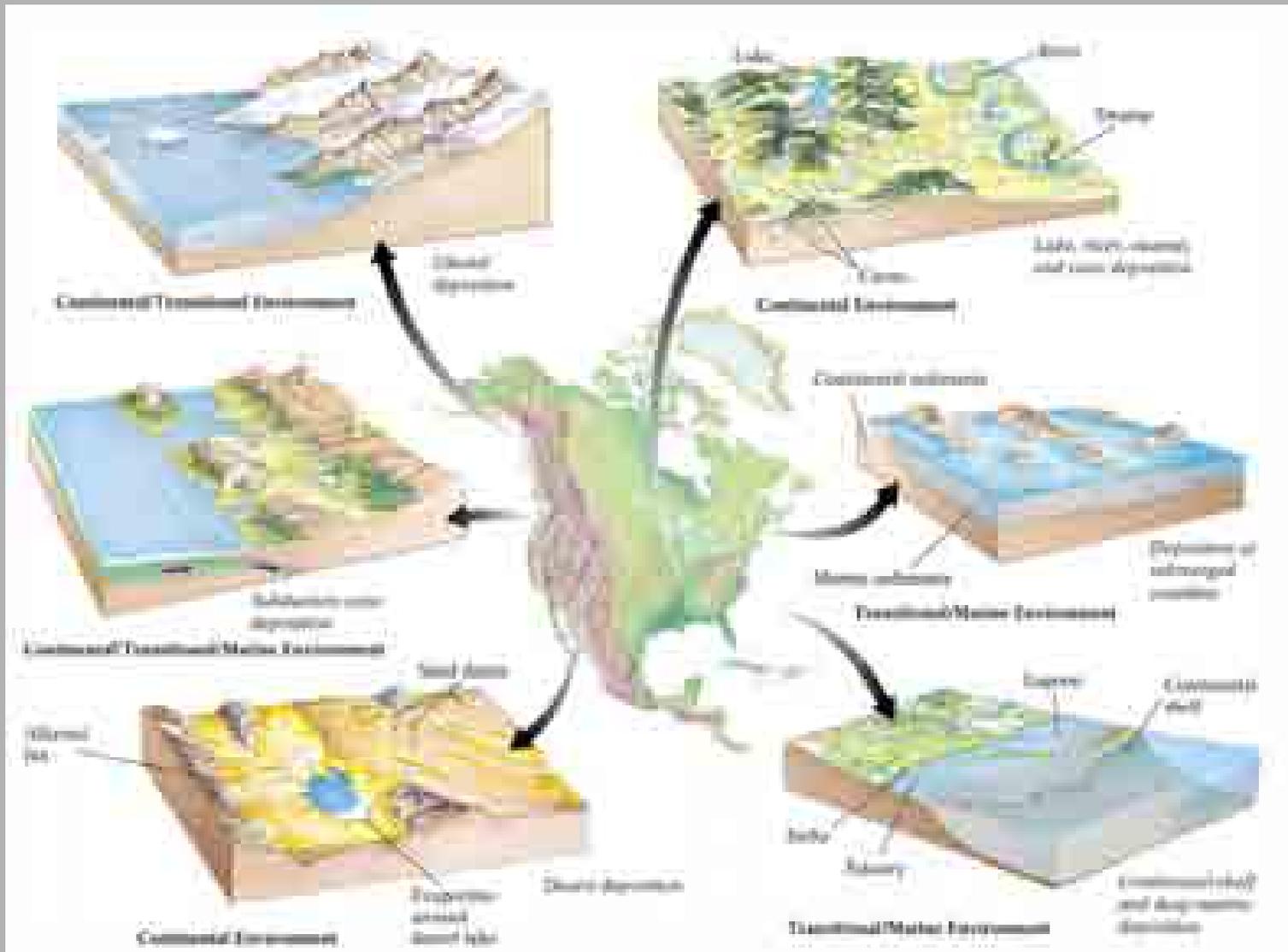


http://www.ga.gov.au/image_cache/GA1782.gif



<http://atlas.geo.cornell.edu/people/brew/Figures/Chapter5/ghab.jpg>

Common geological environments



Chernicoff & Whitney (2002)