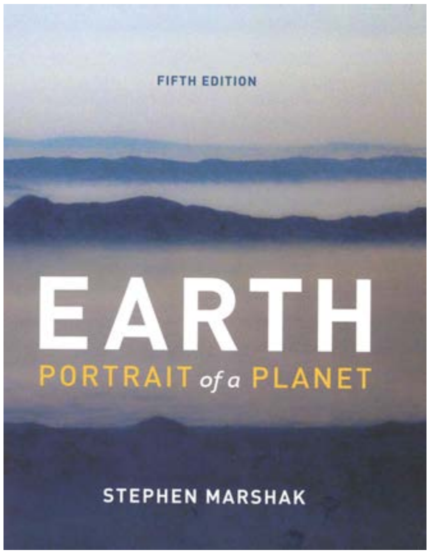
CE/SC 10110-20110

A Surface Veneer:
Sediments and Sedimentary Rocks



Earth

Portrait of a Planet

Fifth Edition

Chapter 7

Sediments and Sedimentary Rocks

Sedimentary rocks form layers like the pages of a book. The layers record a history of ancient events and ancient environments on the ever-changing face of planet Earth. Like a book, this history can be read by geologists.

Sediments and Sedimentary Rocks

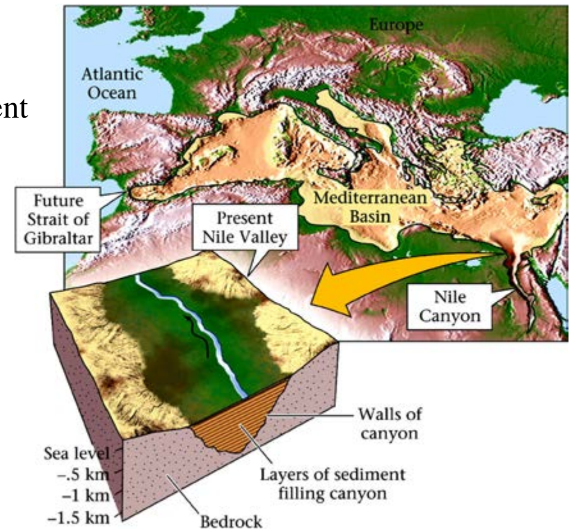
Sediment: sand, mud, gravel, accumulations of shells, halite, gypsum, gravel.

Sedimentary Rock: forms at or near the surface of the Earth by precipitation of minerals from water, by growth of skeletal material in organisms, or by the cementing together of shell fragments or loose grains derived from pre-existing rock.

Layers of sediment and sedimentary rock record ancient events and ancient environments.

Study of sediments shows that the Nile River once flowed through a canyon bigger than the Grand Canyon - now it is flowing close to sea level.

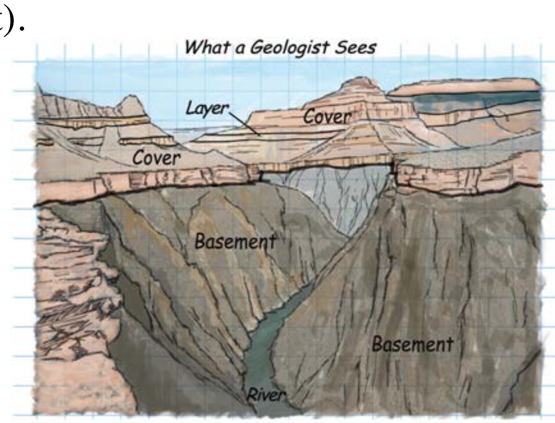
In order for this to occur, "base level" must have been lowered.



Evaporite deposits underlie the floor of the Mediterranean Sea - must have dried up several times in the past (lower sea level).

Sediments & Sedimentary Rocks

Only occur in the upper part of the crust - form a veneer or cover over older, metamorphic rocks (basement).



Can accumulate several kilometers in sedimentary basins.

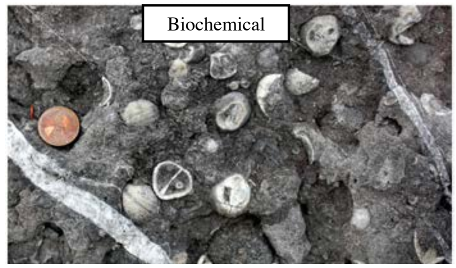
Contain the bulk of Earth's energy resources.

Some sediments transform into soil - essential for life.

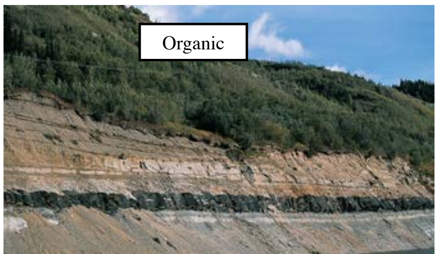
Sedimentary Rocks

Four major classes:

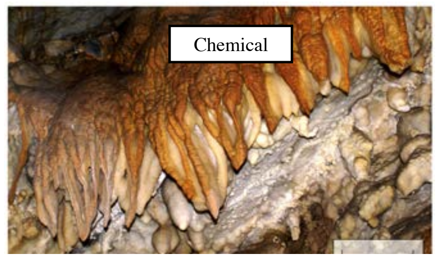
1) **Clastic**: cemented solid fragments/ grains from pre-existing rocks.



2) **Biochemical**: made up of the shells of organisms.

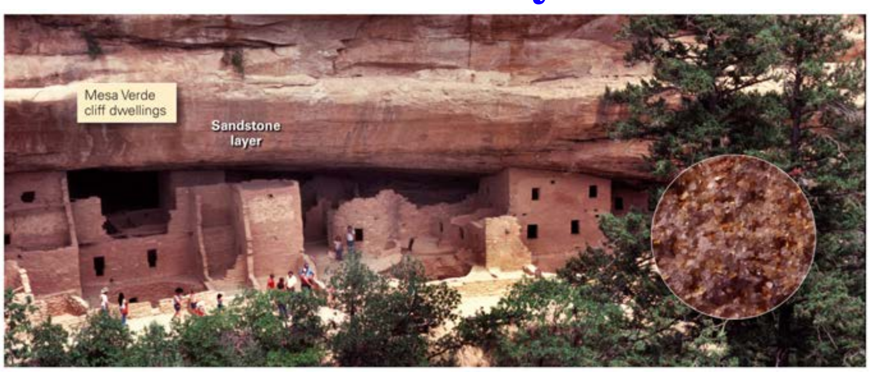


3) **Organic**: carbon-rich sedimentary rocks.

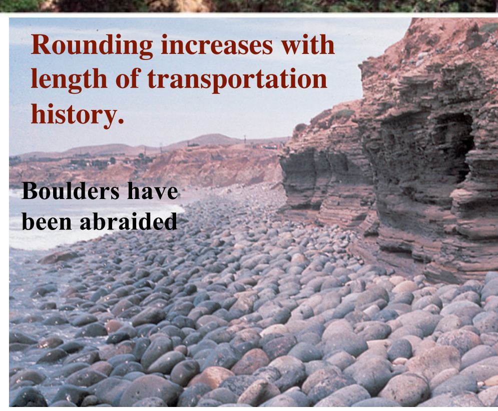


4) **Chemical**: made up of minerals precipitated from water.

Clastic Sedimentary Processes

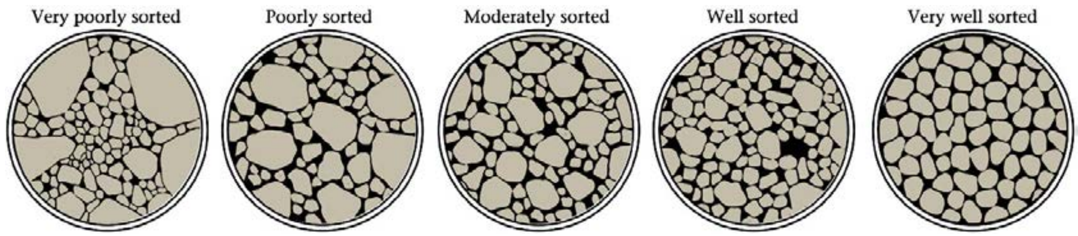


Transportation: Rounding - increases with length of transportation history.



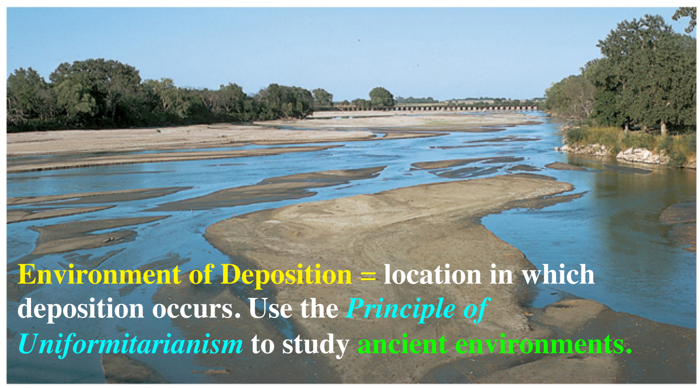
Clastic Sedimentary Processes

Sorting: increases with length of transportation history (weaker minerals broken down).



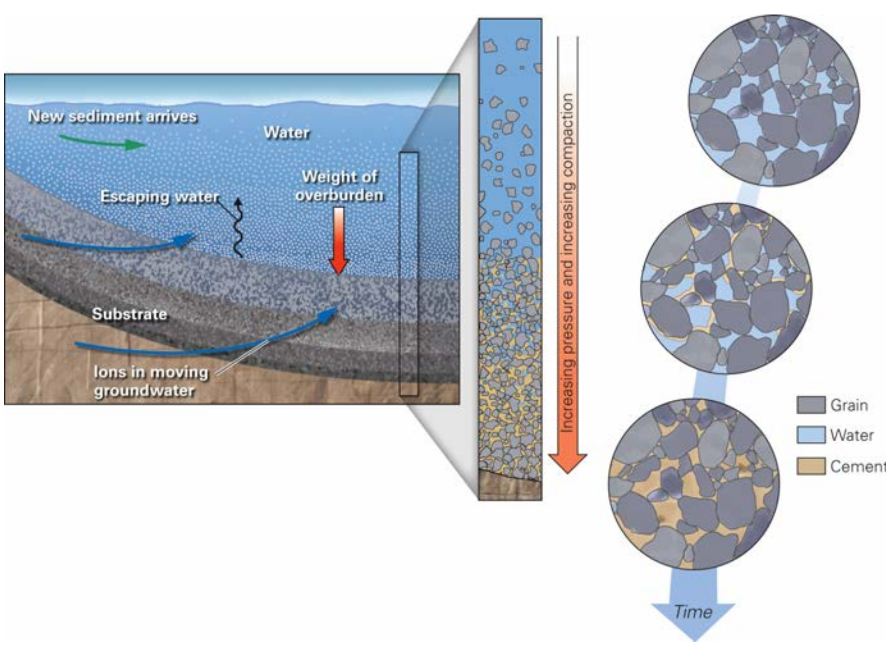
Deposition: any process that lays down material.

Environment of Deposition: location in which deposition occurs. Use the ***Principle of Uniformitarianism*** to study ancient environments.

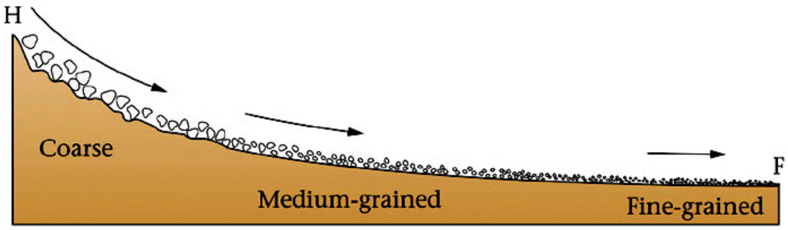


Clastic Sedimentary Processes

Preservation: deposition and burial in a basin. Reworking degrades preservation.
Lithification: compaction & cementation.



Clastic Sedimentary Processes



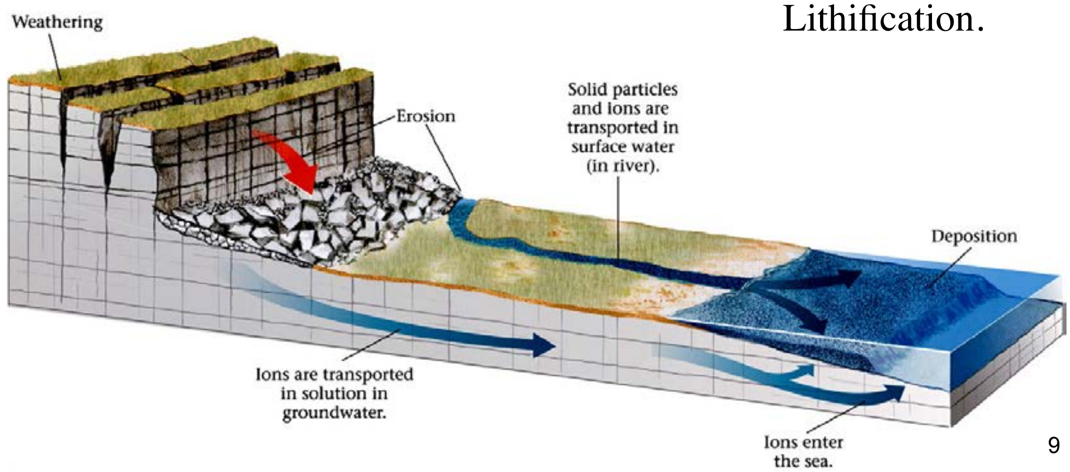
Weathering;

Erosion;

Transportation;

Deposition;

Lithification.



Describing & Classifying Clastic Sedimentary Rocks

Clast Size: Size of the bits.

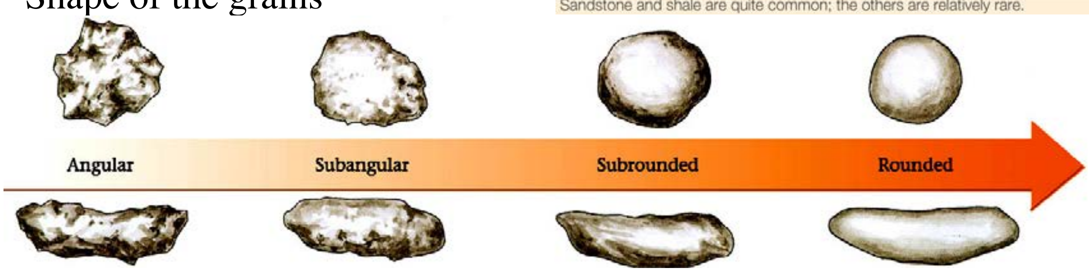
Clast Composition: rock or lithic fragments + mineral fragments. Latter is finer grained rocks.

Angularity/Sphericity: Shape of the grains

Sediment Particles & Clastic Sedimentary Rocks

Diameter (mm)	Sediment		Sedimentary Rock
256	Boulder	Gravel	**Breccia** (angular particles) or **Conglomerate** (rounded particles)
64	Cobble		
2	Pebble		
1/16	Sand		**Sandstone**
1/256	Silt	"Mud"	Siltstone (mostly silt)
	Clay		**Shale** or mudstone (mostly clay)

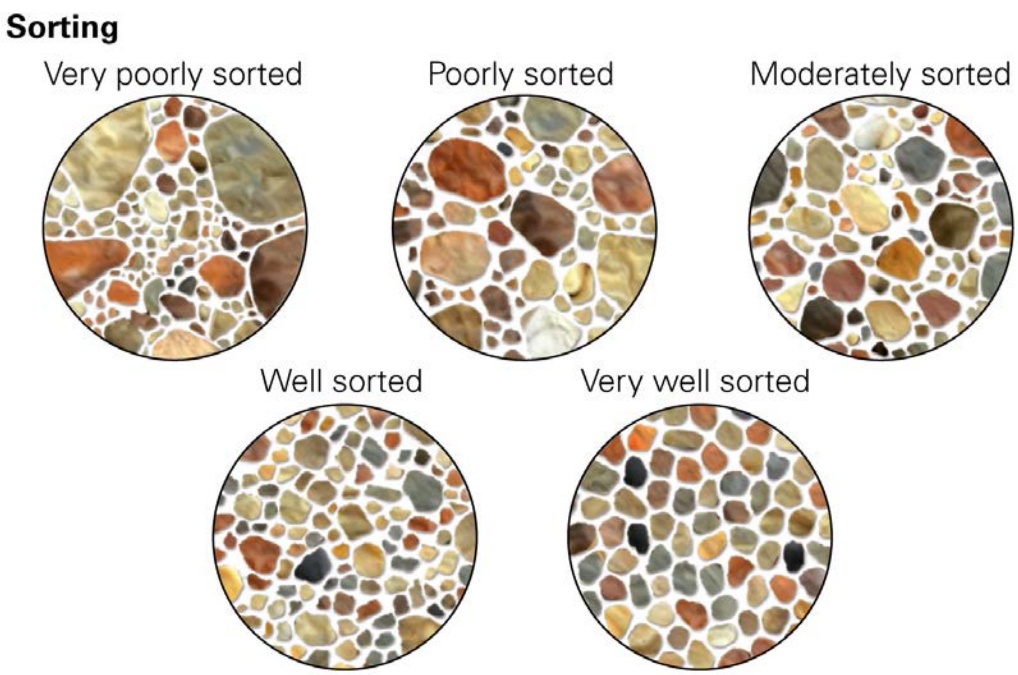
Sandstone and shale are quite common; the others are relatively rare.



Sorting: Composition, size, and shape

Character of the Cement: Composition.

Describing & Classifying Clastic Sedimentary Rocks



Describing & Classifying Clastic Sedimentary Rocks

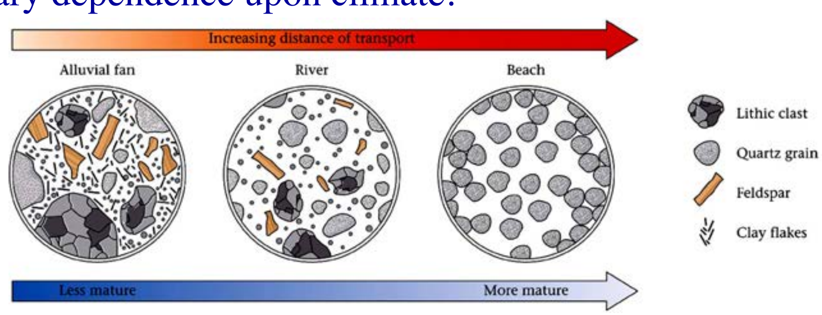
Grains: main or large “bits” of sediment
Matrix: fine interstitial particles.

Grain and matrix composition depends upon:

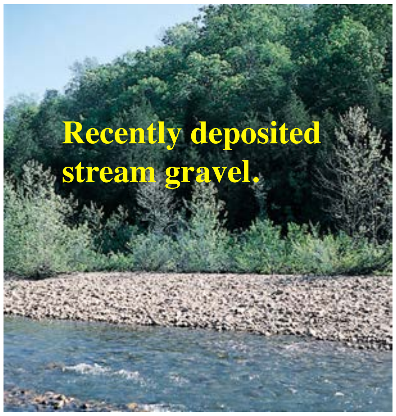
Source material – what type of rock is being weathered and eroded?

The chemical and physical properties of the minerals – stronger ones are at the bottom of Bowens Reaction Series (e.g., Quartz).

Degree of weathering and erosion processes to transport – secondary dependence upon climate.



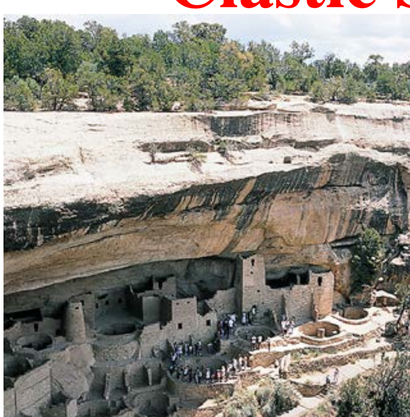
Clastic Sedimentary Rocks

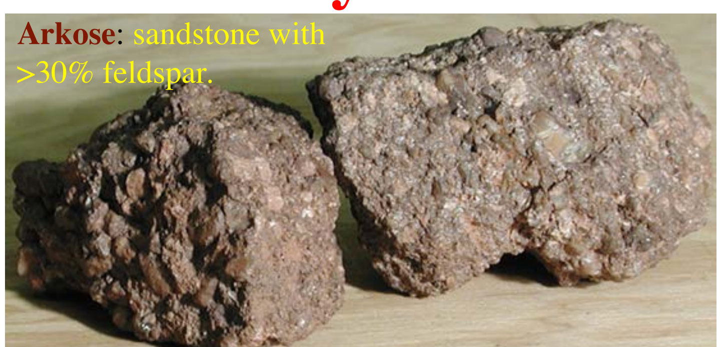


Breccia: coarse grained, angular fragments.

Conglomerate: coarse grained, rounded fragments.

Clastic Sedimentary Rocks





Arkose: sandstone with >30% feldspar.

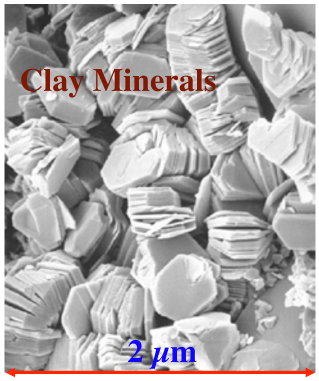
Sandstone: predominantly quartz.

Clastic Sedimentary Rocks

Siltstone: finer grained sandstone.

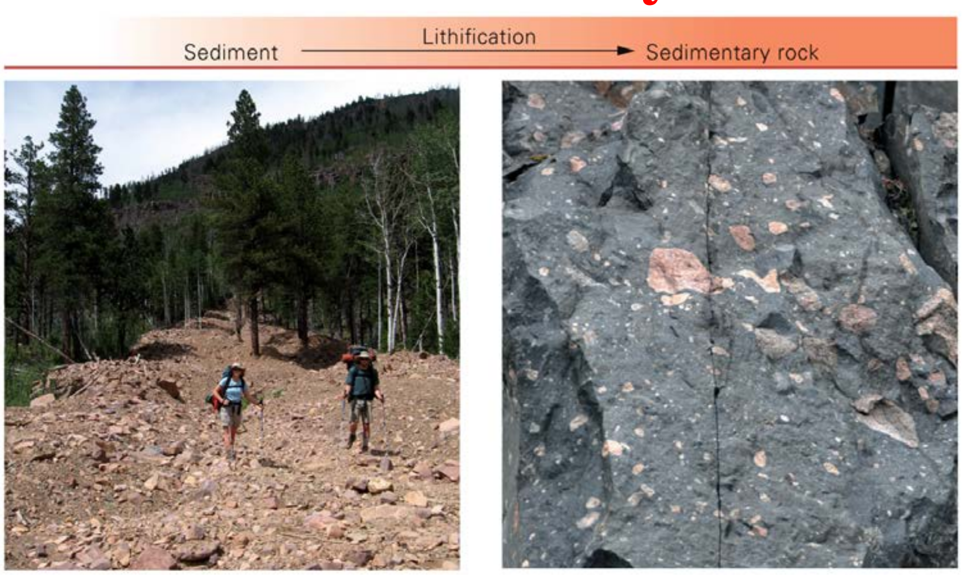
Shale: lithified mud (fissile).

Mudstone: lithified mud.



Mica "wannabees"

Clastic Sedimentary Rocks



Diamictite: forms from debris flows (slurries of mud and larger clasts) on land, under water, or under ice. Clasts of all sizes.

Wacke (usually Greywacke): submarine avalanche deposit.

Wacke and Diamictite are immature deposits.

Biochemical/Organic Sedimentary Rocks

Calcium Carbonate: Calcite, Aragonite (polymorphs).
Forms shells, corals, etc
Silica: also used for shells.
Biochemical deposits form from these when the critter dies.

Organic Deposits: plant/organism remains.

Biochemical Limestone

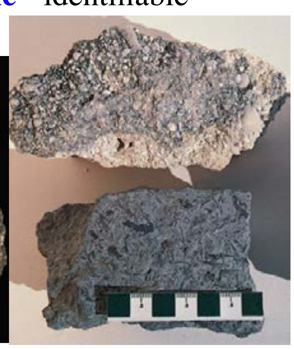
A limestone composed of $CaCO_3$ derived from the hard parts of once living organisms.
Hard parts = calcite and aragonite (polymorphs of $CaCO_3$) - the latter is metastable and reverts to the calcite structure.

Four common types:
Coquina - made up entirely of shell fragments;
Fossiliferous Limestone - identifiable shells/shell fragments;
Micrite - lime mud (tiny calcite grains);
Chalk - plankton shells.

Biochemical Sedimentary Rocks

Four common types:

Fossiliferous Limestone - identifiable shells/shell fragments.



Coquina - made up entirely of shell fragments.

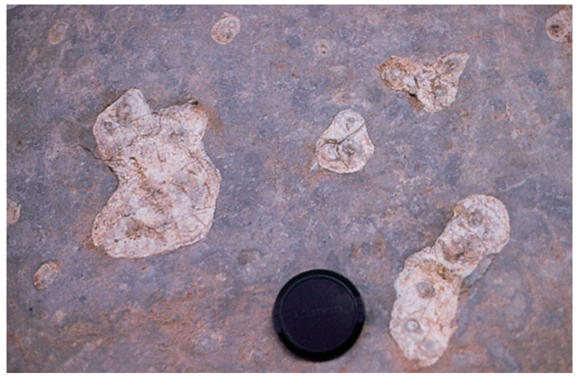
Chalk - plankton shells.

Micrite - lime mud (tiny calcite grains);

Biochemical Sedimentary Rocks

Biochemical Chert

Radiolaria and Diatoms (types of plankton) have silica shells.
Skeletons accumulate in silica-rich “oozes” on sea floor (pelagic).
Chert = cryptocrystalline (can see individual grains).
Can form beds or nodules, depending upon concentration.



Organic Sedimentary Rocks

Coal

Black rock, > 50% carbon

Accumulation of dead plants (forest or swamp setting - no oxidation).

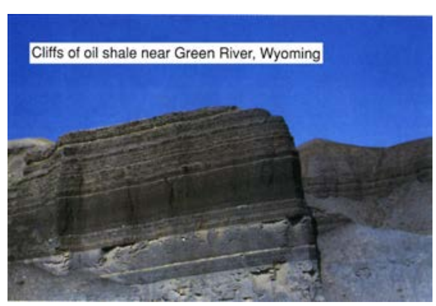
Burial compacts the deposit and heat drives of volatiles, concentrating the carbon.

Oil Shale

Fat and protein derivatives (from plankton/algae) can be incorporated in muds and form organic-rich shales. Over time (and related to burial depth) the organics may transform to oil = oil shale.

If just organic rich = black shale.

Collectively: Carbonaceous rocks.



Chemical Sedimentary Rocks

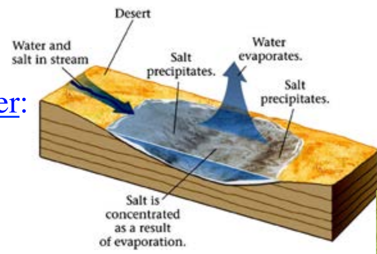
Precipitates from solution - often called "evaporite deposits".

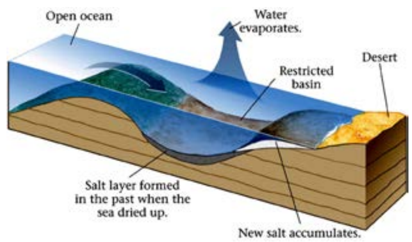
E.g., the Great Salt Lake, Utah, was once much bigger - Lake Bonneville.

Change in tectonic regime can limited water supply (e.g., Mediterranean Sea).

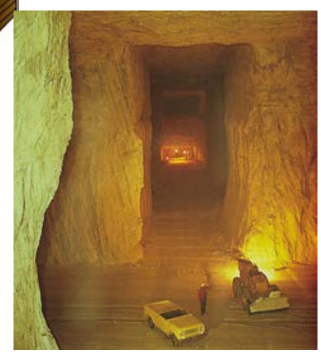
Precipitation sequence from seawater:

Calcite ($CaCO_3$)
Anhydrite ($CaSO_4$)
Gypsum ($CaSO_4.H_2O$)
Halite (NaCl)
Sylvite (KCl)





Salt Mine



Chemical Sedimentary Rocks

Also, limestone, oolitic limestone (with "ooliths").

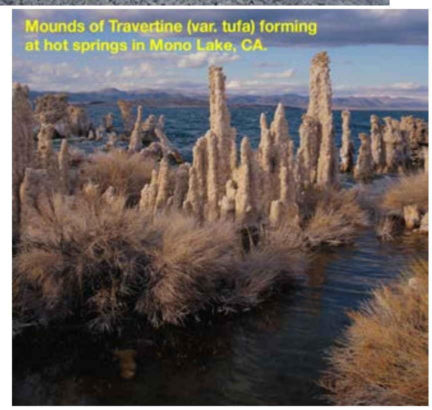
Oolitic Limestone:
Ooliths/ooids and Pisoliths formed by current action. Center = sand grain, shell fragment, etc.

Chemical Sedimentary Rocks

Travertine (with flow structures formed in caves).

Precipitated from groundwater that "degasses" - loses some CO_2, which makes it less acidic so it holds less dissolved $CaCO_3$.
Microbes live where travertine forms and may contribute to the precipitation.
Some travertines (a type called "**tufa**") contain abundant large pores or "vugs".

Also formed at hot springs.



Chemical Sedimentary Rocks

Dolostone (Mg-rich limestone).

Formed by secondary partial replacement of Ca with Mg in limestones via percolating groundwater to give $Ca,Mg(CO_3)_2$.

Dolostone looks like limestone, except it has a sugary texture, and often weathers to a buff, tan color.

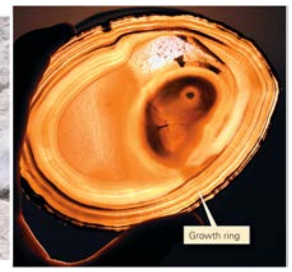
Chemical Sedimentary Rocks

Chert (microcrystalline quartz).

Silica precipitated from percolating groundwater can replace Calcite in limestones to give chert nodules/horizons.

Petrified wood - percolating groundwater replaces cellulose. Can preserve growth rings. Forms when silicic ash covers a forest.

Black chert = ***flint***;
Red chert = ***jasper***;
Agate = grown in hollows - layers reflect impurities.



Diagensis: term used for all physical, chemical, and biological processes that transform sediment (clastic, biochemical, inorganic) into sedimentary rock, and that alter characteristics of sedimentary rock once the rock has formed.

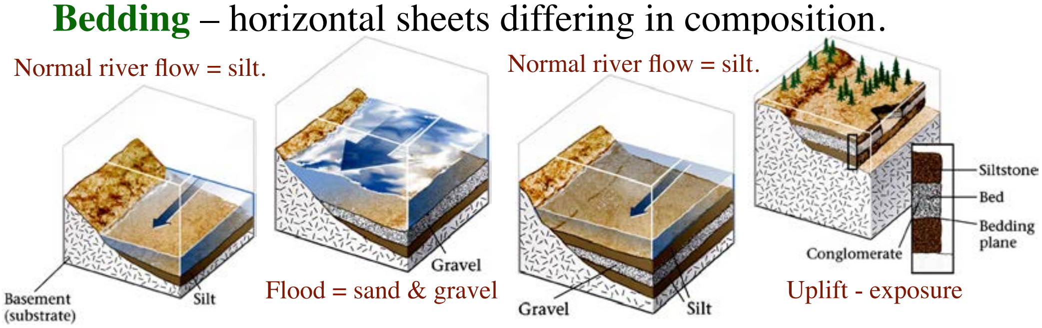
Sedimentary Structures

Give evidence of depositional environments.
Sedimentary rocks are deposited originally in horizontal beds.
Later deformation causes the beds to be inclined.

Which was the original way up?
Structures can give that information.

Sedimentary structures can give idea of ***paleocurrents***.

Bedding – horizontal sheets differing in composition.

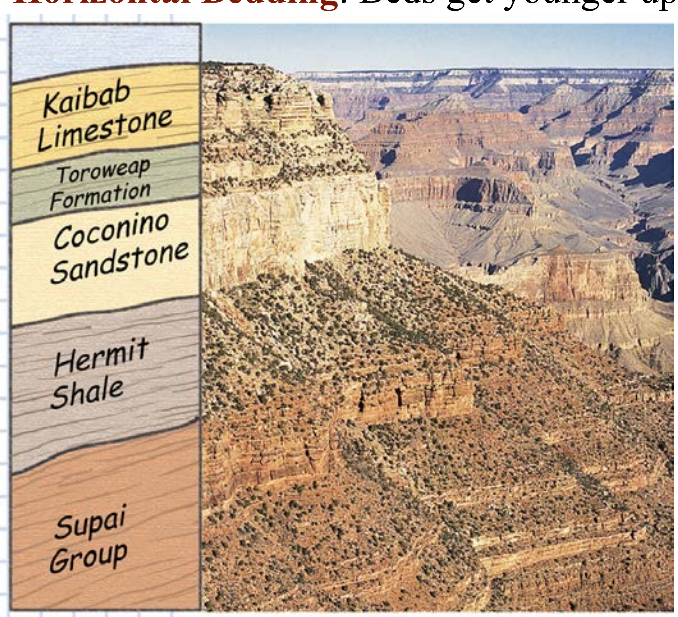


Several beds together = **strata**; study of strata = **stratigraphy**.

Sedimentary Structures

Sedimentary Structures

Horizontal Bedding: Beds get younger upward.



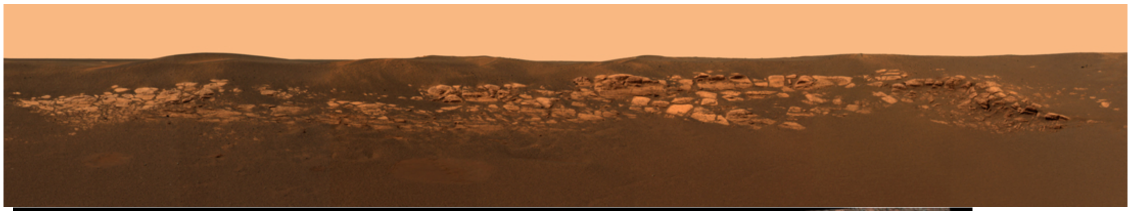
Stratigraphic Formation (or **Formation**): sequence of similar strata traceable across a wide area (made up of several beds).

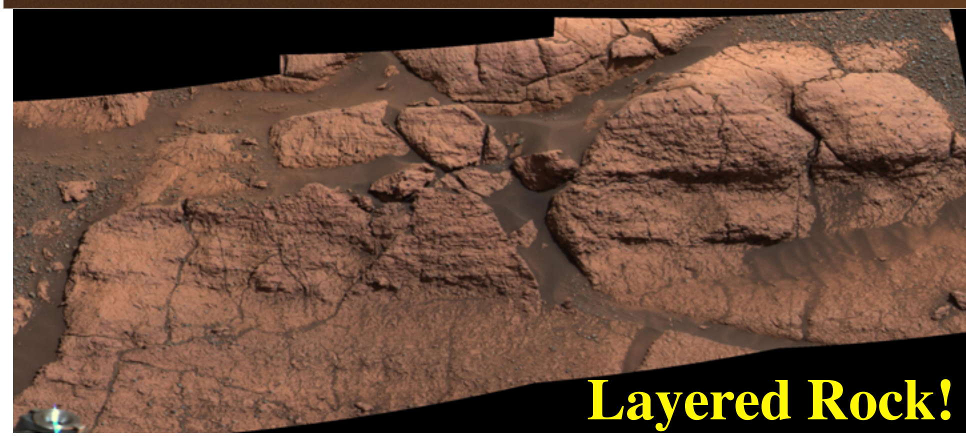
Stratigraphic Group: A succession of two or more contiguous or associated formations with significant and diagnostic lithologic properties in common.

Bioturbation: action of burrowing organisms - can destroy bedding.

Sedimentary Structures

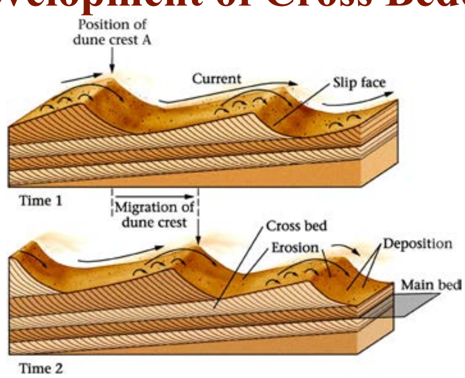
OPPORTUNITY- Meridiani Planum

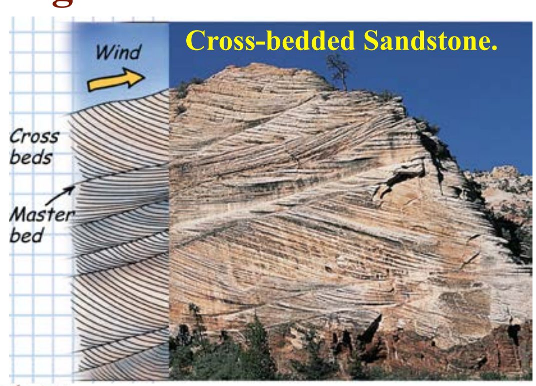


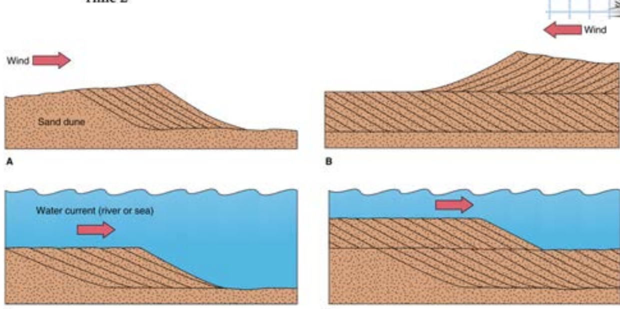


Sedimentary Structures

Development of Cross Bedding



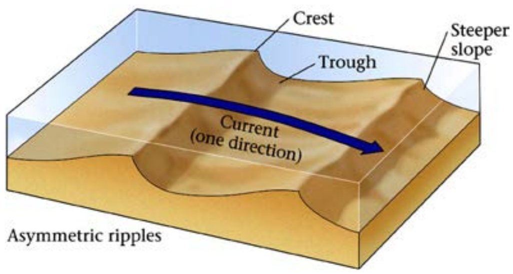


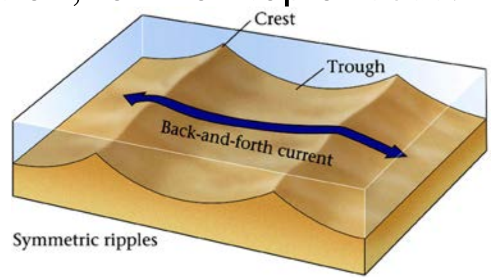


Denser material/minerals

Sedimentary Structures

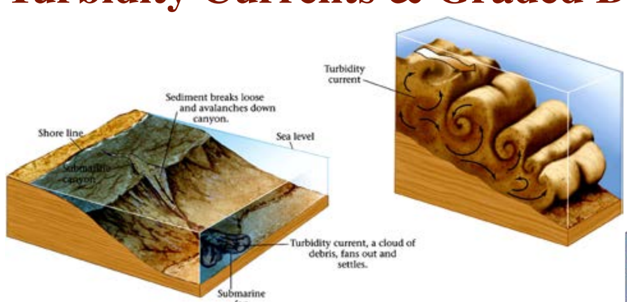
Ripple Marks – wave action, form on top of beds.



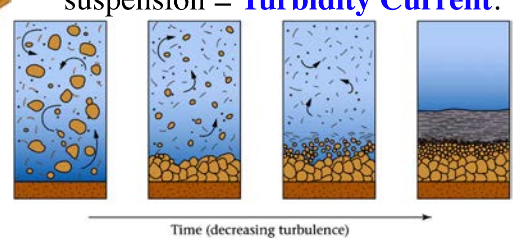


Sedimentary Structures

Turbidity Currents & Graded Beds

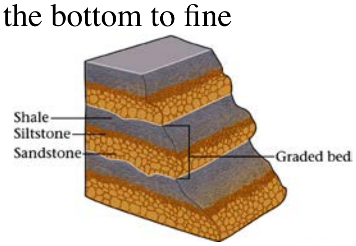


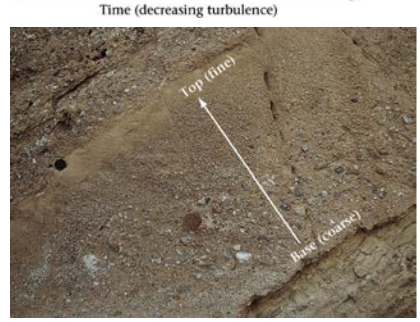
Rapid movement of sediment down the continental slope (earthquake or storm may be the trigger). This moving submarine suspension = **Turbidity Current**.



When the slope becomes gentler or the turbidity current spreads out, the movement slows and deposition occurs.
Largest particles settle first, then the finer material = **Graded Bedding** (beds grade from coarse grained at the bottom to fine grained at the top).

Turbidite = sequence of graded beds.

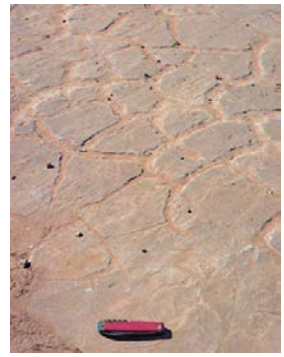




Sedimentary Structures

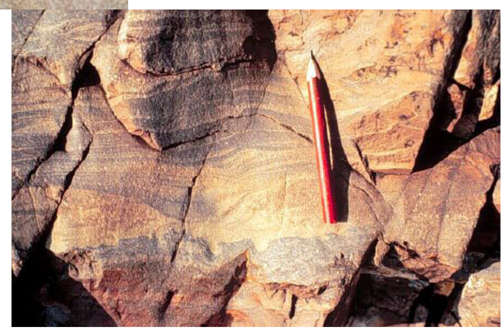
Bed Surface Markings

Mud Cracks - drying out of the top of a bed. The cracks later become filled with sediment and the structure is preserved.



Fossils.

Load (Lode) Casts - These are bulbous protrusions that are formed when compaction causes sediment to be pushed downward into softer sediment



Sedimentary Structures

Bed Surface Markings

Scour Marks - currents flowing over a sediment can scour out small troughs.

Tracks and Trails - marks left by organisms moving across the surface.

Flute Casts (Sole Marks) - Flutes are elongated depressions that form on the bottom of a body water as the current erodes. The flutes may form a mold into which new sediment is deposited. Preservation of the overlying sediment as a cast result in flute casts, which are sometimes referred to as sole marks. Flute casts are excellent indicators of current direction and tops/bottoms of beds.

Sedimentary structures are important for determining the way up of a sequence of strata, current direction, climate, and environment of deposition.

Sedimentary Environments

Terrestrial (Nonmarine) Environments

Sediments deposited in these environments may oxidize ("rust") when undergoing lithification in oxygenated water or if in contact with air. Such beds may be called "**Redbeds**",

Glacial Environments - unsorted sediments deposited at the end of a glacier = ***glacial till*** or ***tillite*** if lithified. Generic name = ***diamictite***. Clasts of all sizes found. Immature deposits.

Mountain Stream Environments - lot of energy and abrasion. Coarse conglomerates would be common here. Relatively immature deposits.

Sedimentary Environments

Terrestrial (Nonmarine) Environments

Alluvial Fan Environments - mountain fronts. Deposit occurs because fast flowing stream spreads out. Conglomerate, arkose, and sandstone are typical rock types. Relatively immature.

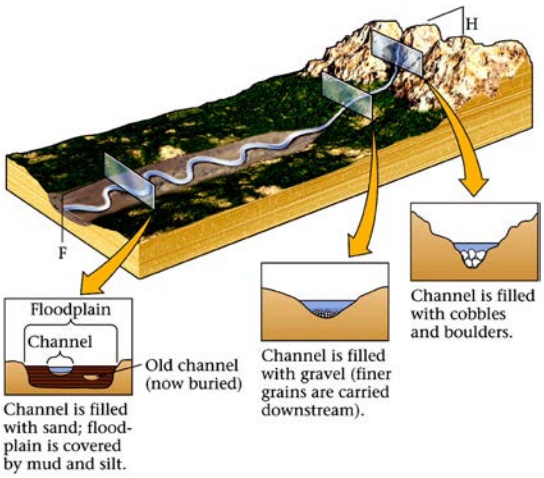
Sand Dune Environments - deserts. Cross-bedded sandstones.

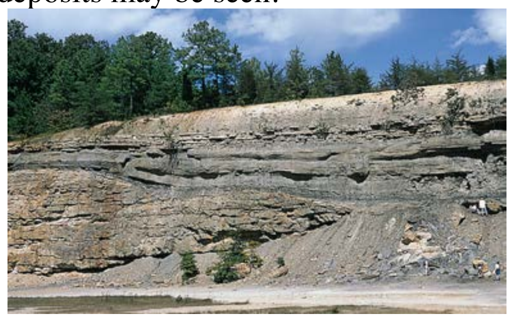
Lake Environments - coarse material typically settles out close to shore. Only fine material to the center. Finely laminated shales are typical. Lake sediments are also called "***lacustrine sediments***".

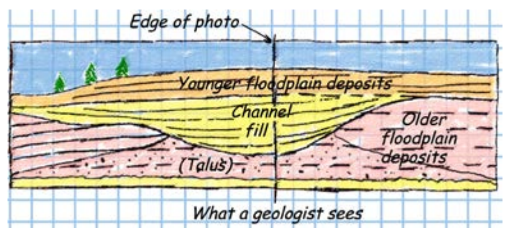
Sedimentary Environments

Terrestrial (Nonmarine) Environments

River Environments - fine material deposited on flood plains and may develop mud cracks. Rivers transport mud, silt, sand, and even boulders in times of flood. Finer sediment may contain ripple marks and small cross beds. River sediments are also called "***fluvial sediments***". Channel deposits may be seen.
Relatively mature sediments.







Sedimentary Environments

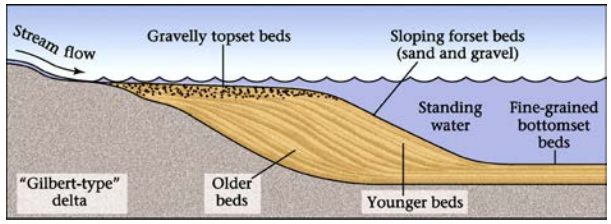
Terrestrial (Nonmarine) Environments

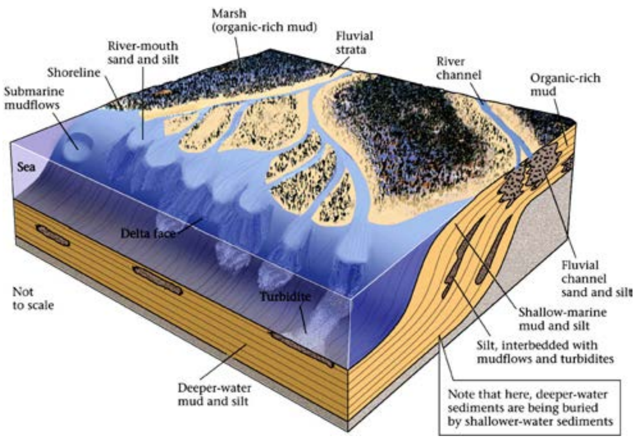
Glacial Environments – poorly sorted material deposited in moraines (sinuous hills) or layers blanketing the terrain.

Sedimentary Environments

Marine Environments

Marine Delta Environments - deltas contain 3 components: **topset** beds, **forset** beds and **bottomset** beds.



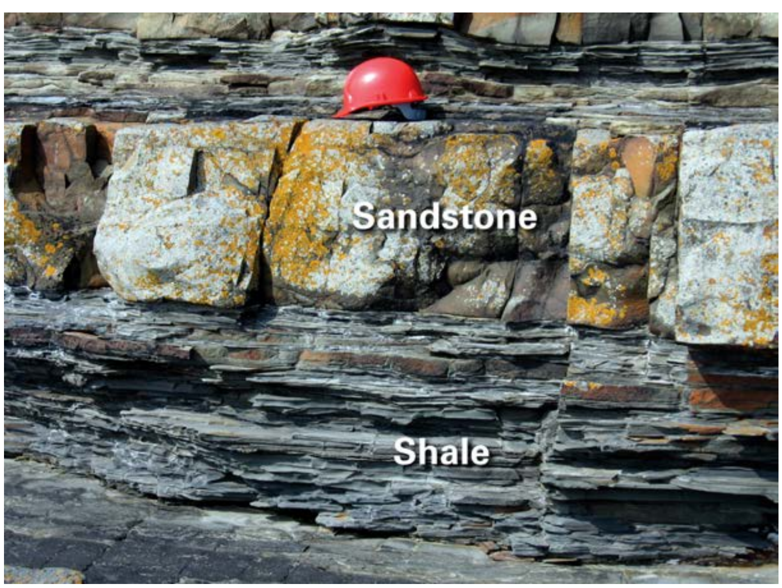


Large deltas have both marine and fluvial environments. Turbidity currents may occur as material slips down the seaward-sloping face of the delta. Sea level changes may cause the delta to migrate. Important environment for forming coal.

Sedimentary Environments

Marine Environments

Shallow-Marine Clastic Deposits - in deeper water, wave action is not so intense, so finer sediment accumulates. Fine-grained, well-sorted, well-rounded silt. Fossiliferous and may contain bioturbation structures.

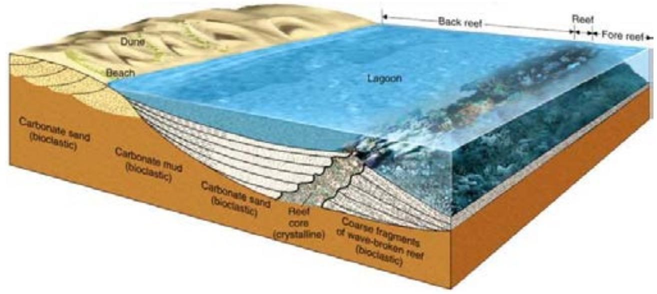


Sedimentary Environments

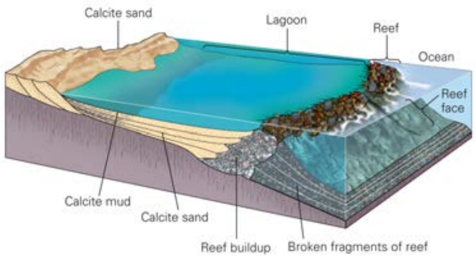
Marine Environments

Coastal Beach Sands - well-sorted, medium grained sandstone +/- ripple marks. Constant wave action removes weaker materials.

Shallow-Water Carbonate Environments - warm, clear water required for carbonate to accumulate (far from river mouths). Margins of tropical islands are ideal.



Can develop reefs. Beach deposits will form fossiliferous limestone and quiet lagoons will form micrite.



Sedimentary Environments

Marine Environments

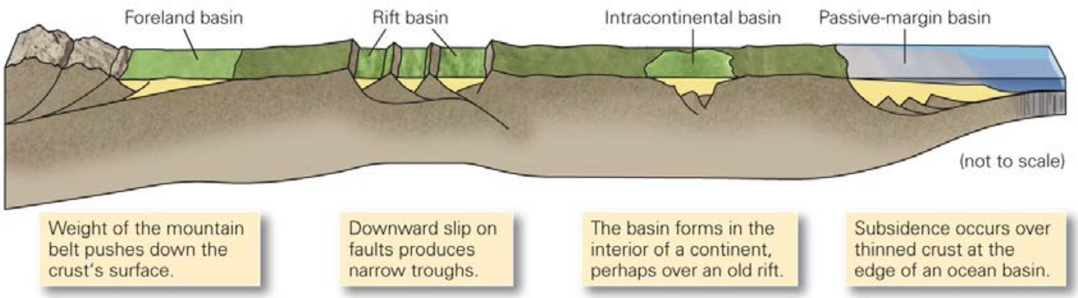
Deep-Marine Deposits - turbidites along continental slope-abyssal plain transition. On the abyssal plain: shales/mudstone, chalk, and bedded cherts (the latter two are due to accumulation of plankton remains.

Sedimentary Basins

Thick sedimentary sequences (up to 20 km) accumulate in sedimentary basins - important for oil exploration. For basins to form, subsidence is required.

Rift Basins: stretching of the continental lithsophere produces a low-lying basin next to hills/mountains. Also, when the hot lithosphere, heated by the asthenosphere that is now closer to the surface, cools down it increases in density and promotes “thermal subsidence”.

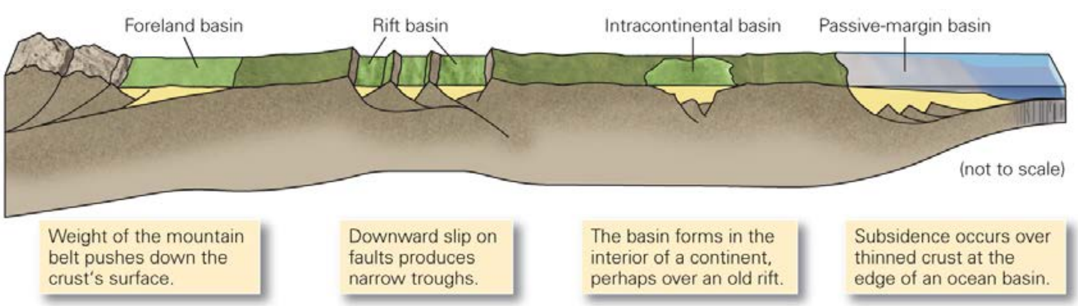
Passive Margin Basins: continued thermal subsidence after rifting - passive margin is not a plate margin.



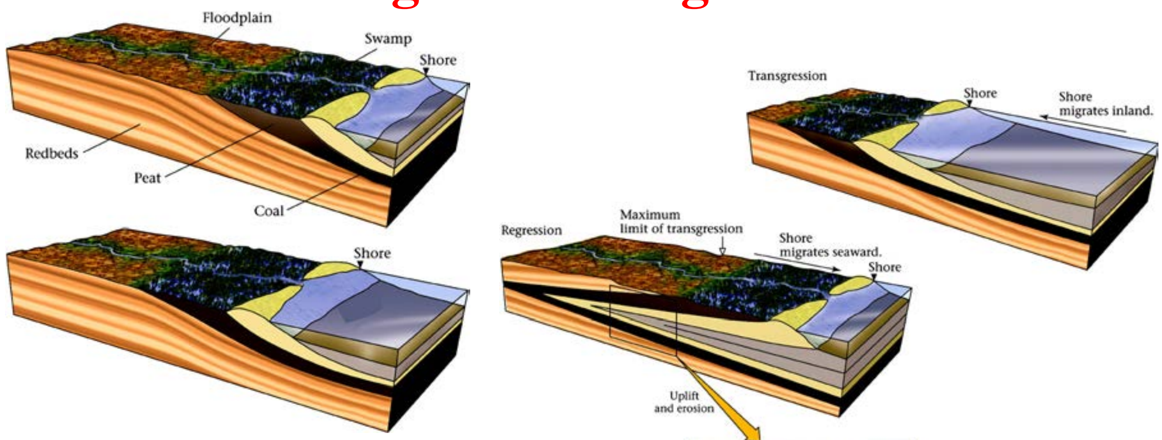
Sedimentary Basins

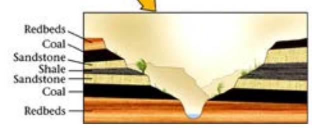
Intracontinental Plate Margin Basins: these initially develop because of thermal subsidence associated with a failed rift. Subsidence and sediment accumulation may occur for hundreds of millions of years. This occurred beneath Illinois and Michigan where up to 7 km of sediment accumulated.

Foreland Basins: form on the continent side of a mountain belt. As the mountain belt grows, large slices of rock are piled up by low-angle “thrust” faults. This depresses the lithosphere and creates a wedge-shaped basin adjacent to the mountain belt. Fluvial and deltaic strata accumulate.



Transgression-Regression





Transgression: shoreline --> inland.
Regression: shoreline --> seaward.

Can see cyclic sedimentation from terrestrial sediments, to transitional deltaic (swamp) deposits, to shallow marine, to deep marine, and back again.

Summary

Sediments & Sedimentary Rocks.

Weathering: Mechanical/Physical & Chemical (biological overlaps both of these).

Spheroidal Weathering - an example of physical & chemical weathering working together.

Soil Development: Soil Horizons, Factors Controlling Soil Development, Soil Types.

Clastic Sedimentary Rocks: Clastic Sedimentary Processes.

Describing & Classifying Sedimentary Rocks.

Types of Clastic Sedimentary Rocks.

Biochemical Sedimentary Rocks.

Organic Sedimentary Rocks.

Chemical Sedimentary Rocks.

Sedimentary Structures.

Sedimentary Environments.

Sedimentary Basins.

Transgression - Regression.