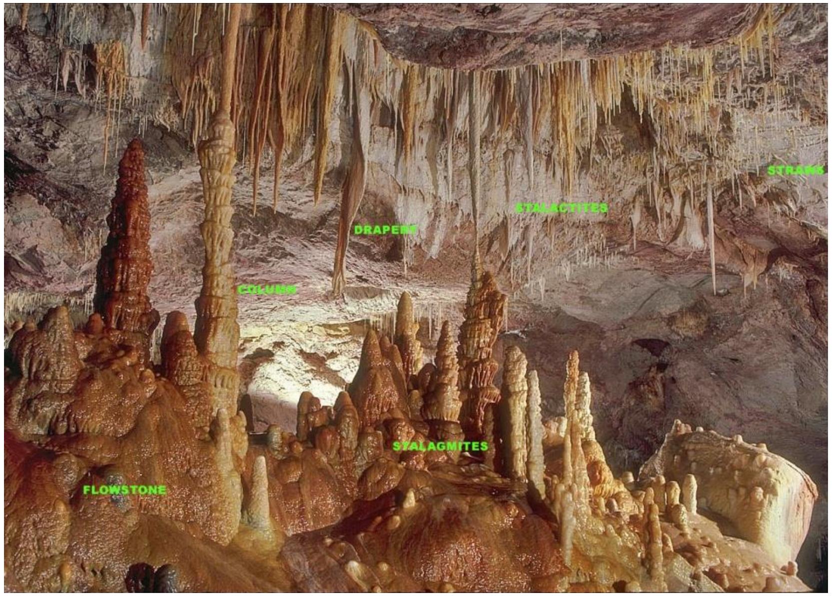
# IDC 203: INTRODUCTION TO EARTH SCIENCES



# Sedimentary rocks

**Weathering –Decomposition and disintegration of pre-existing rock into small fragments or new minerals**

**Transportation of the sediments to a sedimentary basin**

**Deposition of the sediment**

**Burial and Lithification to make sedimentary rock**

# Sedimentary stages in the rock cycle

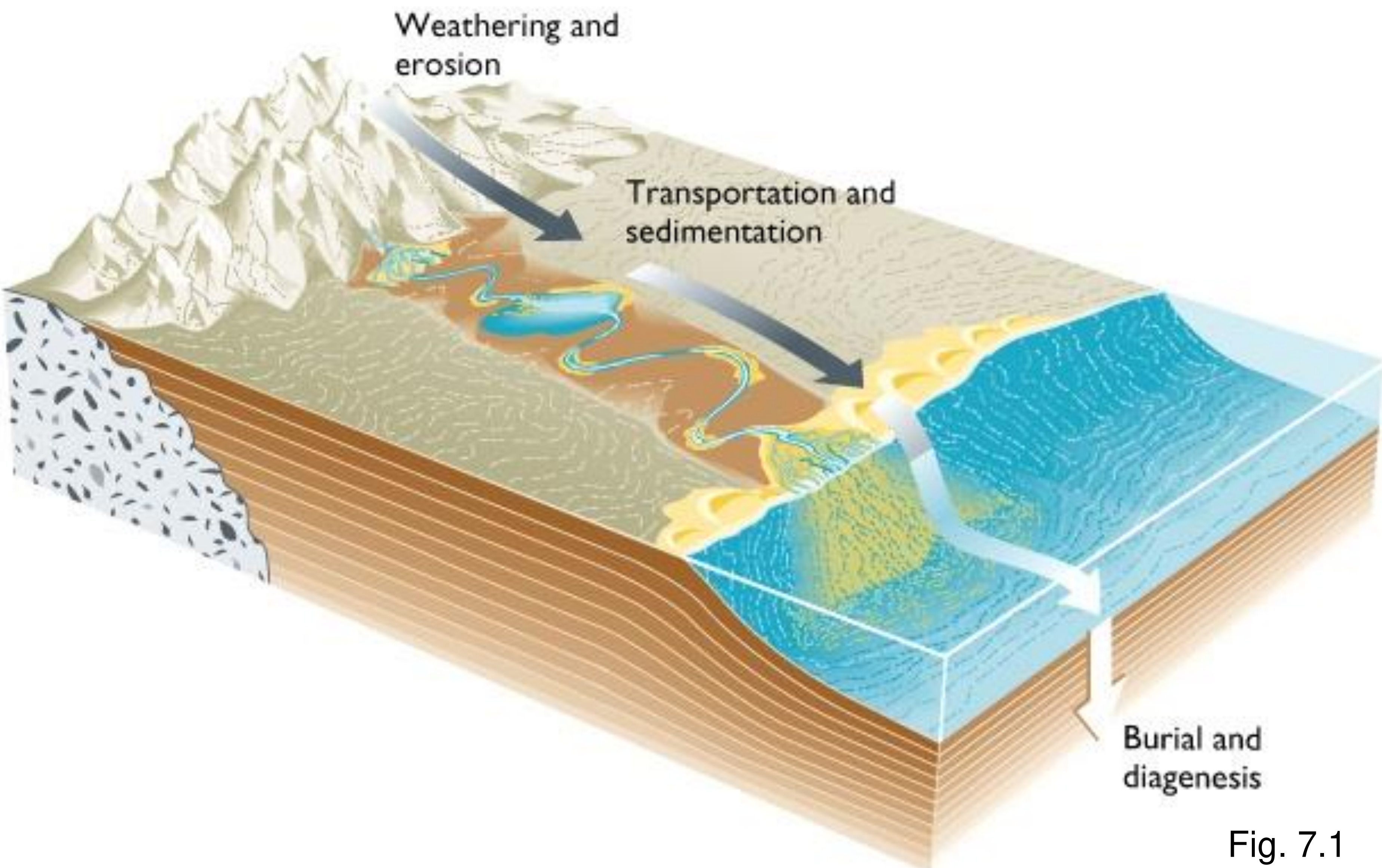



Fig. 7.1

# Sedimentary rocks

**Weathering process**

**Types of sedimentary rocks**

**Depositional environments**

# Weathering process

1. Physical (Mechanical): Large rocks broken into smaller fragments with no change in composition

2. Chemical: Rocks dissolved –
chemical and mineralogical composition can be altered
   - new minerals may form

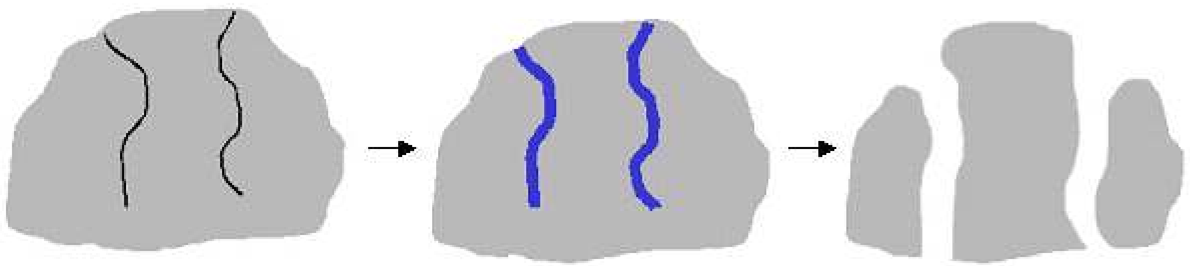
3. Biological : plants & animals

# Physical weathering

1. **Joints** (also termed extensional fractures) are planes of separation on which no shear displacement has taken place

# Physical Weathering

## 2. Frost wedging



The black lines in the rock represent fractures that are occurring in the rock.

The blue lines in the rock represent water soaking into the fractures.

The water freezes and expands. If this cycle of freezing, expansion, and thawing continues, the rock will gradually disintegrate.

# Physical Weathering

**3. Salt precipitation**

# Physical Weathering

## 4. Abrasion

**Physical grinding of  rock fragments**


# Chemical Weathering

**Chemical weathering** is the weakening and subsequent disintegration of rock by chemical reactions.

These reactions include

i) Hydration

ii) Hydrolysis

iii) Carbonation

# Chemical Weathering

**Carbonation** is the process of rock minerals reacting with carbonic acid. Carbonic acid is formed when water combines with carbon dioxide. Carbonic acid dissolves or breaks down minerals in the rock.

$CO_2 + H_2O \rightarrow H_2CO_3$

(carbon dioxide + water → carbonic acid)

$CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2HCO_{3-}$

(calcite + carbonic acid → calcium + bicarbonate)

# Chemical Weathering

**Hydrolysis** is a chemical reaction caused by water.

Water changes the chemical composition and size of minerals in rock, making them less resistant to weathering.

$$2KAlSi_3O_8 + 2H^+ + 9H_20 \rightarrow H_4Al_2Si_2O_9 + 4H_4SiO_4 + 2K^+$$

# Chemical Weathering

**Hydration** is the absorption of water into the mineral structure.

A good example of hydration is the absorption of water by anhydrite, resulting in the formation of gypsum. Hydration expands volume and also results in rock deformation.

# Biological Weathering

- This form of weathering is caused by activities of living organism

# Factors affect the rates of weathering process

- **Climate**
- **Structural weakness**
- **Topography**
- **Time**
- **Nature of rocks and minerals**

# Weathering process

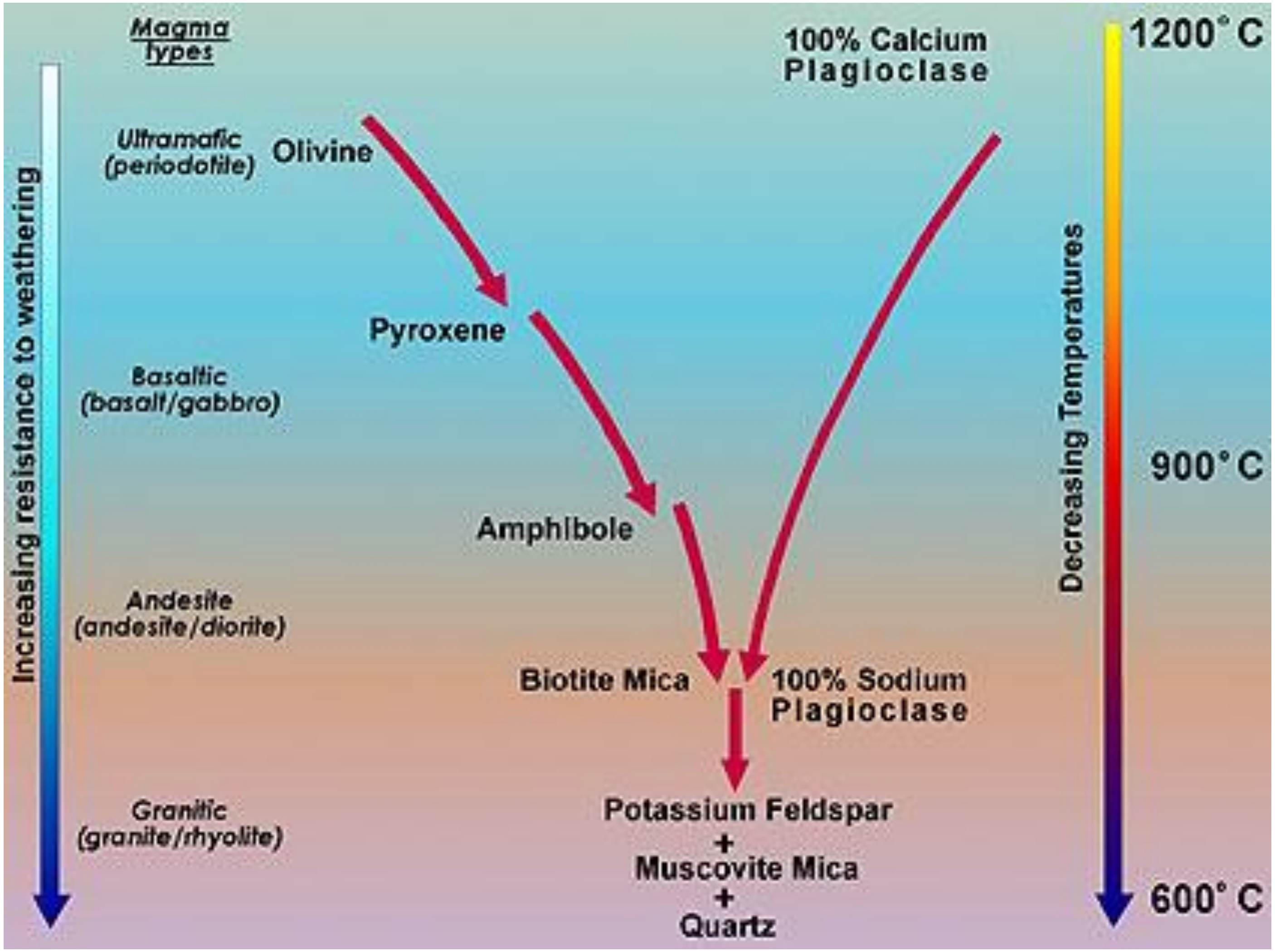
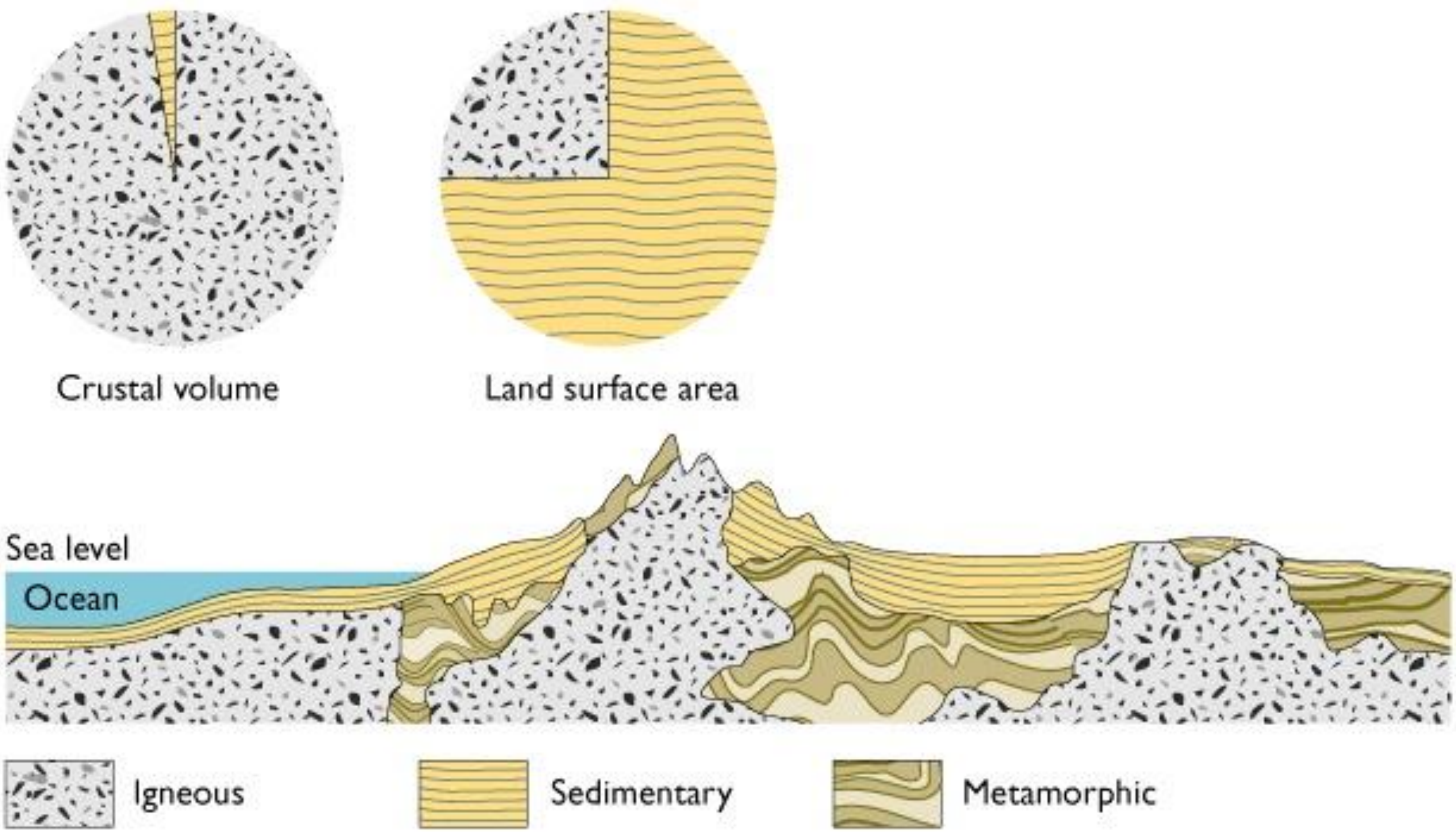


Table 7.1

## Minerals Remaining in Clastic Sediments Derived from an Average Granite Outcrop Under Varying Intensities of Weathering

| Intensity of Weathering | | |
|---|---|---|
| **Low** | **Medium** | **High** |
| Quartz | Quartz | Quartz |
| Feldspar | Feldspar | Clay minerals |
| Mica | Mica | |
| Pyroxene | Clay minerals | |
| Amphibole | | |

# HOW COMMON ARE SEDIMENTARY ROCKS?



# Sedimentary Rocks

- *Detrital* (clastic) rocks produced from rock fragments
- *Chemical* rocks produced by precipitation of dissolved ions in water
- *Organic* rocks produced by accumulation of biological debris, such as in swamps or bogs

Sedimentary rock types and *sedimentary structures* within the rocks give clues to *past environments*

# Transport and deposition of Clastic sediments

- Movement of sediment by wind, ice or water.

- Mode of transport produces distinctive deposits.

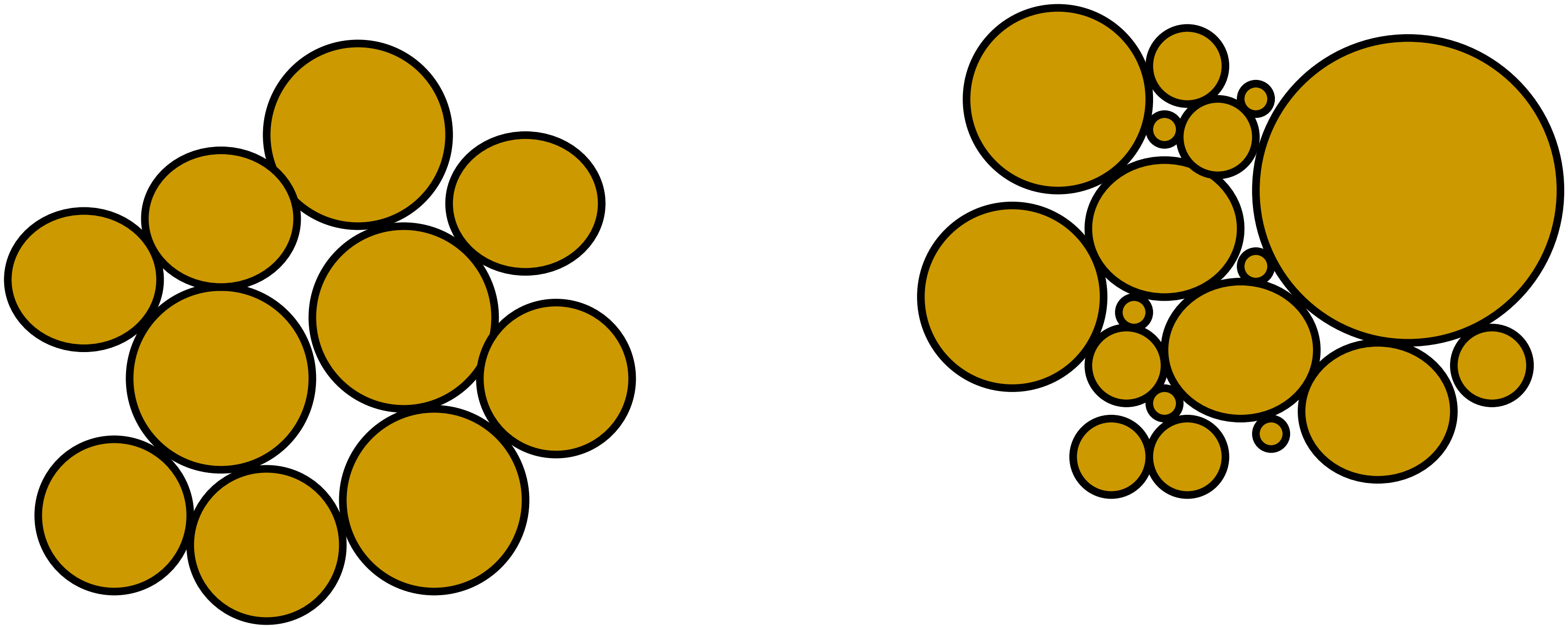
# Transport affects the sediment in several ways

***Sorting***: measure of the variation in the range of grain sizes in a clastic rock or sediment

- Well-sorted sediments indicate that they have been subjected to prolonged water or wind action.

- Poorly-sorted sediments are either not far-removed from their source or deposited by glaciers.

# Sorting



**Well-sorted sand**

**Poorly-sorted sand**

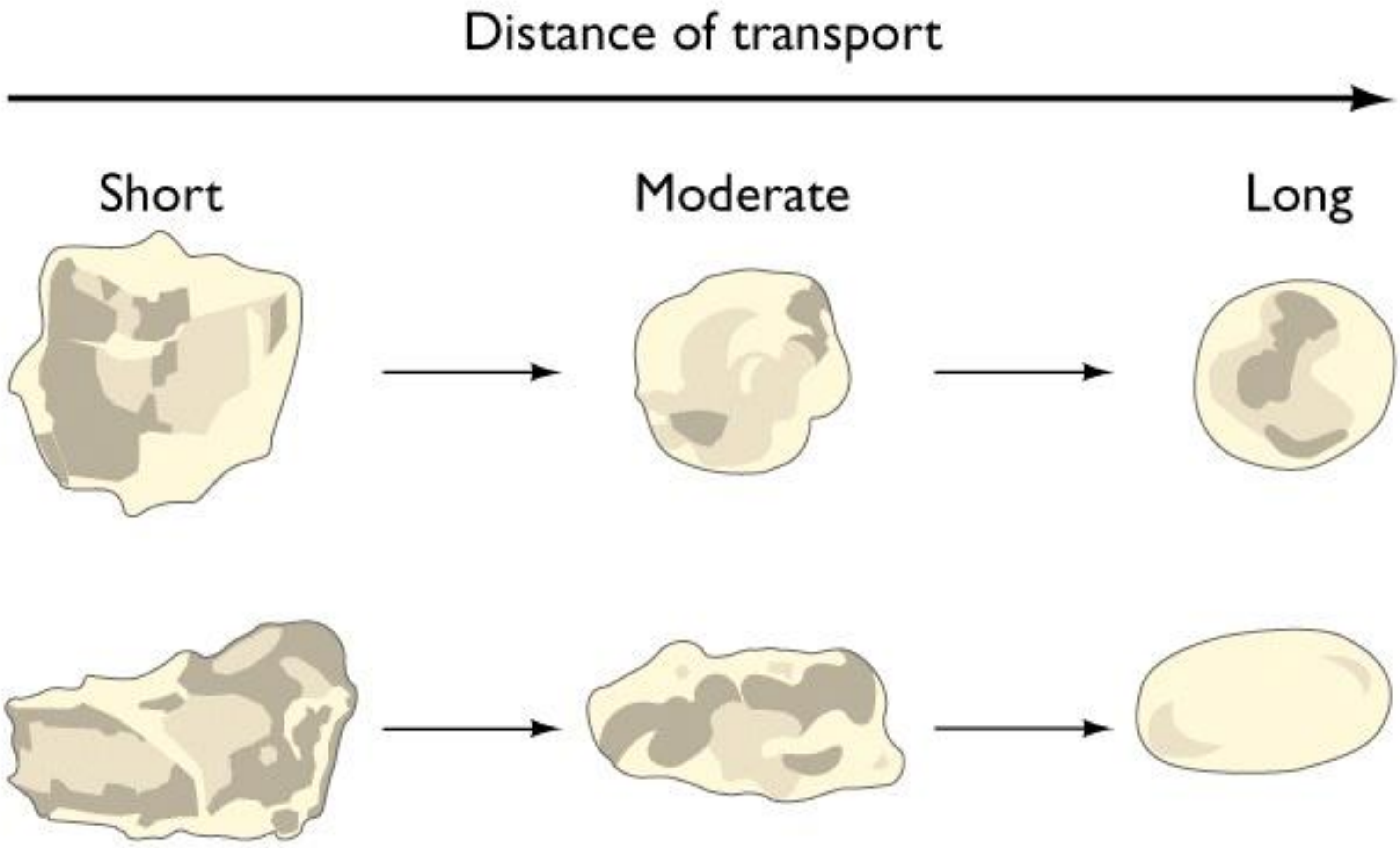
# Transport affects the sediment in several ways

***Roundness***: measure of how rounded the corners are

***Sphericity***: measure of how much it is like a sphere

**Sorting, roundness, and sphericity all increase with amount of transport.**

# Roundness and sphericity



# Types of detrital rocks

**Largely based on the size of the particles, which may be anything.**

- *Sediment* -classified by *particle size*
  - Boulder - >256 mm
  - Cobble - 64 to 256 mm
  - Pebble - 2 to 64 mm ---- Gravel
  - Sand - 1/16 to 2 mm
  - Silt - 1/256 to 1/16 mm
  - Clay - <1/256 mm

# Types of detrital rocks

Conglomerate

Breccia

Sandstone (quartzite, arkose, greywacke)

Shale

Mudstone

Siltstone

# Clastic sedimentary rocks

- ***Breccia and Conglomerate***
  - *Coarse-grained clastic* sedimentary rocks
  - Sedimentary breccia composed of coarse, *angular rock fragments* cemented together
  - Conglomerate composed of *rounded gravel* cemented together

# Conglomerate

# Breccia

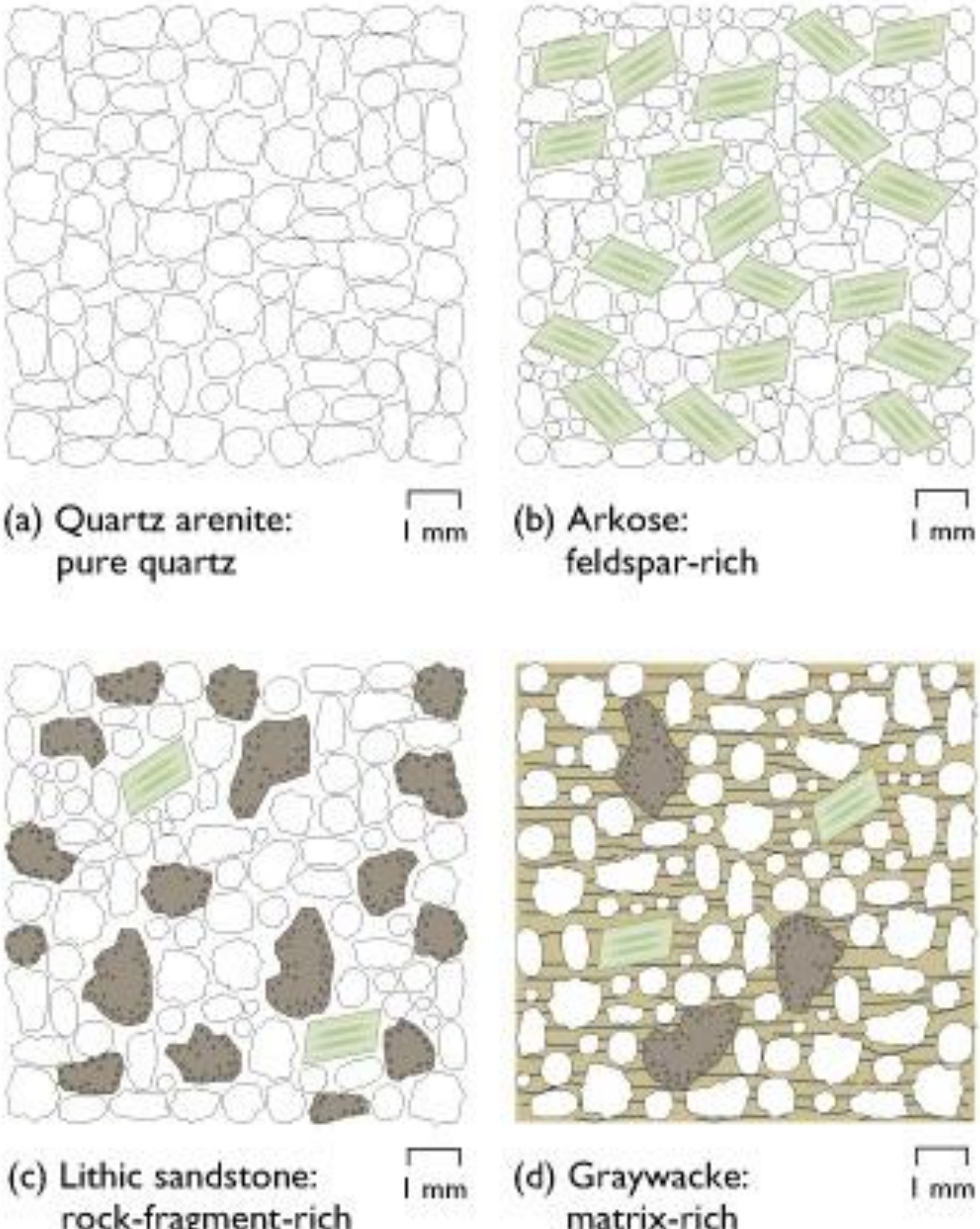
Breck Kent

# Clastic sedimentary rocks

- ***Sandstone***
  - *Medium-grained clastic* sedimentary rock
  - Types determined by composition
    - *Quartz sandstone* - >90% quartz grains
    - *Arkose* - mostly feldspar and quartz grains
    - *Graywacke* - sand grains surrounded by dark, fine-grained matrix, often clay-rich

# Sandstone

Breck Kent




# Four major groups of sandstones

# Shale

**Shales are clastic rocks, made up mainly fine silt/clay**

**They are most abundant sedimentary rocks, accounts for about 80% of them**

**Often contain fossils**

**Mostly hydrous aluminum silicate in composition = from weathered feldspars**

**Deposition takes place under low fluvial regime or under weak water current. Eg. Offshore or in Lagoon**

- Shales are made of fine well sorted silt and clayey sediments, where normally one can expect high porosity and permeability.

# Shale

# Types of chemical sedimentary rocks

| | |
|---|---|
| **Limestone** | **$CaCO_3$** |
| **Chert** | **$SiO_2$** |
| **Salt** | **$NaCl$, $KCl$, $K_2SO_4$** |
| **Gypsum** | **$CaSO_4 \cdot 2H_2O$** |
| **Coal** | **altered organic debris** |

# Chemical sedimentary rocks

- *Carbonates*
  - Contain $CO_3$ as part of their chemical composition
  - *Limestone* is composed mainly of *calcite*
    - Most are *biochemical*, but can be *inorganic*
    - Often contain easily recognizable fossils

## Chemical sedimentary rocks

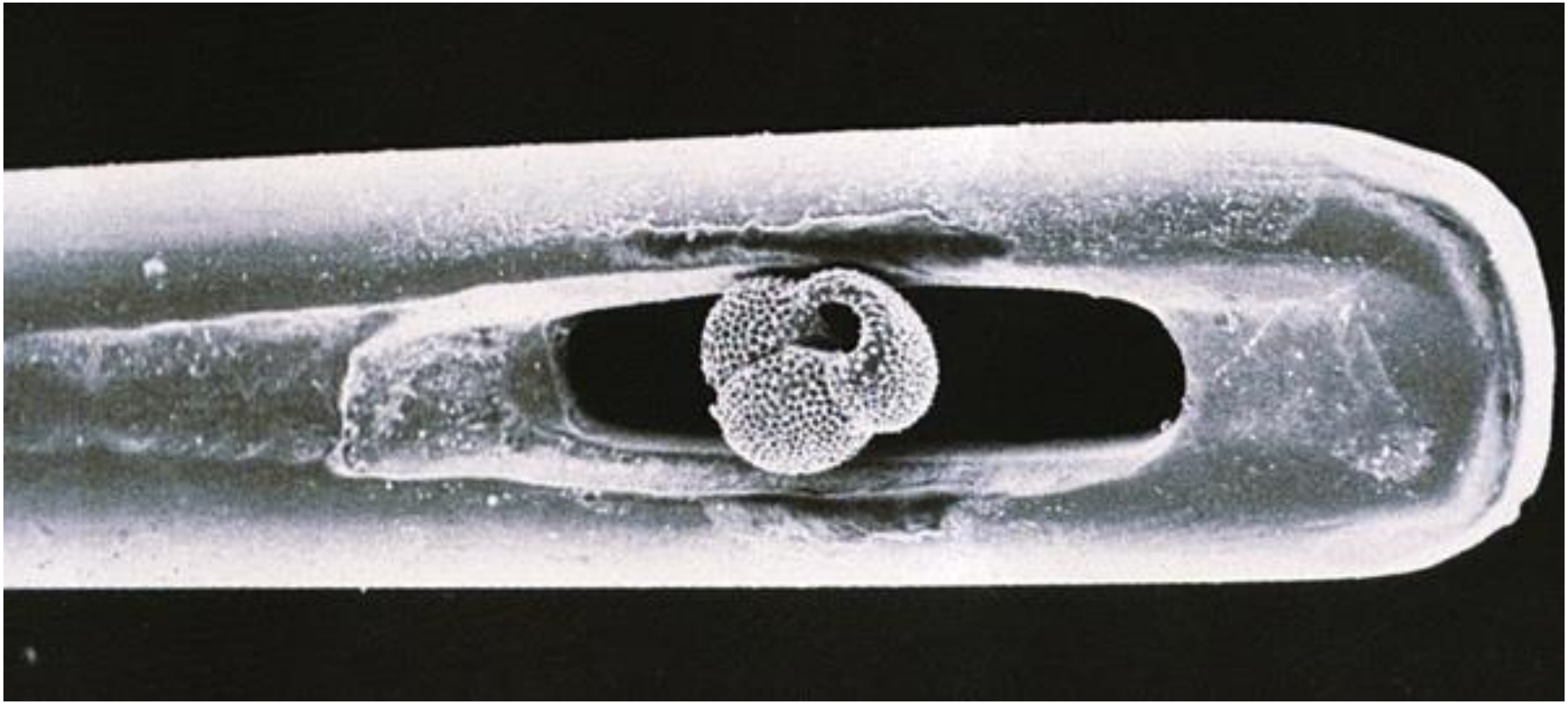
**Limestone:** It is a non-clastic rock formed either chemically or due to precipitation of calcite ($CaCO_3$) from organisms usually shell. These remains will result in formation of a limestone.

Limestones formed by chemical precipitation are usually fine grained, whereas, in case of organic limestone the grain size vary depending upon the type of organism responsible for the formation

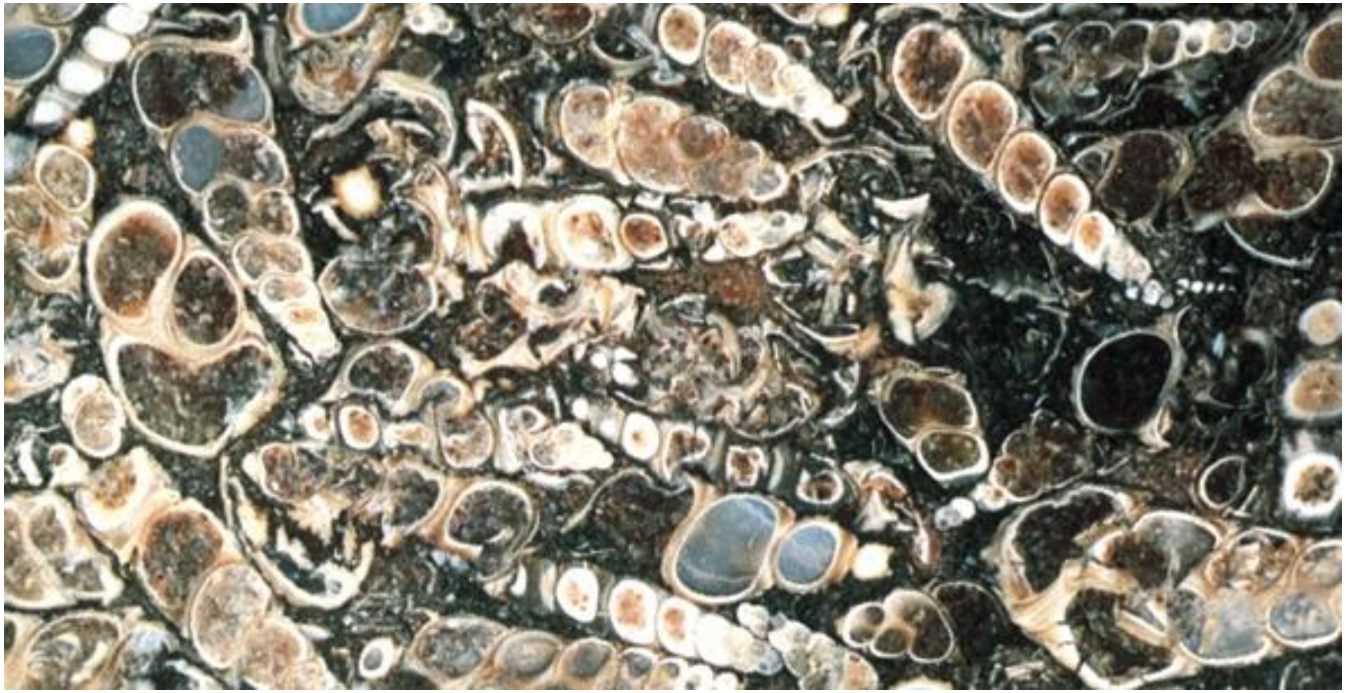
**Fossiliferous Limestone: which medium to coarse grained, as it is formed out of cementation of Shells.**

# Limestone

# Foraminifera in the eye of a needle



# Fossiliferous limestone



# Chemical sedimentary rocks

## Chert

- Hard, compact, fine-grained, formed almost entirely of silica
- Can occur as layers or as lumpy nodules within other sedimentary rocks, especially limestones

# Evaporites

- These rocks are formed within the a depositional basin from chemical substances dissolved in the seawater or lake water

- Characteristic of arid conditions

# Evaporites

**Minerals precipitate according to solubility.**

**Gypsum**

**50%**

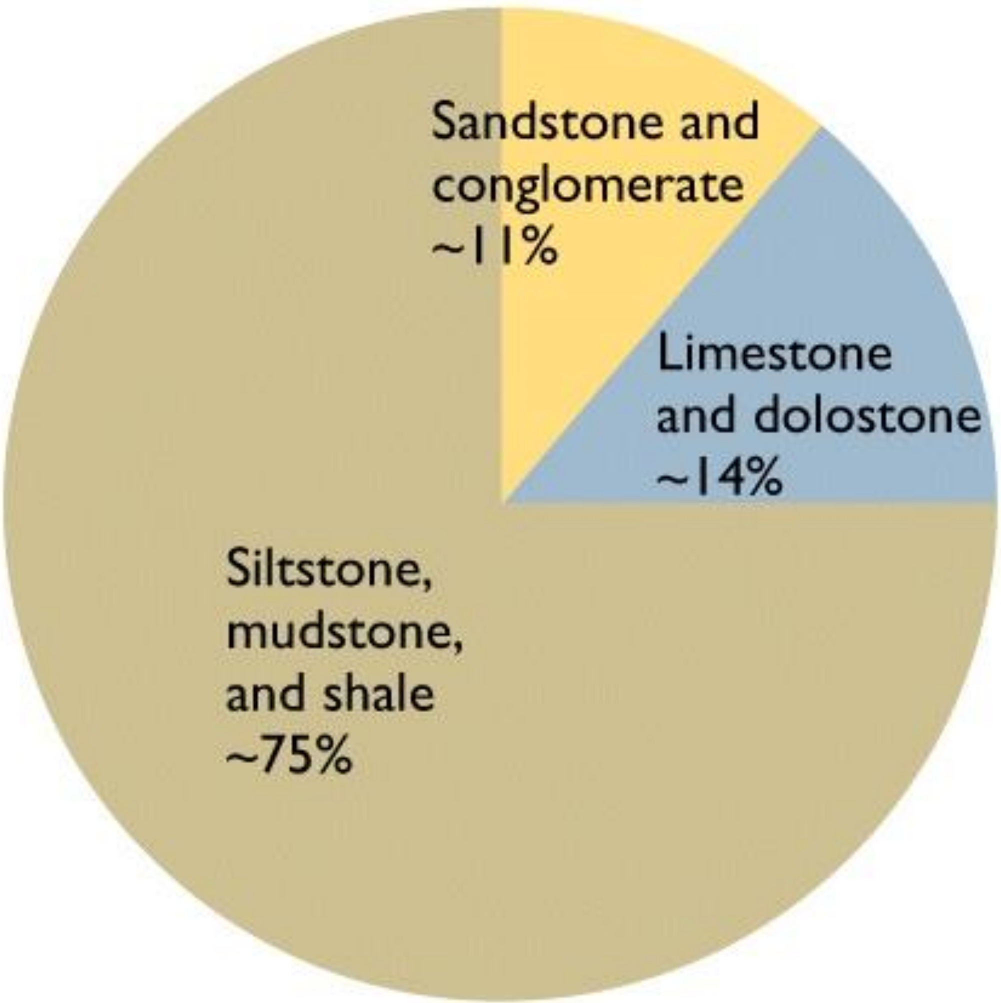
**$CaSO_4.2H_20$**

**Halite**

**90%**

**NaCl**

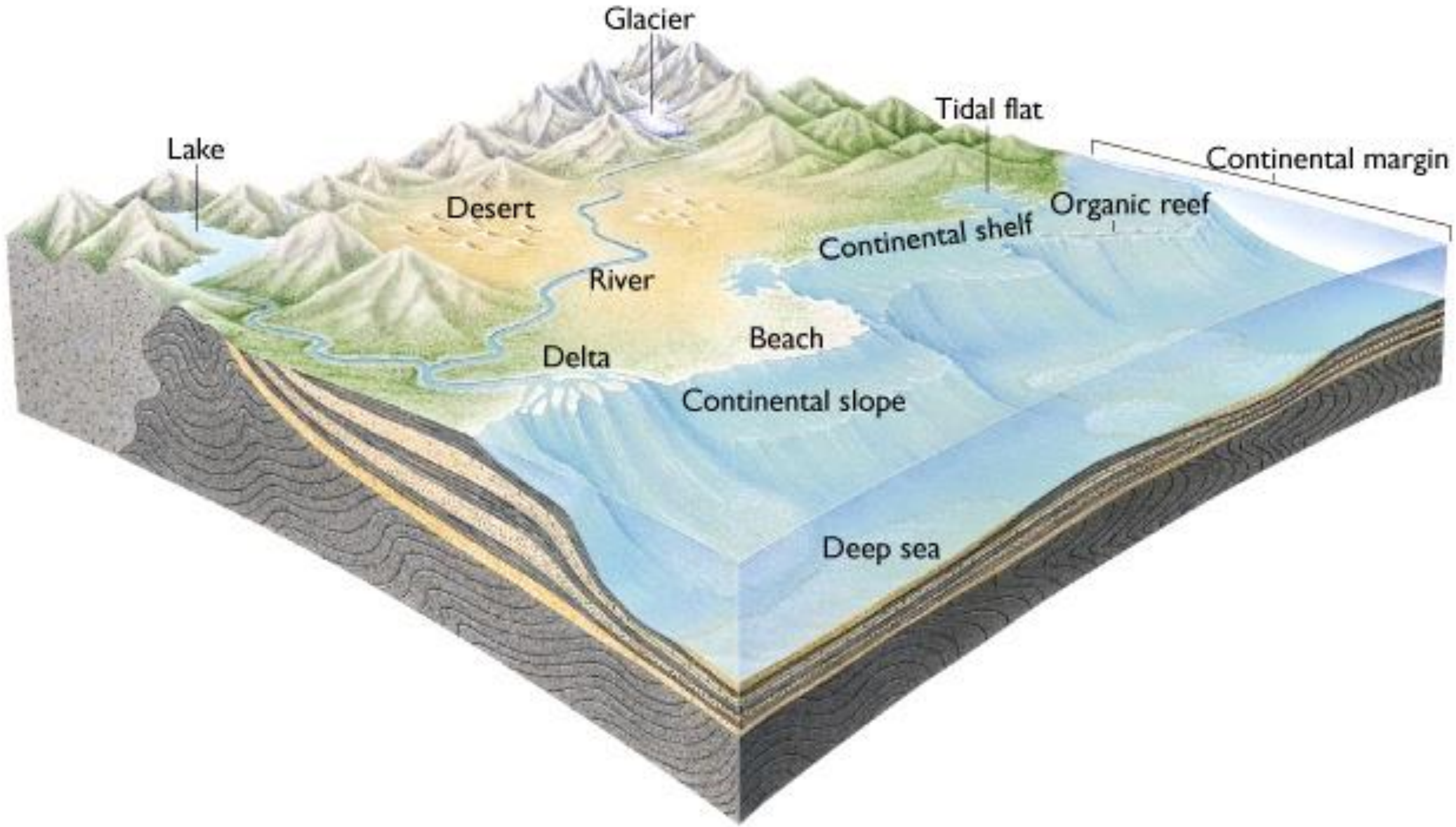
# Relative abundance of sedimentary rock types



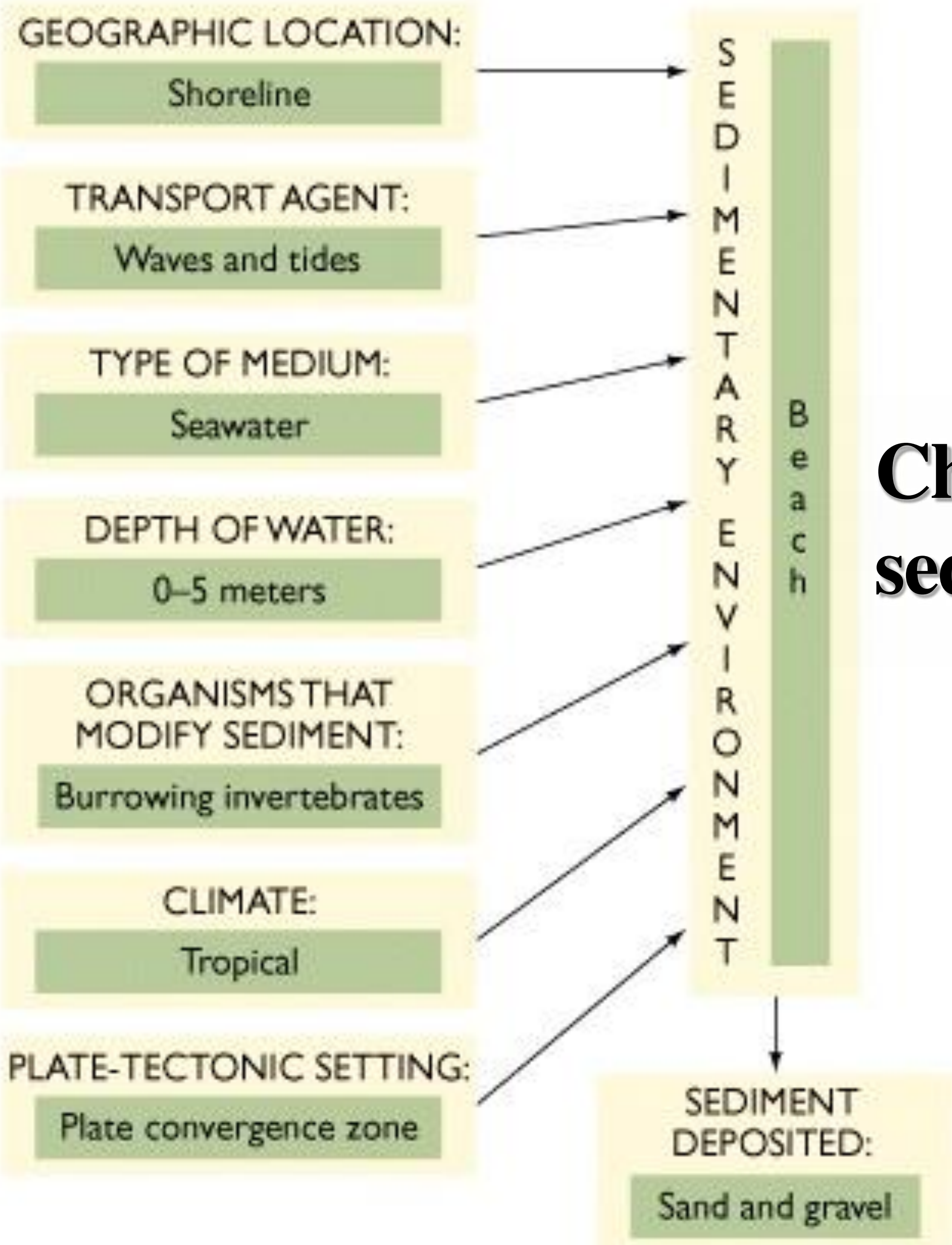
## Sedimentary environment

- Sediments accumulate in some environment of deposition or **depositional environments**
- These areas receive net deposition
- Erosion may occur, but deposition dominates
- Features of these depositional environments are preserved in the rock record
- Examples:
    - Sediment texture
    - Fossils of organisms that lived in the environment
- **Ancient environments can be reconstructed from the clues that are preserved in the sedimentary rocks**

# Common sedimentary environments



# Characteristics of a sedimentary environment



## Table 7.2 Clastic Sedimentary Environments

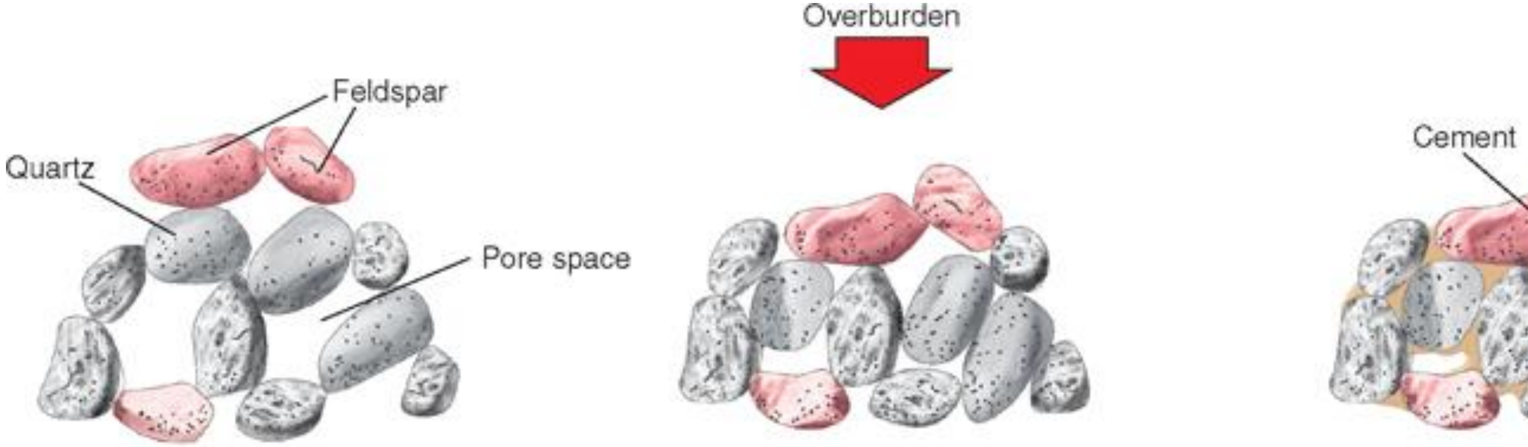
| Environment | Agent of Transportation, Deposition | Sediments |
|---|---|---|
| CONTINENTAL | | |
| Alluvial | Rivers | Sand, gravel, mud |
| Desert | Wind | Sand, dust |
| Lake | Lake currents, waves | Sand, mud |
| Glacial | Ice | Sand, gravel, mud |
| SHORELINE | | |
| Delta | River + waves, tides | Sand, mud |
| Beach | Waves, tides | Sand, gravel |
| Tidal flats | Currents | Sand, mud |
| MARINE | | |
| Continental shelf | Waves, tides | Sand, mud |
| Continental margin | Ocean currents | Mud, sand |
| Deep sea | Ocean currents, settling | Mud |

Table 7.3

## Major Chemical and Biochemical Sedimentary Environments

| Environment | Agent of Precipitation | Sediments |
|---|---|---|
| SHORELINE AND MARINE | | |
| Carbonate (includes reef, bank, deep sea, etc.) | Shelled organisms, some algae; inorganic precipitation from seawater | Carbonate sands and muds, reefs |
| Evaporite | Evaporation of seawater | Gypsum, halite, other salts |
| Siliceous: deep sea | Shelled organisms | Silica |
| CONTINENTAL | | |
| Evaporite | Evaporation of lake water | Halite, borates, nitrates, other salts |
| Swamp | Vegetation | Peat |

# Lithification




A After deposition B Compaction C Cementation

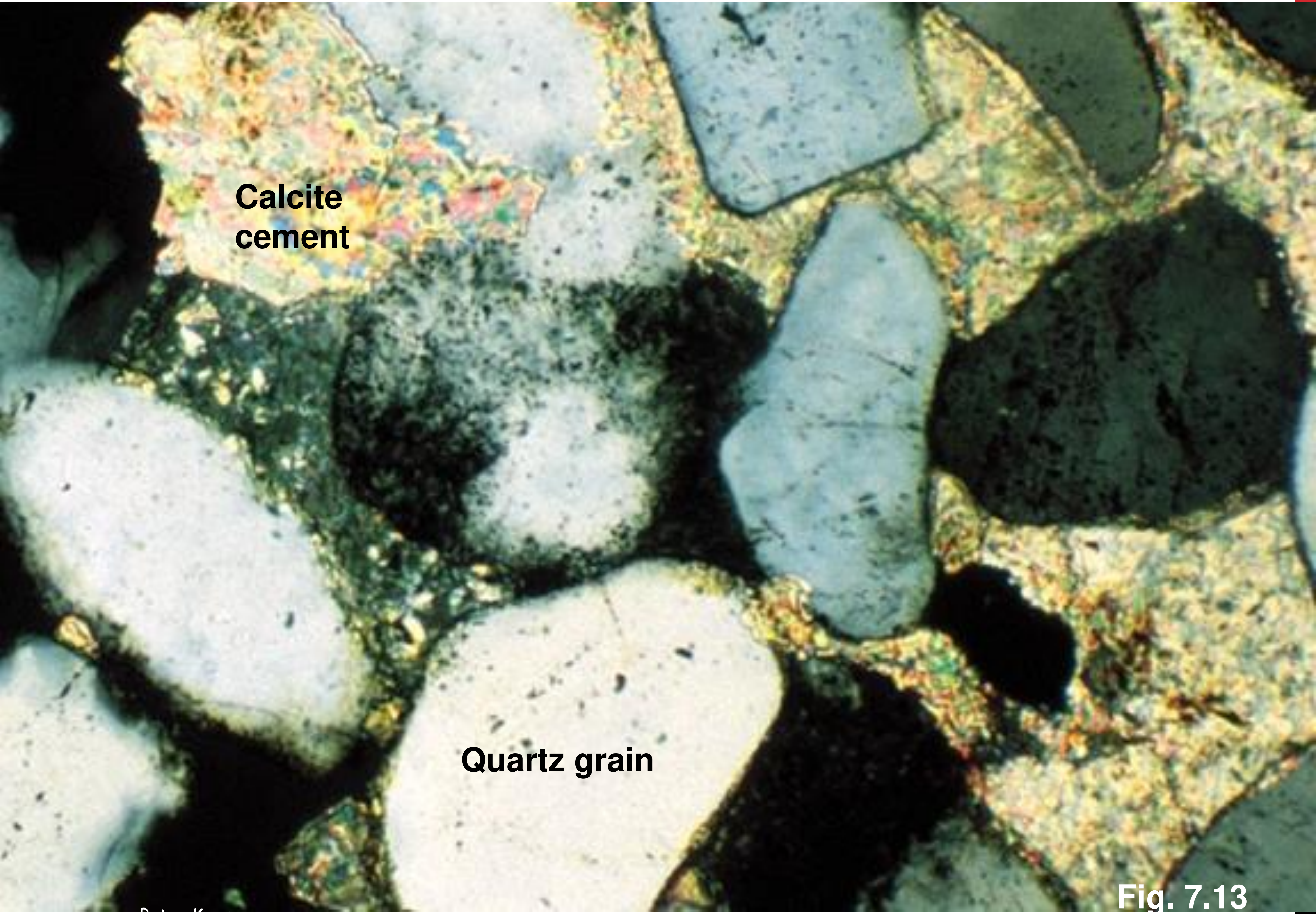



Fig. 7.13

# Products of lithification

| | | |
|---|---|---|
| Mud | → | Mudstone and shale |
| Sand | → | Sandstone |
| Gravel | → | Conglomerate |
| Lime muds, sands, oozes | → | Limestone and dolomite |

# From sediment to sedimentary rock (lithification)

***Compaction***: reduces pore space

**Clays and muds are up to 60% water; 10% water after compaction.**

***Cementation***: **chemical precipitation of mineral material between grains ($SiO_2$, $CaCO_3$, $Fe_2O_3$) binds sediment into hard rock.**

***Recrystallization***: ***P*** **and** ***T*** **increase with burial 30°C/km or 1°C/33 m.**

# Compaction (Primarily of Muds)


**Precipitation of new minerals or additions to existing ones**

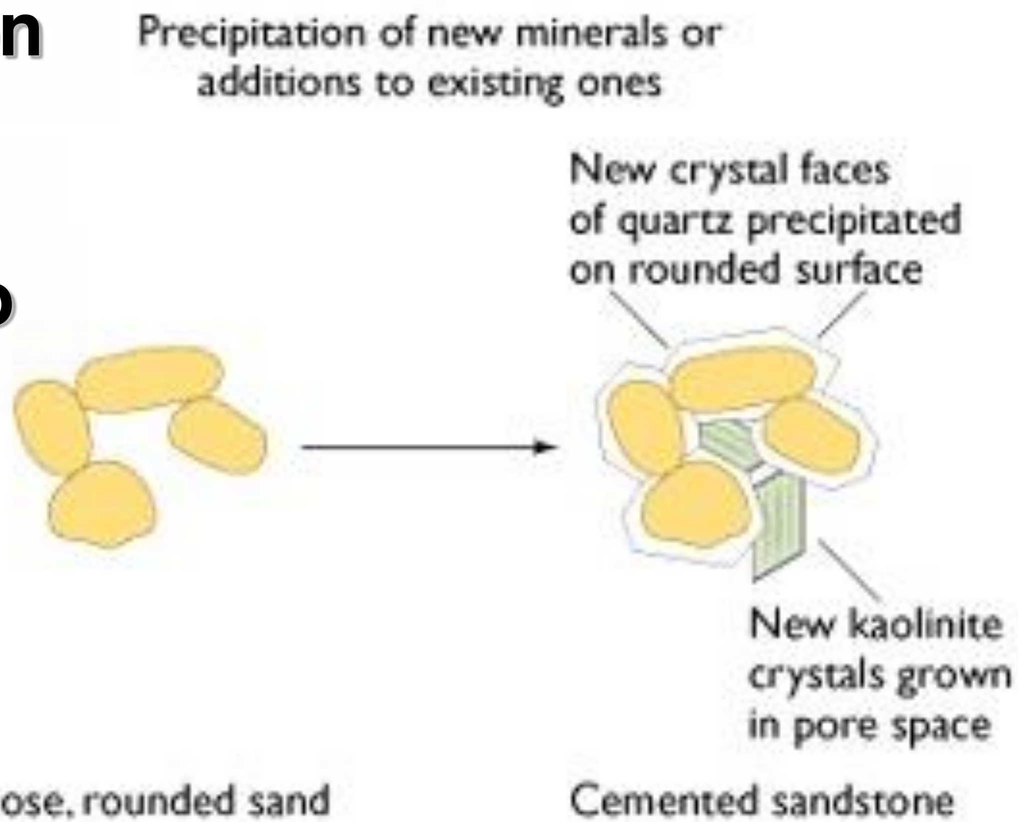
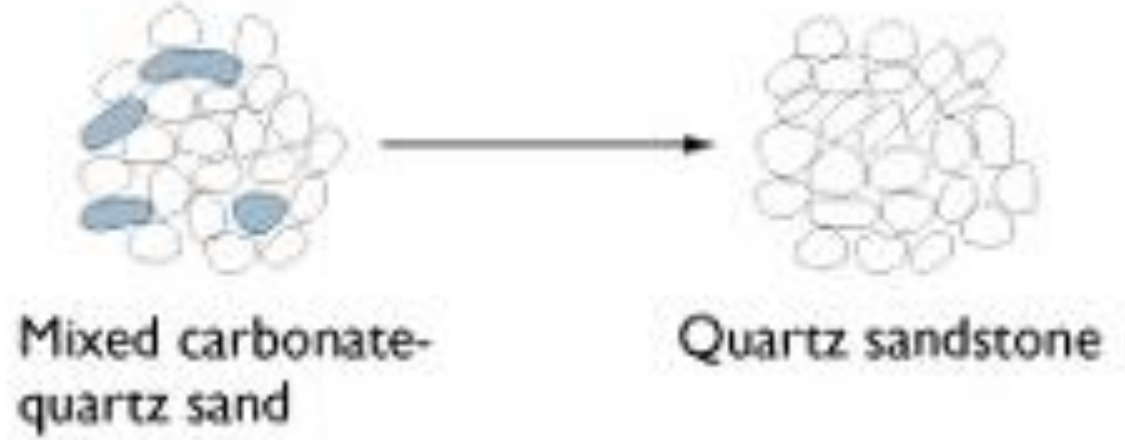
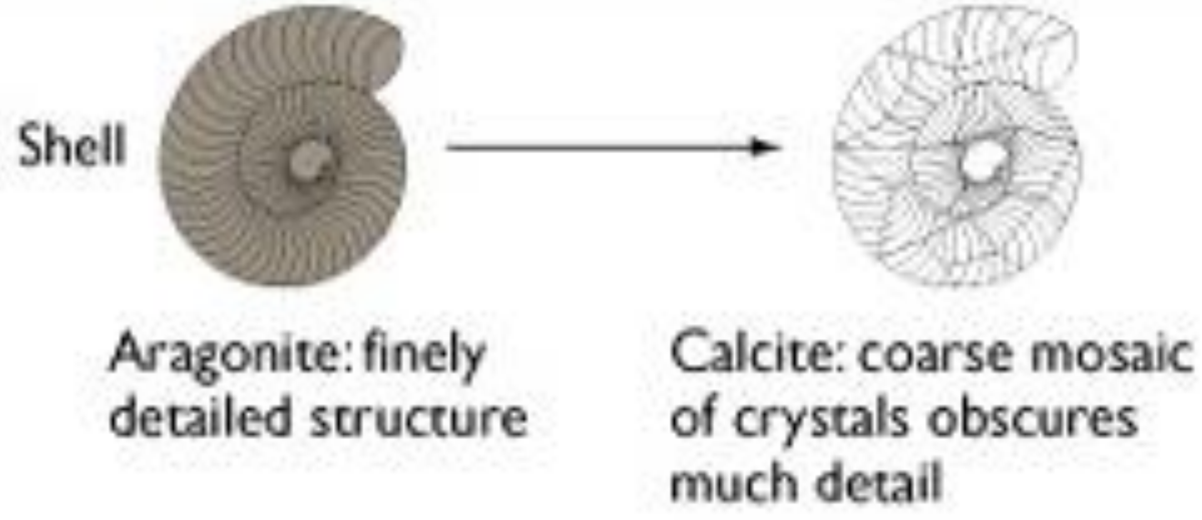



Fig. 7.12

# Dissolution of More Soluble Minerals




# Recrystallization of Unstable Minerals



# Clues to interpreting sedimentary environment

- Sedimentary structures
- Sorting, roundness, sphericity
- Sequence of beds

# Environment of deposition

**Modern Analogue**

- Key to interpreting transport history of sediments and rocks

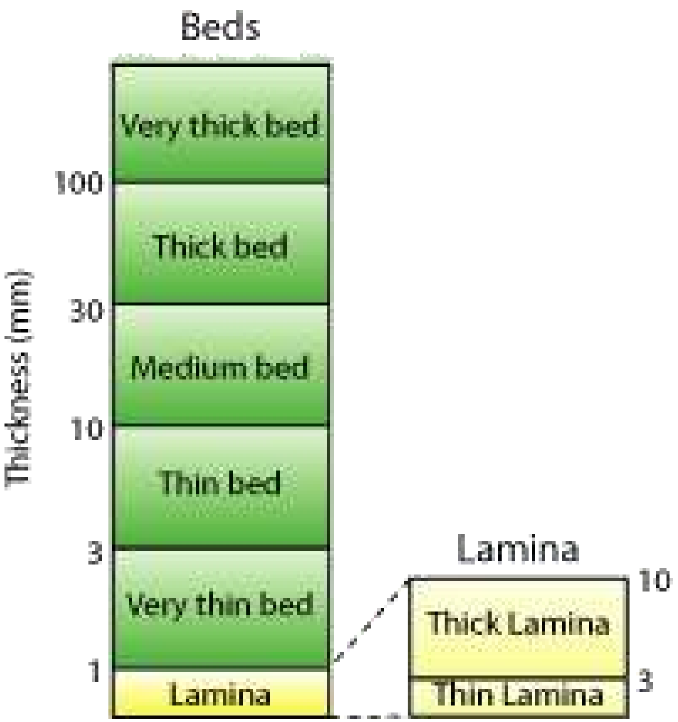
**Model**

- Based on idea that a "particular set of environmental conditions operating at a particular intensity will produce a sedimentary deposit with a unique set of properties that will identify if as the product of a particular environment"

(Boggs, 2001)

# Sedimentary Structures

- *Bedding*
  - Series of visible layers within a rock
  - Most common sedimentary structure




Laminae & Beds (Modified from Boggs 2001)

# Sedimentary structures

**Stratification = bedding = layering**

**Produced due to differences in**

1. **size of particles**
2. **kinds of particles**

# Sedimentary structures

**Particular structural features can give information about the environment of deposition.**

**Structures also help determine if a bed is right-side-up.**

**— this is important in deformed rocks**

# Environment of deposition

**Modern Analogue**

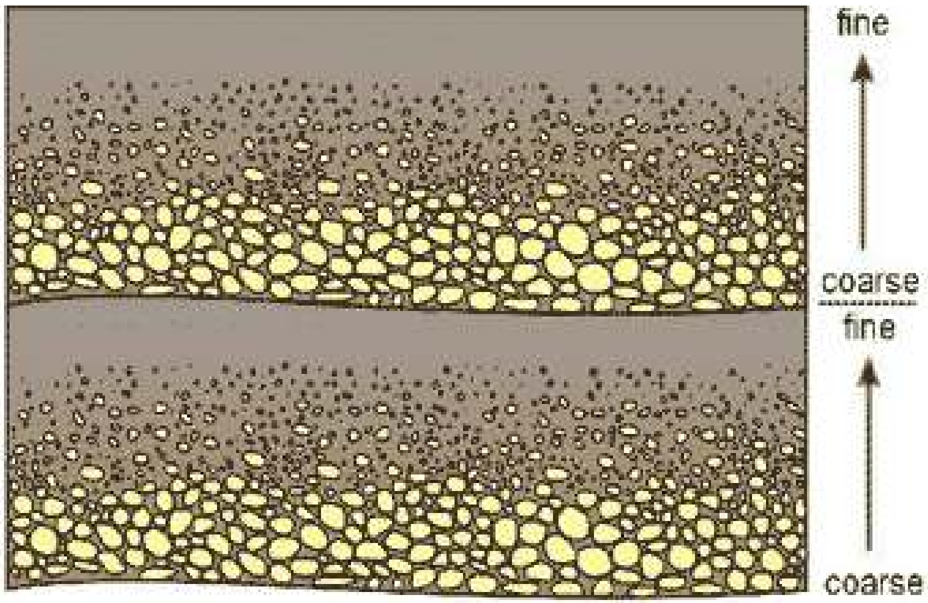
- Key to interpreting transport history of sediments and rocks

**Model**

- Based on idea that a "particular set of environmental conditions operating at a particular intensity will produce a sedimentary deposit with a unique set of properties that will identify if as the product of a particular environment"

(Boggs, 2001)

# Graded bedding




Scale may be mm to m

# Fossils

- Traces of plants or animals preserved  in rock

- Hard parts (shells, bones) more easily preserved as fossils

# Bioturbation tracks and tunnels

# Fossils

# Streams: transport to the ocean

# Rivers and streams

***Stream*** **: body of water flowing in a channel**

**The floor of the channel is called the *bed*.**

**When rainfall is very heavy or snow melts rapidly, bodies of water overflow their banks and water covers the adjacent land called the *floodplain*.**

# RIVERS AND STREAMS

**Carry away runoff to lakes and seas**

**Erode land (degradation)**

**Transport and deposit sedimentary debris**

# STREAM BEHAVIOR

**Mostly determined by velocity and shape of channel.**

**These factors combine to allow either laminar or turbulent flow.**

**Turbulent flow is much more erosive.**

**Stream velocities may vary from 0.25 to 7 m/s.**

# LAMINAR FLOW

Smooth sheet-like flow at a low velocity

Usually confined to edges and top of stream

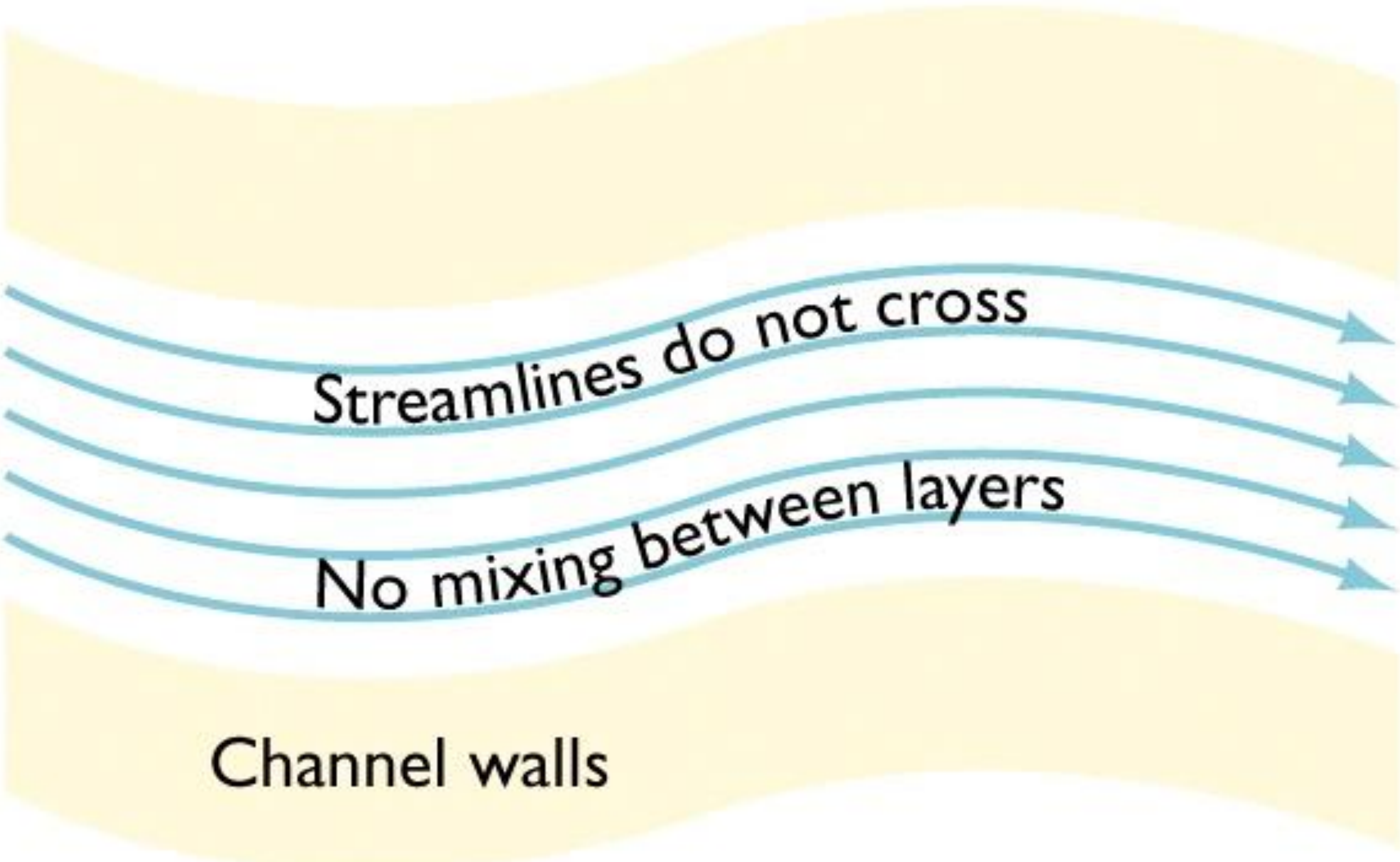
# TURBULENT FLOW

**Irregular swirling flow**

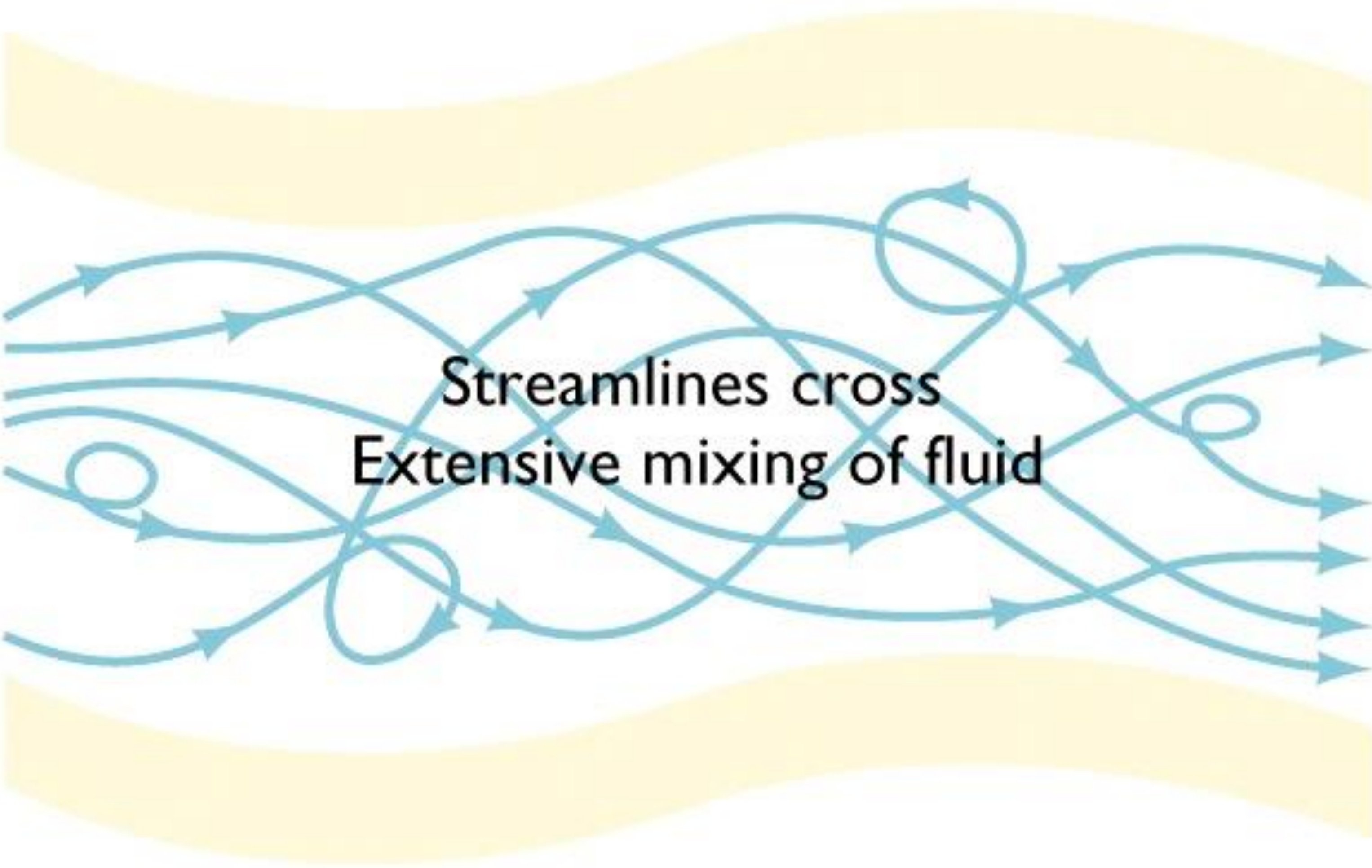
**Occurs at most rates of stream flow**

**Keeps particles in suspension**

# LAMINAR FLOW

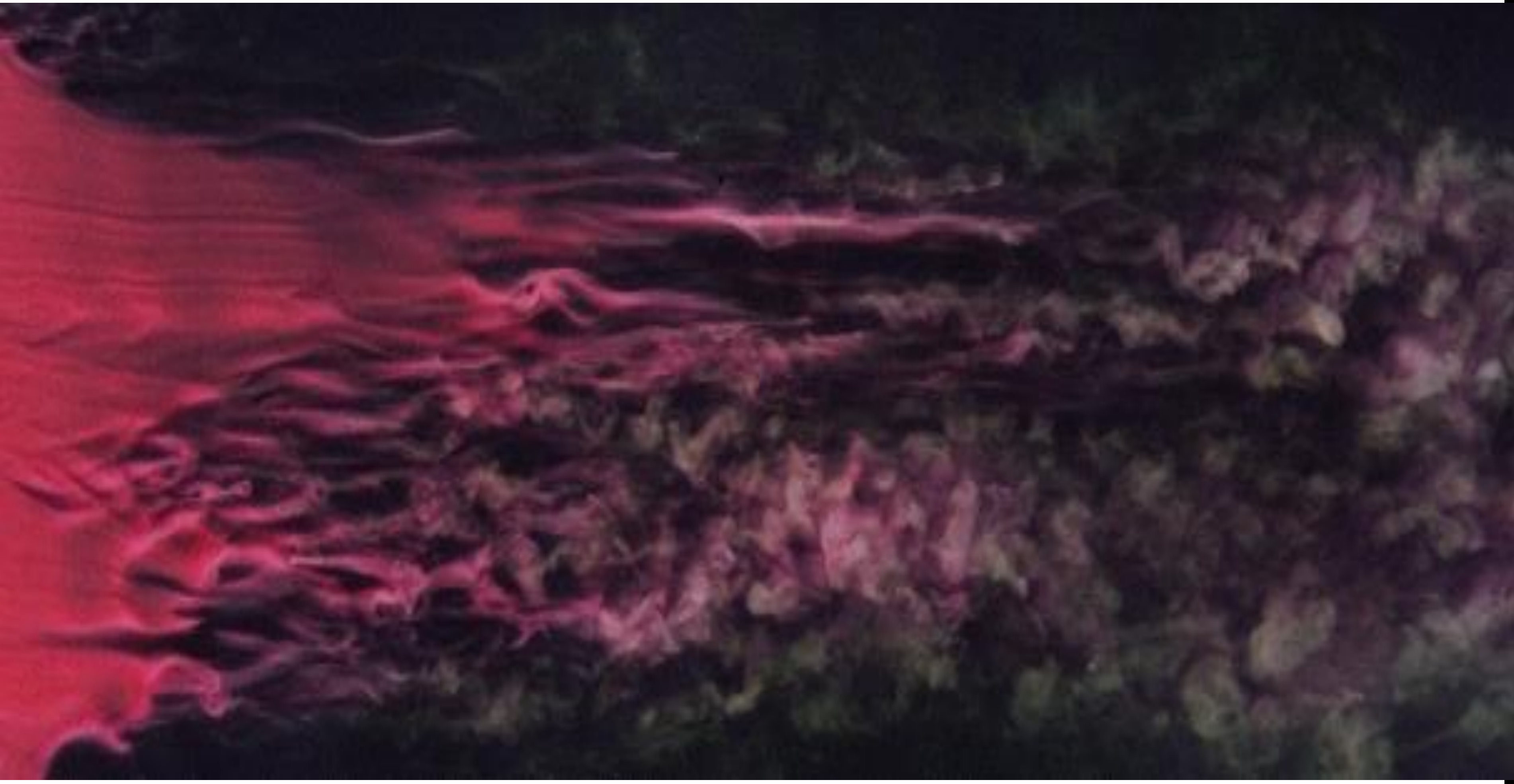


# TURBULENT FLOW



# LAMINAR TO TURBULENT TRANSITION

**Laminar flow** **Turbulent flow**



ONERA

Fig. 13.1c

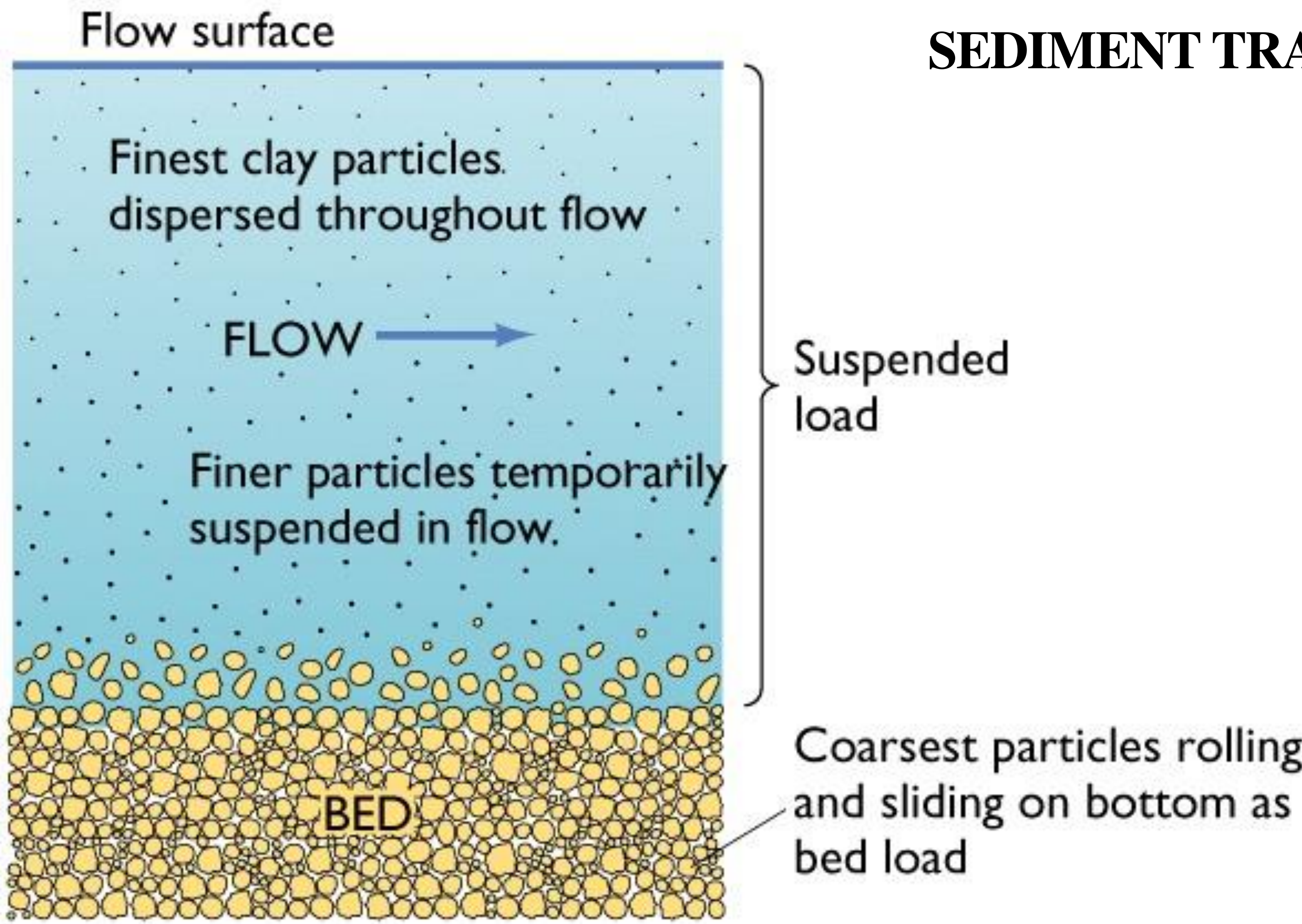
# STREAMS MOVE MATERIAL IN THREE FORMS

**Dissolved load**

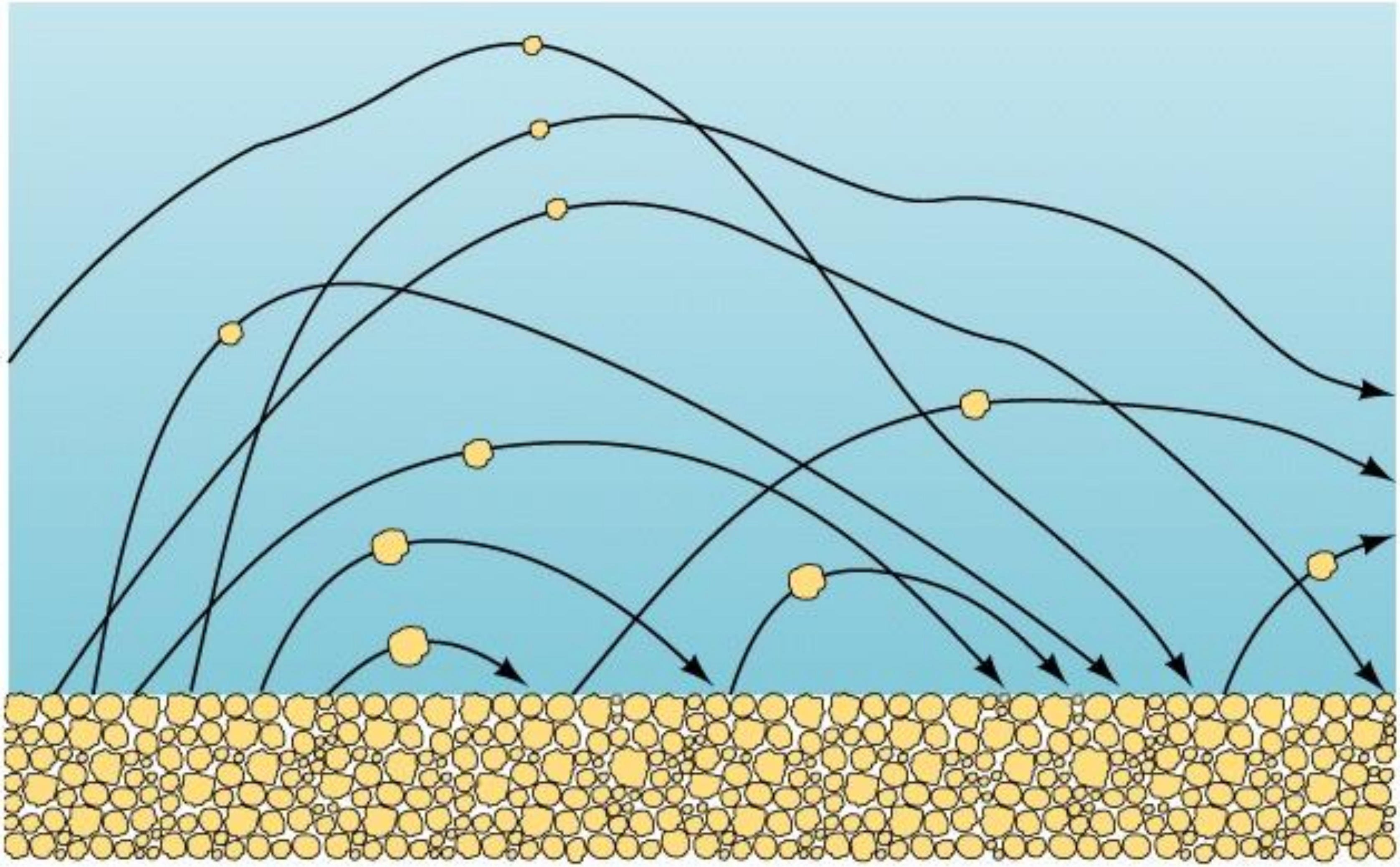
**Suspended load**

**Bed load (traction and saltation)**

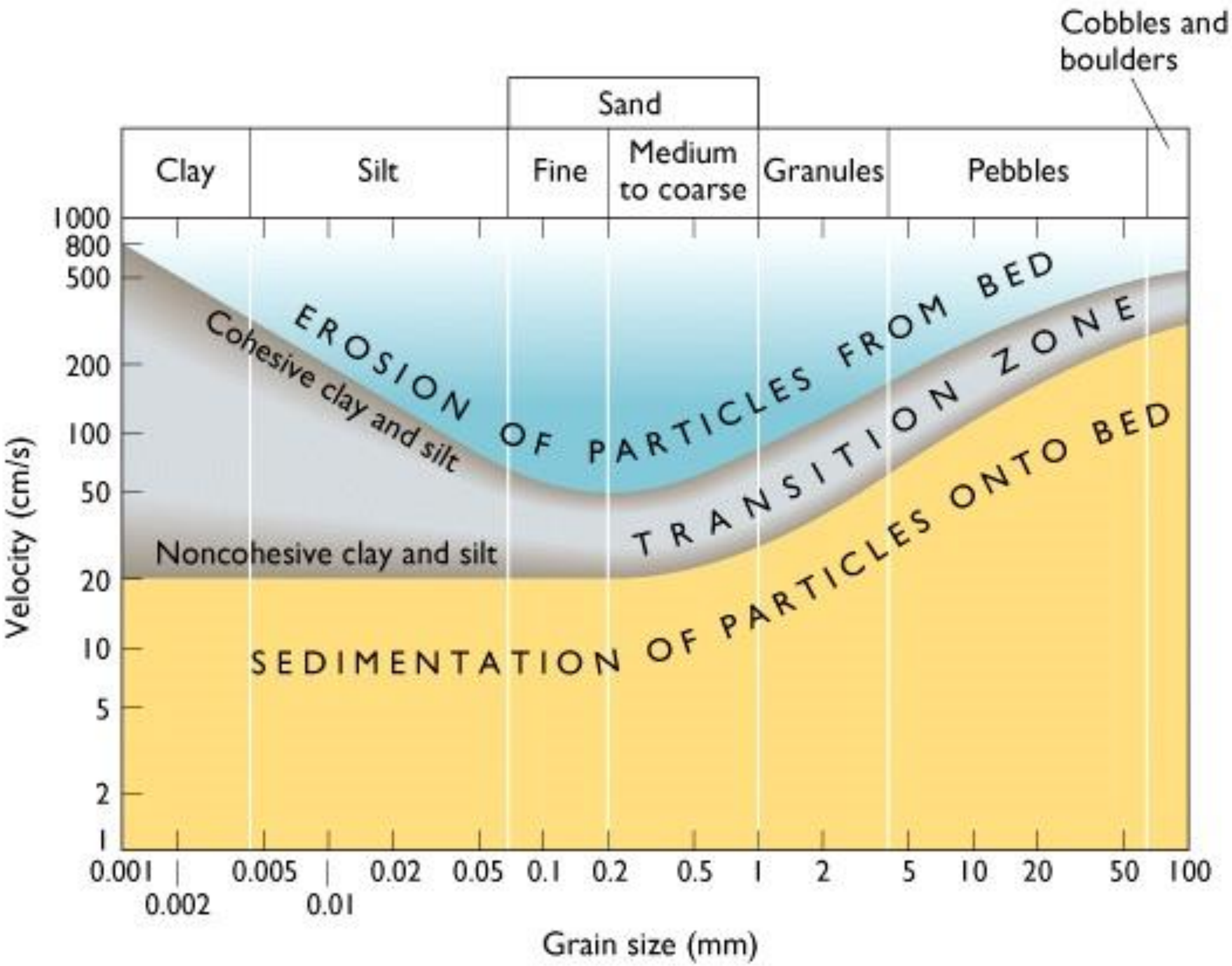
# SEDIMENT TRANSPORT



# SALTATION



# GRAIN SIZE AND FLOW VELOCITY



# STREAM TERMS

*competence*: **measure of the largest particles a stream can transport** ***proportional to*** $v^2$

*capacity*: **maximum quantity of sediment carried by stream** ***proportional to Q and v***

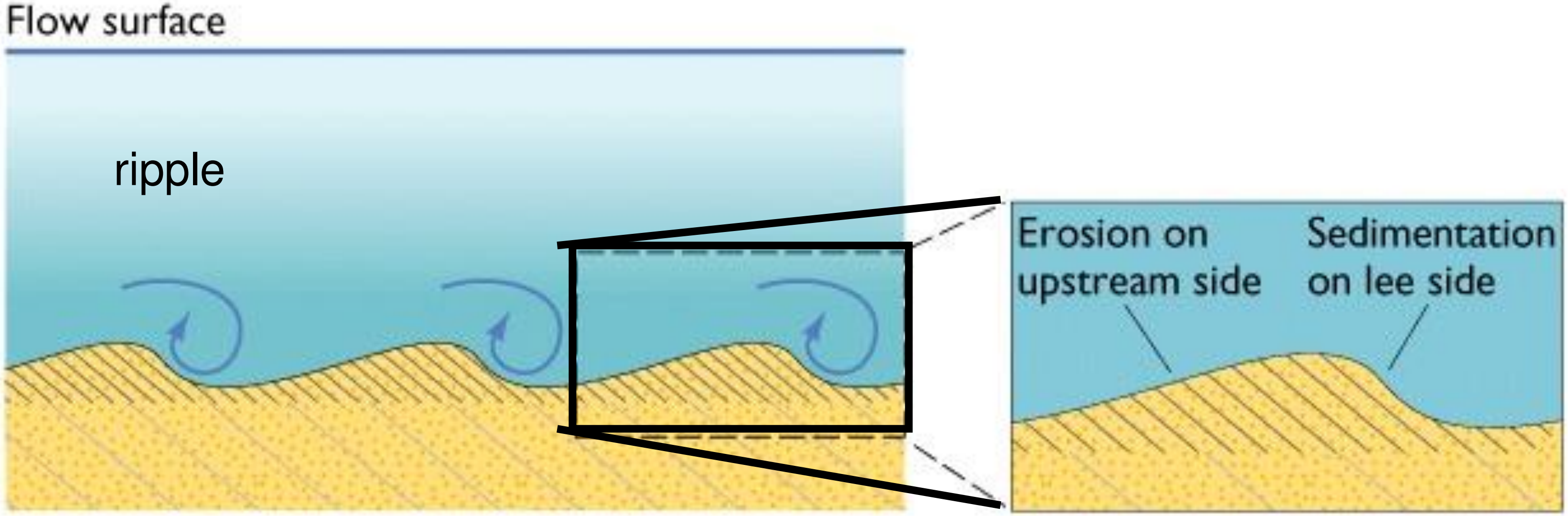
# DISCHARGE

**Total amount of water that passes a given point in a stream per unit time**

$$Q = w\,d\,v$$

Discharge ($m^3$/s) = width (m) × depth (m) × average velocity (m/s)

# LOWER VELOCITIES FORM RIPPLES




(a) Lower velocity

# HIGHER VELOCITIES FORM DUNES

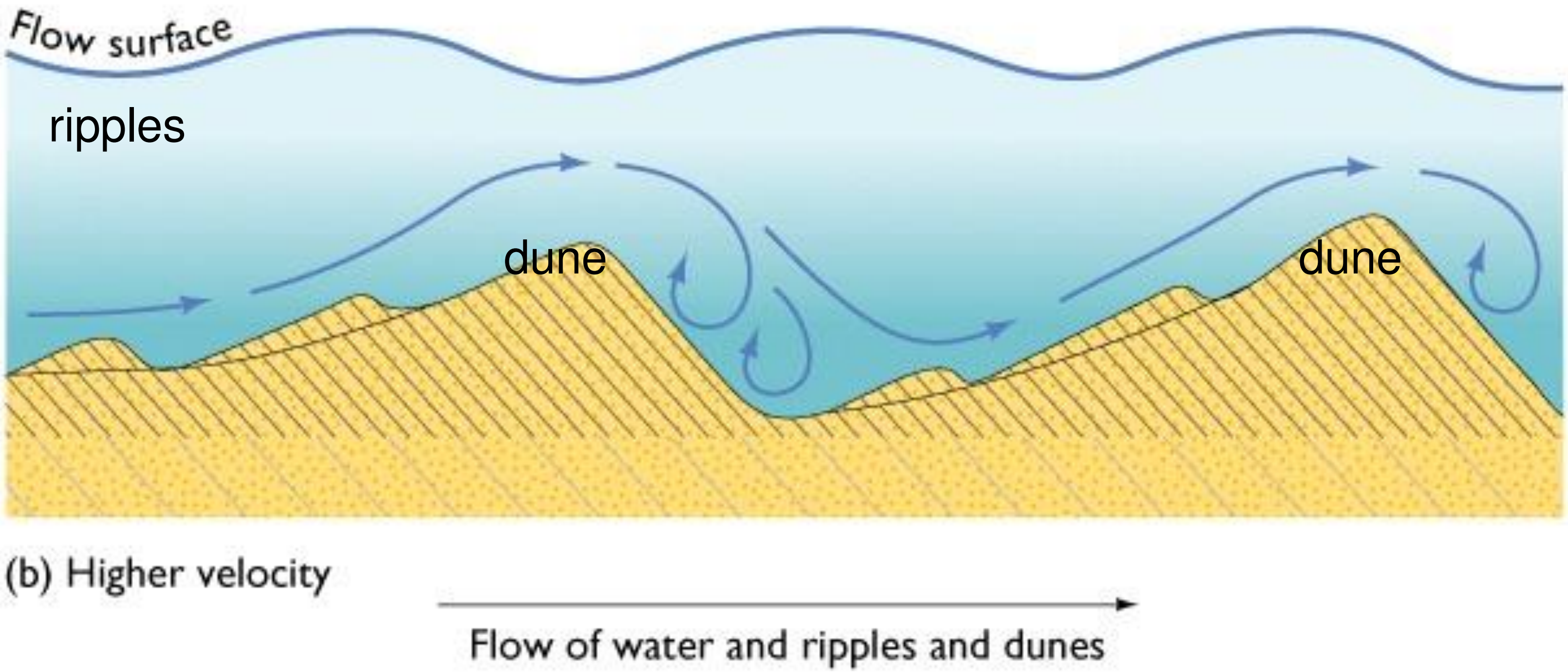
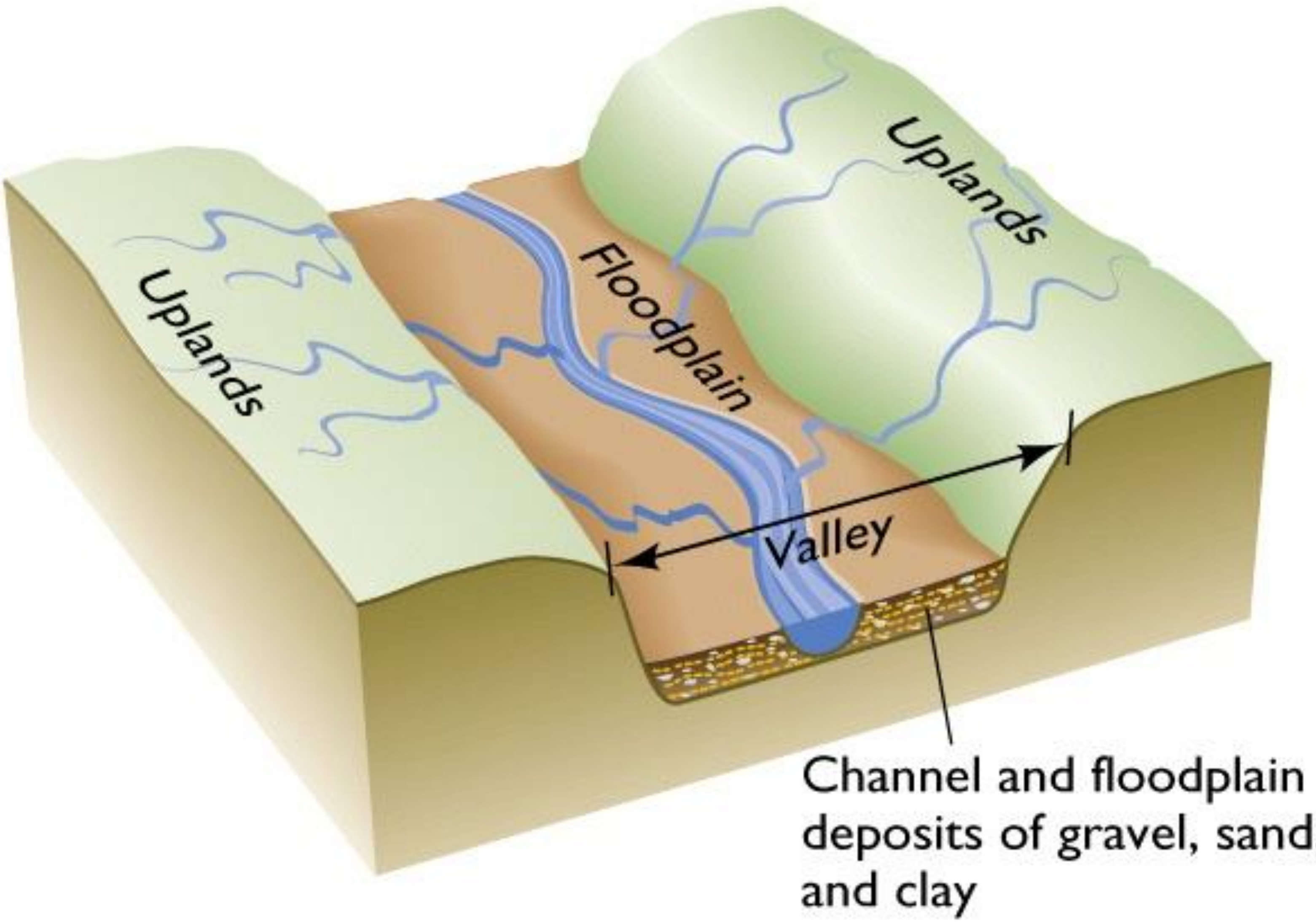



Fig. 13.5b

# ATERFALL RETREATING
# PRIVER


Fig. 13.7

# PARTS OF A RIVER SYSTEM



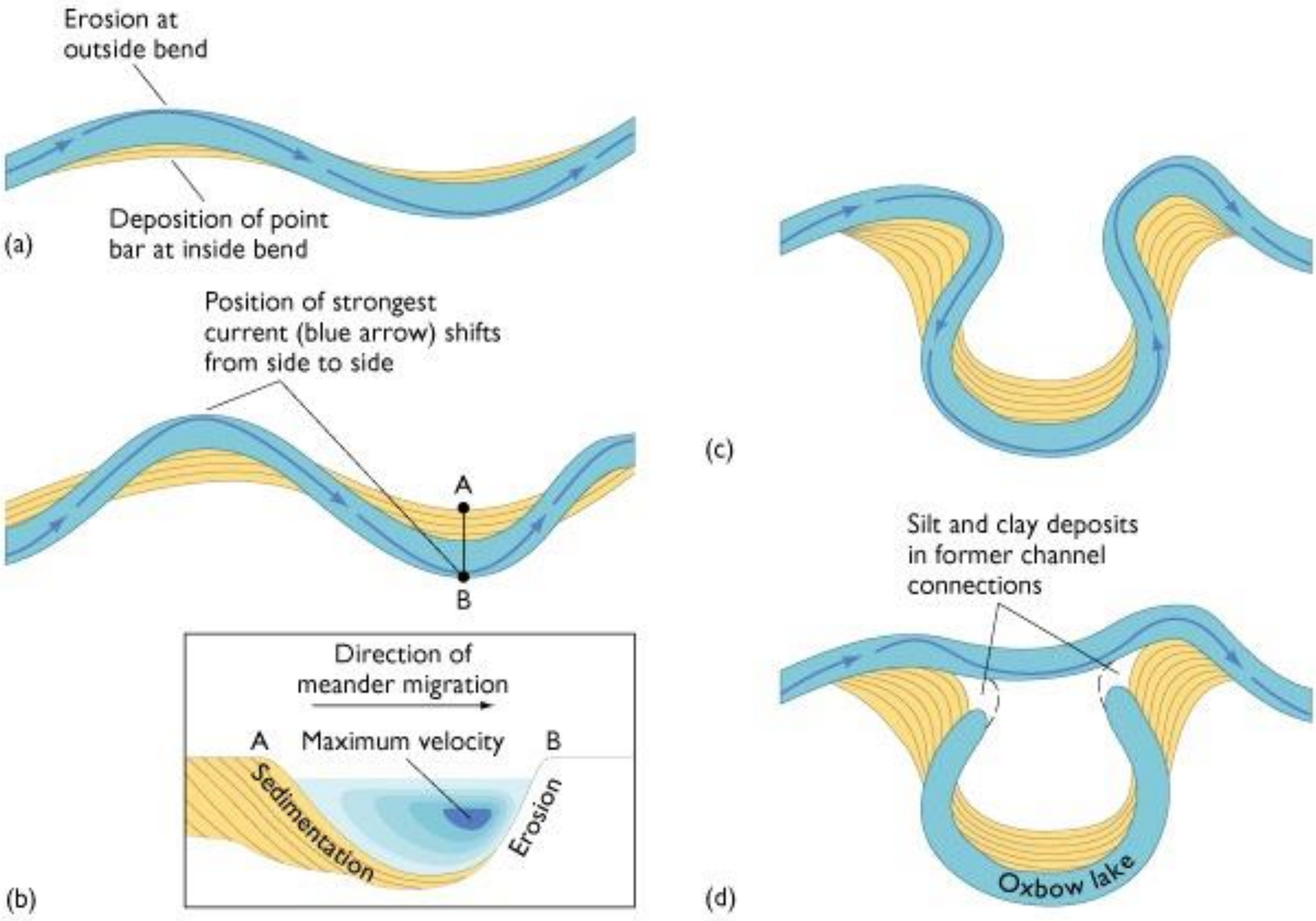
# TWO IMPORTANT STREAM TYPES

## 1. Meandering Streams

**A meander, in general, is a bend in a sinuous watercourse or river.**

**A meander forms when moving water in a stream erodes the outer banks and widens its valley, and the inner part of the river has less energy and deposits silt**

# MEANDERING RIVER OVER TIME



# INCISED MEANDERS, UTAH

Tom Bean

# MEANDERING RIVER

# TWO IMPORTANT STREAM TYPES

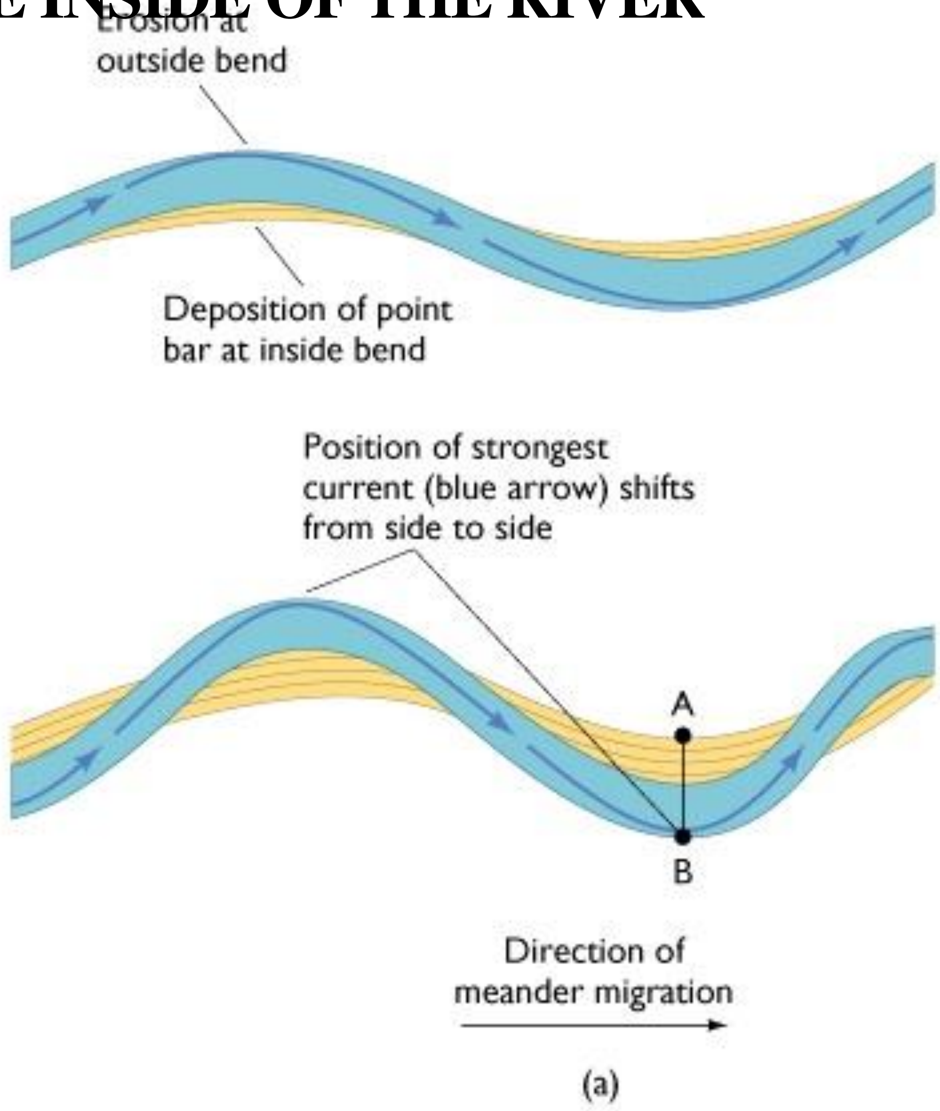
## 2. Braided Streams

**Sediment supply greater than amount stream can support.**

**At any one moment the active channels may account for only a small proportion of the area of the channel system, but essentially all is used over one season.**

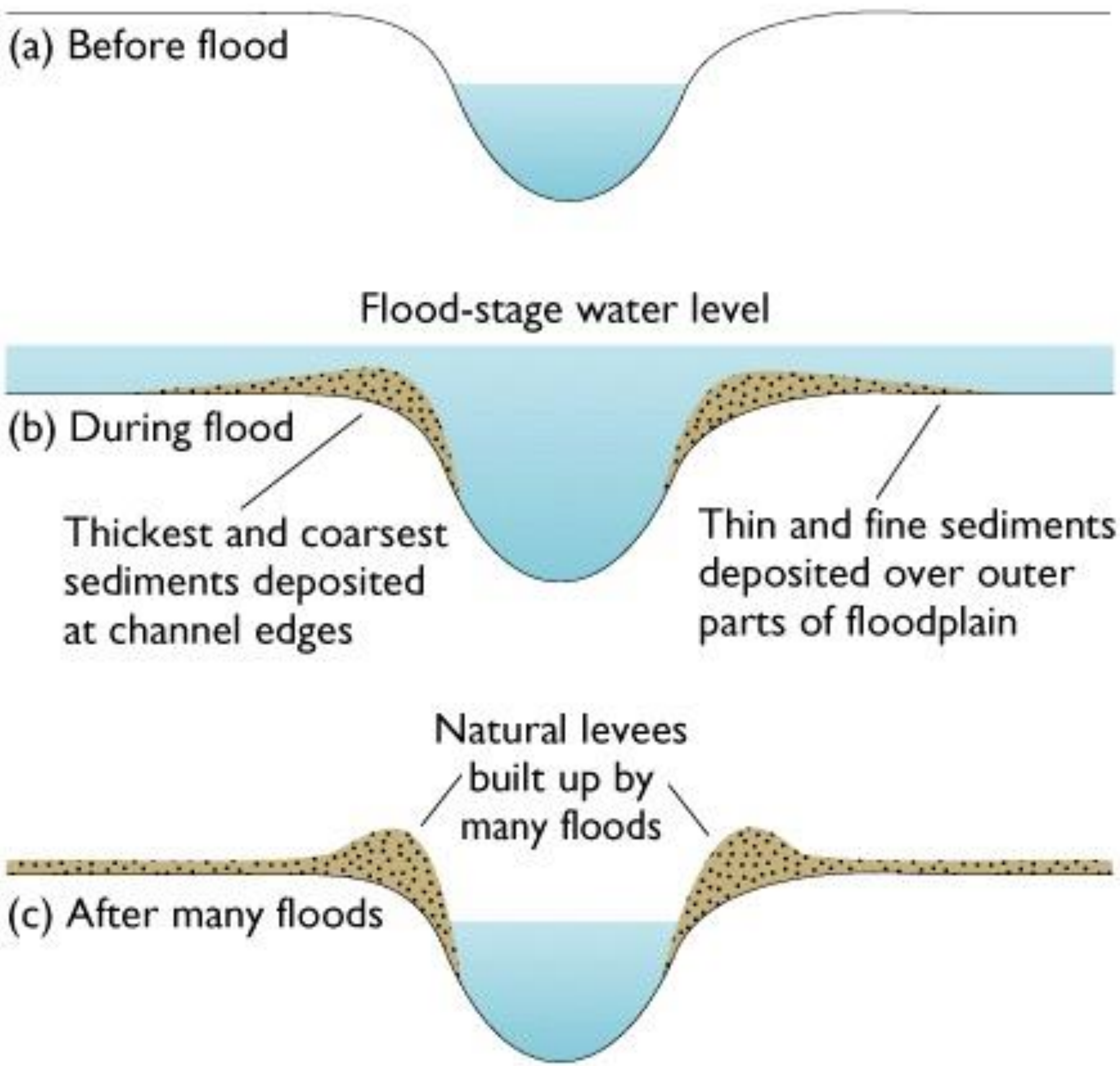
**Common in glacial, deserts, and mountain regions.**

# LATERAL MIGRATION BY EROSION AT THE OUTSIDE & DEPOSITION ON THE INSIDE OF THE RIVER



# BRAIDED RIVER

# FORMATION OF NATURAL LEVEES



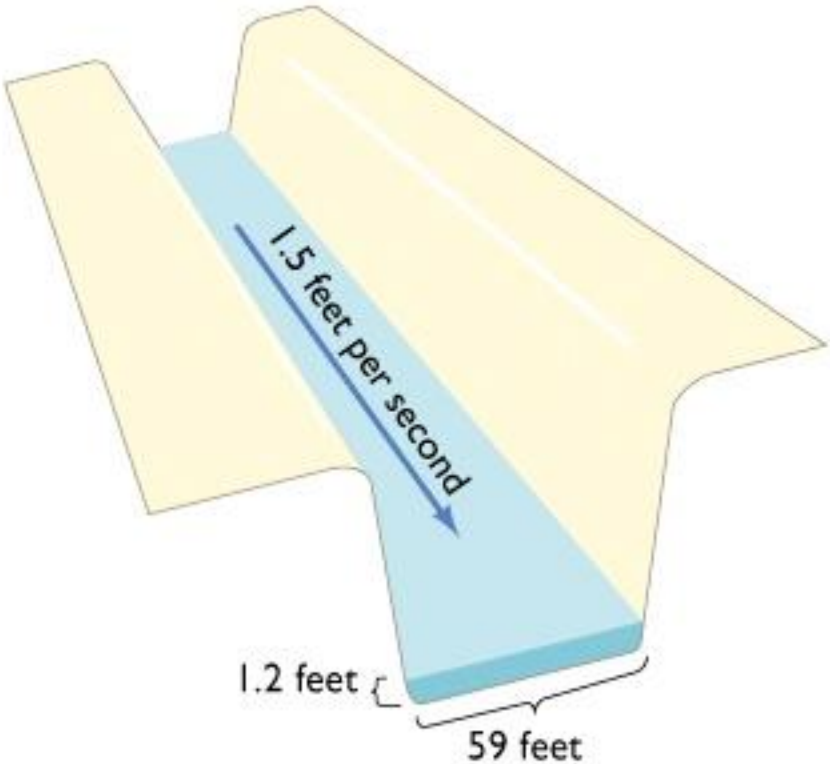
# DISCHARGE

**Total amount of water that passes a given point in a stream per unit time**

$$Q = w\,d\,v$$

Discharge ($m^3/s$) = width (m) × depth (m) × average velocity (m/s)

# RIVER AT LOW DISCHARGE



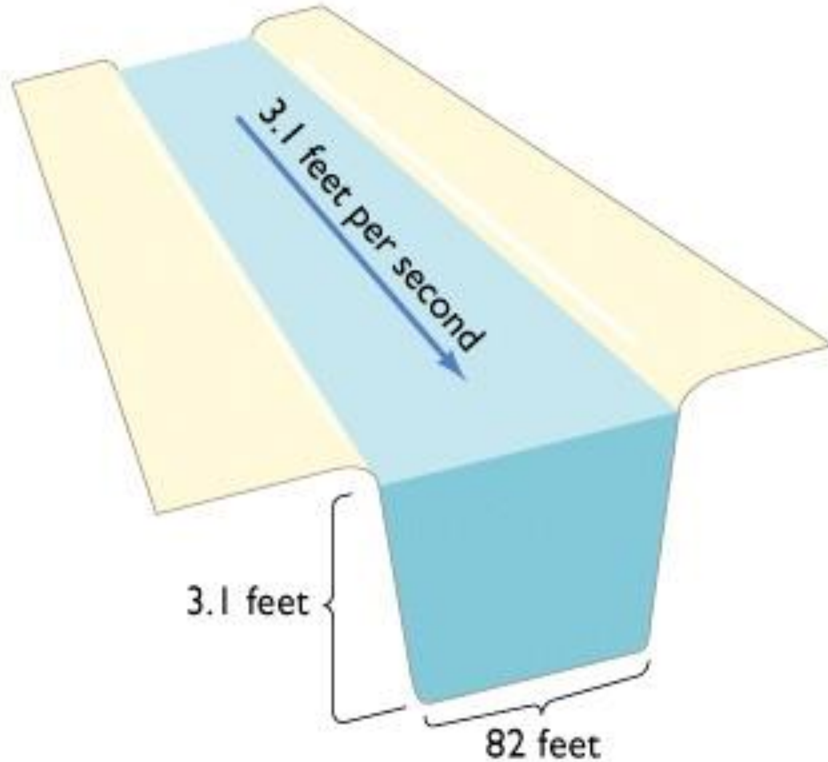

(a) River at average level

Cross-sectional area low:
1.2 feet × 59 feet = 70.8 feet$^2$

Velocity low: 1.5 feet/s

Discharge low:
70.8 feet × 1.5 feet = 106.2 feet$^3$/s

# RIVER AT HIGH DISCHARGE




(b) River at high level

Cross-sectional area high:
$3.1 \text{ feet} \times 82 \text{ feet} = 254.2 \text{ feet}^3$

Velocity high: 3.1 feet/s

Discharge high:
$254.2 \text{ feet}^2 \times 3.1 \text{ feet/s} = 788.02 \text{ feet}^3\text{/s}$

# FLOODING

**Water in the stream is greater than the volume of the channel.**

**Interval between floods depends on the climate of the region and the size of the channel**

# CITY BUILT ON A FLOODPLAIN

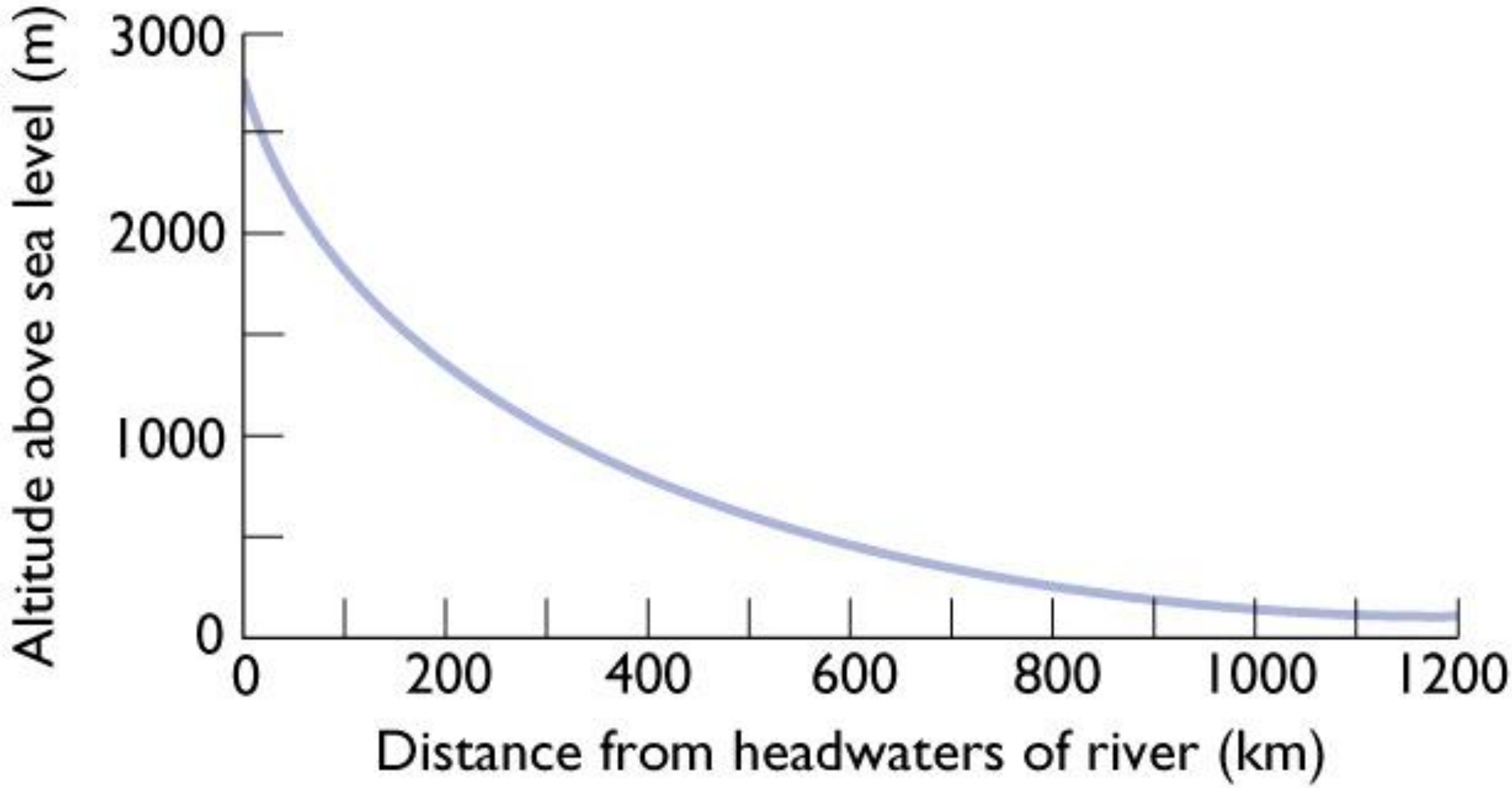
# RECURRENCE INTERVAL

**A*verage* time between the occurrences of a given event**

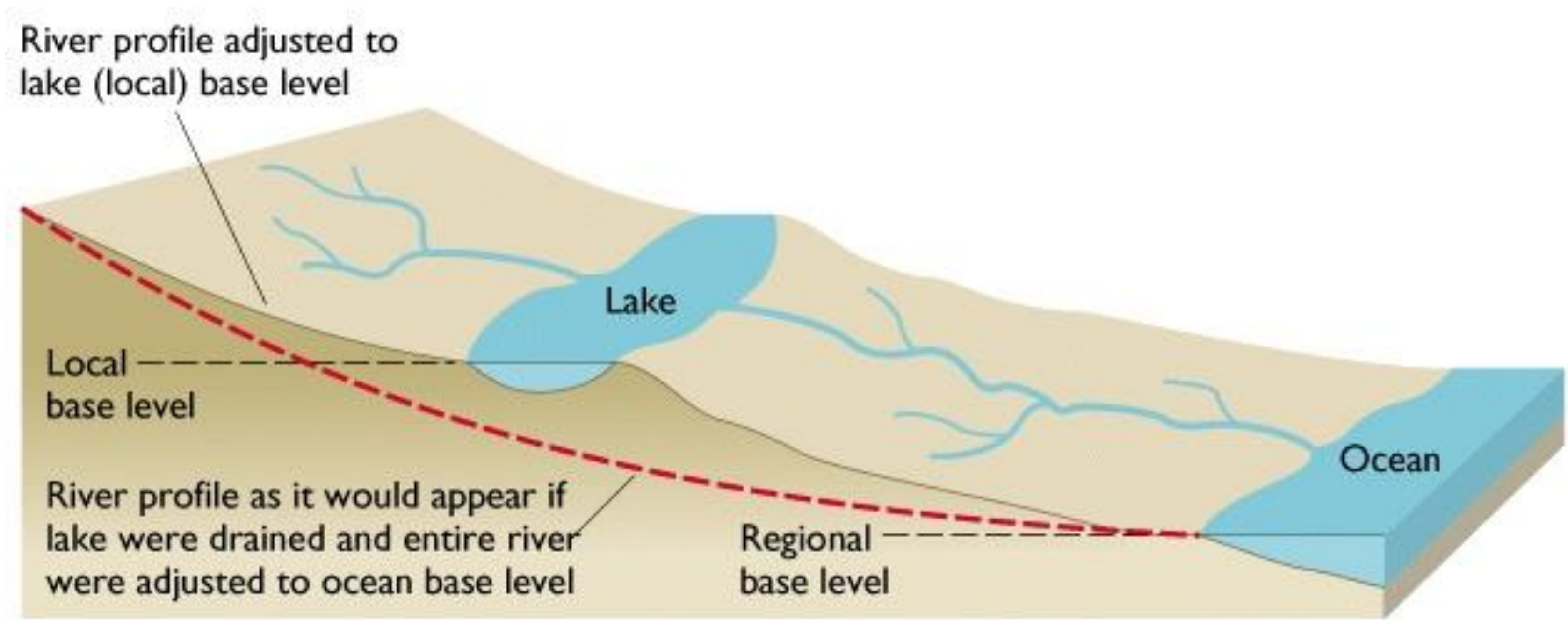
**The recurrence interval of a flood of a given size at a given place depends on:**

- **climate of the region**
- **width of the floodplain**
- **size of the channel**

# LONGITUDINAL STREAM PROFILE OF THE PLATT AND SOUTH PLATT RIVERS



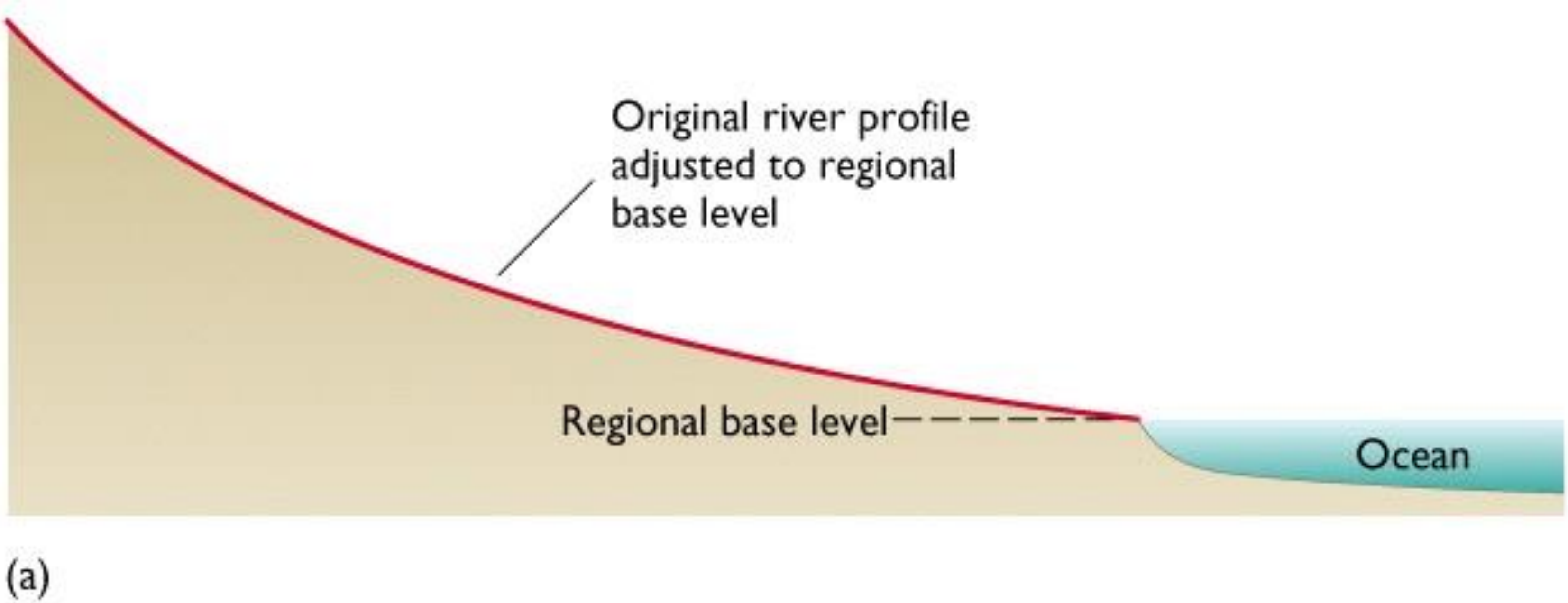
# ROLE OF BASE LEVEL IN CONTROLLING LONGITUDINAL PROFILE OF RIVERS



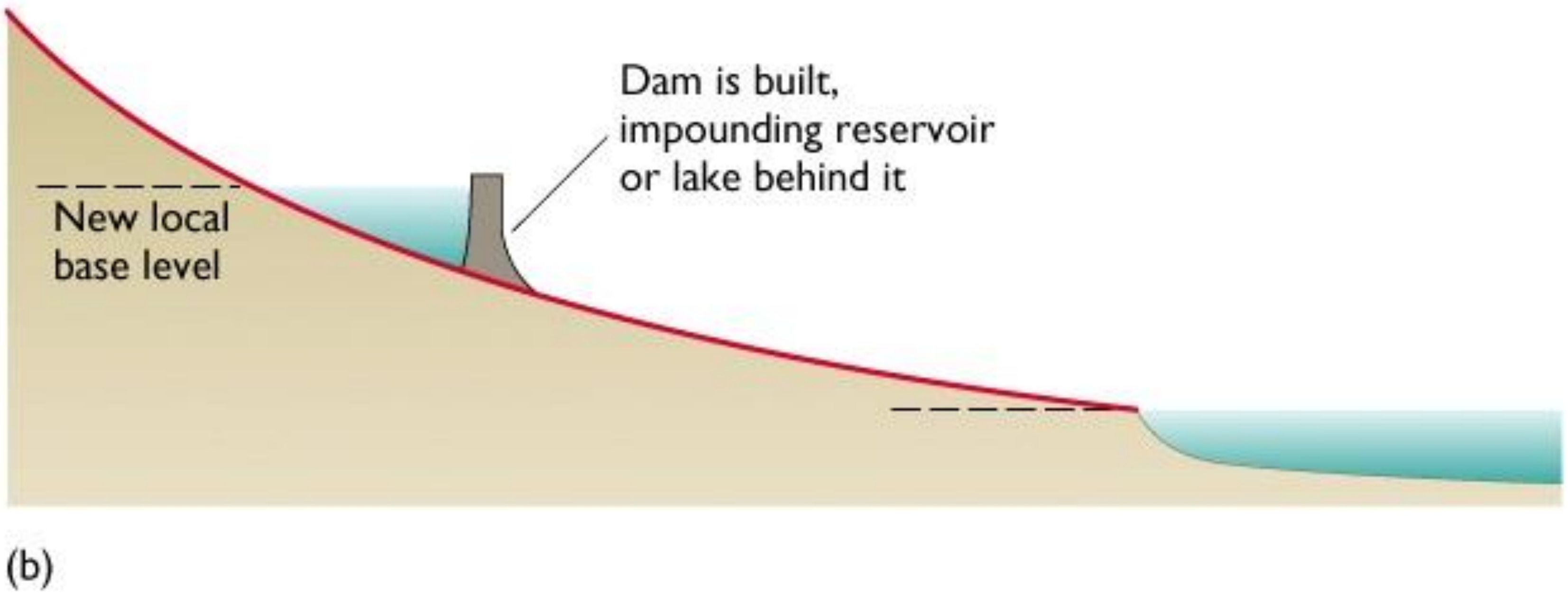
# BASE LEVEL

**Elevation at which a stream enters a large body of water such as a lake or ocean**

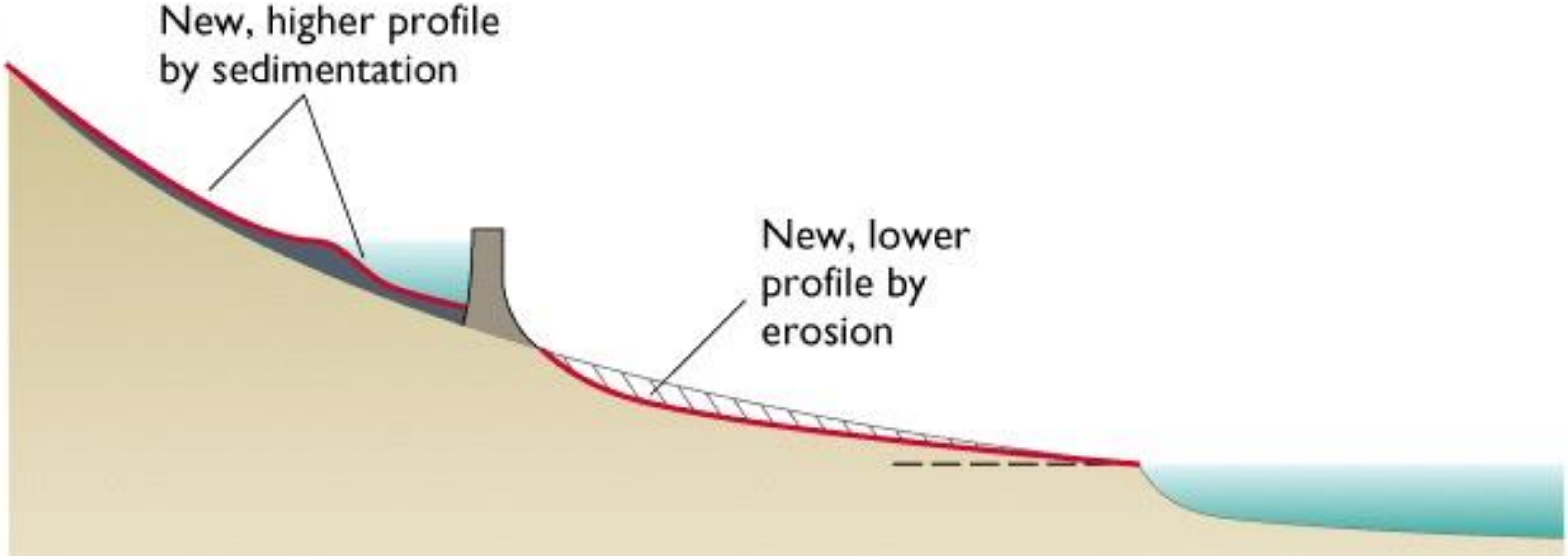
# EFFECTS OF BUILDING A DAM ORIGINAL PROFILE GRADED TO REGIONAL BASE LEVEL



# EFFECTS OF BUILDING A DAM : DAM FORMS NEW LOCAL BASE LEVEL



# EFFECTS OF BUILDING A DAM DEPOSITION UPSTREAM AND EROSION DOWNSTREAM



(c)

# GRADED STREAM

**Stream in which neither erosion nor deposition is occurring, due to an equilibrium of slope, velocity, and discharge.**

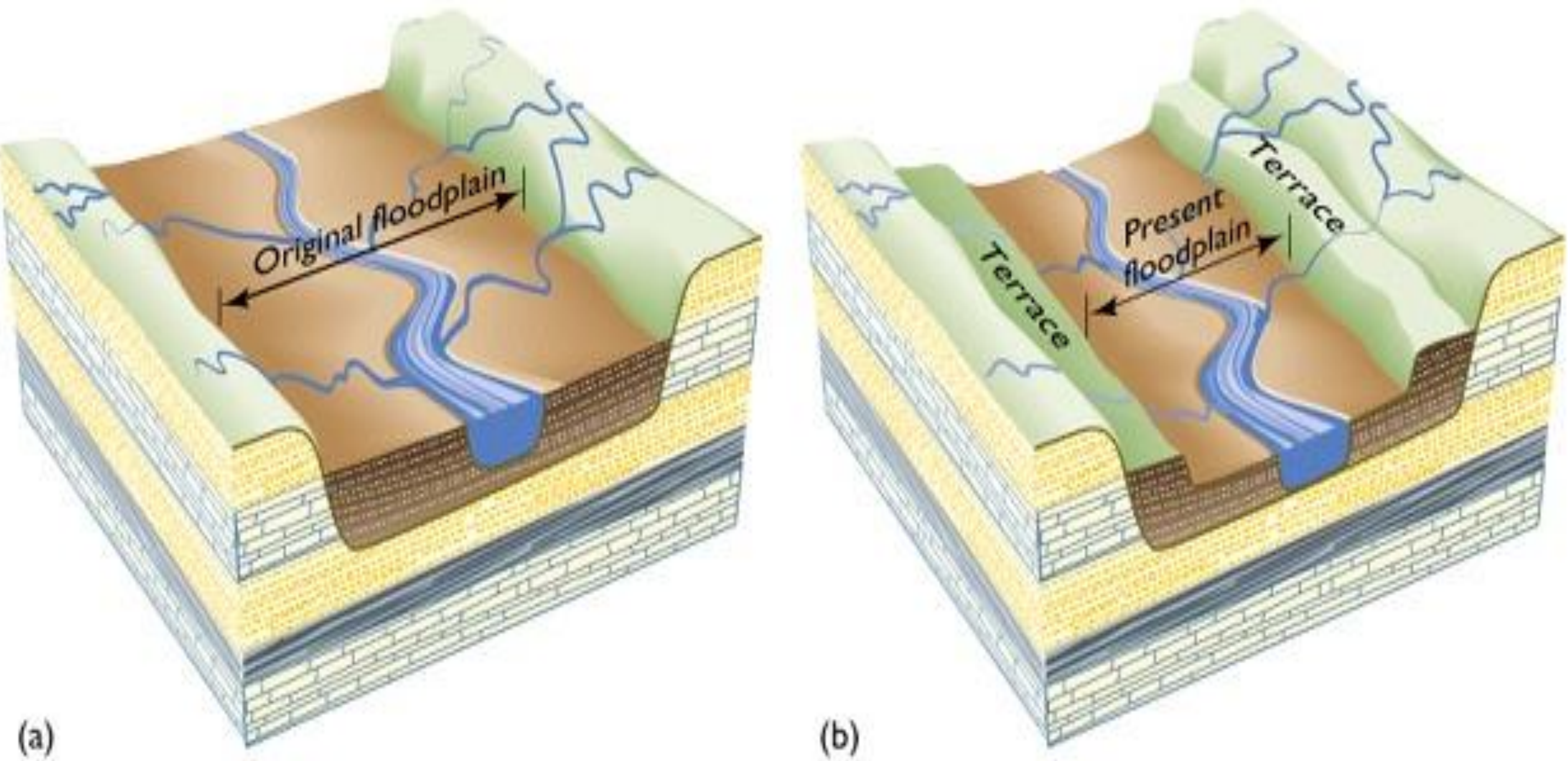
# GEOLOGIC EVIDENCE OF CHANGES IN STREAM EQUILIBRIUM

**Alluvial fans**

**Terraces: erosional remnants of former floodplains**

# Alluvial fans

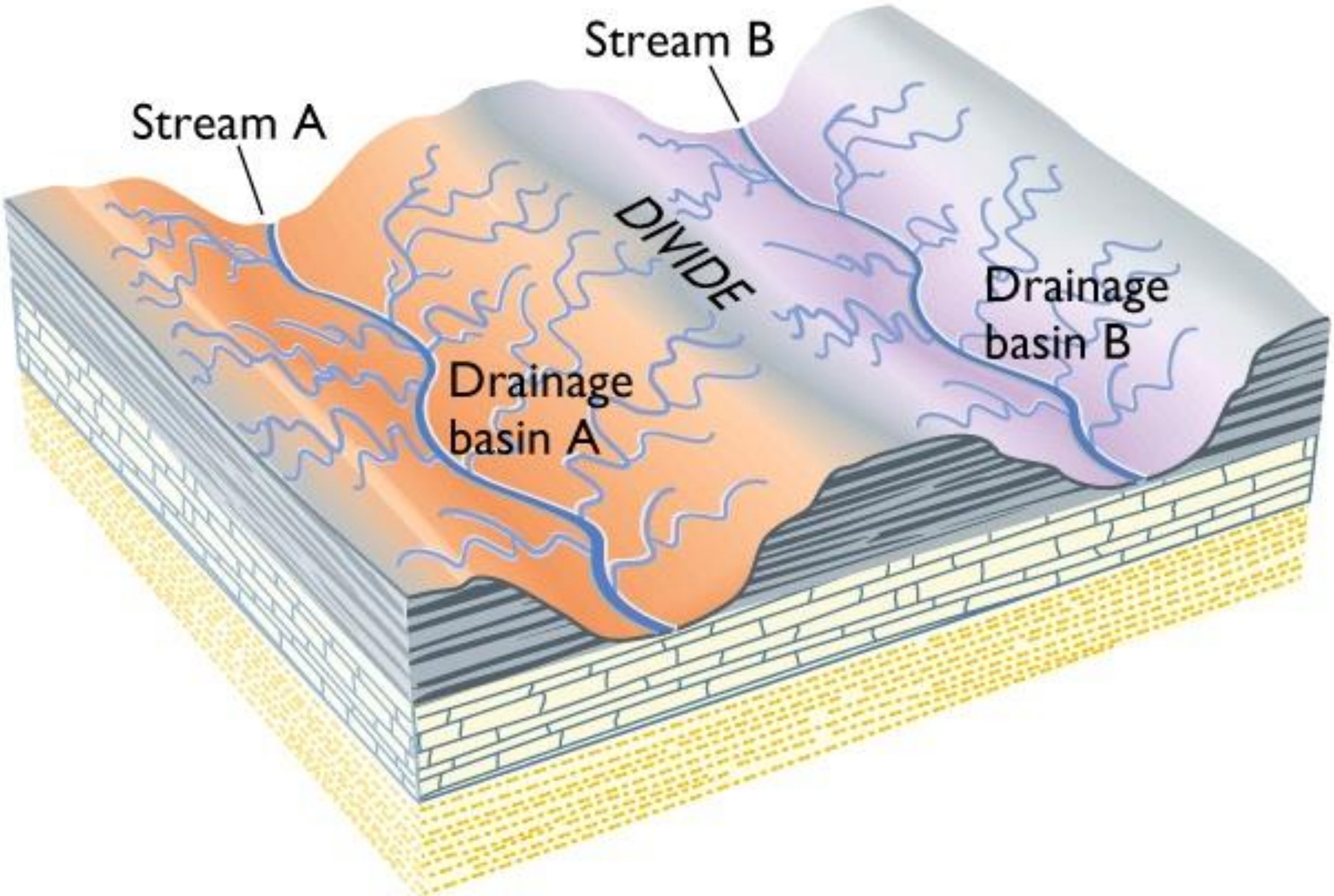
# FORMATION OF RIVER TERRACES



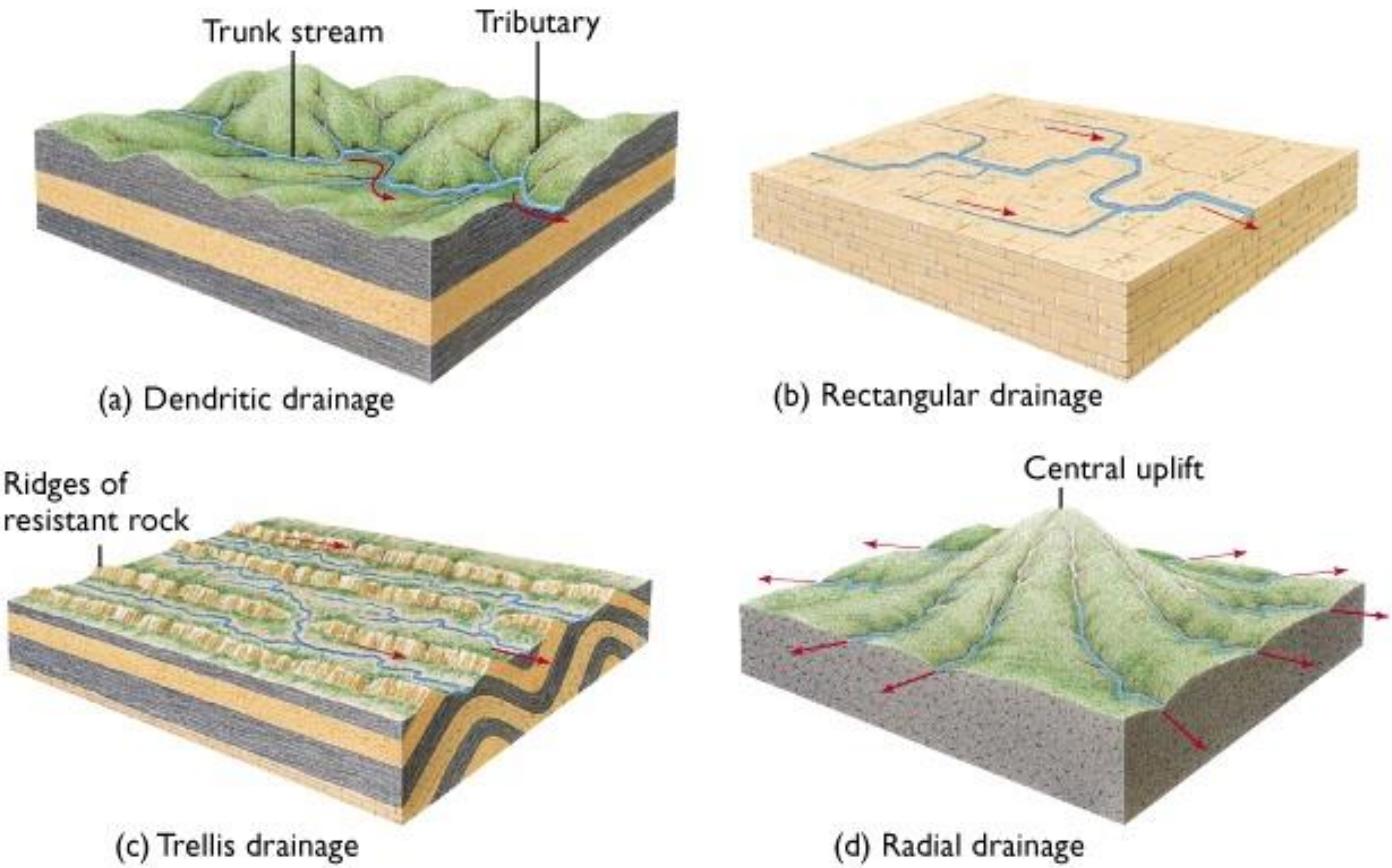
# DRAINAGE BASIN

**Area of land surrounded by topographic divides in which all the water is directed to a single point**

# GE DIVIDES SEPARATE ADJACENT DRAINAGE BASINS



# TYPICAL DRAINAGE NETWORKS



# DELTA

**Location of significant sedimentation where a river meet the sea.**

# TYPICAL LARGE MARINE DELTA

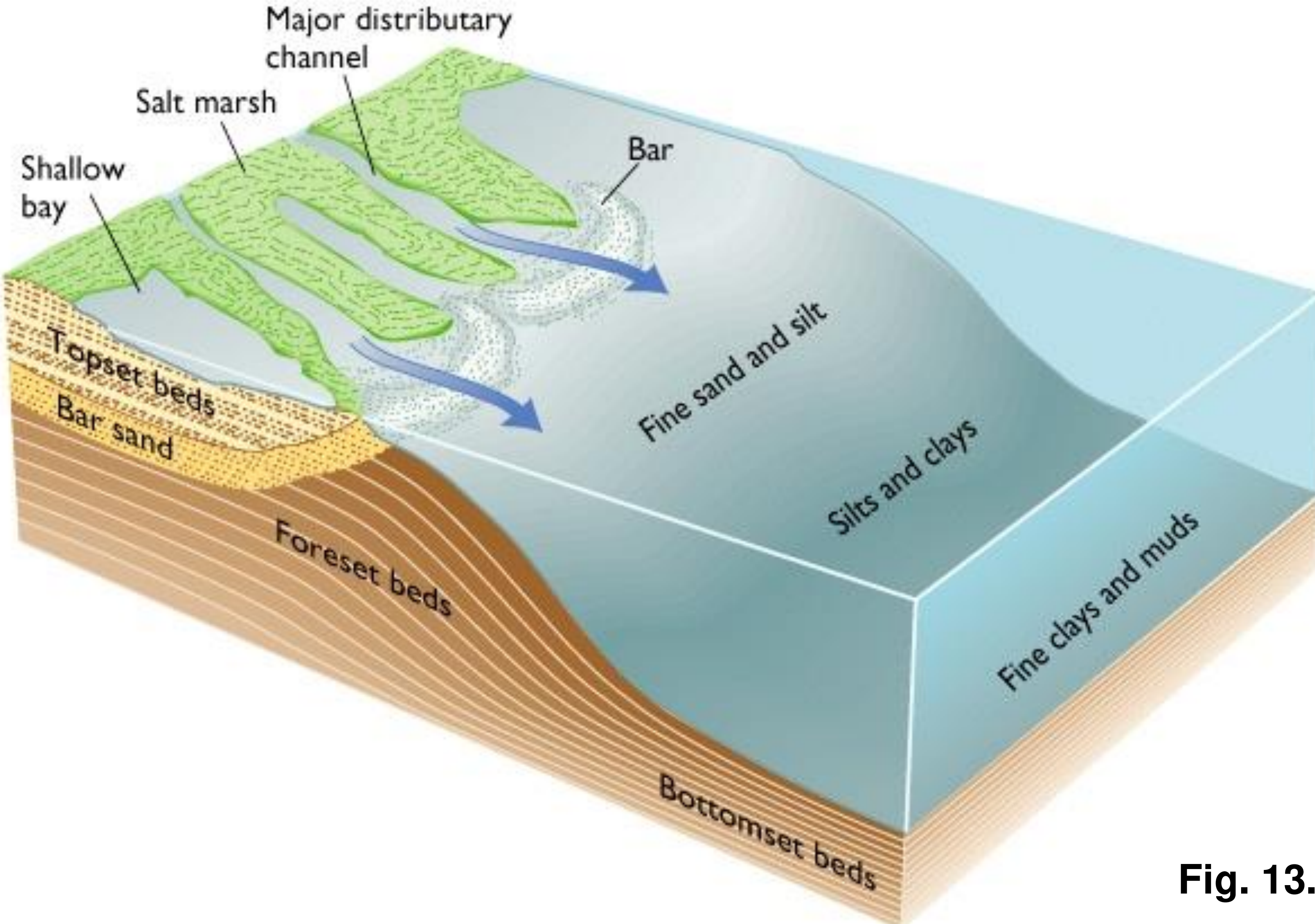
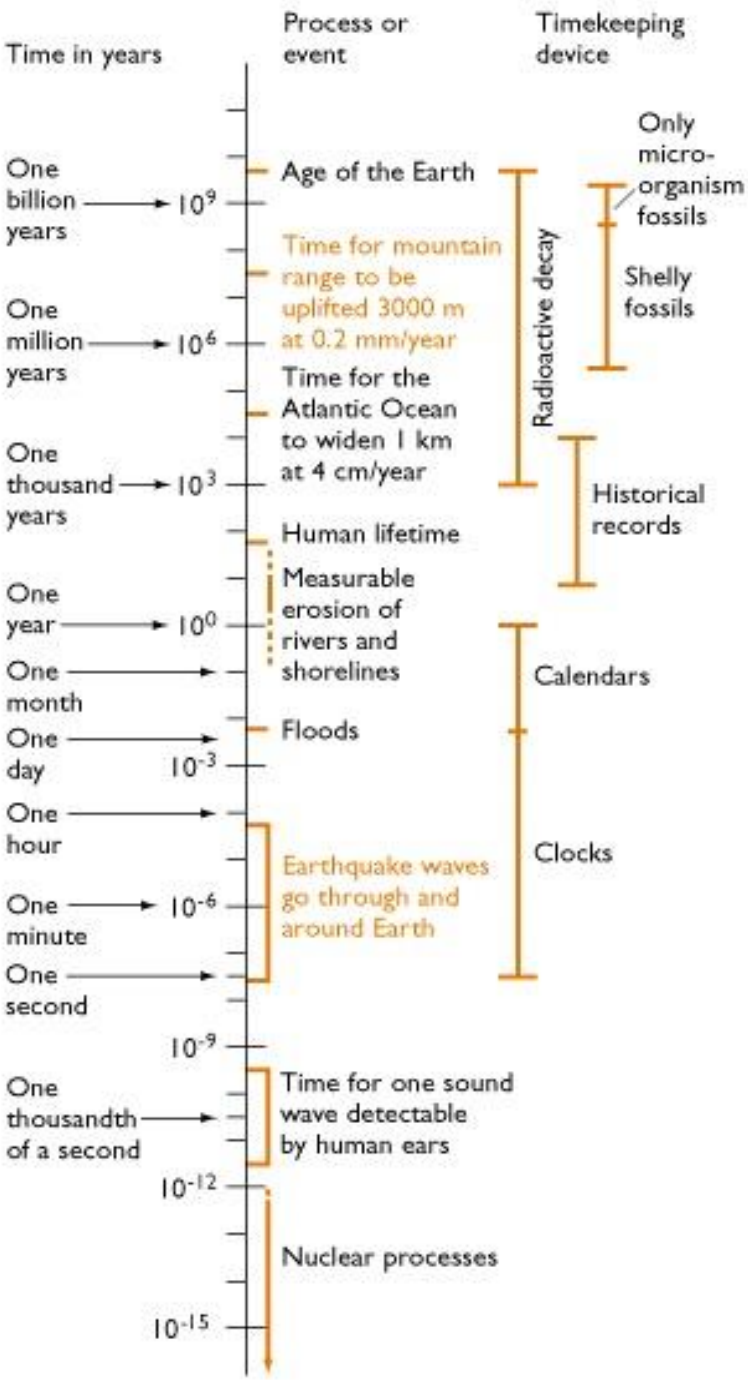



Fig. 13.27

# Geologic time




# Amount of time required for some geologic processes and events

# Geologic time

A major difference between geologists and most other scientists is their attitude about time.

A "long" time may not be important unless it is > 1 million years.

# Two ways to date  geologic events

1) Relative dating (fossils, structure)

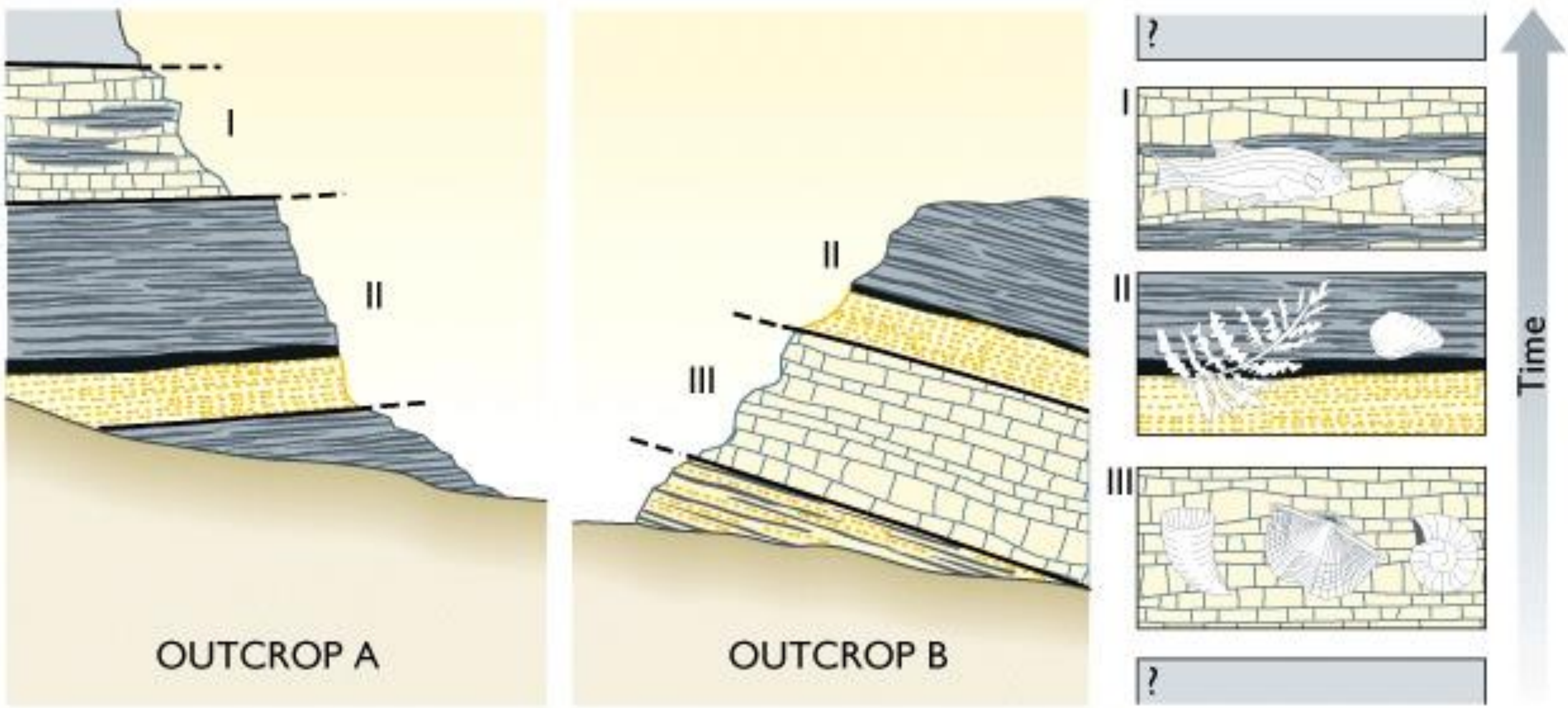
2) Absolute dating (isotopic, radioactive dating)

# Ammonite Fossils

# Petrified Wood


Fig. 9.4

# Using fossils to correlate rocks




Outcrops may be separated by a long distance

# Steno's laws

**Nicolaus Steno (1669)**

**Principle of Superposition**

**Principle of Original Horizontality**

**Principle of Lateral Continuity**

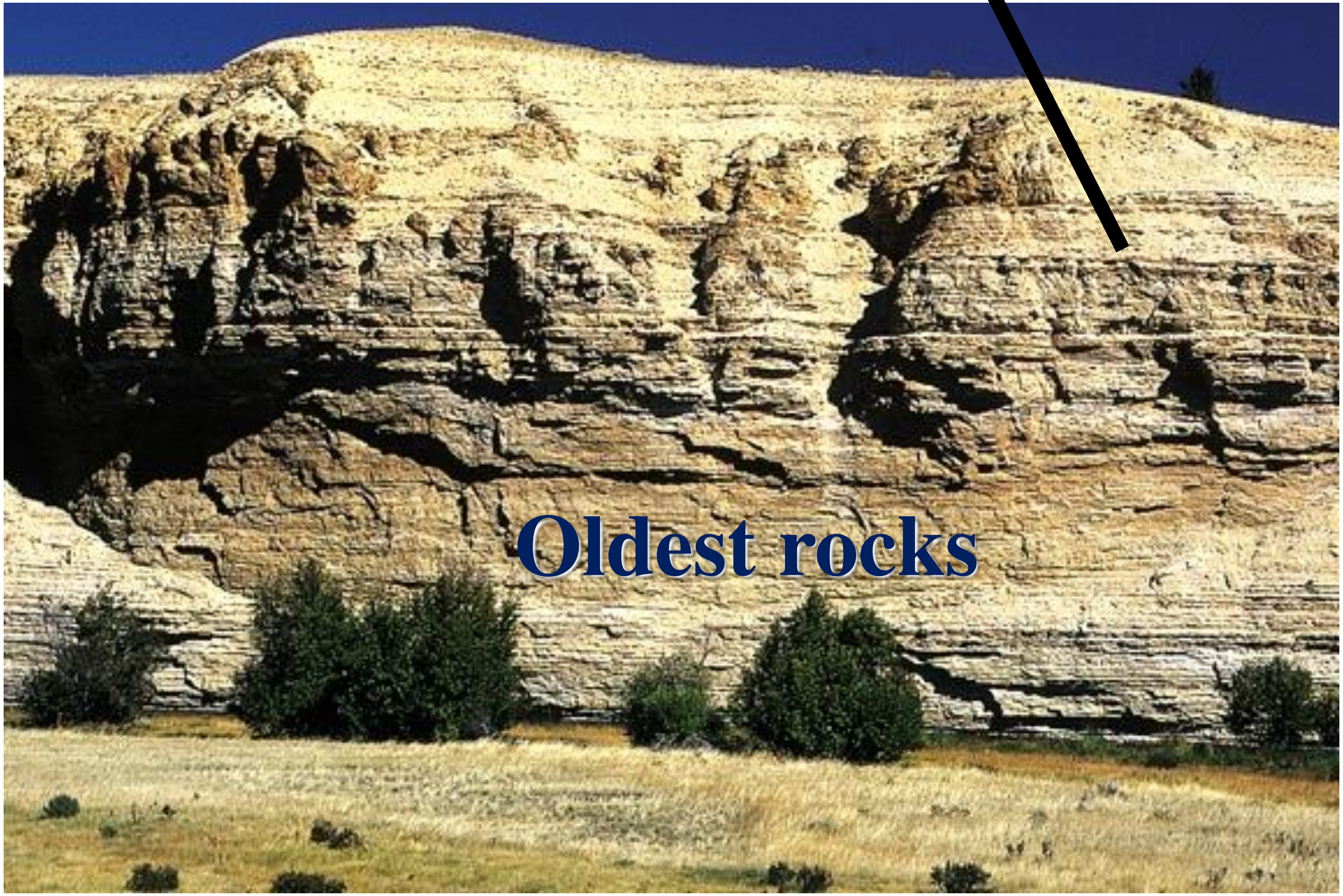
**Laws apply to both sedimentary and volcanic rocks.**

# Principle of superposition

**In a sequence of undisturbed layered rocks, the oldest rocks are on the bottom.**

# Principle of superposition

Youngest rocks



# Principle of original horizontality

**Layered strata are deposited horizontal or nearly horizontal or nearly parallel to the Earth's surface.**

# PRINCIPLES OF ORIGINAL HORIZONTALITY AND SUPERPOSITION

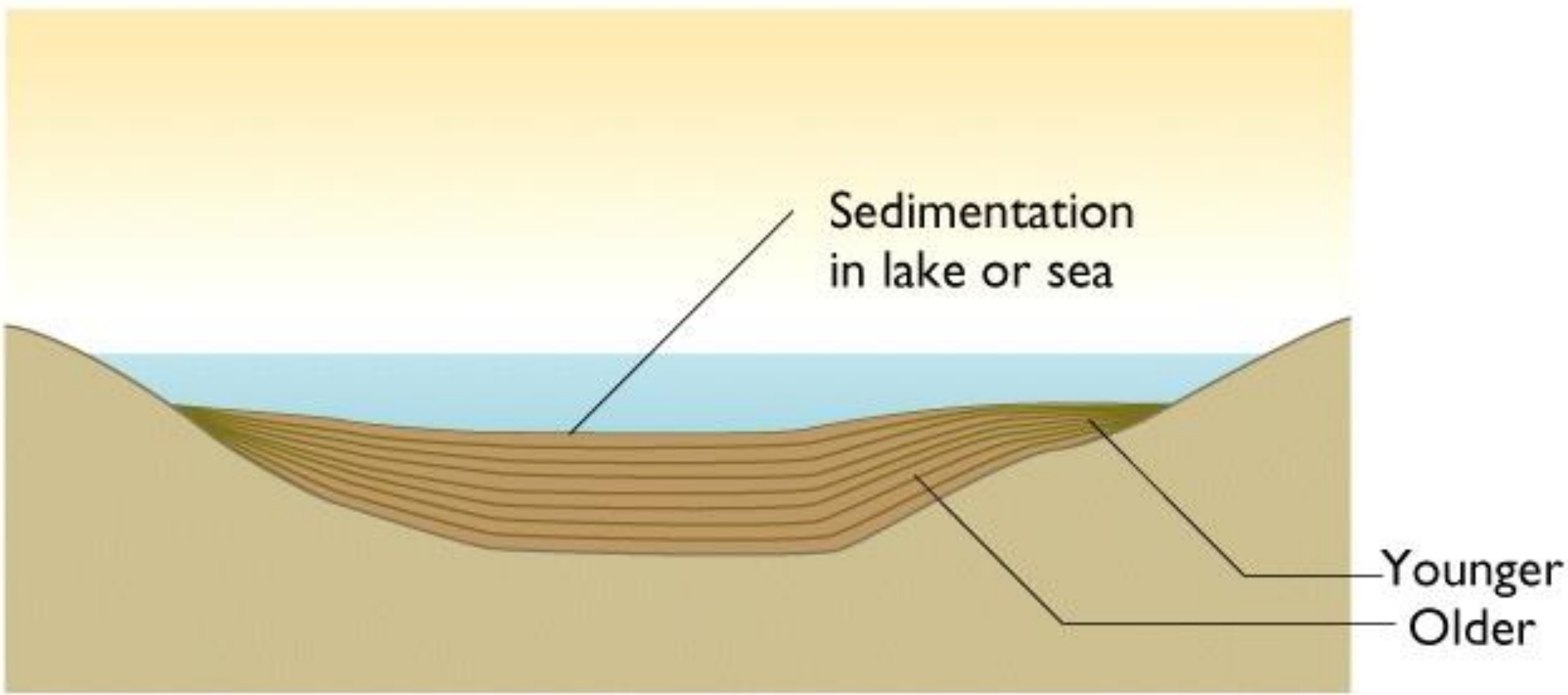
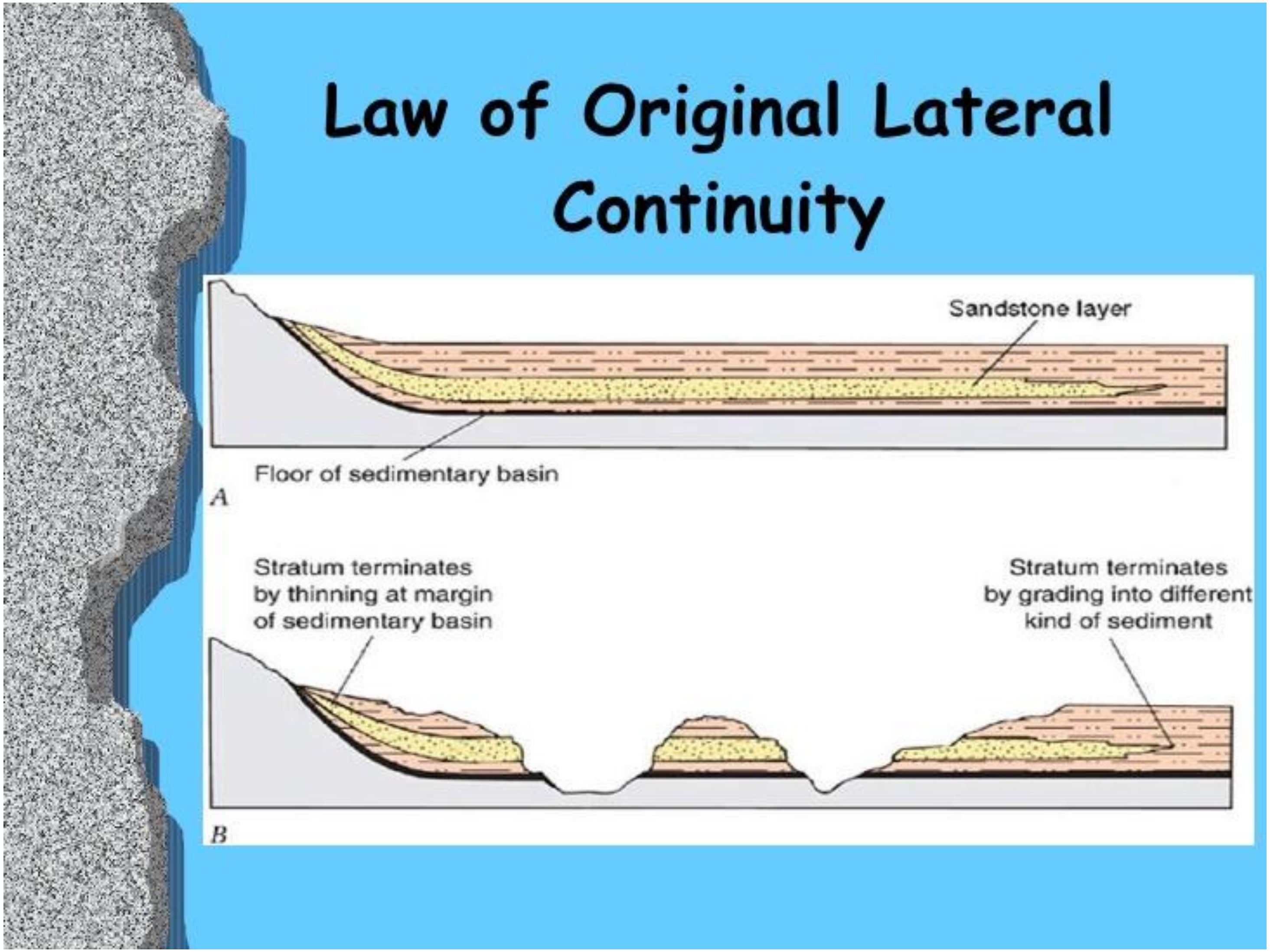



Fig. 9.3a

## Principle of lateral continuity

**Layered rocks are deposited in continuous contact.**

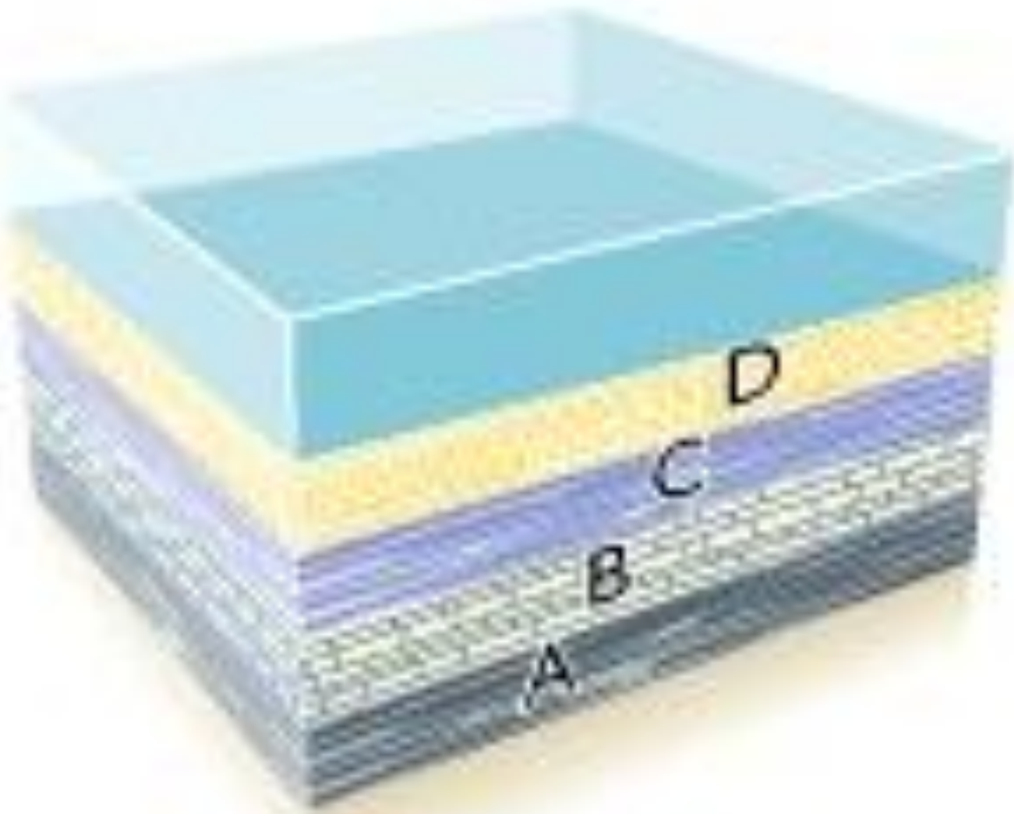
# Principle of lateral continuity



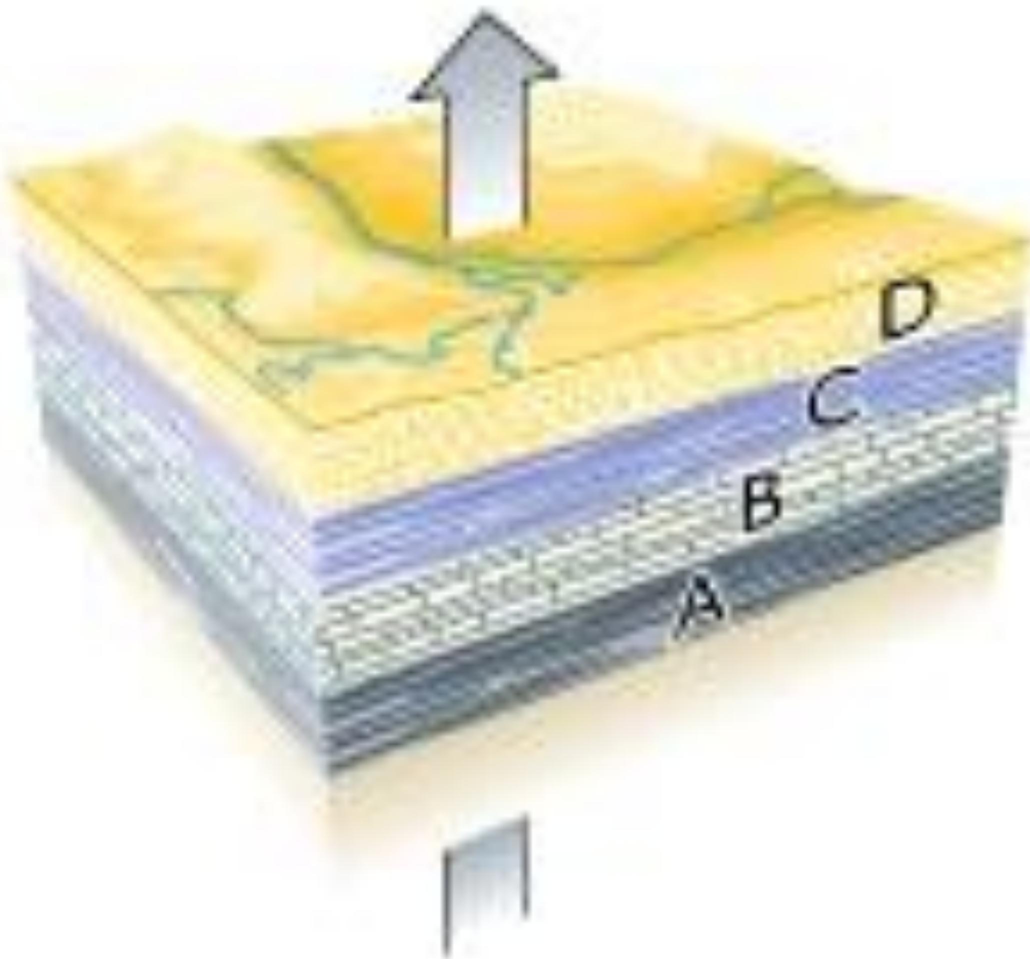
# Unconformity

## Buried surface of erosion

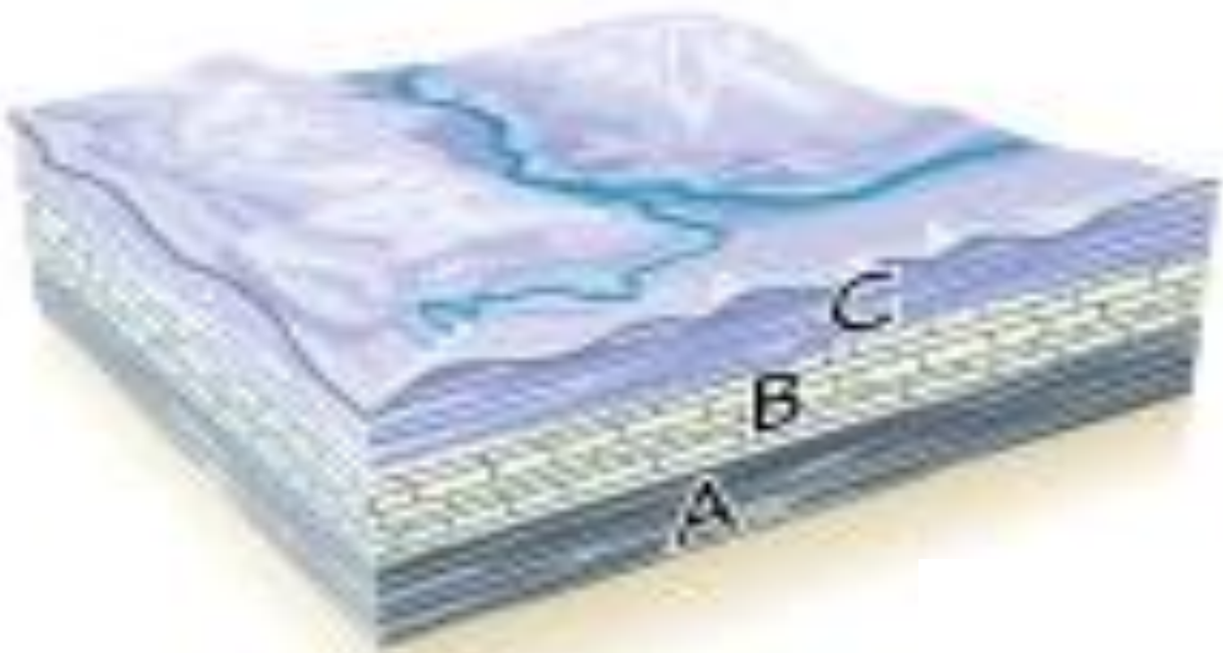
# Sedimentation of beds A-D beneath the sea



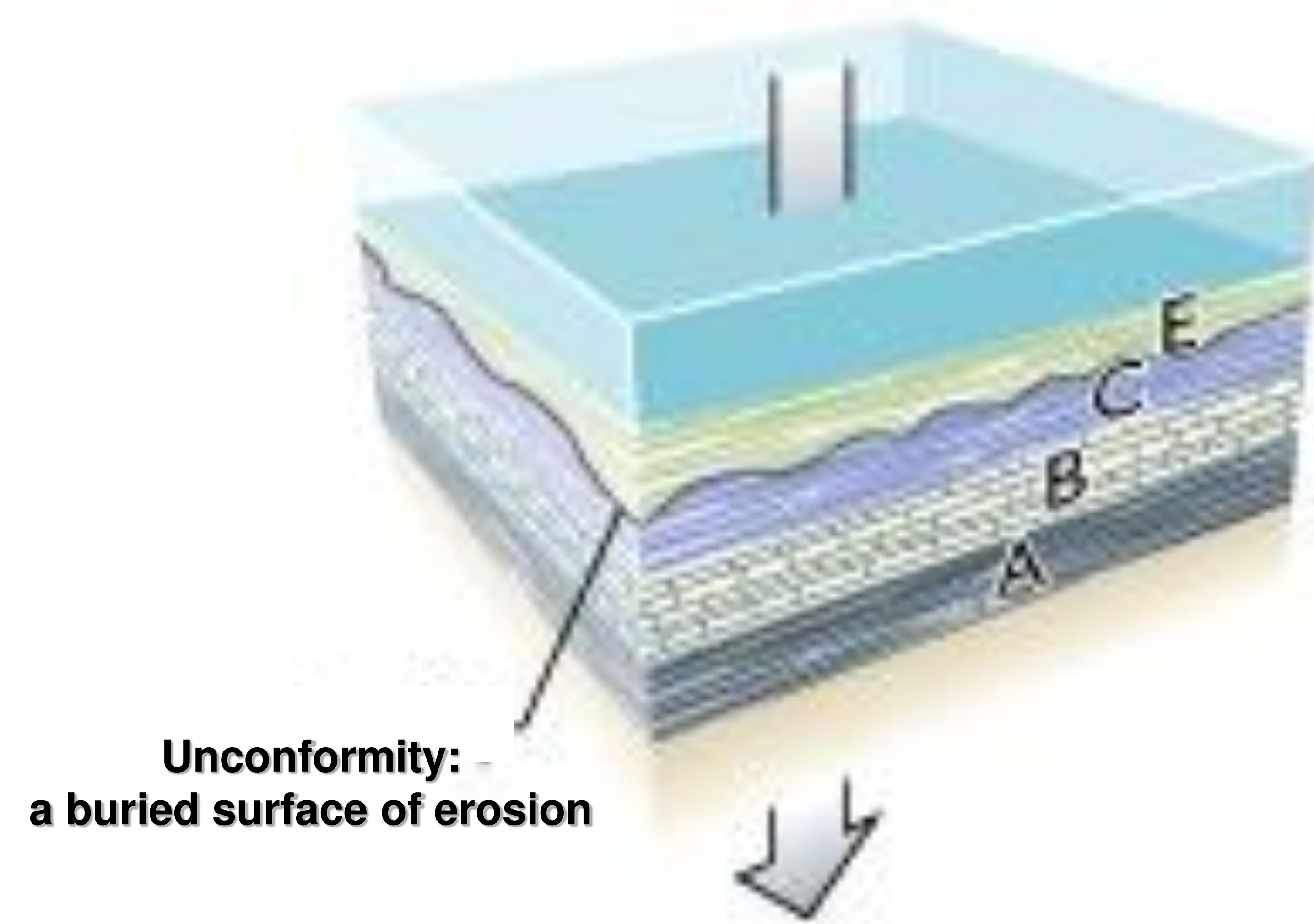
# Uplift and exposure of D to erosion



# Continued erosion removes D and exposes C to erosion

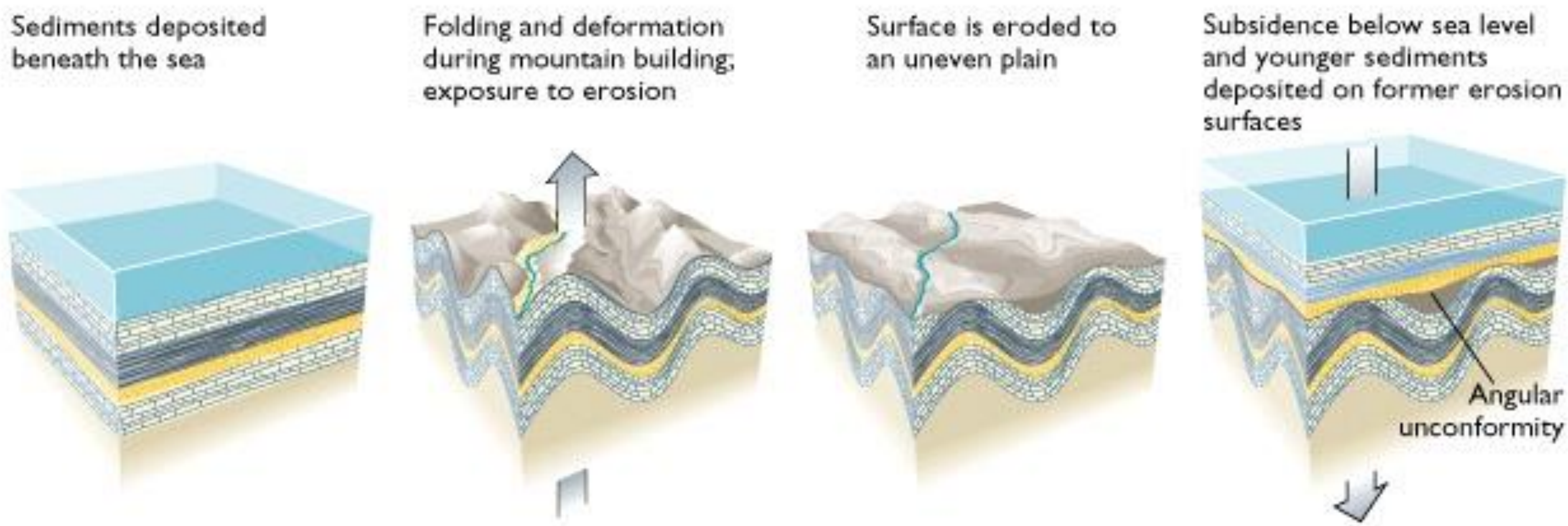


# Subsidence and sedimentation of E over C



# The Great Unconformity of the Grand Canyon

# Formation of an angular unconformity



# Formation of a disconformity

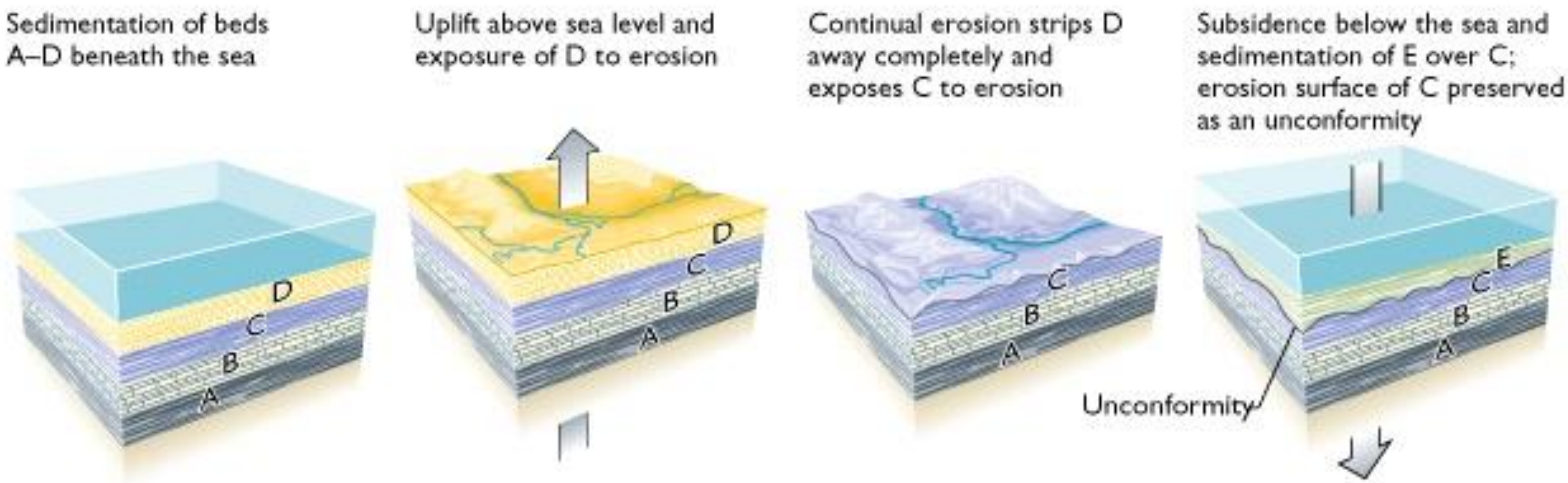
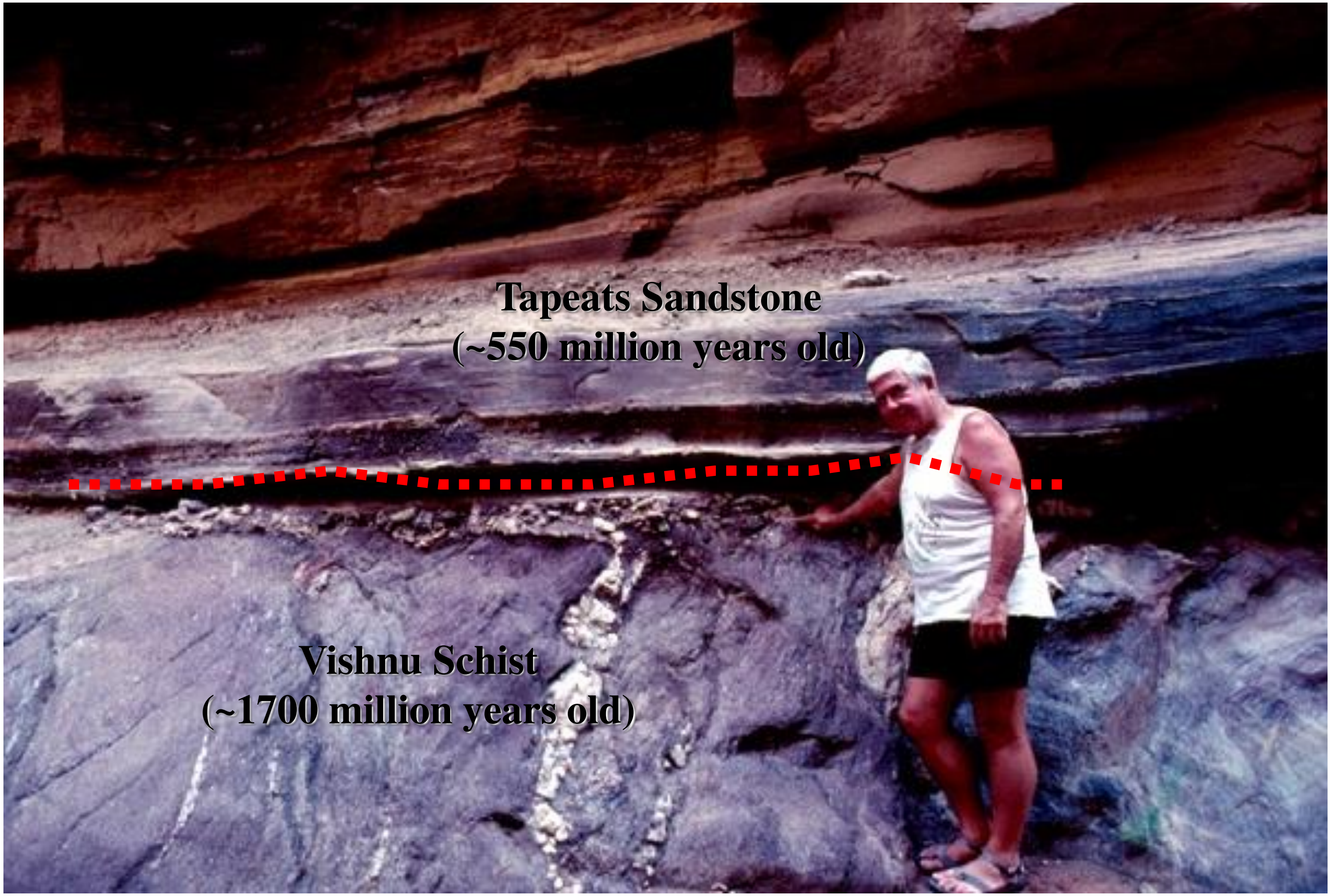



Fig. 9.6

# Angular unconformity, grand  canyon

# Nonconformity in the grand canyon



# Symmetrical ripples