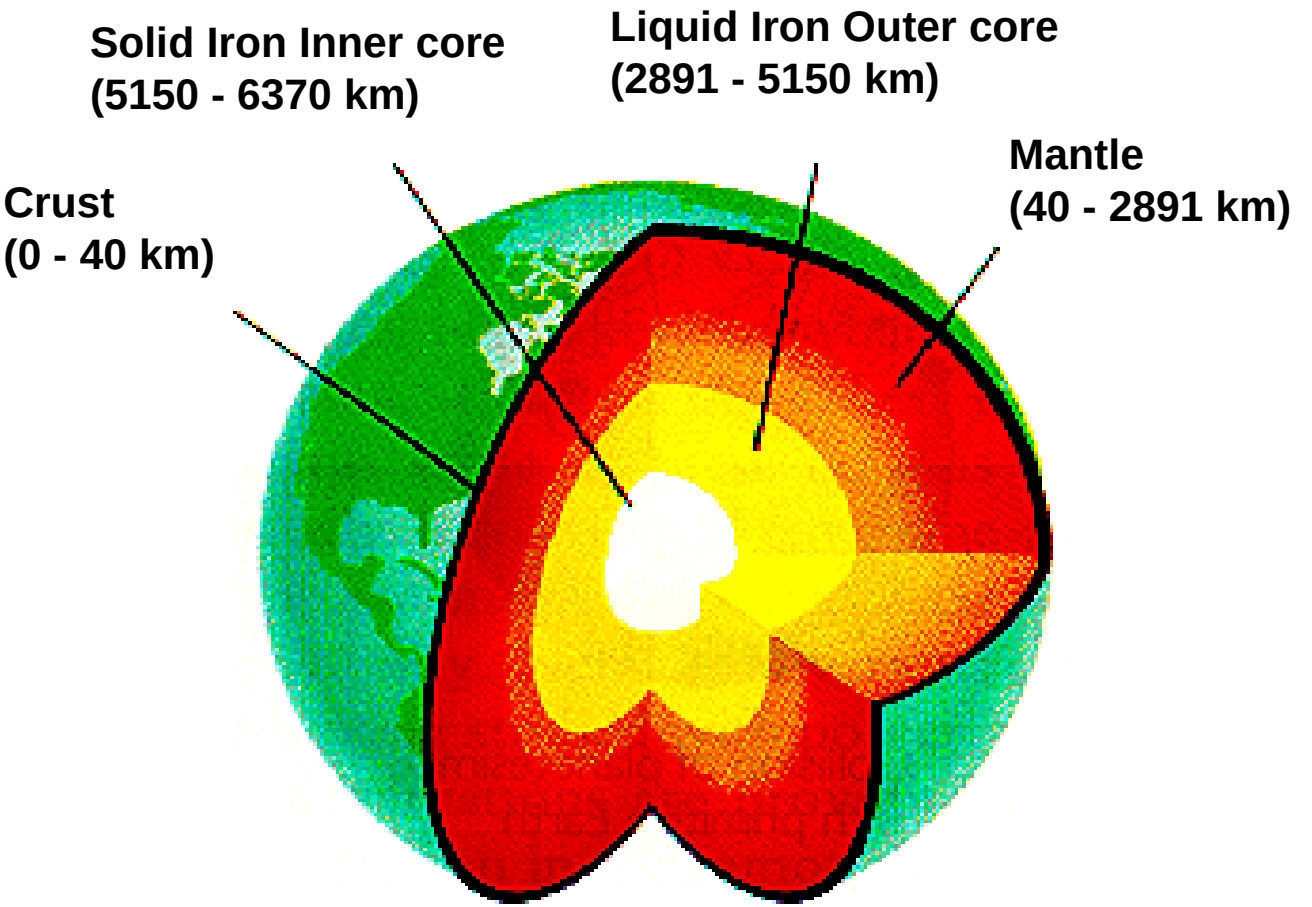
Basic Geology

Geology

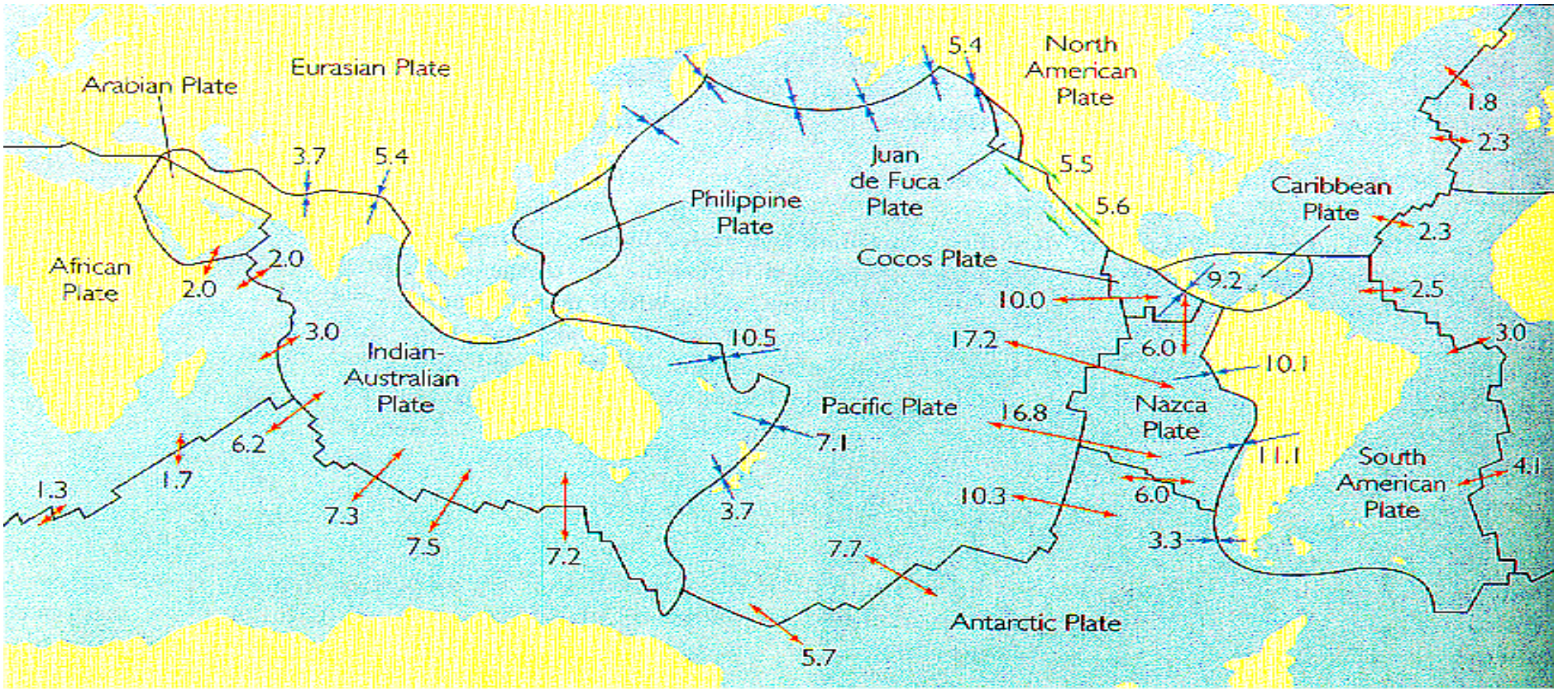
- The Earth
- Structural geology
- Sedimentary geology
- Petroleum geology
- Reservoir characteristics

Earth Model

- Homogeneous
- Layered structure

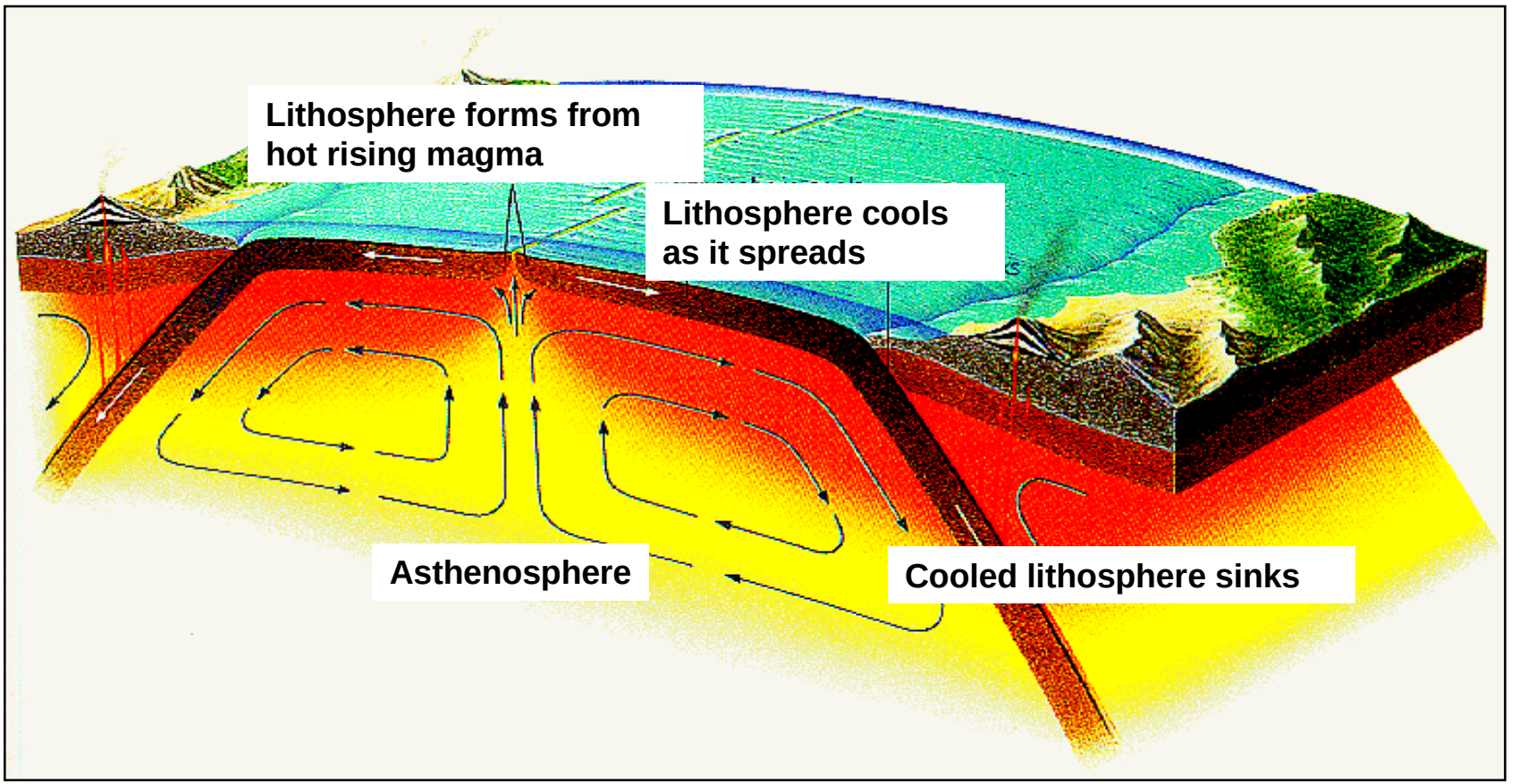


Crustal Plates

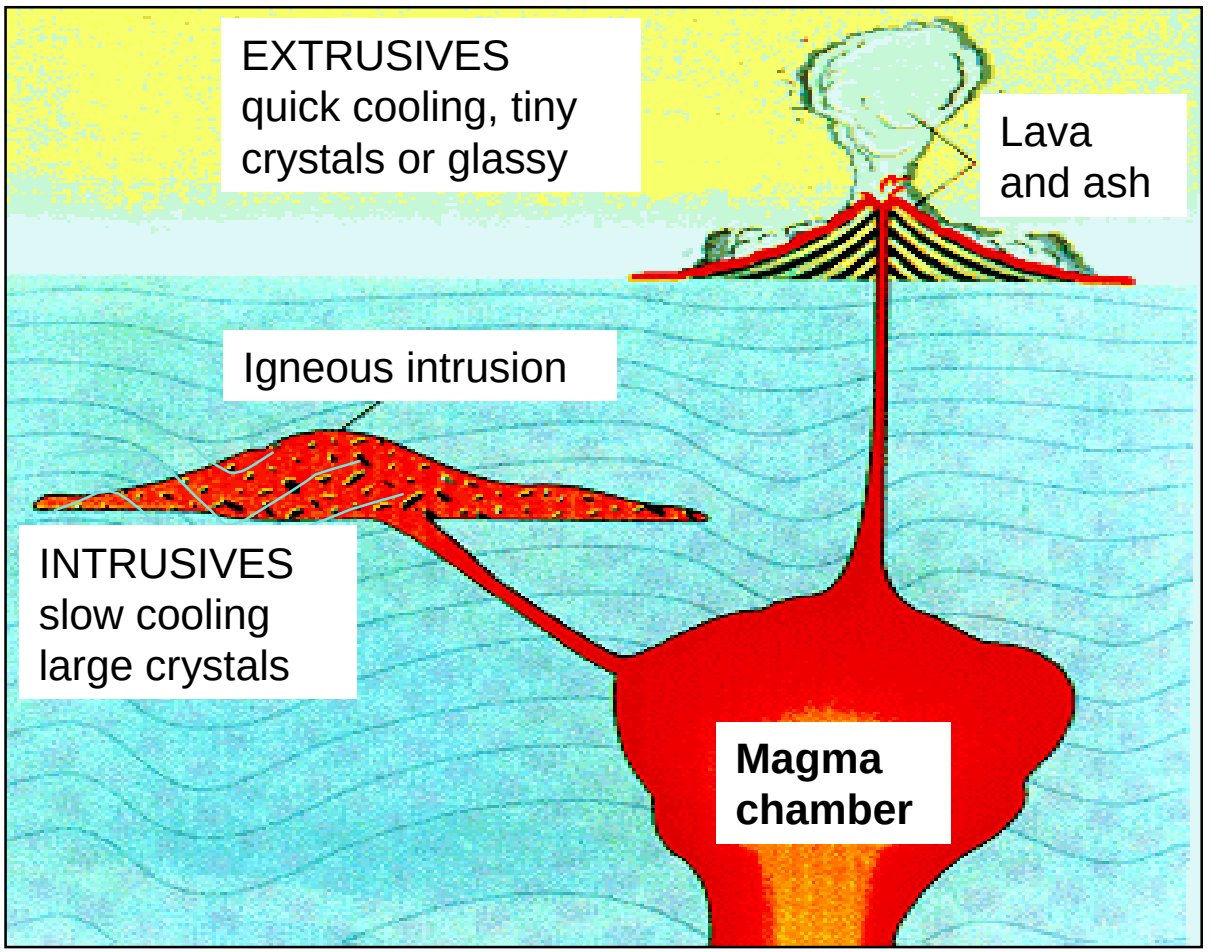


- Plate boundaries
- Relative velocities (cm/yr)
- Continental crust
- Oceanic crust

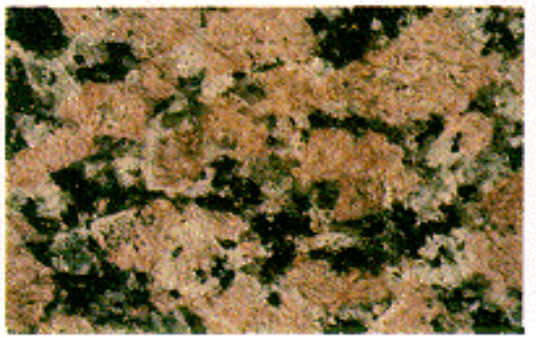
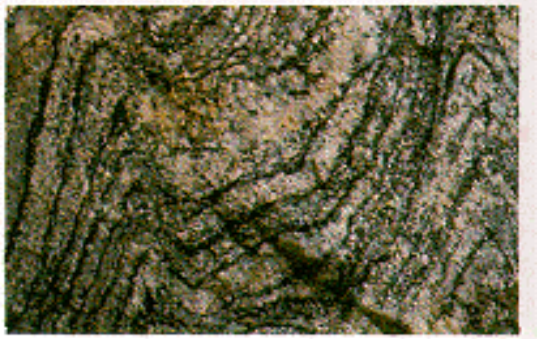
Plate tectonics & mantle convection



Extrusives, Intrusives: model



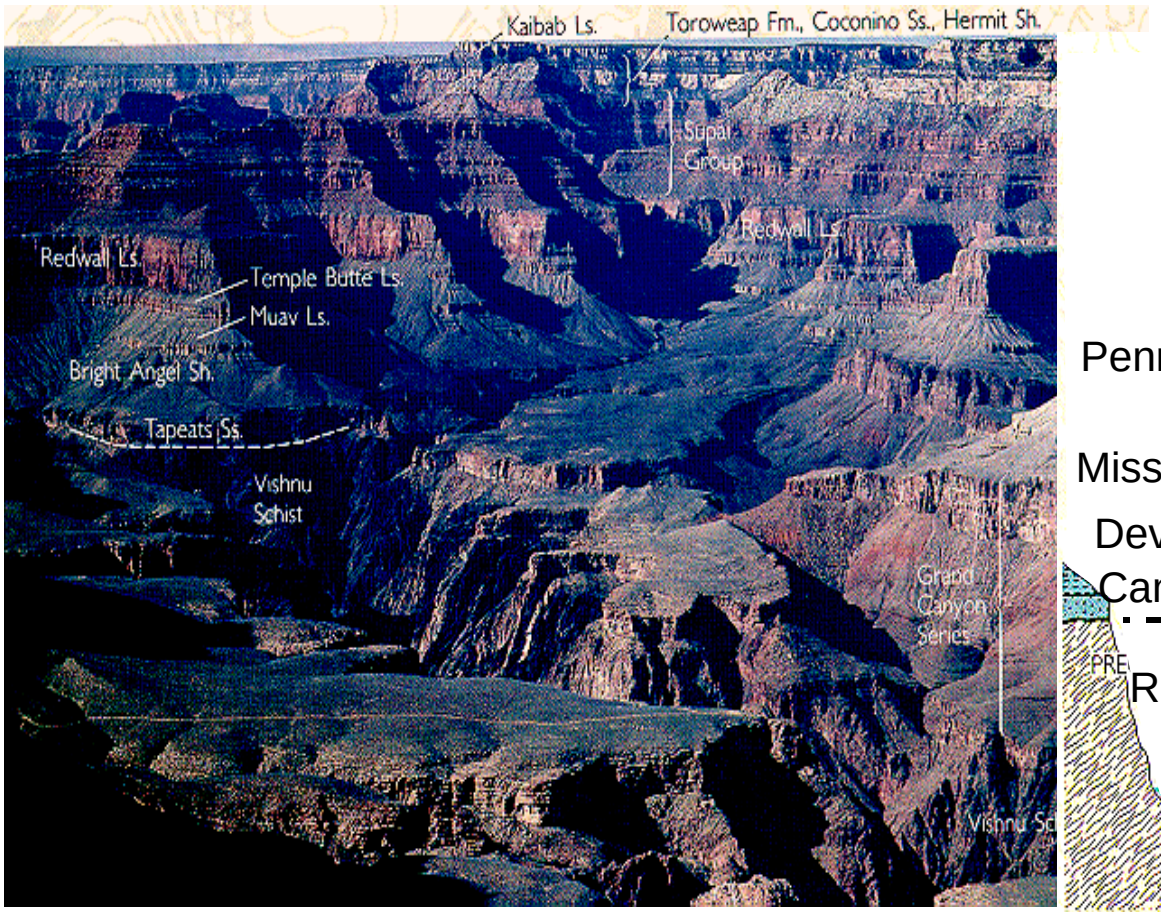
Classification of rocks

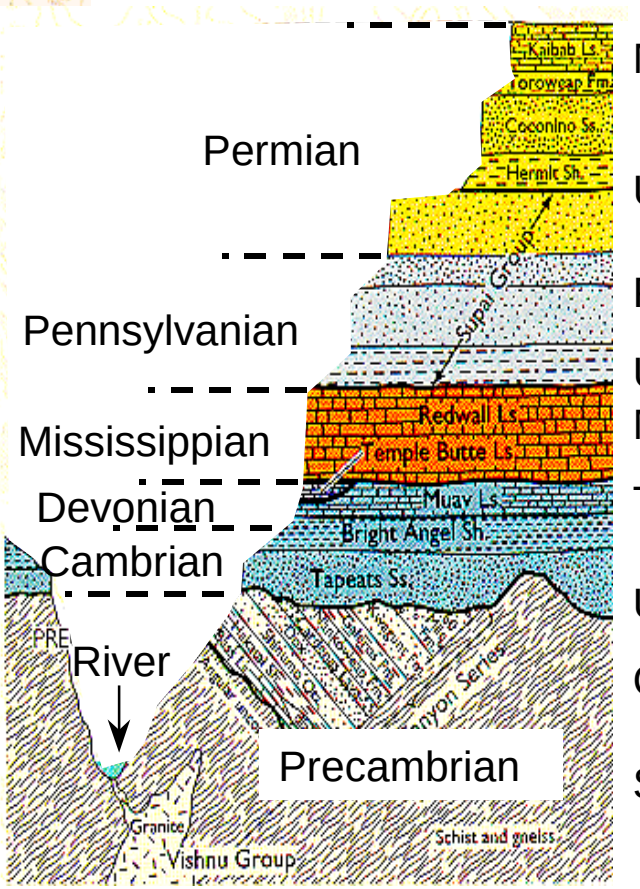
	IGNEOUS	SEDIMENTARY	METAMORPHIC
			
Source of material	Melting of rocks in hot, deep crust and upper mantle	Weathering and erosion of rocks exposed at surface	Rocks under high temperatures and pressures in deep crust
Rock-forming process	Crystallization (Solidification of melt)	Sedimentation, burial and lithification	Recrystallization in solid state of new minerals

Clastic Sedimentary Environments

ENVIRONMENT	AGENT OF TRANSPORTATION DEPOSITION	SEDIMENTS
Alluvial	Rivers	Sand, gravel, mud
Lake	Lake currents, waves	Sand, mud
Desert	Wind	Sand, dust
Glacial	Ice	Sand, gravel, mud
Delta	Rivers & waves, tides	Sand, mud
Beach	Waves, tides	Sand, gravel
Shallow shelf	Waves, tides	Sand, mud
Deep sea	Ocean currents, settling	Mud

Stratigraphic section





Marine fossils

Unconformity

Plant fossils

Unconformity

Marine fossils

Trilobites

Unconformity

Grand Canyon Series

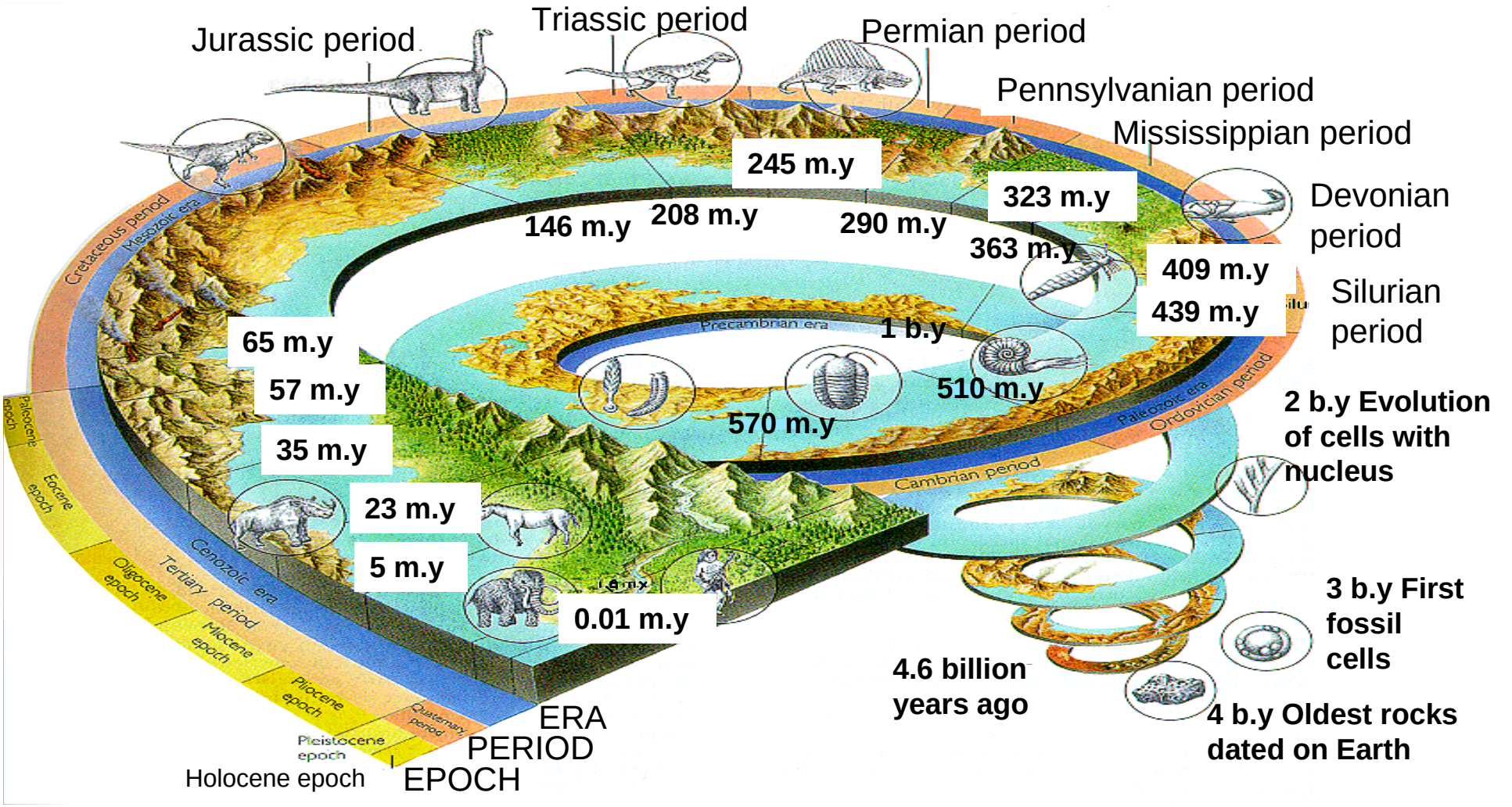
Single-celled organisms

Grand Canyon, USA

Geologic Time Scale

	Epoch	Period	Era	Eon
0	Recent	Quaternary	Cenozoic	Phanerozoic
0.01	Pleistocene			
1.6	Pliocene	Tertiary		
5.3	Miocene			
24	Oligocene			
37	Eocene			
57	Paleocene			
66				
144		Cretaceous	Mesozoic	
208		Jurassic		
245		Triassic		
286		Permian	Paleozoic	
360		Carboniferous		
408		Devonian		
438		Ordovician		
505		Silurian		
570		Cambrian		
				Proterozoic

Geologic Time Scale - Biostratigraphy



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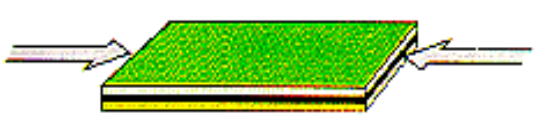
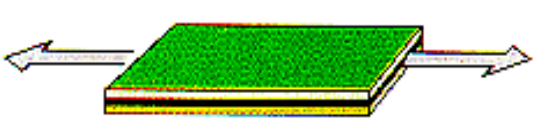
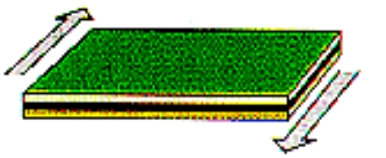
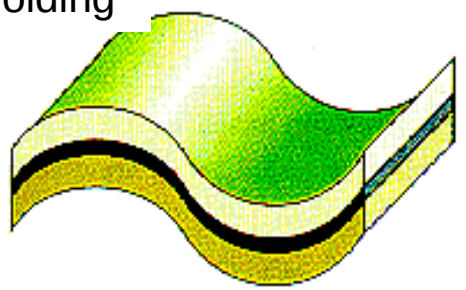
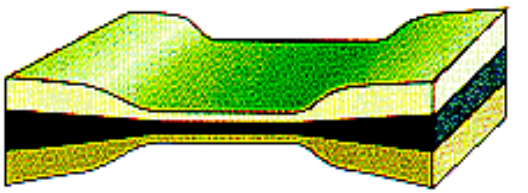
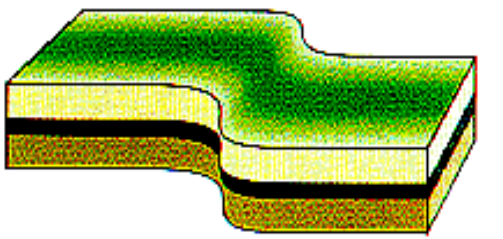
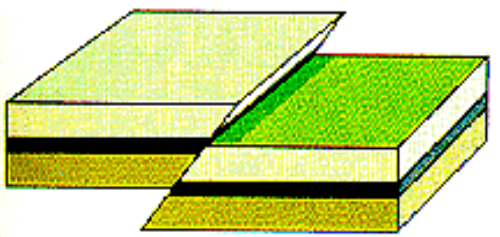
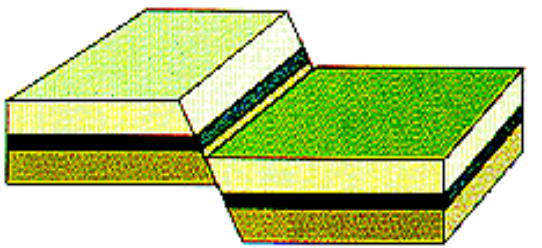
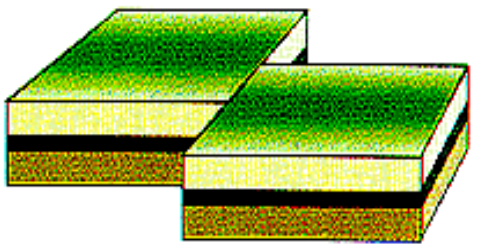
Rock Deformation

Crustal movement causes 2 types of surface deformation

- Folding
- Faulting

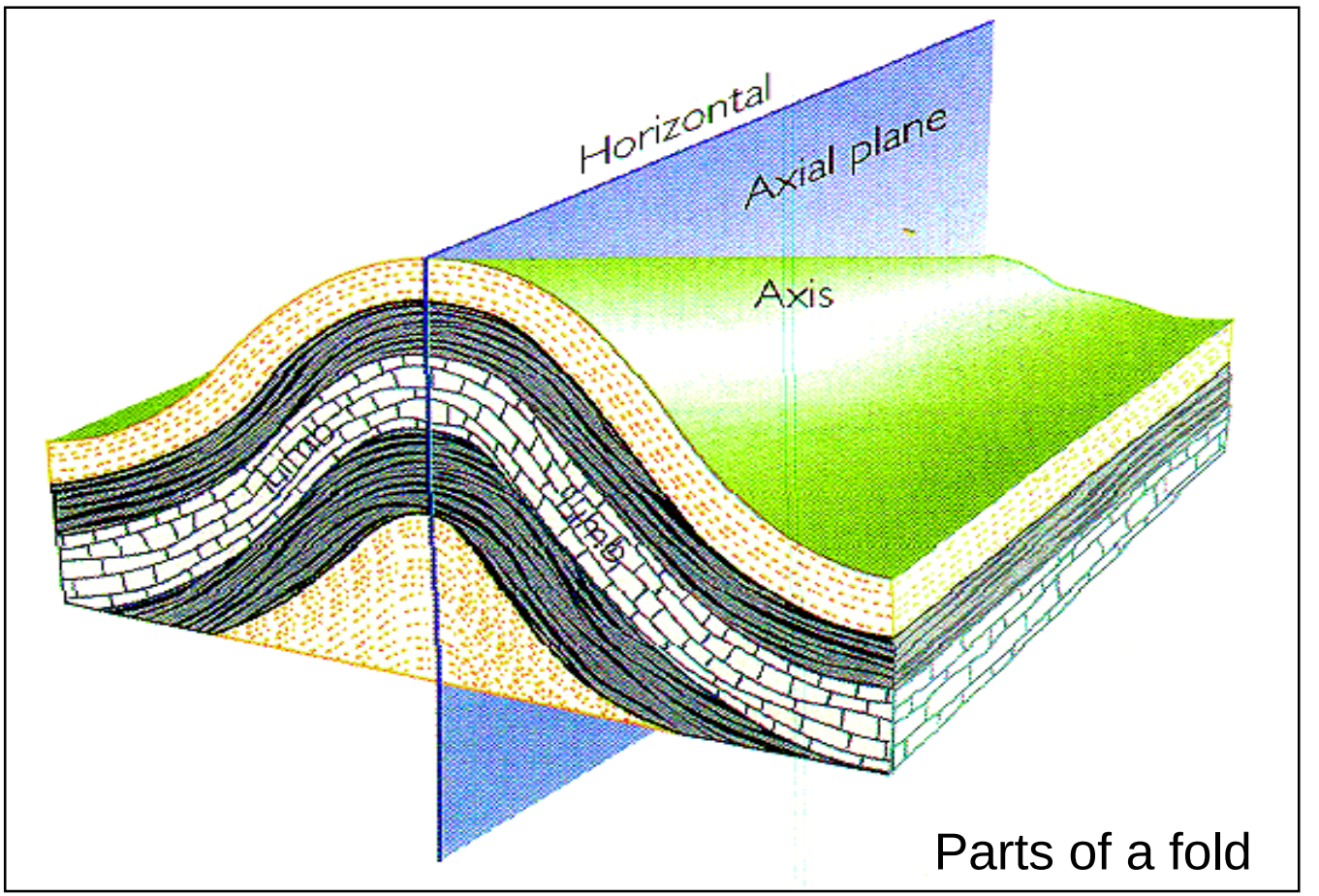
Deformational Features

COMPRESSIVE FEATURES	TENSIONAL FEATURES	SHEARING FEATURES
		
Folding	Stretching and thinning	Shearing
		
Faulting	Faulting	Faulting
		

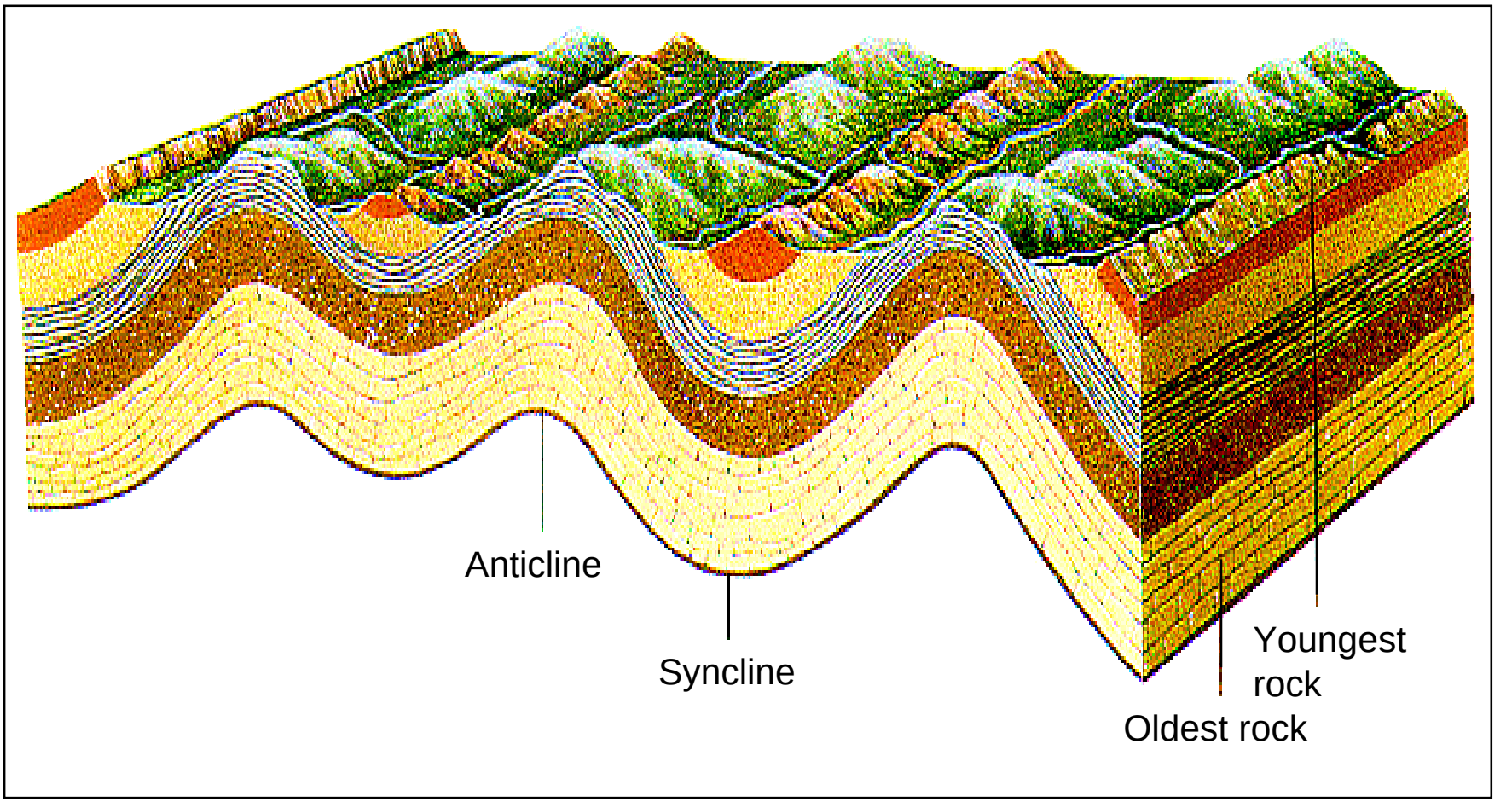
Faults & Folds

Folding

Fold Terminology

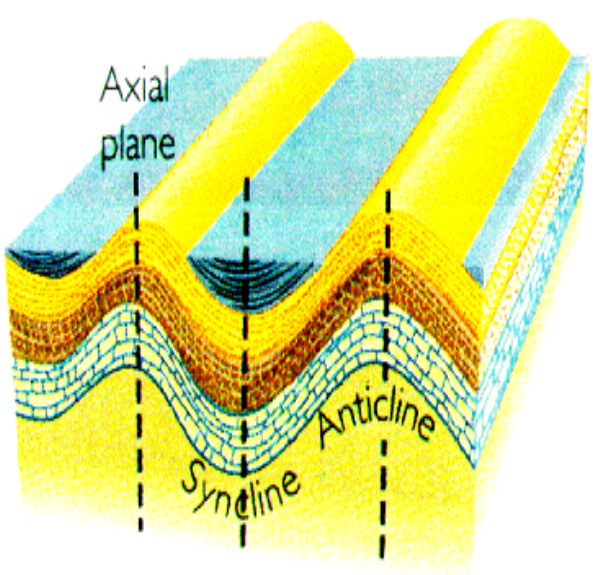


Fold Terminology

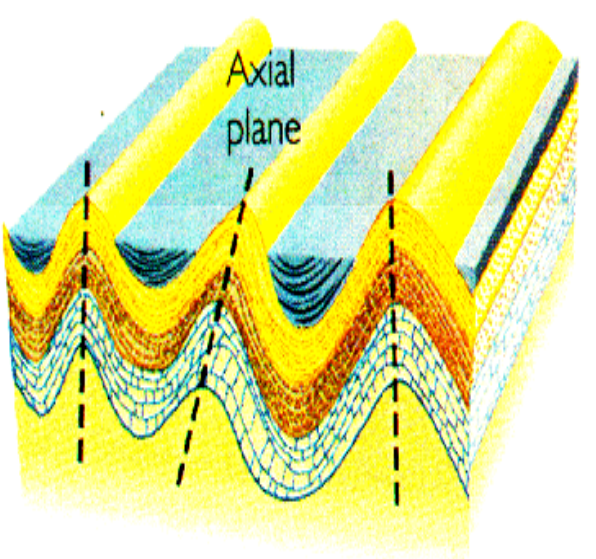


Fold Terminology

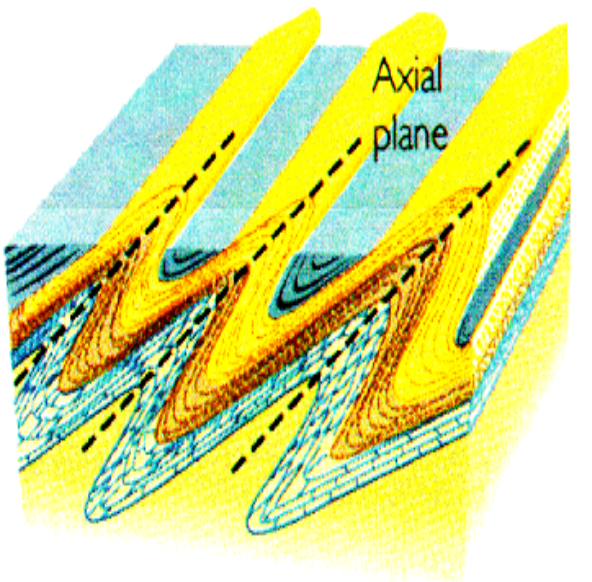
Symmetrical folds



Asymmetrical folds



Overturned folds



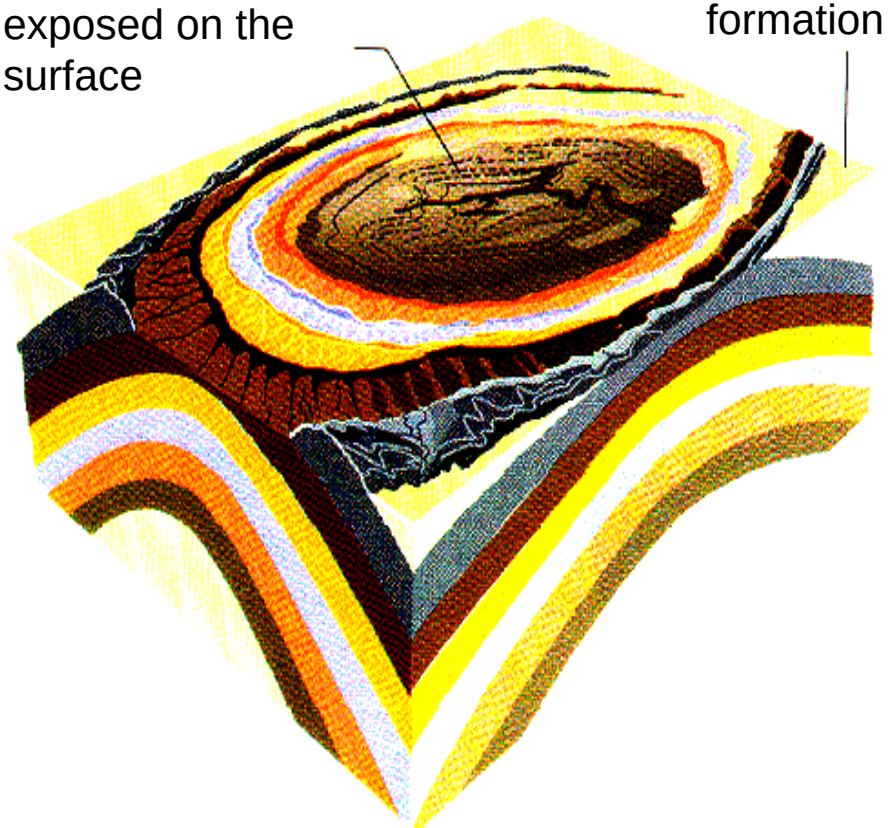
Anticline

Overturned Folds

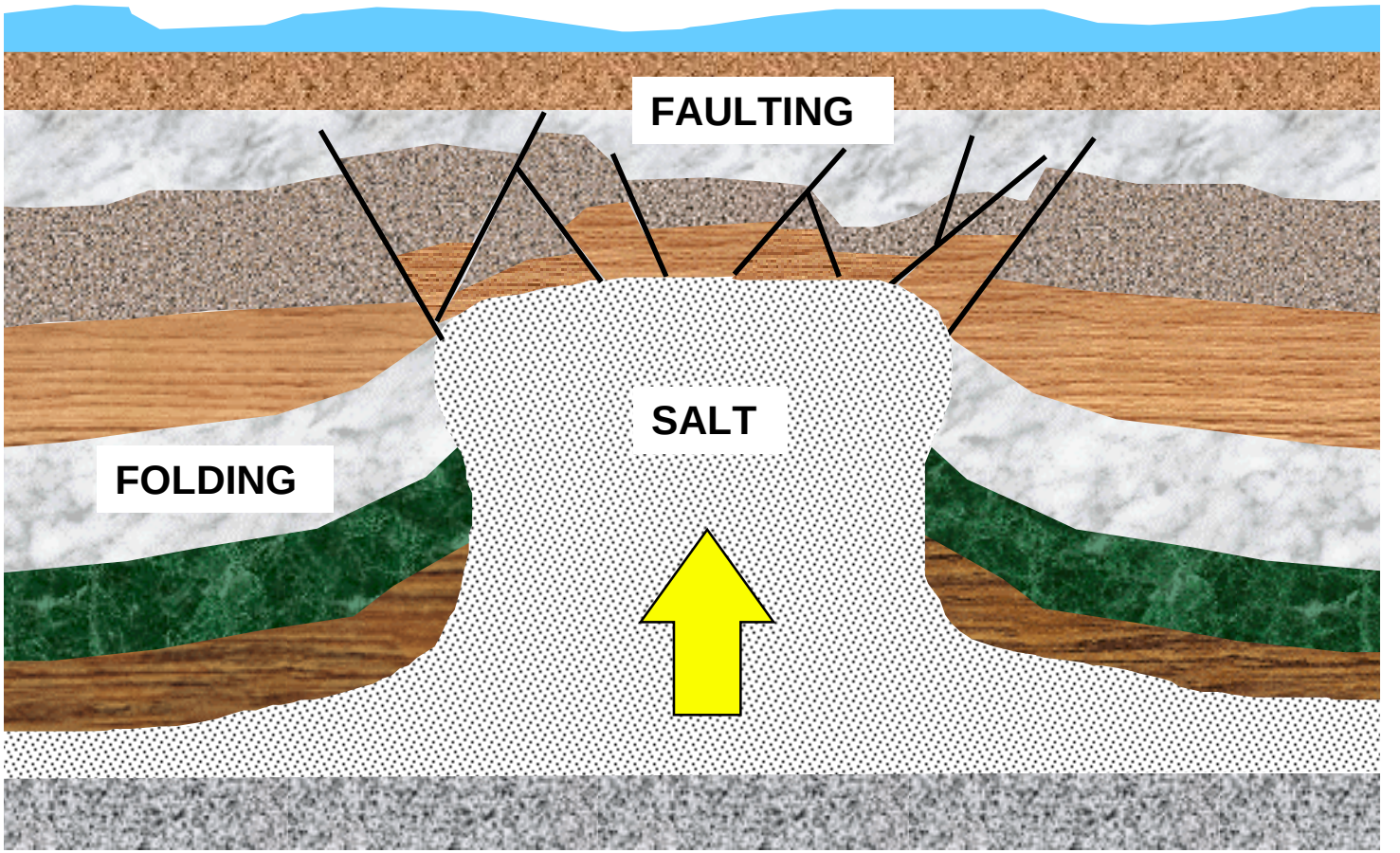
Fold Dome

Oldest formation exposed on the surface

Youngest formation

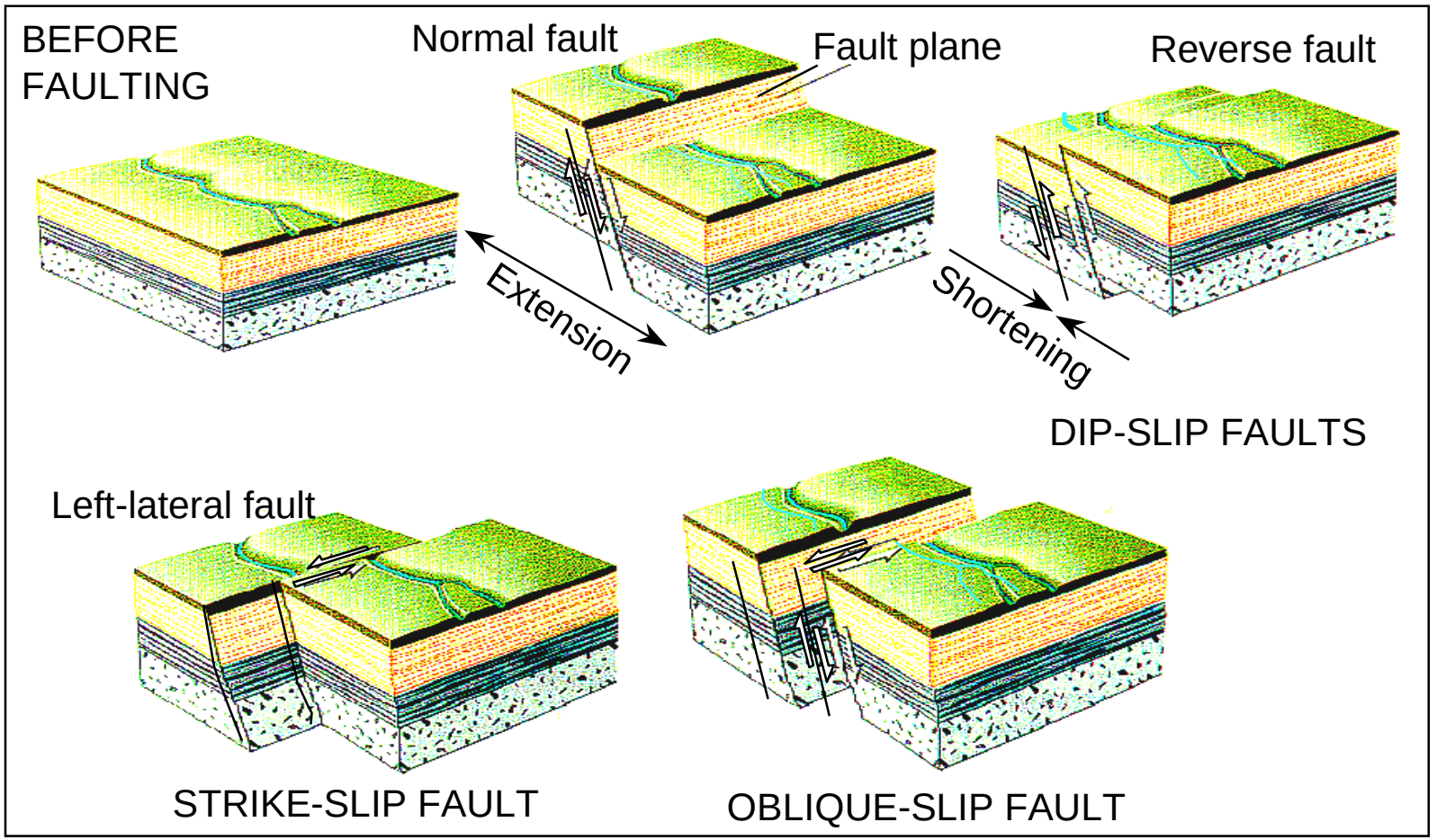


Diapirism



Faulting (normal faults)

Types of Faults



San Andreas Fault, USA

- Transform fault
- Sliding plate boundary

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Clastic Sedimentary Environments

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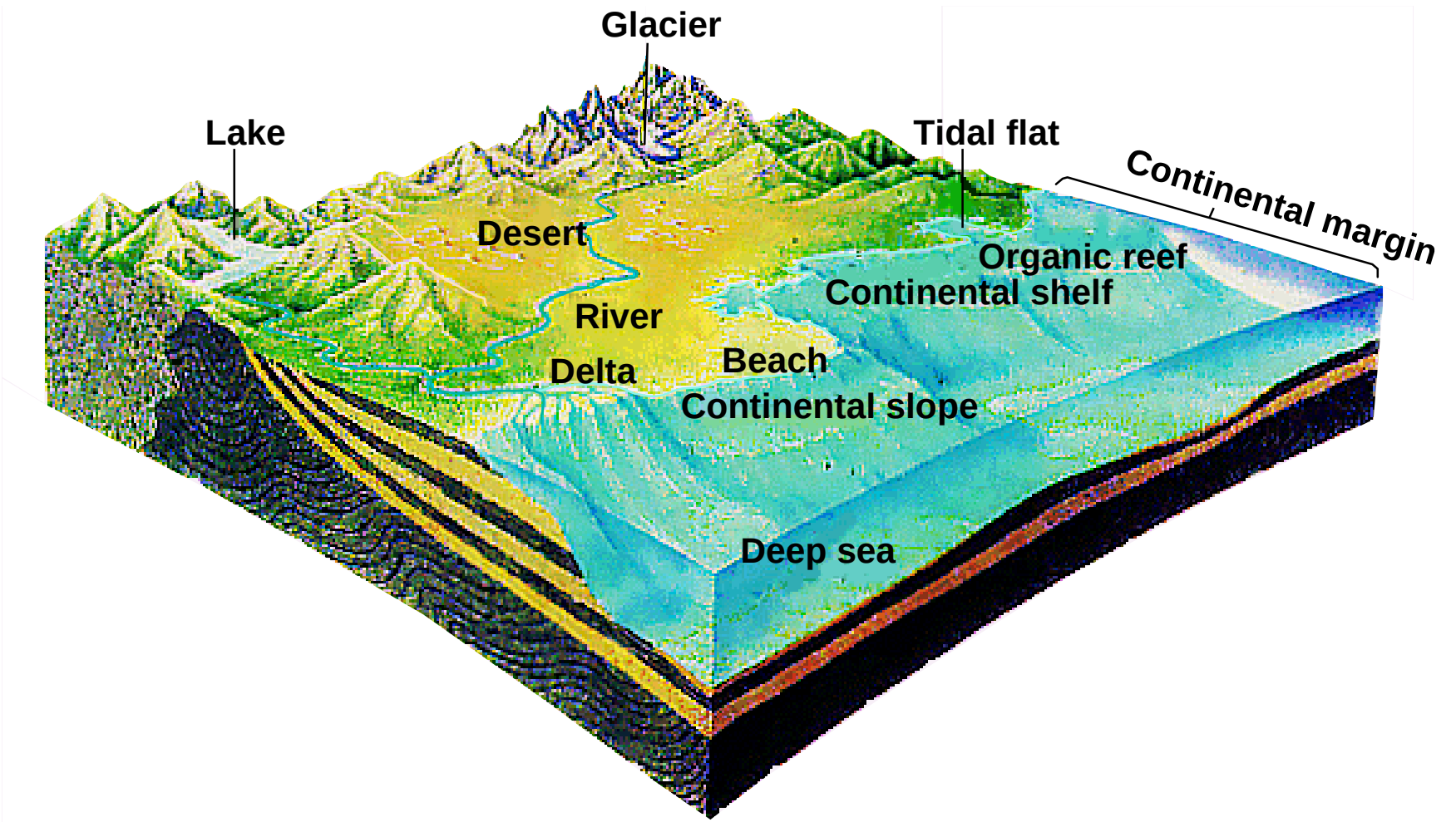
Desert	Wind	Sand, dust
Glacial	Ice	Sand, gravel, mud
Delta	River + waves, tides	Sand, mud
Beach	Waves, tides	Sand, gravel
Shallow shelf	Waves, tides	Sand, mud
Deep sea	Ocean currents, settling	Mud

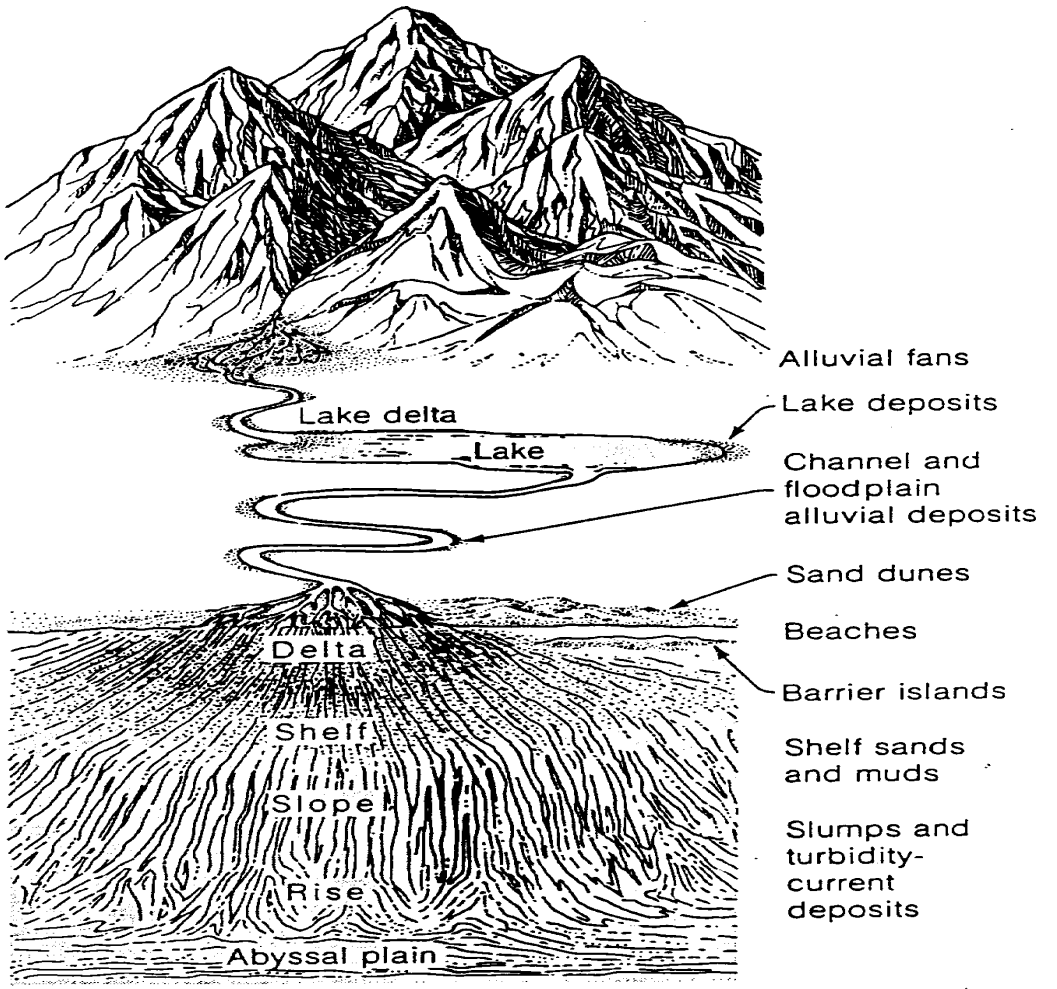
Chemical Sedimentary Environments

ENVIRONMENT	AGENT OF PRECIPITATION	SEDIMENTS
Carbonate (reef, bank, deep sea, etc.)	Shelled organisms, inorganic precipitation from seawater	Carbonate sands and muds, reefs
Evaporite	Evaporation of seawater	Gypsum, halite
Deep sea	Shelled organisms	Silica sediment
Swamp	Vegetation	Peat

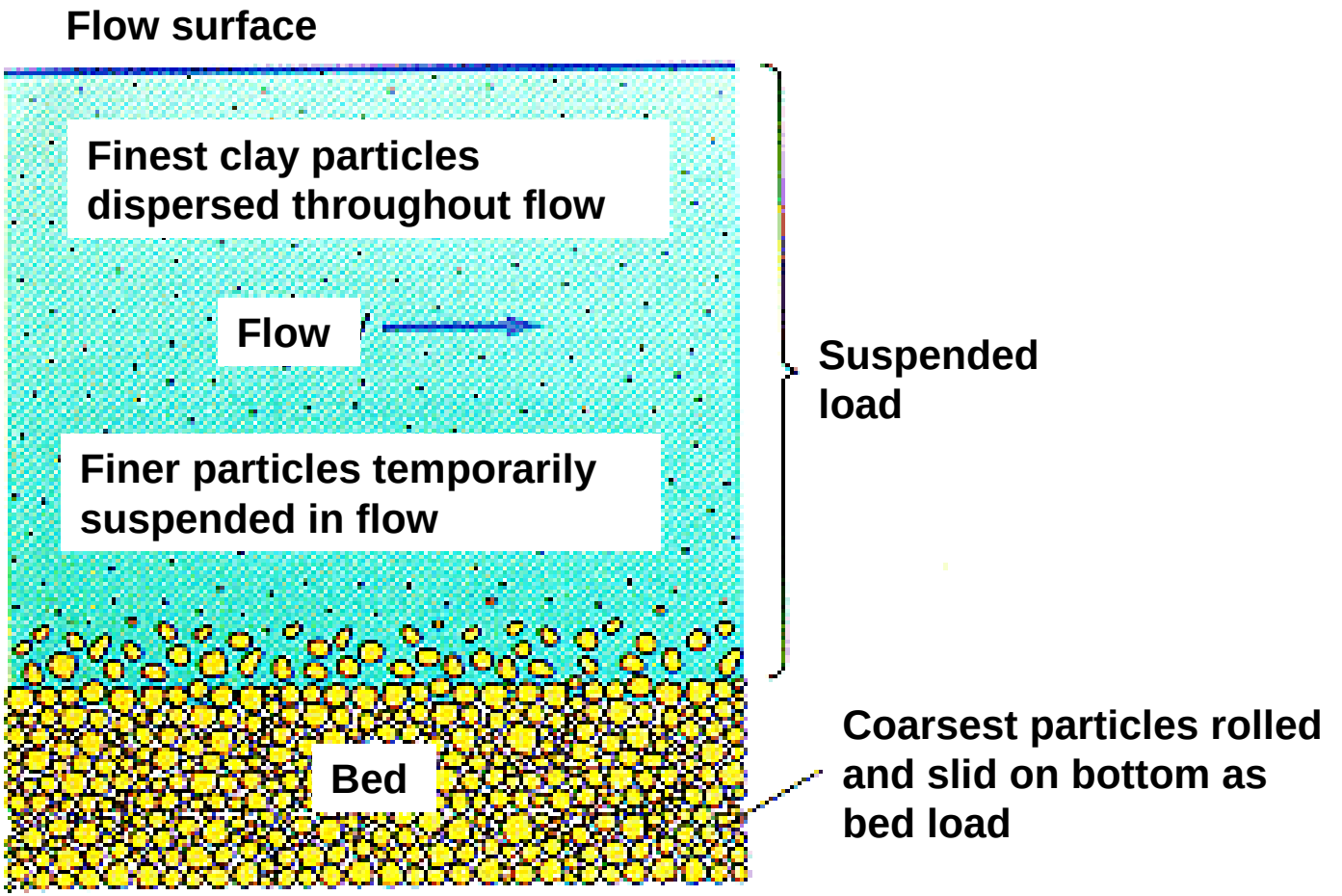
Sedimentary Environments



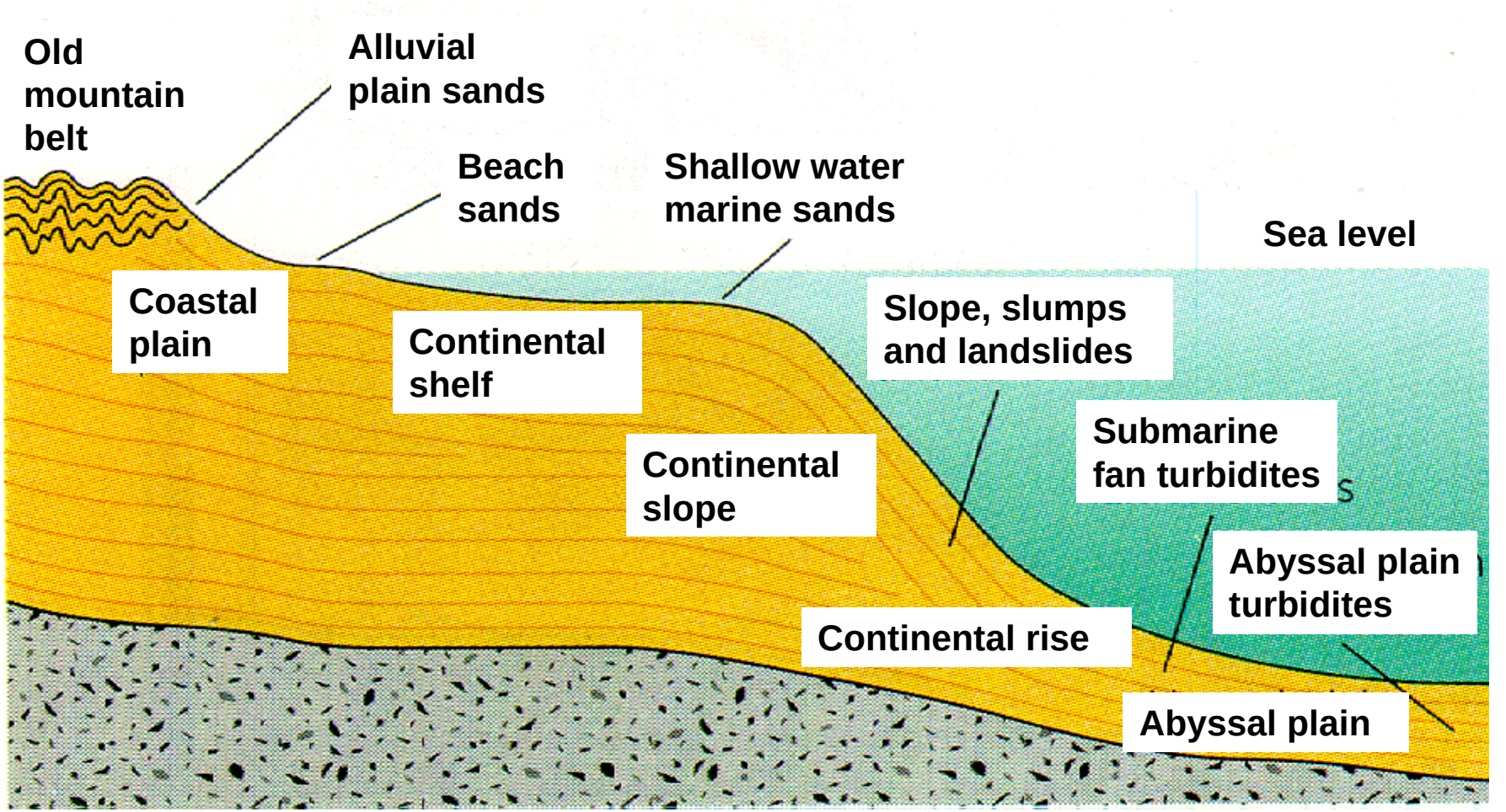
Transport & Depositional Environments



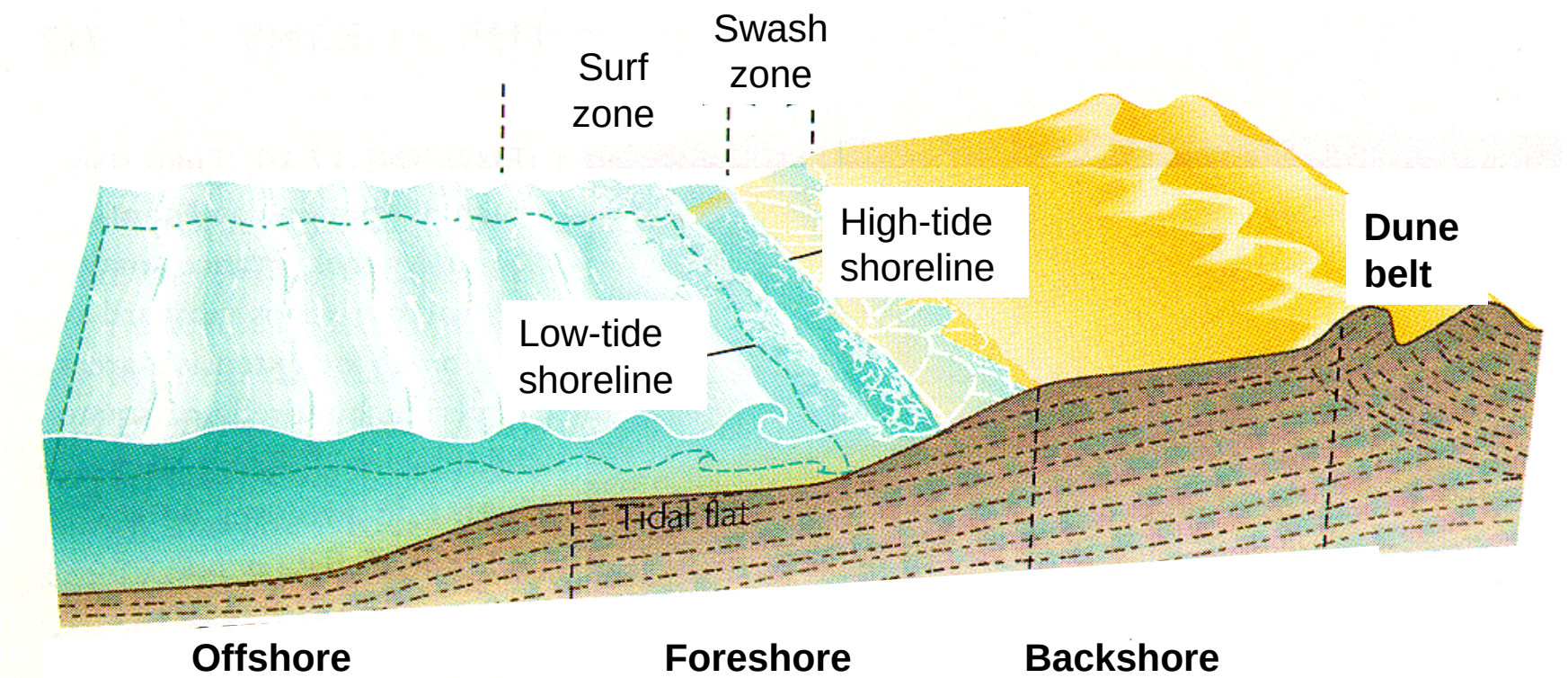
Modes of Particle Transport



Marine Deposits

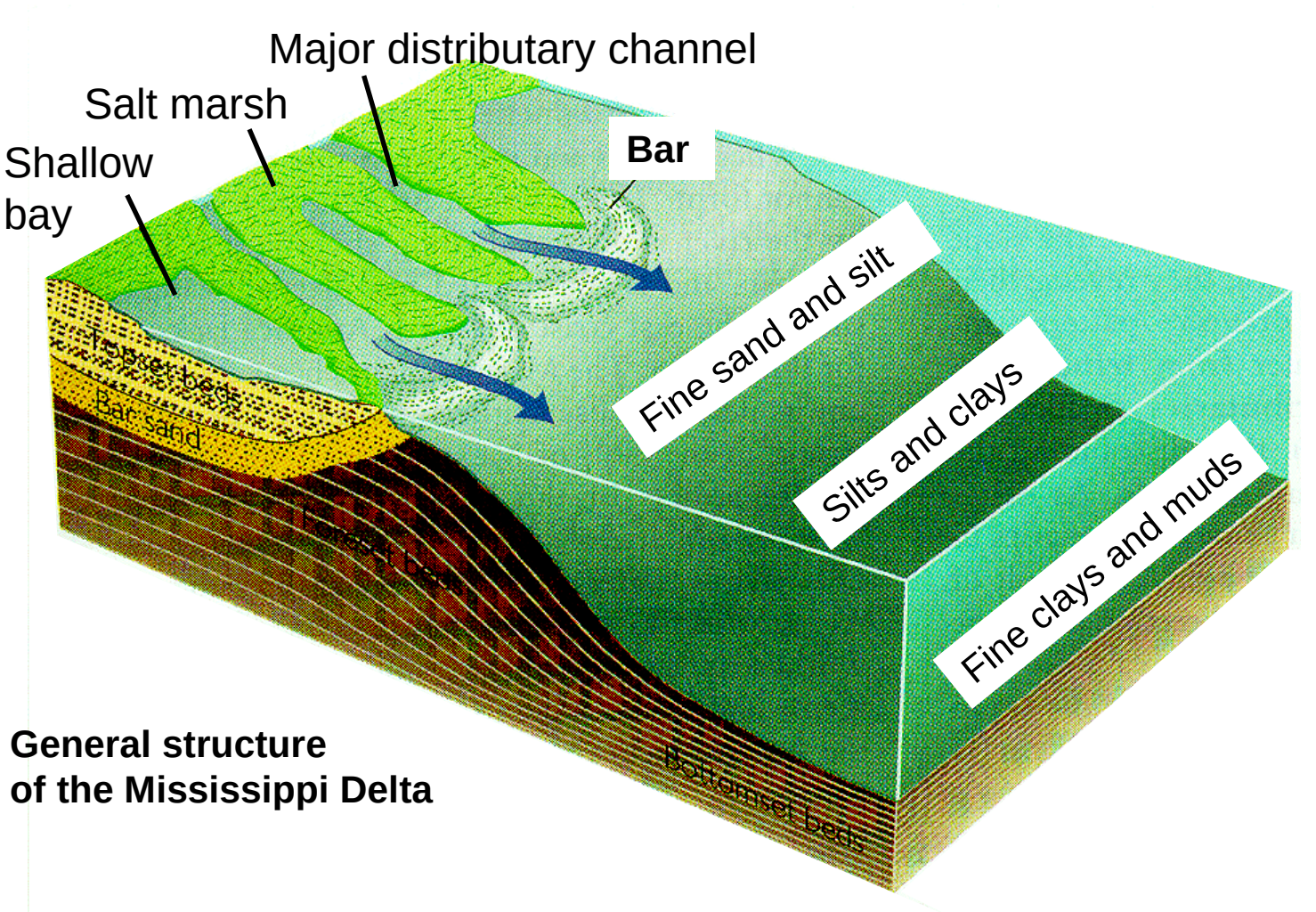


Beach Profile



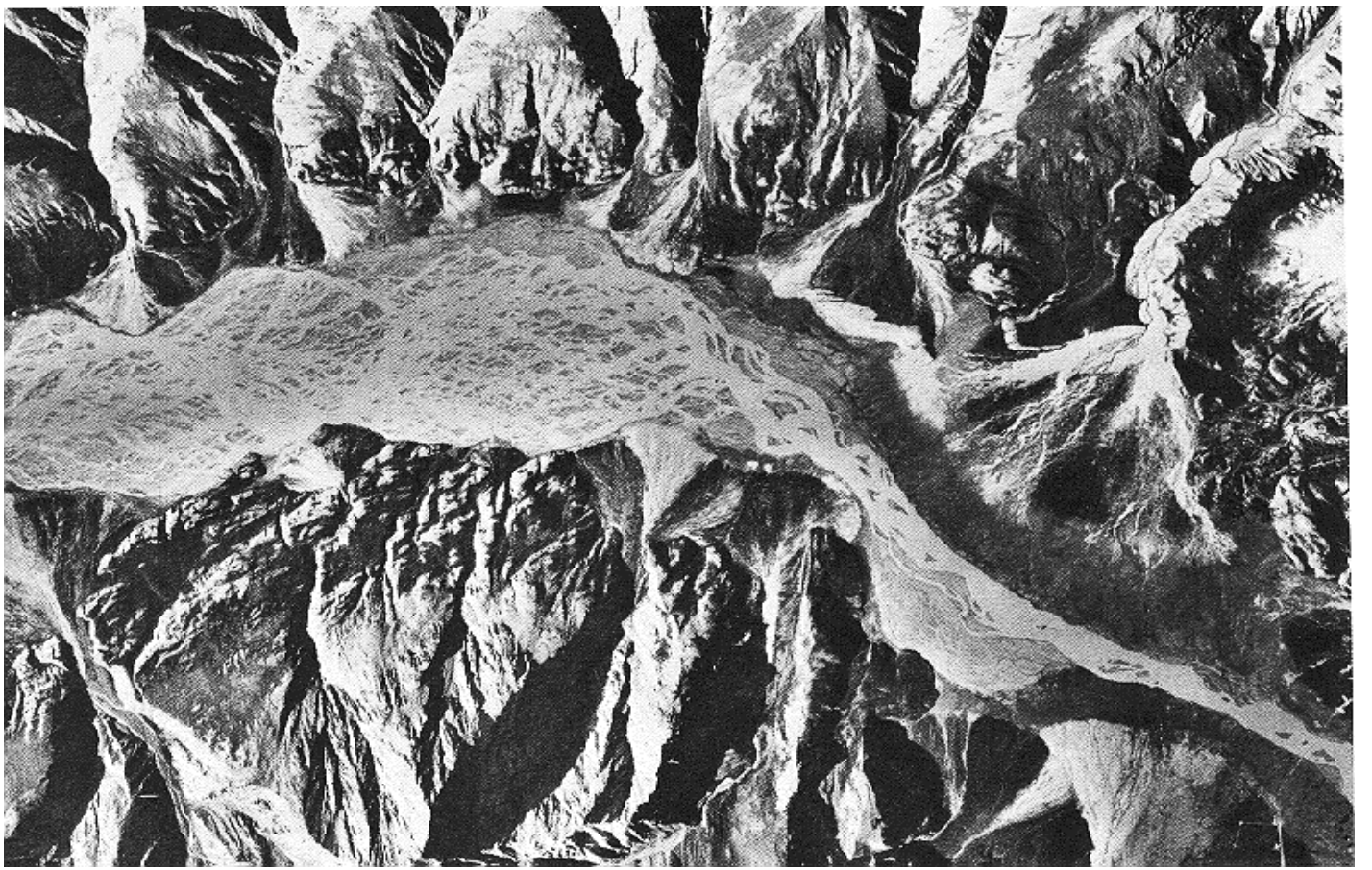
- Dipping strata

River Estuary



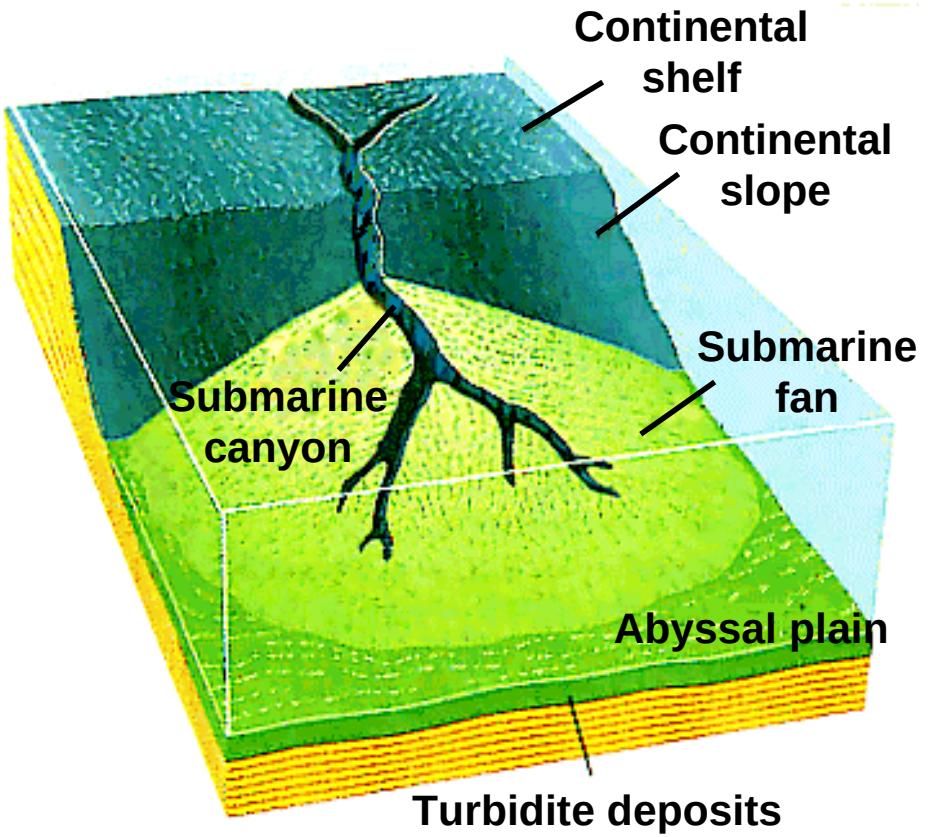
General structure of the Mississippi Delta

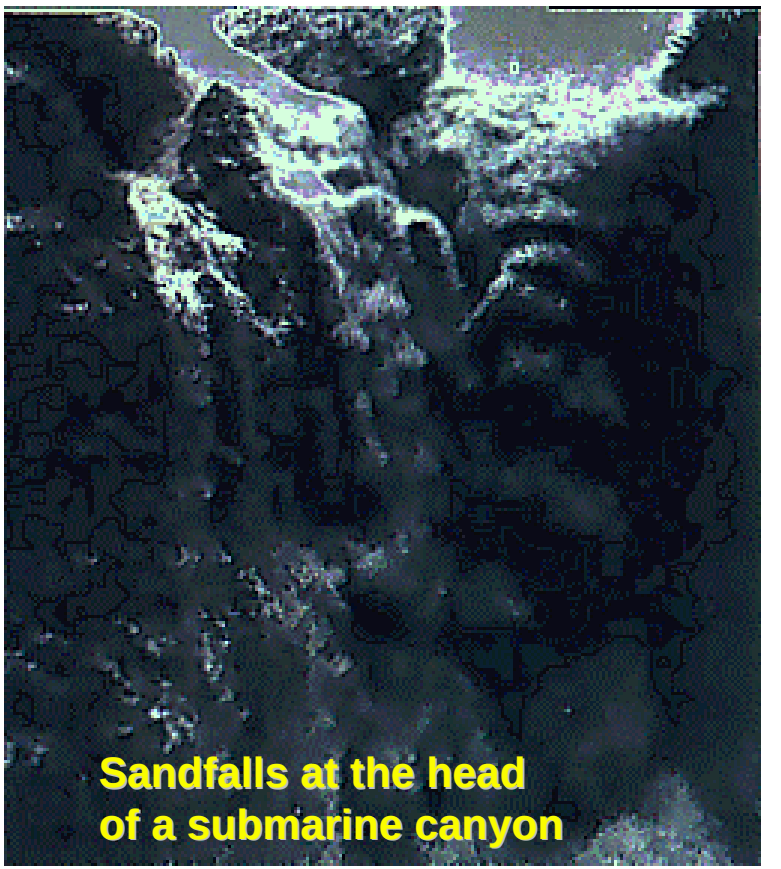
Alluvial Environment



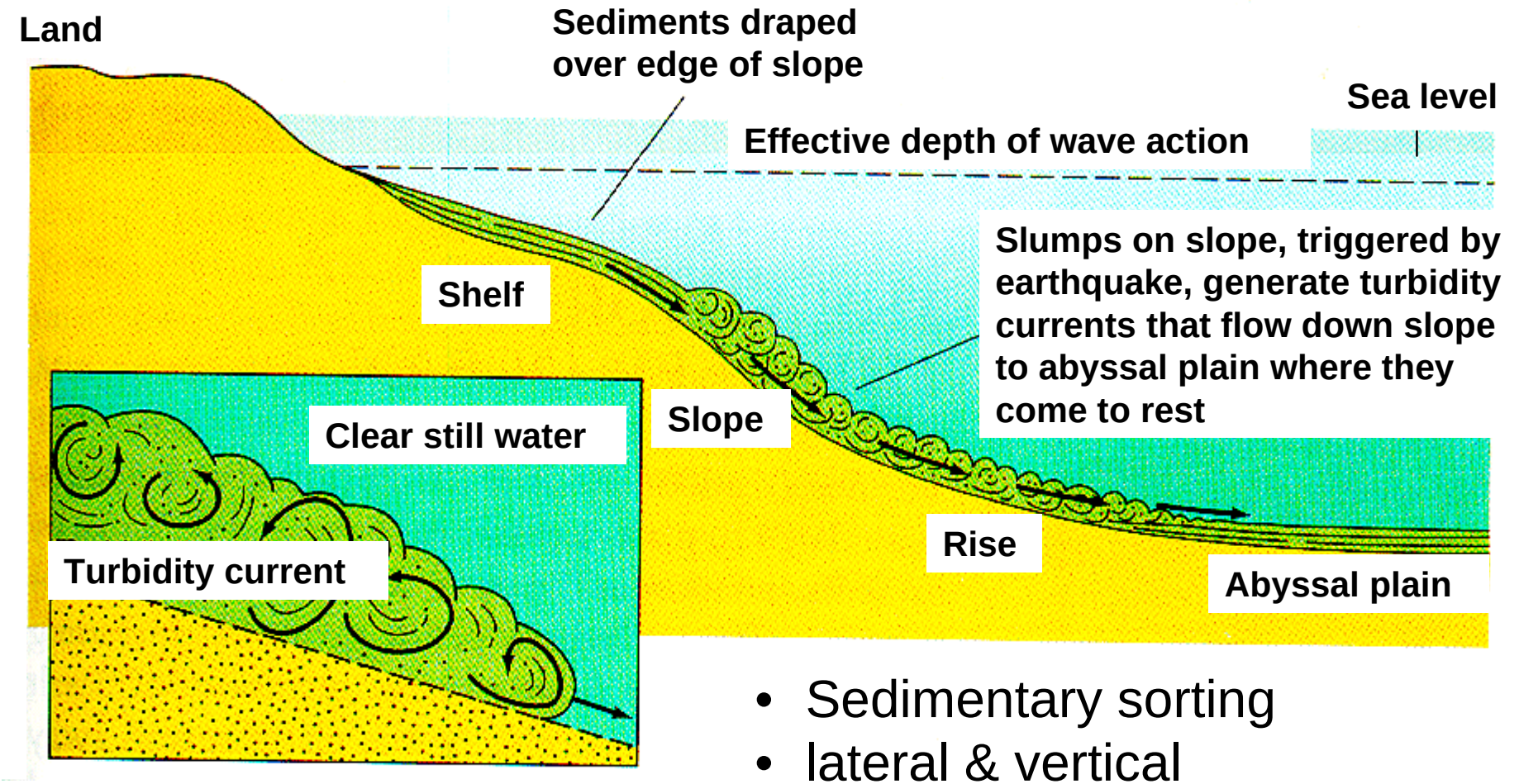
- Rivers
- Fans

Submarine Fan





Turbidity Current



- Sedimentary sorting
- lateral & vertical

Fan Deposition

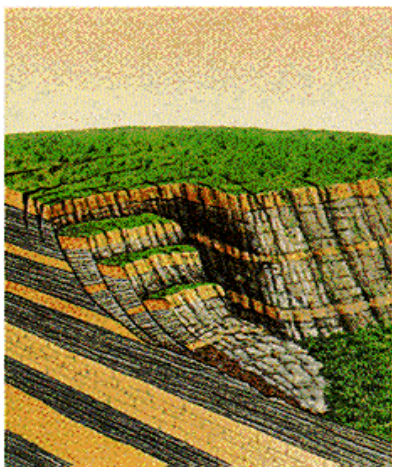
Unconsolidated Mass Movements

Earth flow

Debris flow

Mud flow

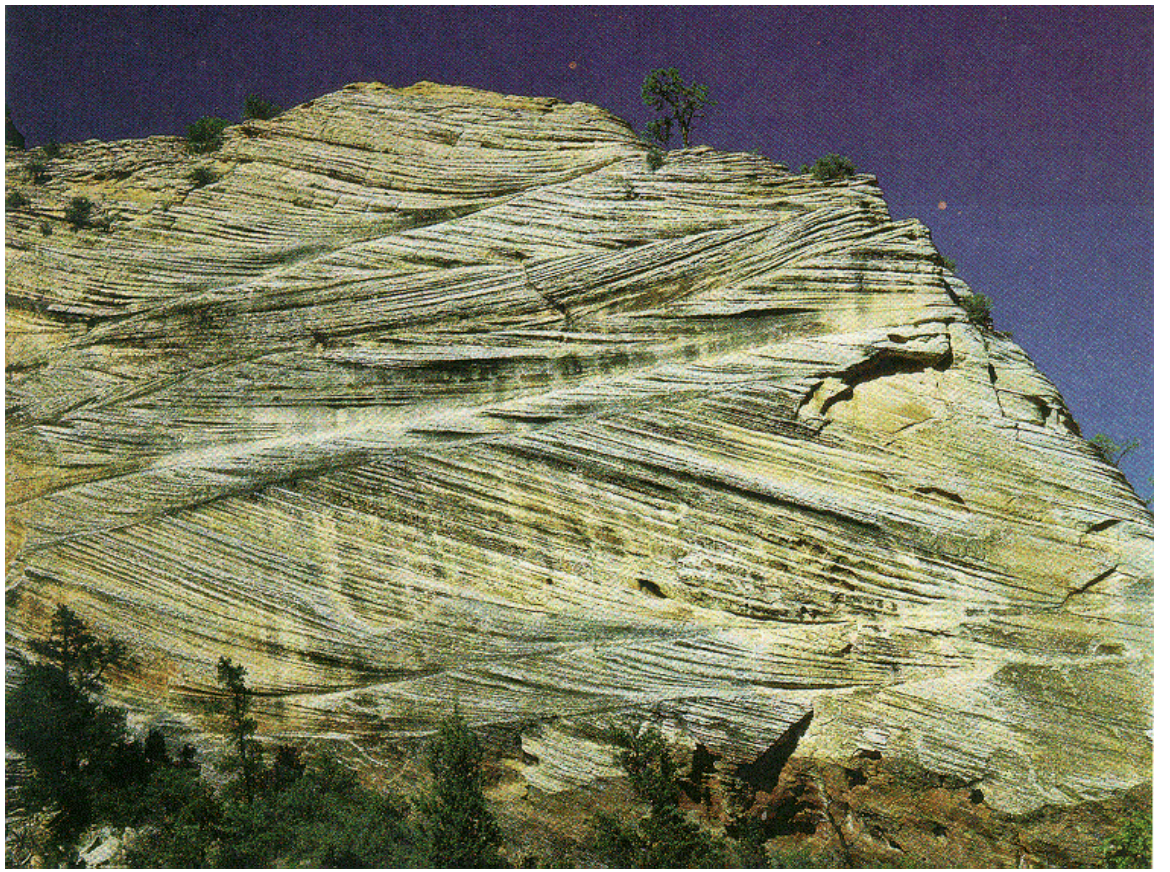
Debris avalanche



Slump

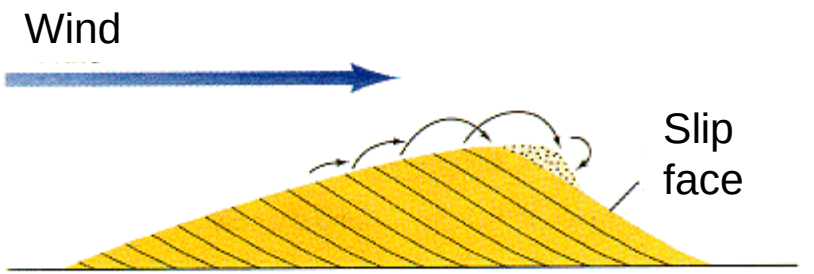
Debris slide

Fossil Dunes

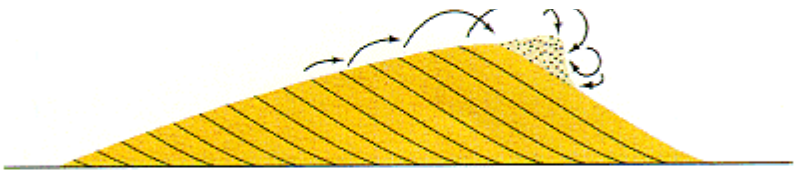


- Sediment sorting
- Constant wind force
- Constant wind direction

“Dune” Ripple Formation



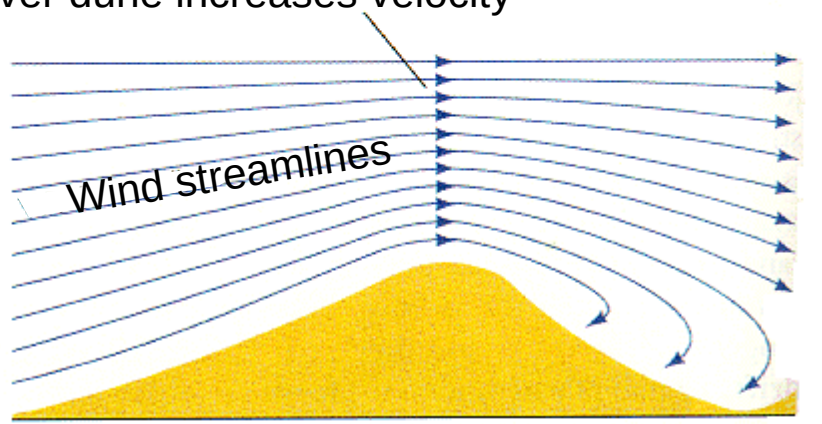
(a) Saltating and rolling grains land on slip face



(b) Unstable accumulationbuild up

(c) Accumulation cascades down to base, advancing the dune

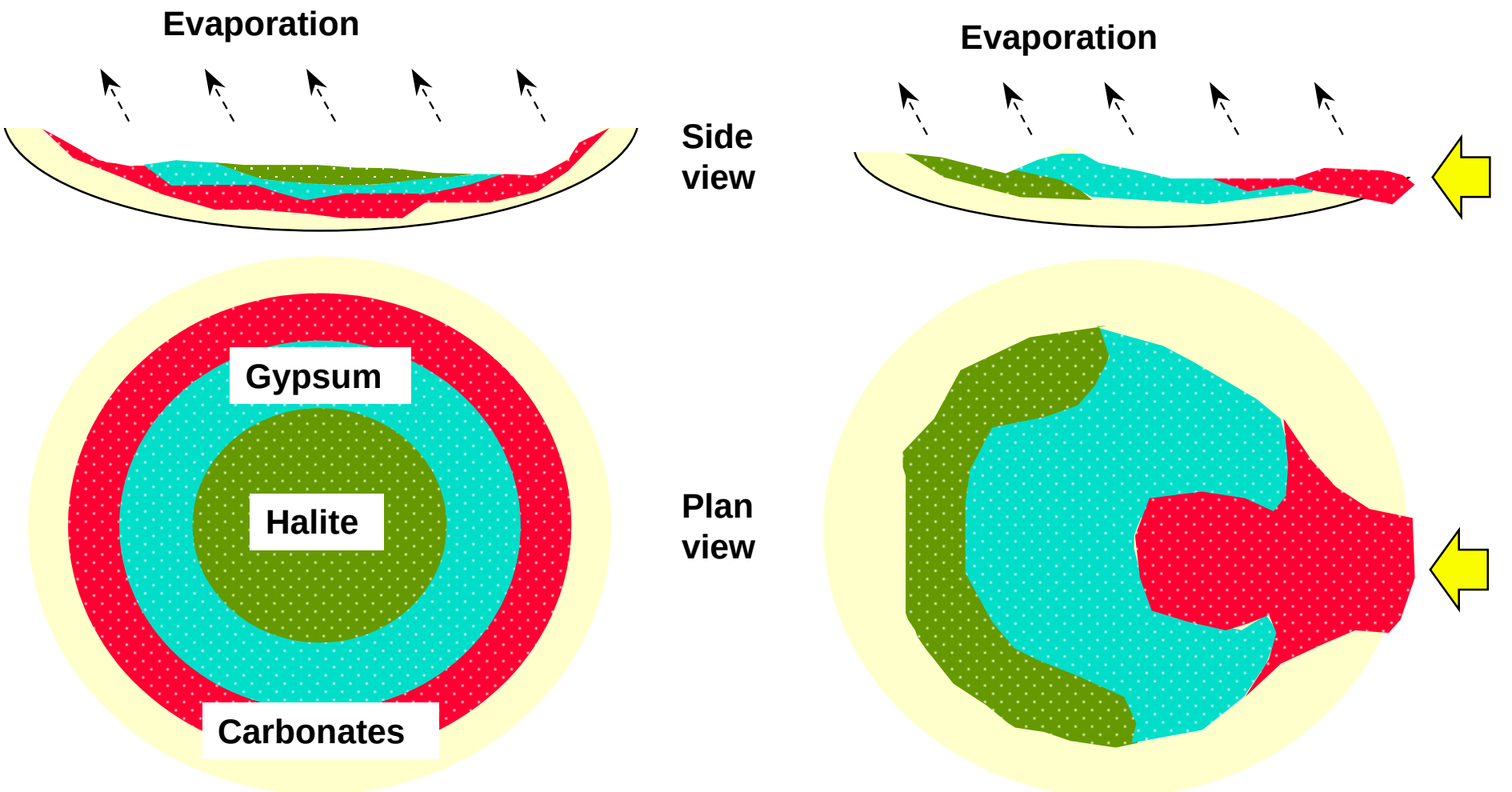
Compression of streamlines over dune increases velocity



Limestone

- Foraminiferal ooze
- Lagoon

Basin Salt Deposition



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(1) Kerogen Chemistry and Maturation

Elements

- Carbon
- Hydrogen
- Nitrogen
- Sulphur
- Oxygen

Compounds

- Paraffins
- Naphthenes
- Aromatics
- Asphaltines

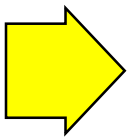
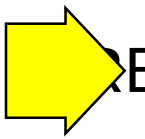
Hydrocarbon Types

- Bitumina
- Crude Oil
- Condensate
- Natural Gas

(1) Kerogen Chemistry and Maturation

- Oil Window
- Geothermal Gradient
- Overpressure

(2) From Source to Reservoir

SOURCE  MIGRATION  RESERVOIR

- Rock Types
  - Shales 65%
  - Carbonates 21%
  - Marl 12%
  - Coal 2%

- Compaction
- Aquathermal pressure
- Buoyancy
- Hydrodynamic regime

- Rock Types
- Porosity
- Permeability

(3) Reservoir Traps and Seals

Traps

- OWC, GWC, Spill Point

Structural

- Anticline 75%
- Fault 1%

Stratigraphic

- Unconformity 3%
- Reef 3%

Combination

- Salt diapir 2%

Seals

Shale 65%
Salt 33%
Carbonate 2%
Fault

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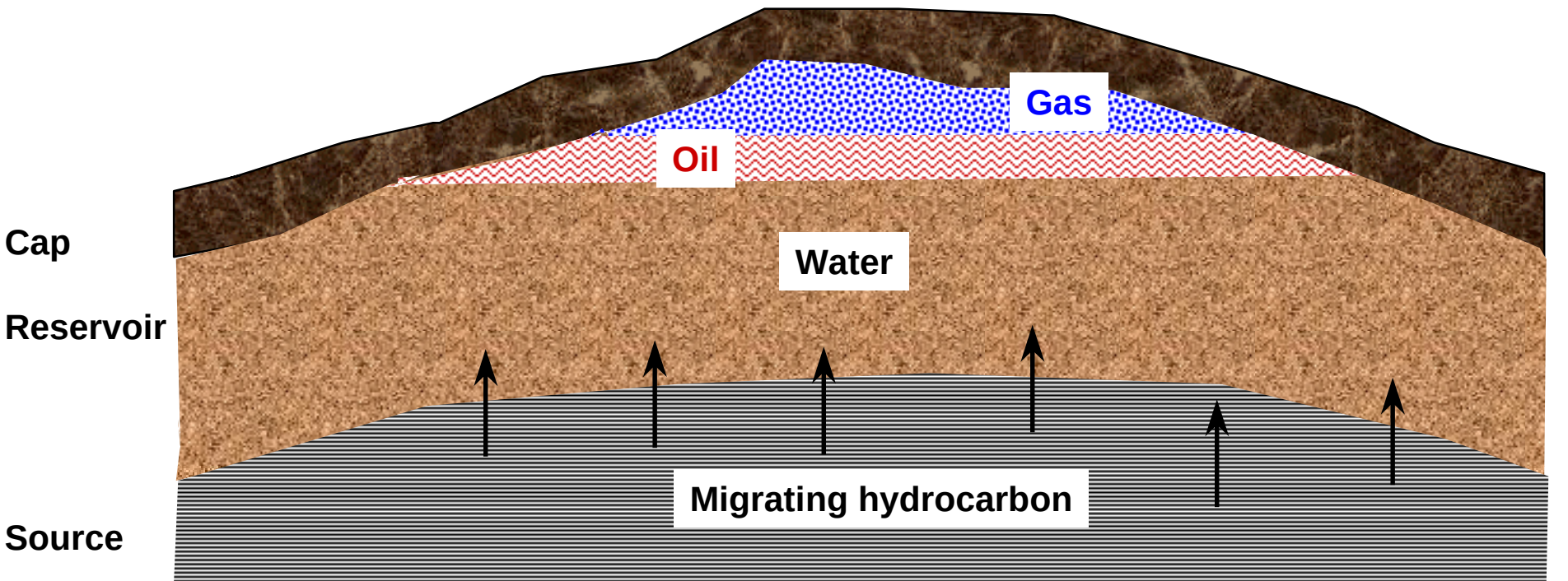
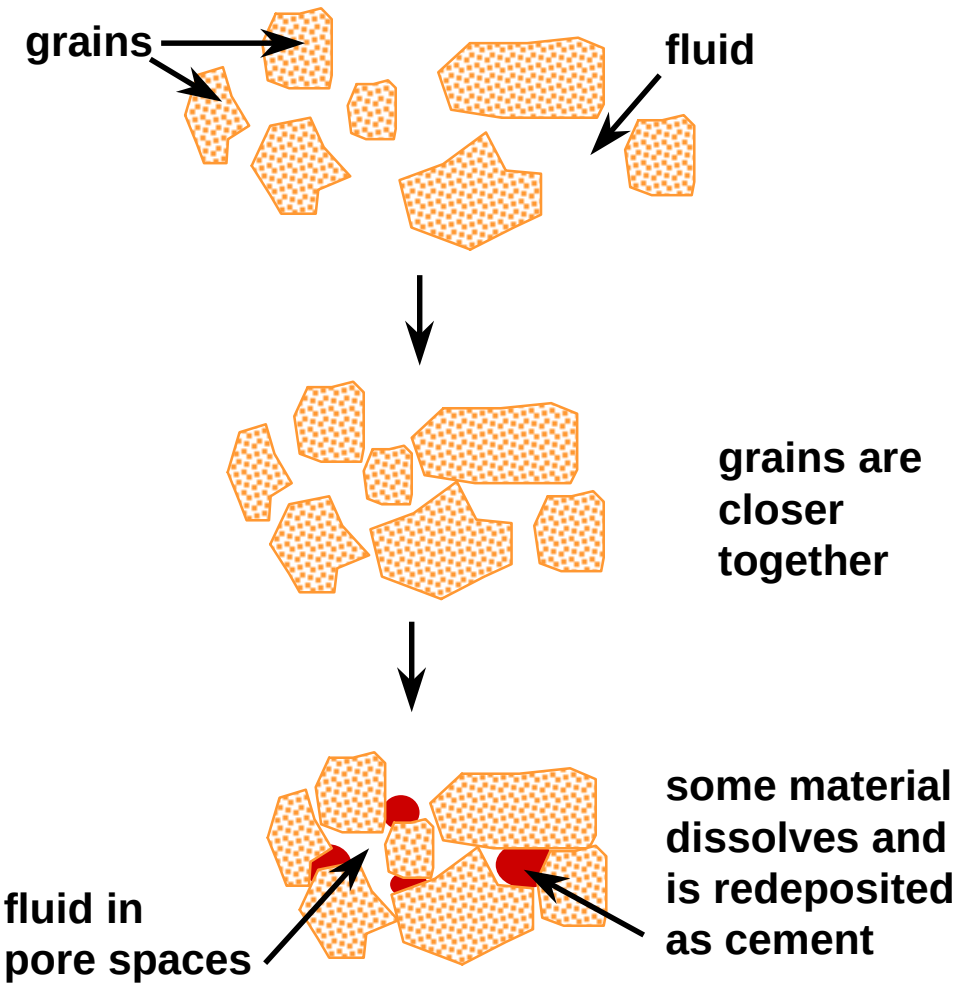
The Reservoir

- A reservoir is a porous rock which contains fluids
- The reservoir has porosity and permeability

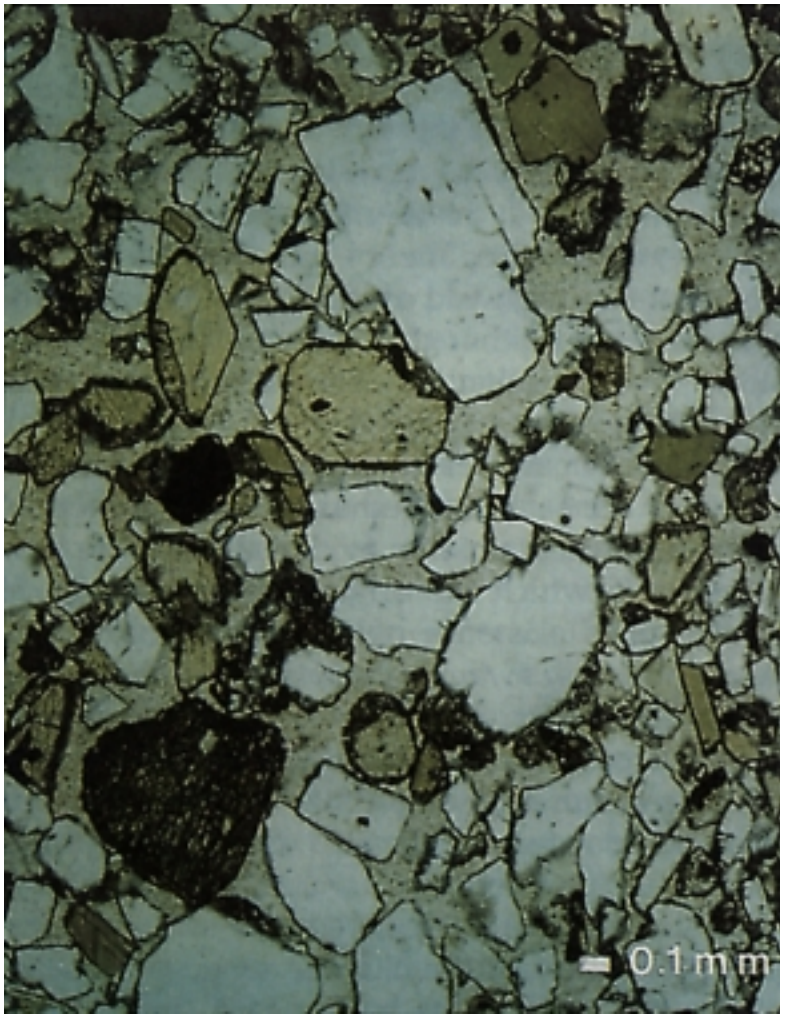


Sedimentation and Diagenesis

- Grains settle to the bottom of the sedimentary basin
- Increased pressure and temperature causes water to be expelled
- Consolidation occurs to form the rock



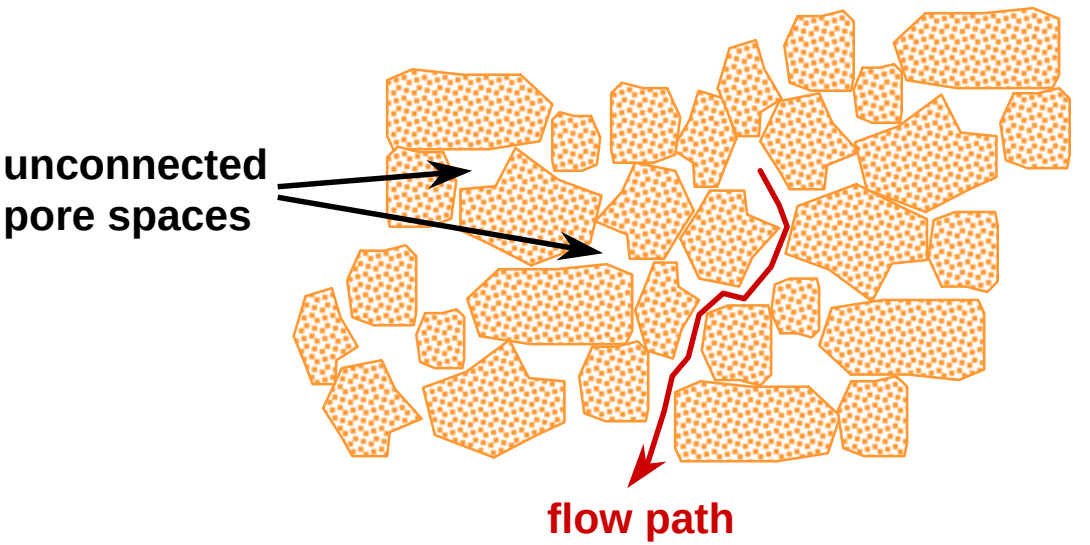
Sandstone Thin Section



- Quartz grains bonded by calcite cement

Reservoir Rock Properties

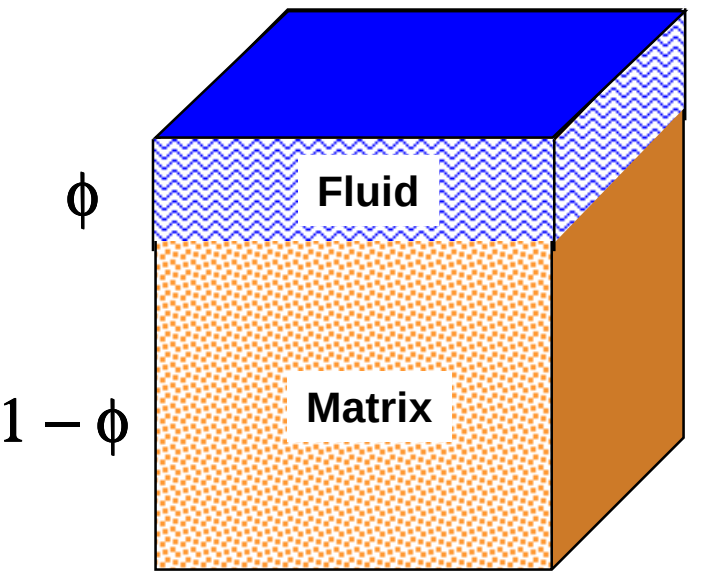
- Porosity to retain fluid AND
- Permeability to allow the fluid to move
- Permeability is a dynamic property which changes during sedimentation



Porosity Definition

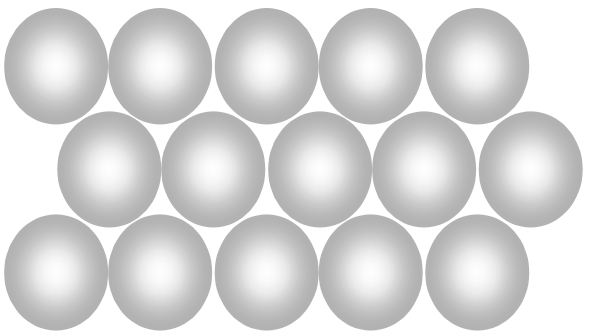
- Porosity (ϕ) = fraction of a unit volume occupied by the pores

$$\Phi = \frac{V_{fluid}}{V_{total}}$$

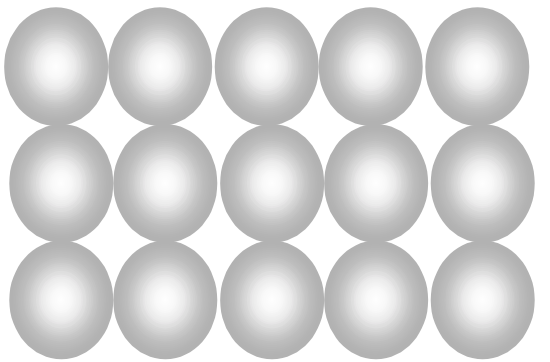


Porosity

- Porosity depends on grain packing NOT grain size
- Rocks with different grain sizes can have the same percentage porosity



- **rhombohedral packing**
- **pore space = 26 % of total volume**



- **cubic packing**
- **pore space = 47 % of total volume**

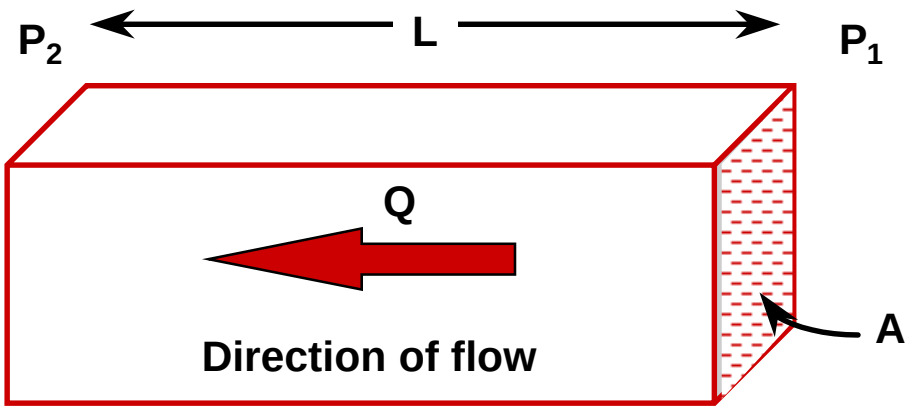
Permeability

- The rate of fluid flow through a reservoir depends on
  - the pressure drop
  - fluid viscosity
  - permeability

- Permeability is a measure of the ease at which a fluid can flow through the reservoir
  - Large grains give high permeability and large flow rate
  - Small grains give low permeability and small flow rate

- Permeability and porosity are related

Darcy's Law of Permeability



$$K = \frac{Q\mu}{A} \bullet \frac{L}{(P_1 - P_2)}$$

K = permeability
(measured in Darcies)

L = length
Q = flow rate
P_1, P_2 = pressures
A = surface area
μ = viscosity

Saturation

- Formation saturation is defined as the fraction of its pore volume occupied by a given fluid

$$saturation = \frac{V_{specific\ fluid}}{V_{pore\ space}}$$

- Definitions

  Sw = water saturation

  So = oil saturation

  Sg = gas saturation

  Sh = hydrocarbon saturation = So + Sg

Saturation

- Amount of water per unit volume = ϕ Sw
- Amount of hydrocarbon per unit volume = ϕ (1 - Sw)