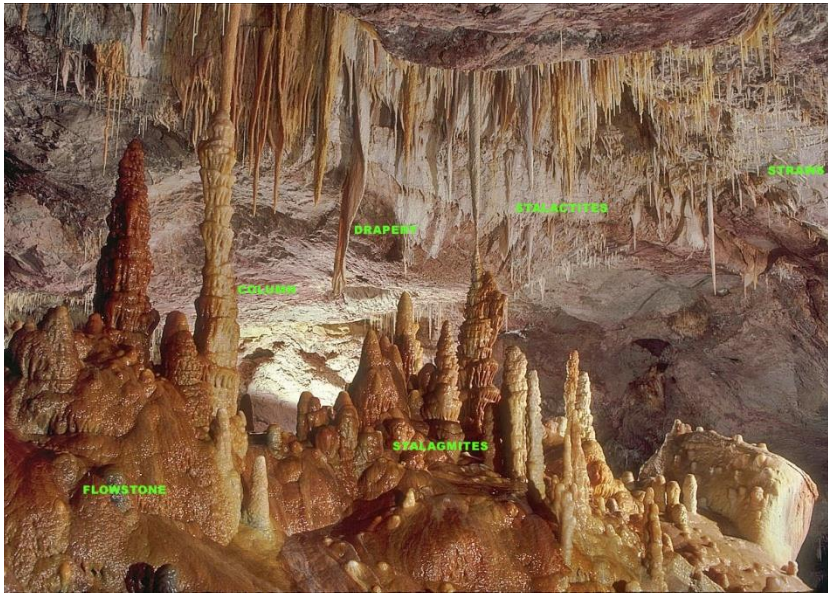
IDC 203: INTRODUCTION TO EARTH SCIENCES



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

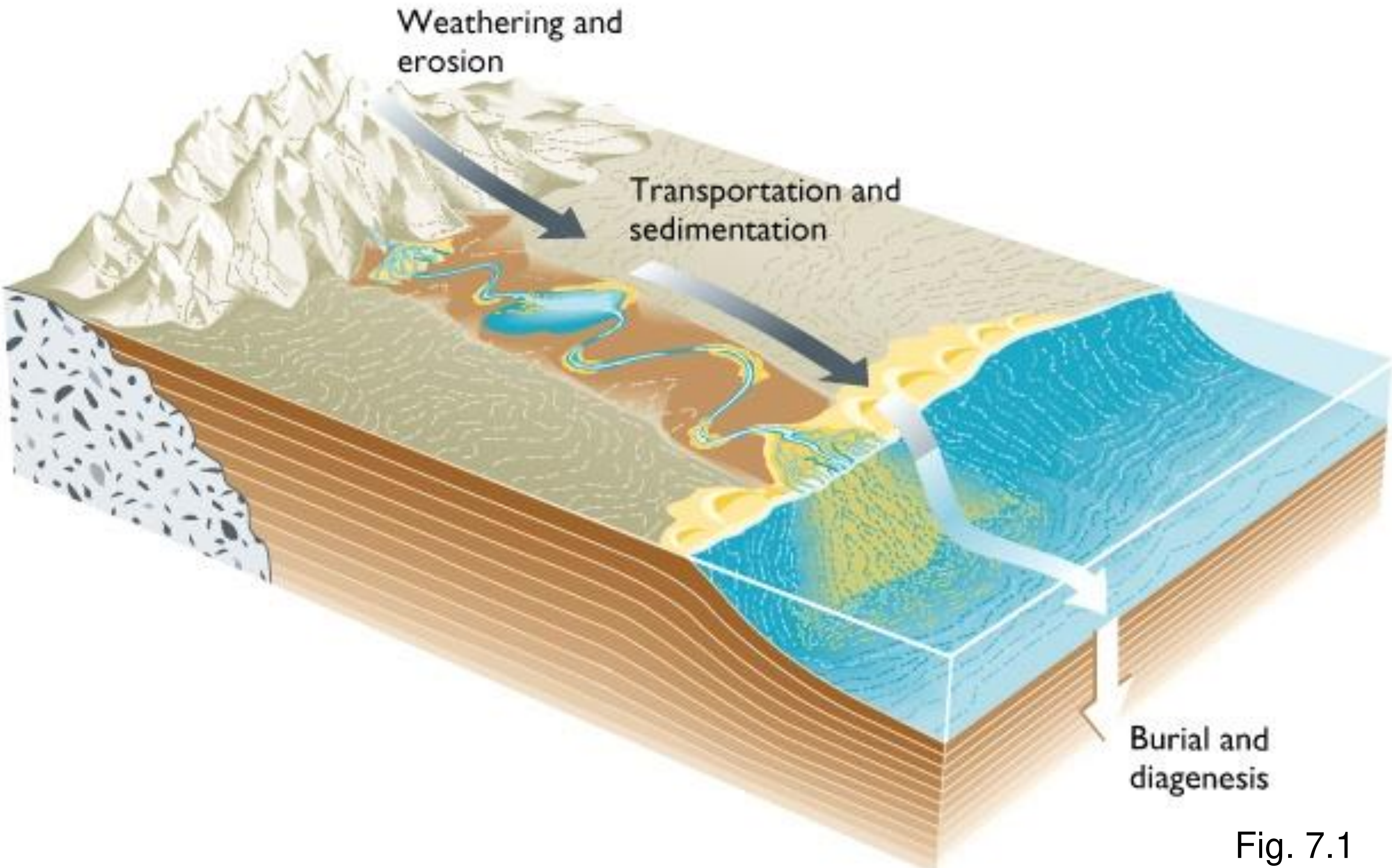


Fig. 7.1

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

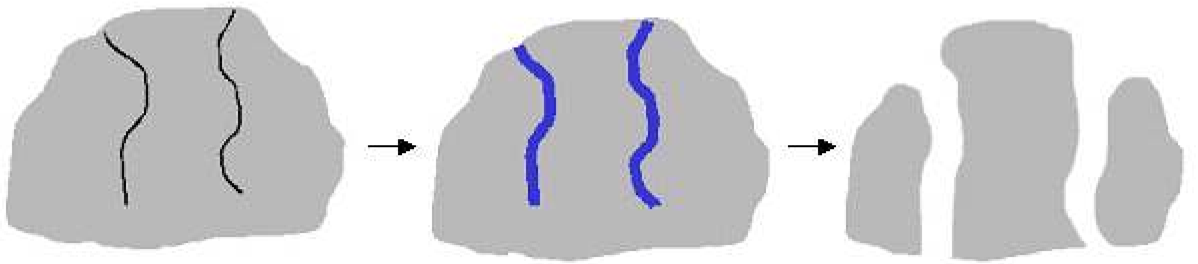
3. Biological : plants & animals

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

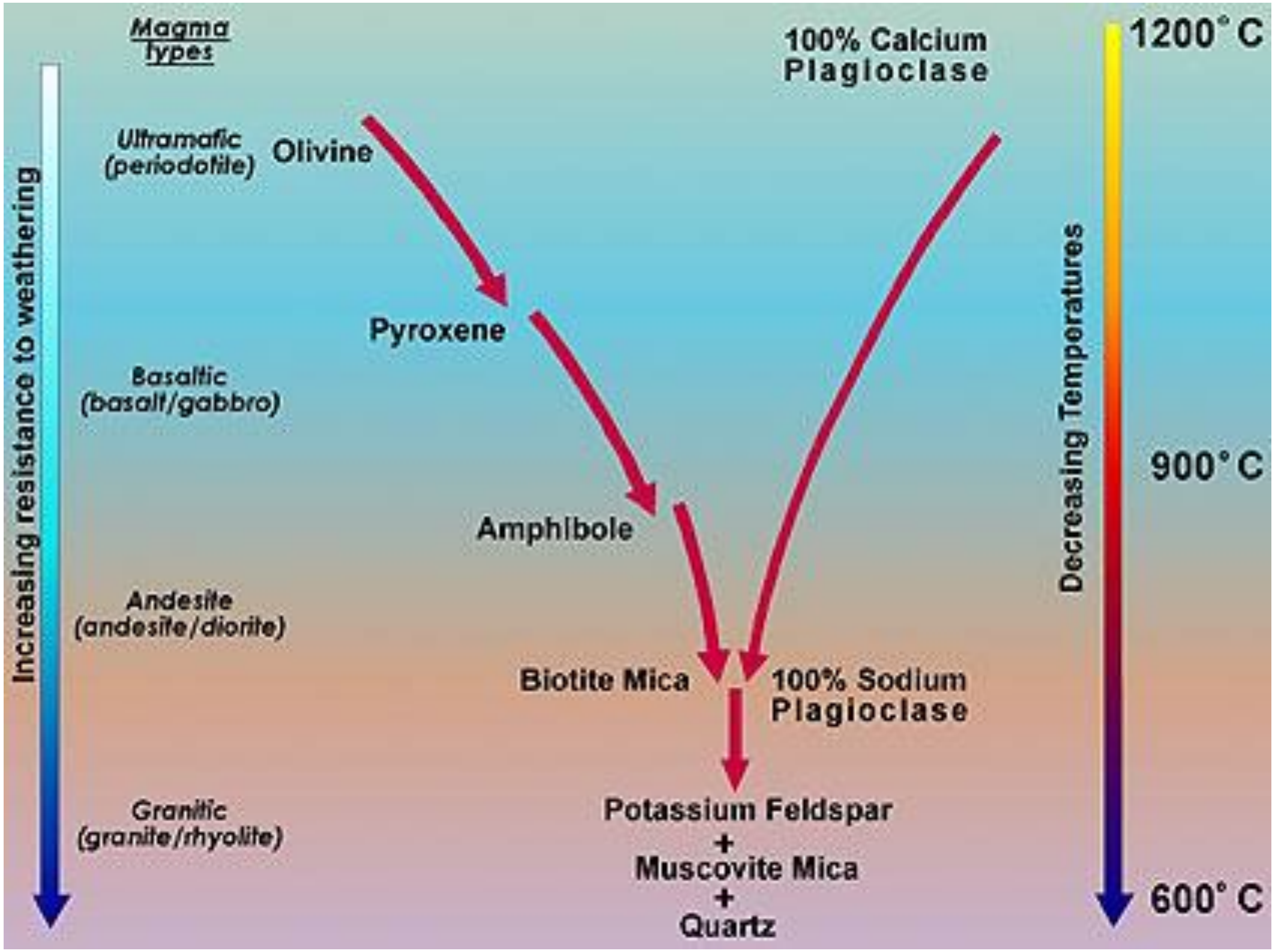
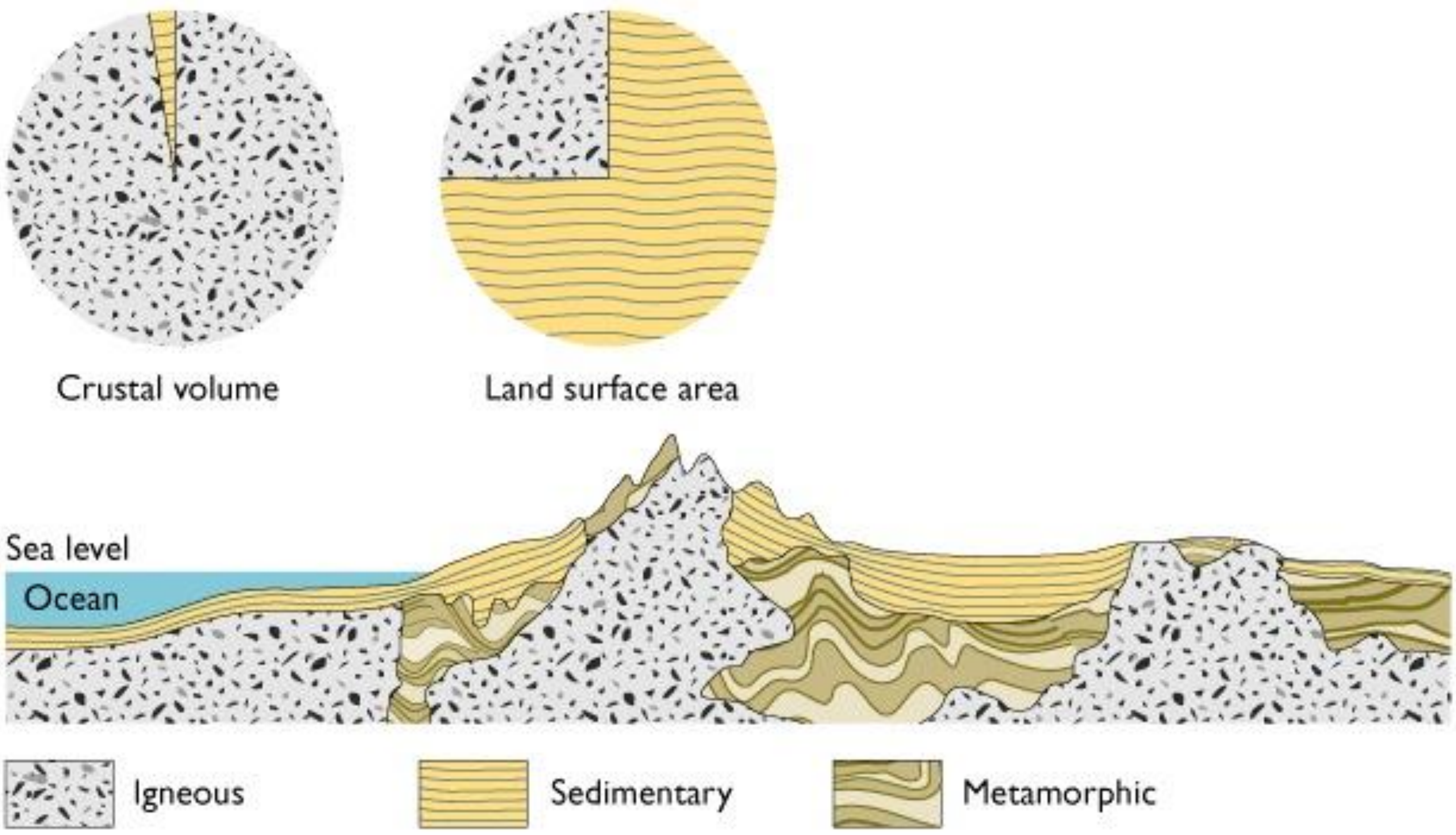


Table 7.1

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.**

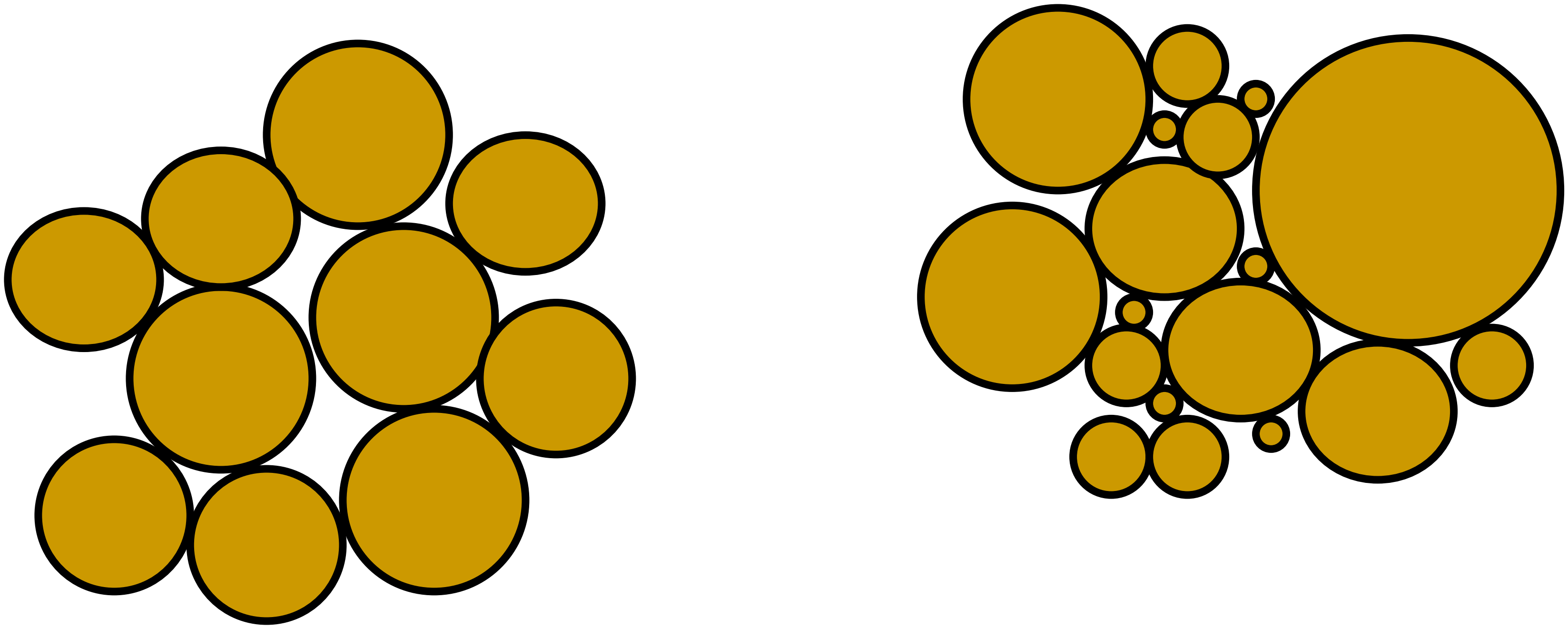
Transport affects the sediment in several ways

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

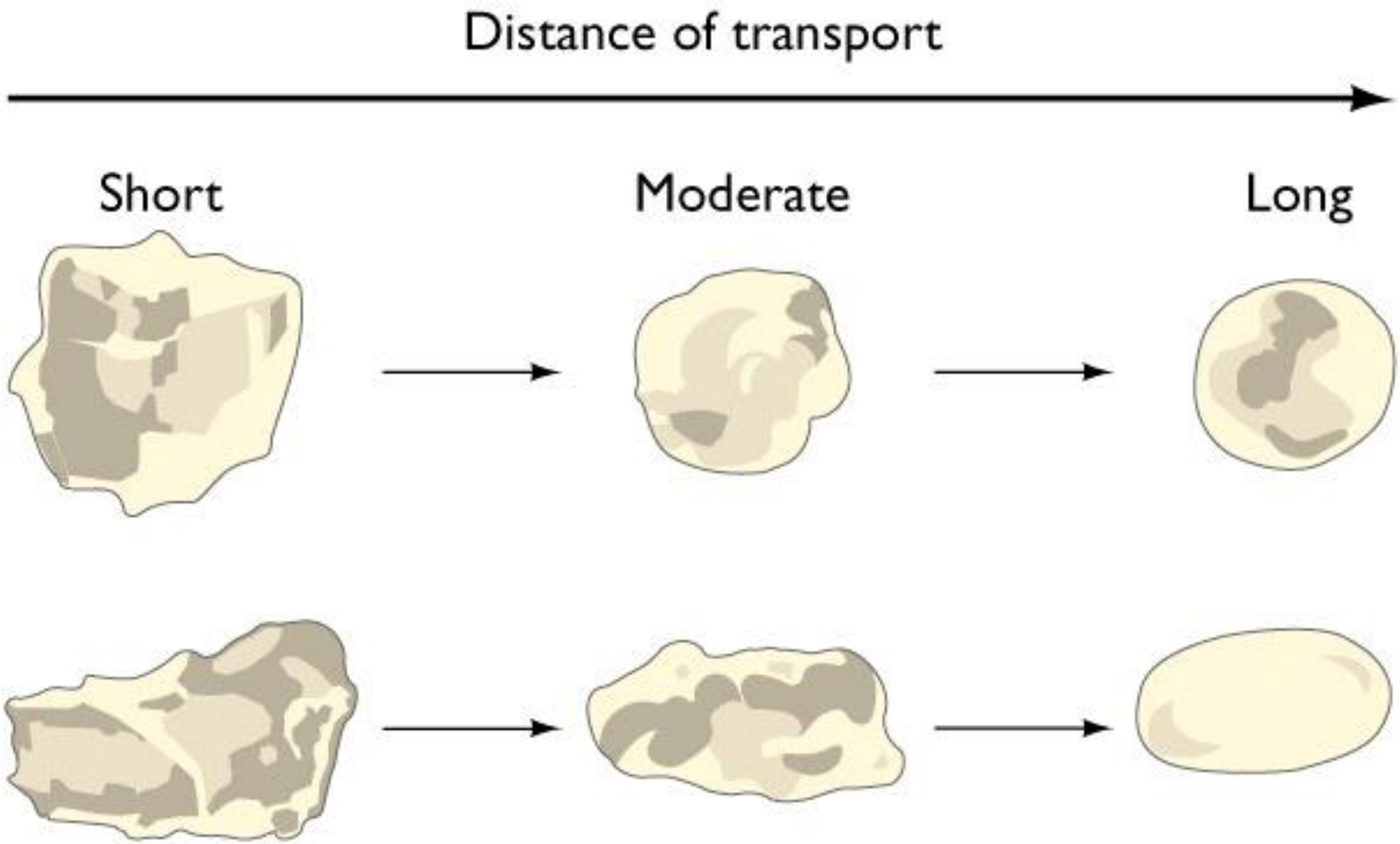
Transport affects the sediment in several ways

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

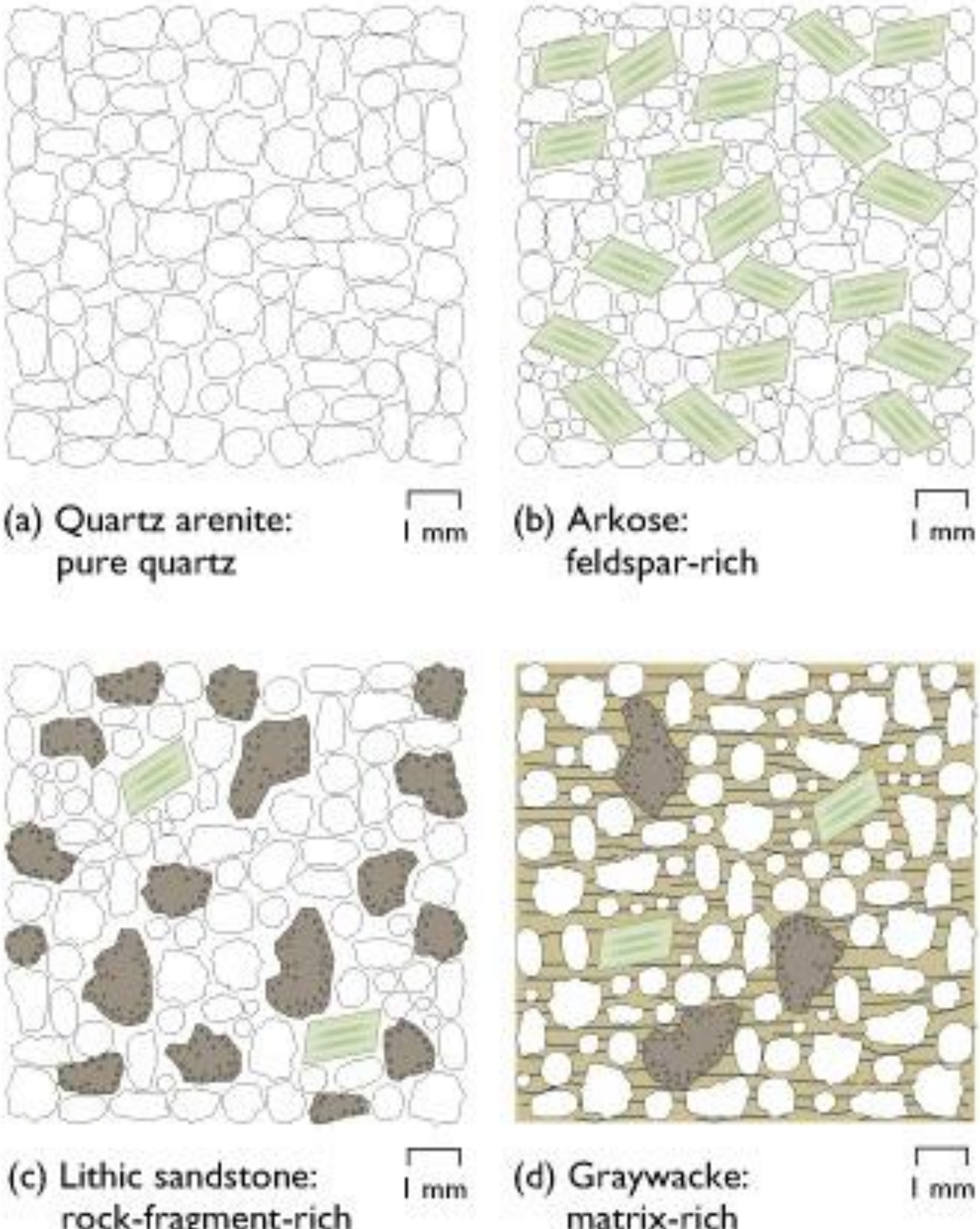
Breck Kent

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

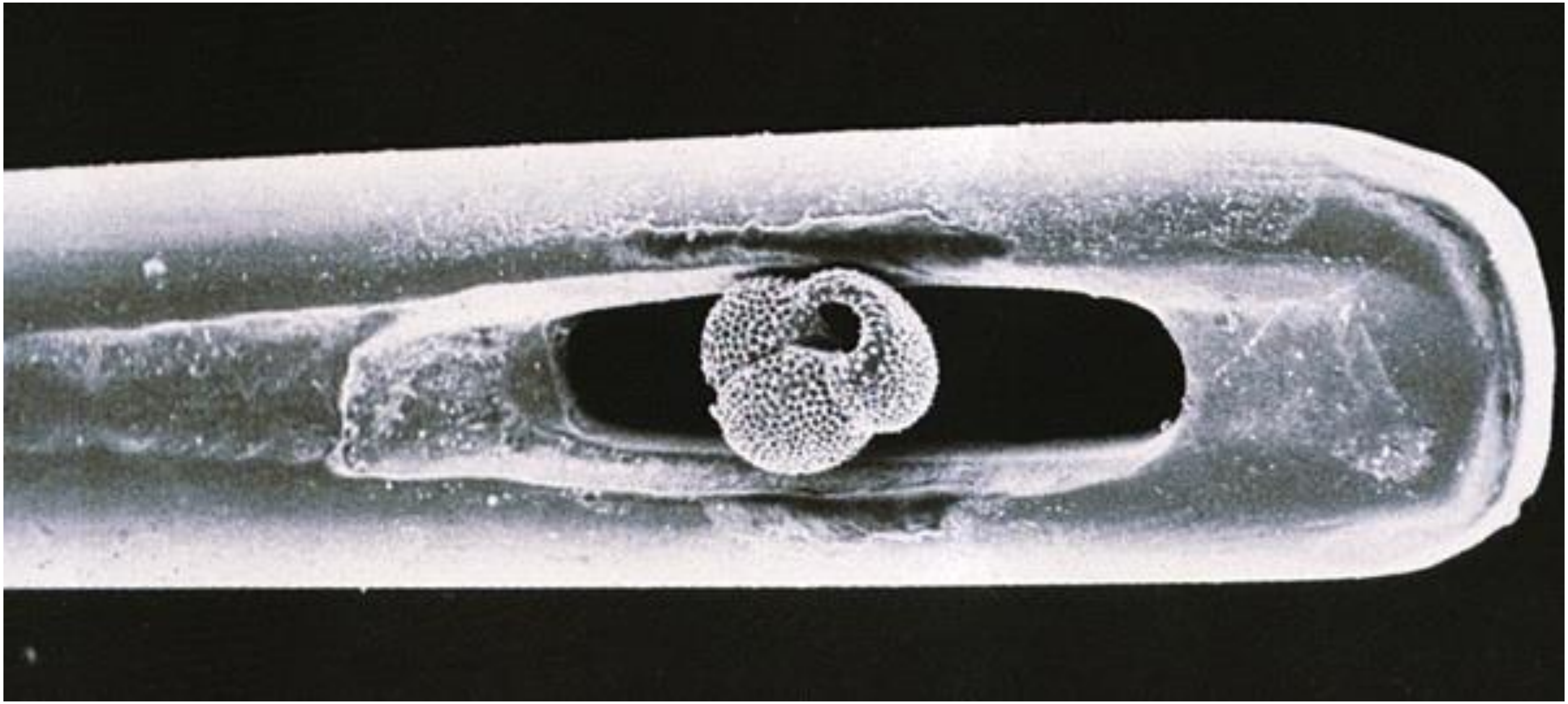
Limestone: It is a non-clastic rock formed either chemically or due to precipitation of calcite ($CaCO_3$) from organisms usually shell. These remains will result in formation of a limestone.

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

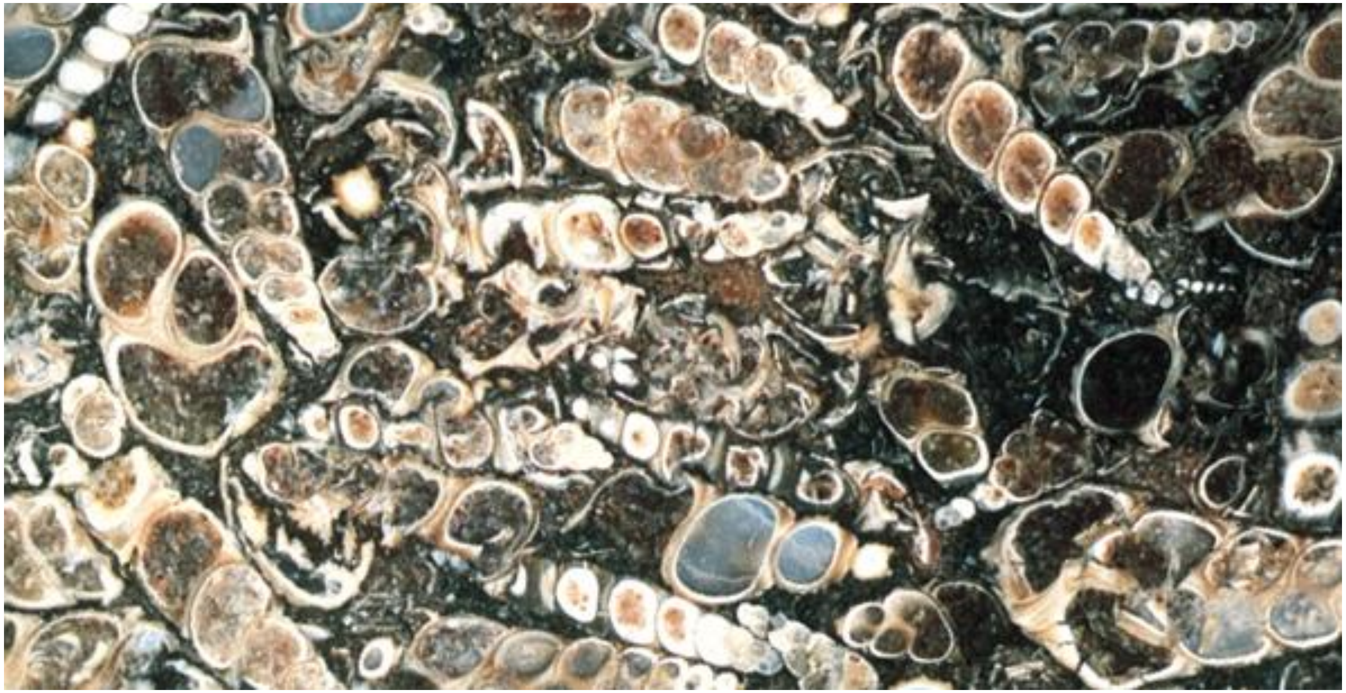
Fossiliferous Limestone: which medium to coarse grained, as it is formed out of cementation of Shells.

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.

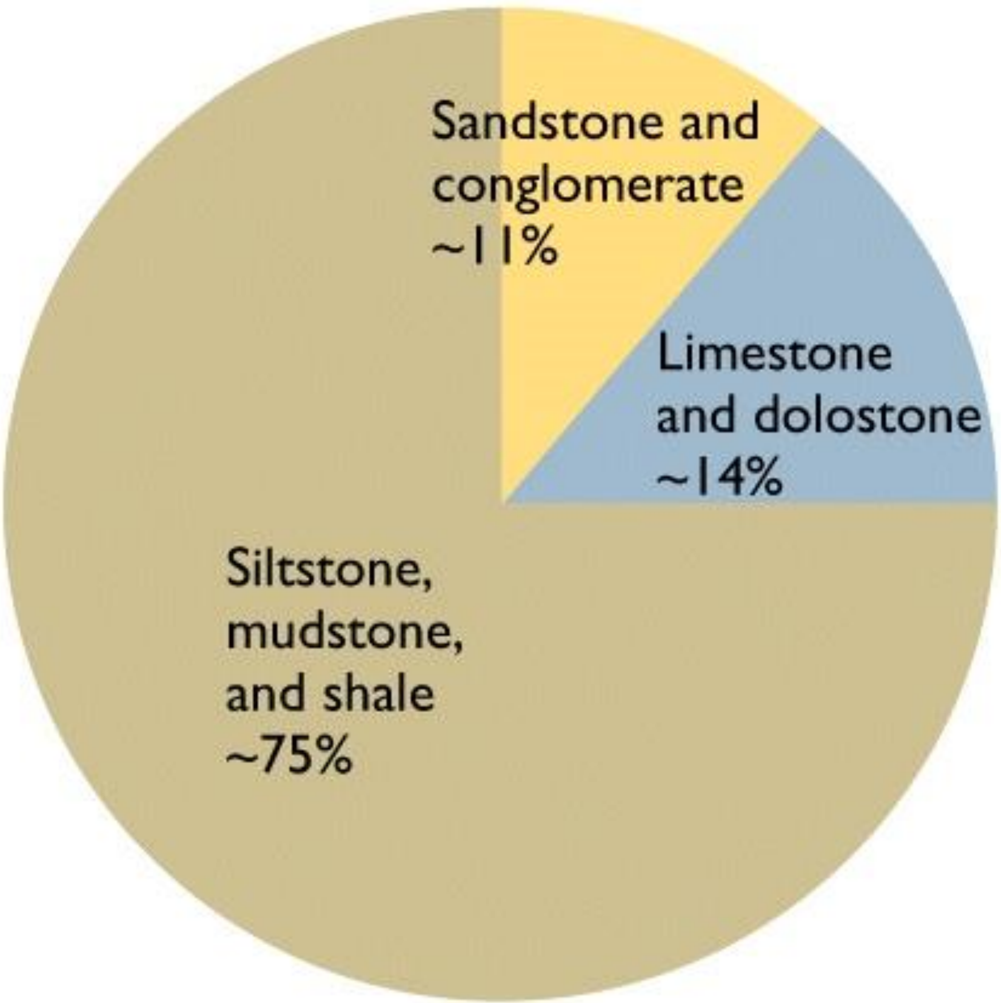
Gypsum | **Halite**

50% | **90%**

$CaSO_4.2H_20$

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

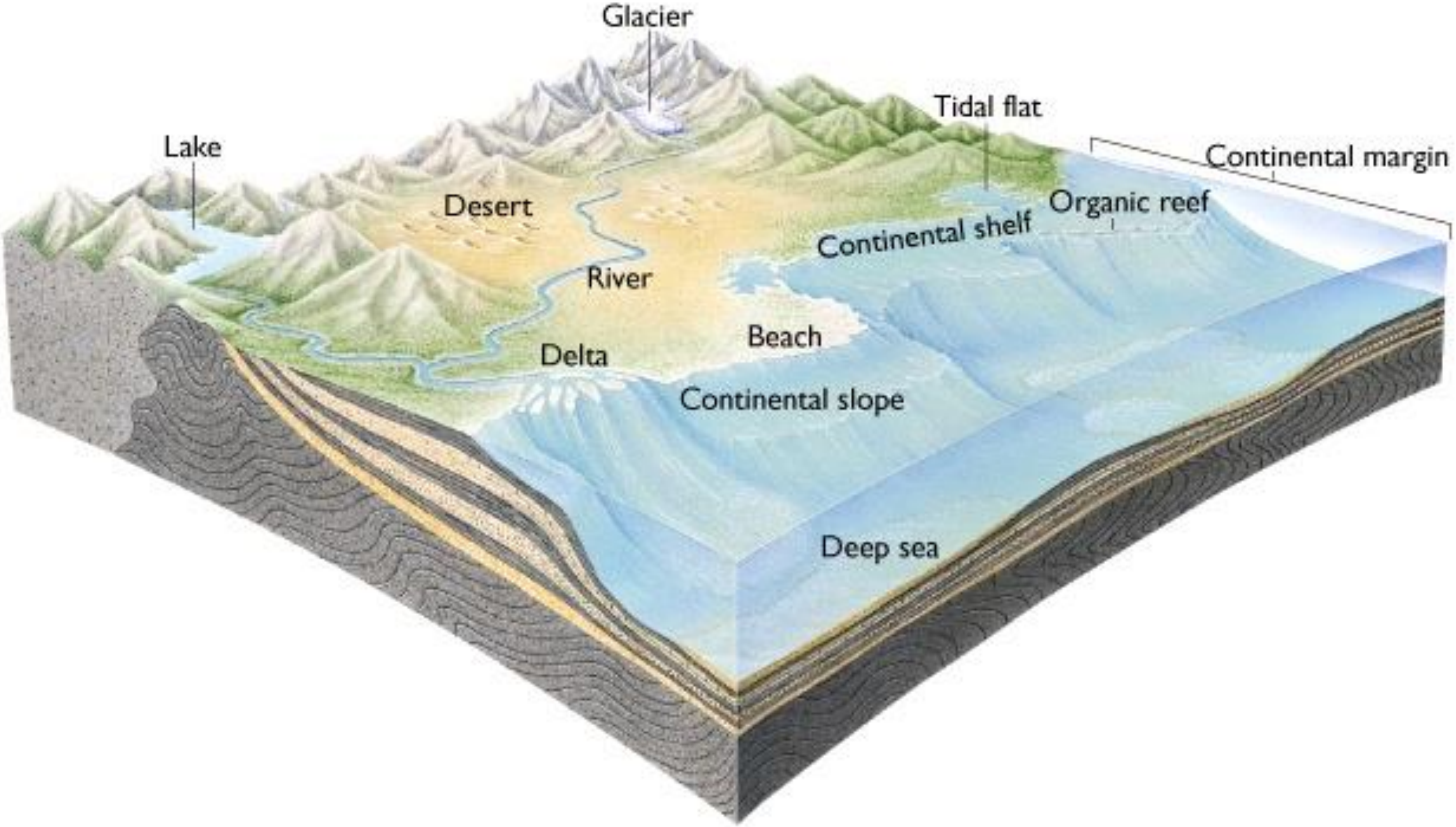
•Features of these depositional environments are preserved in the rock record

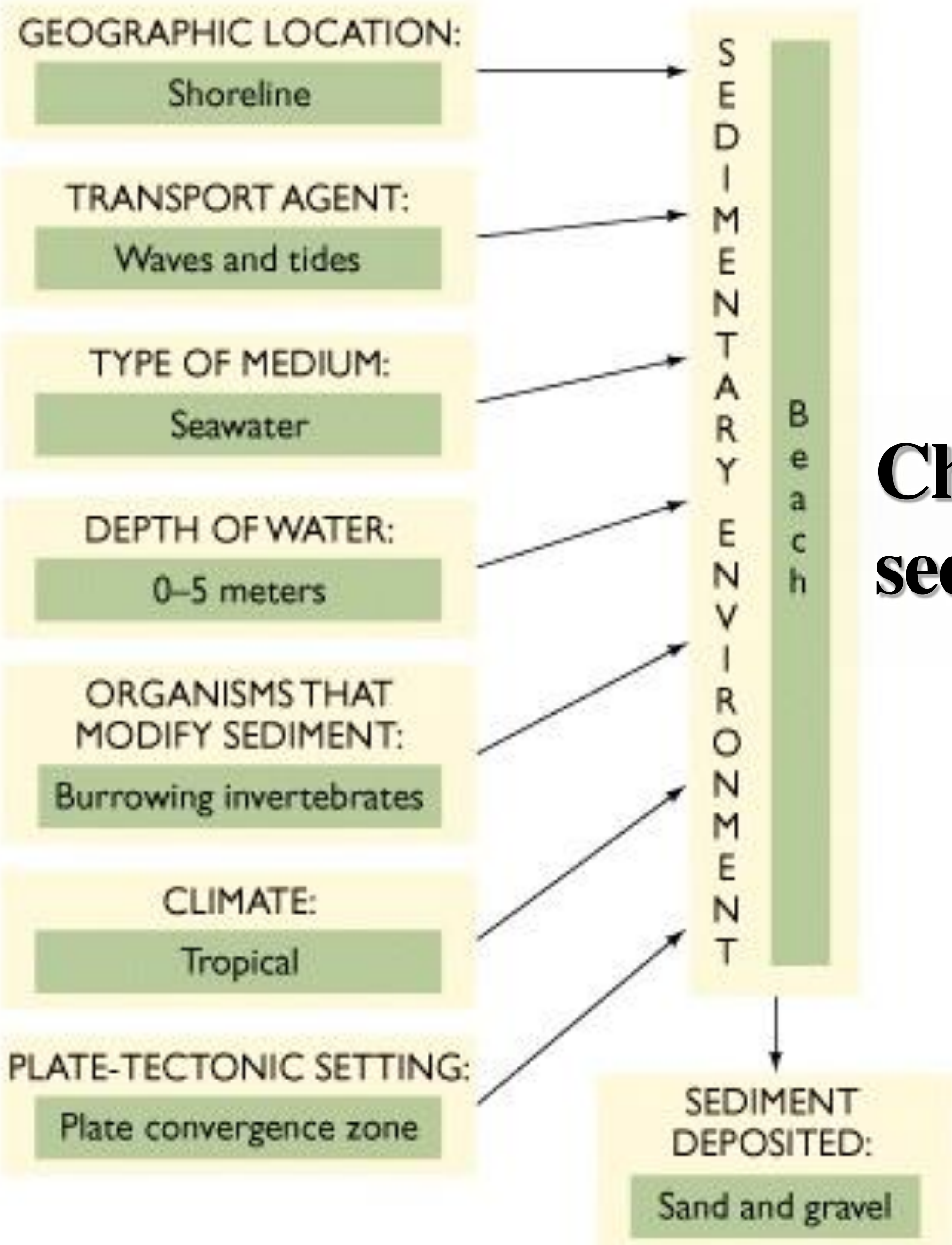
•Examples:

- •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

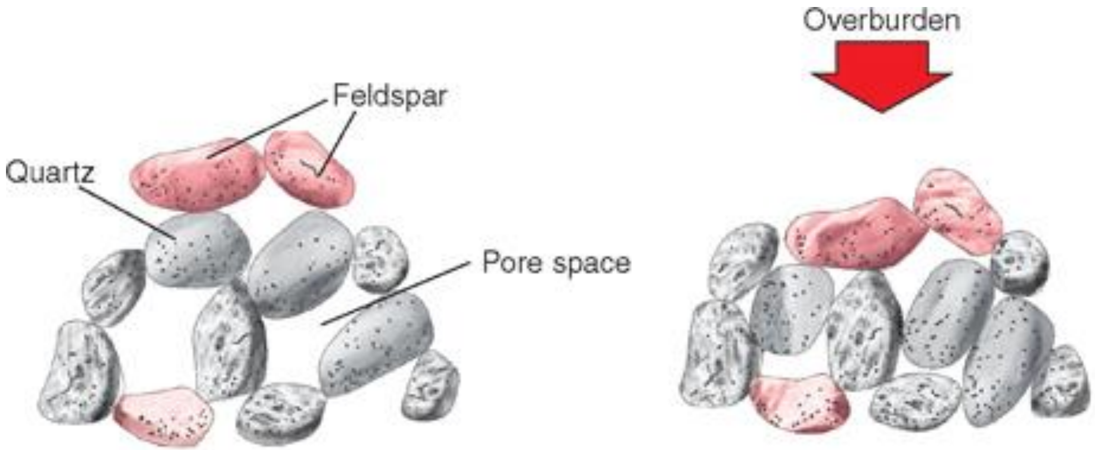
Table 7.2 Clastic Sedimentary Environments

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

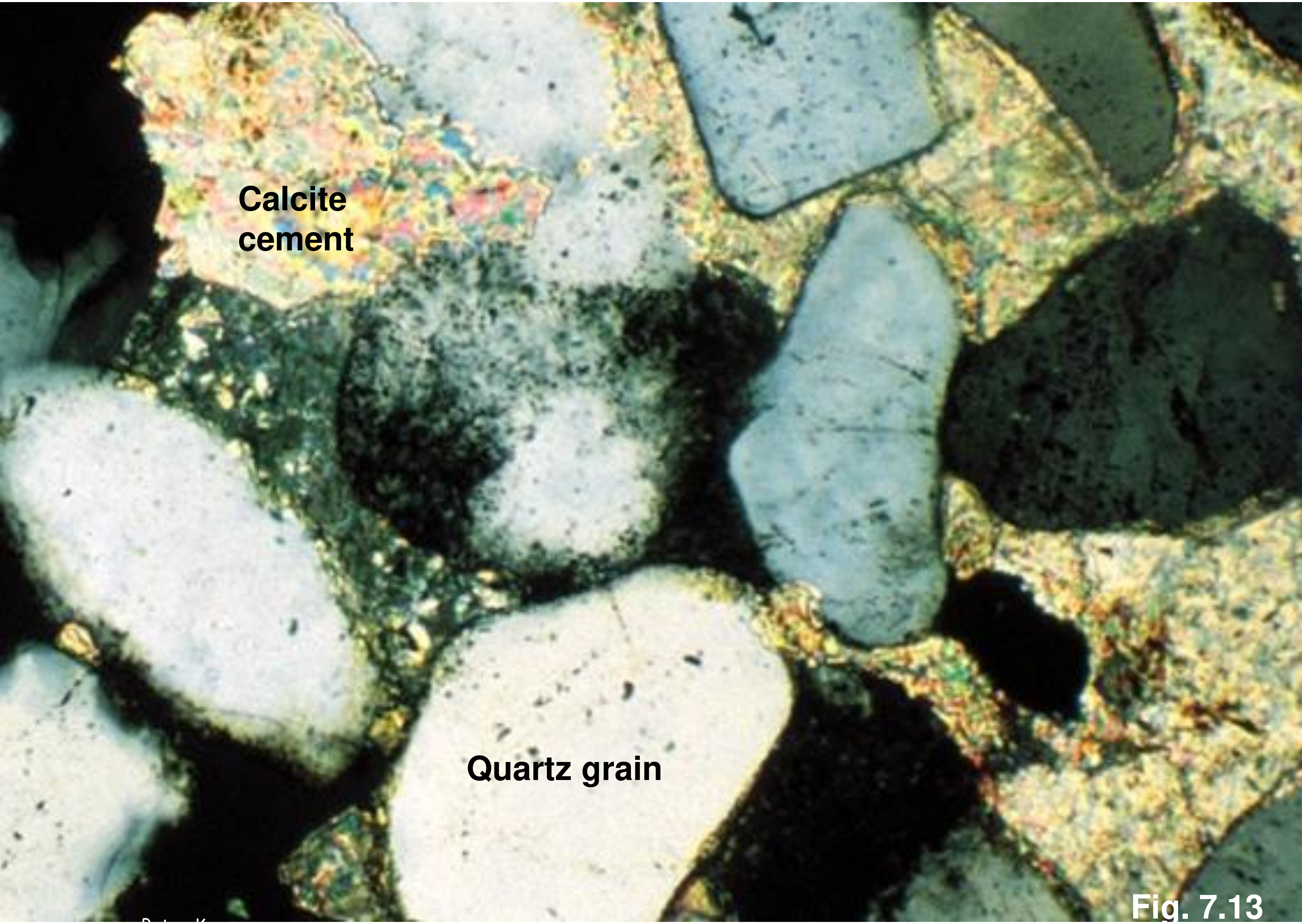


Fig. 7.13

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

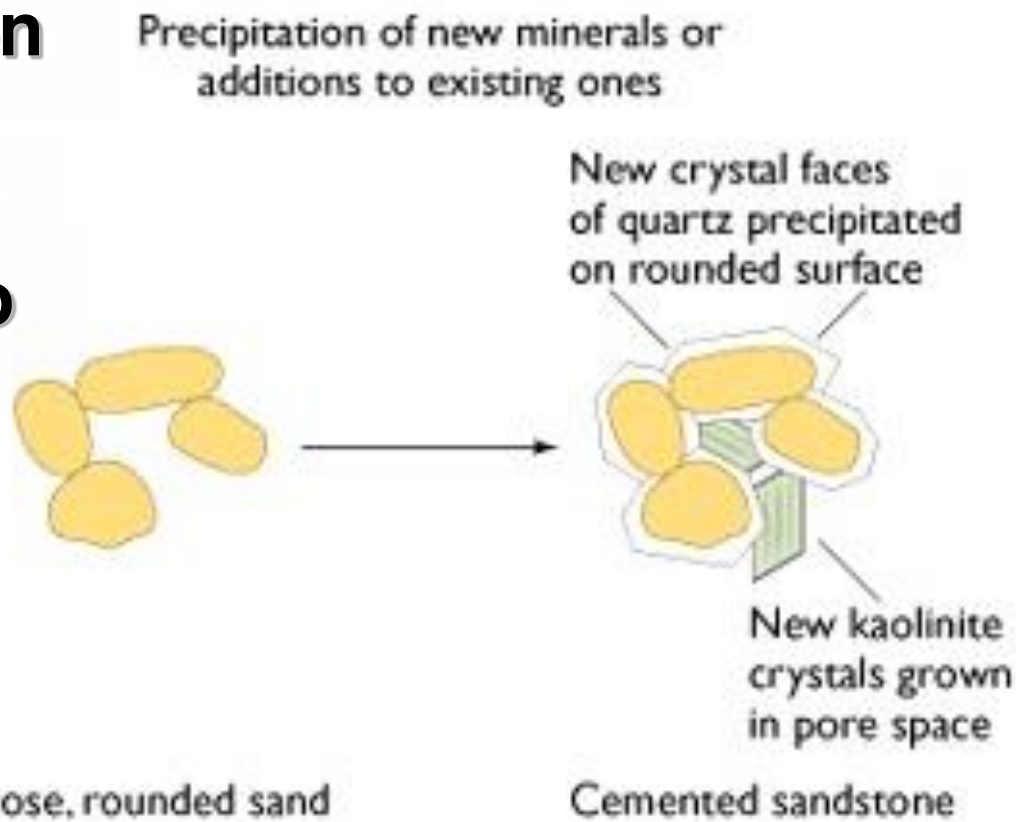
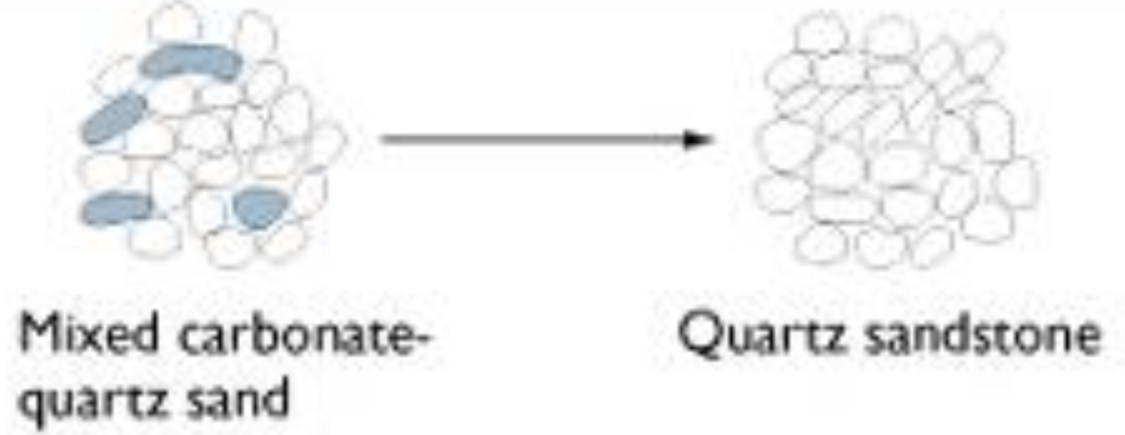
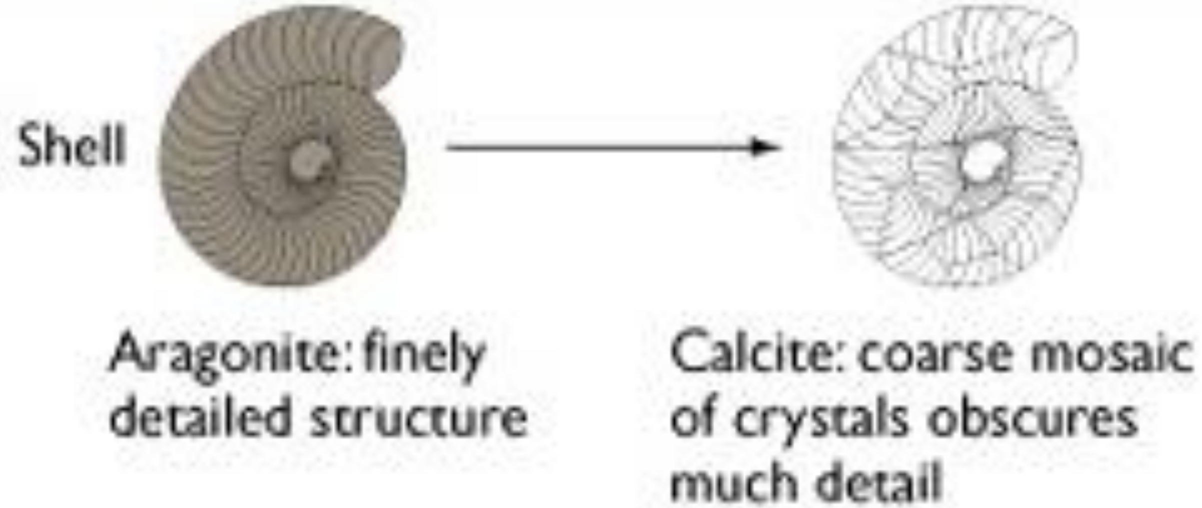


Fig. 7.12

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

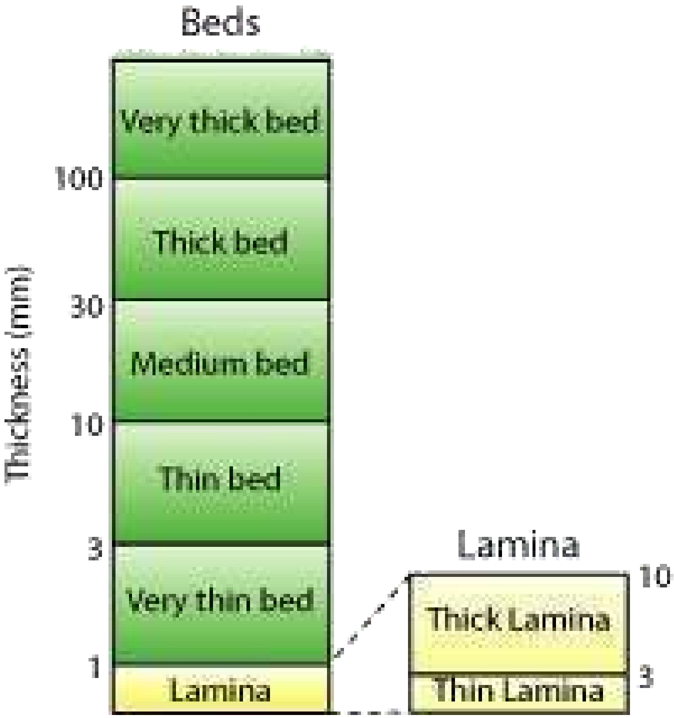
Model

- 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

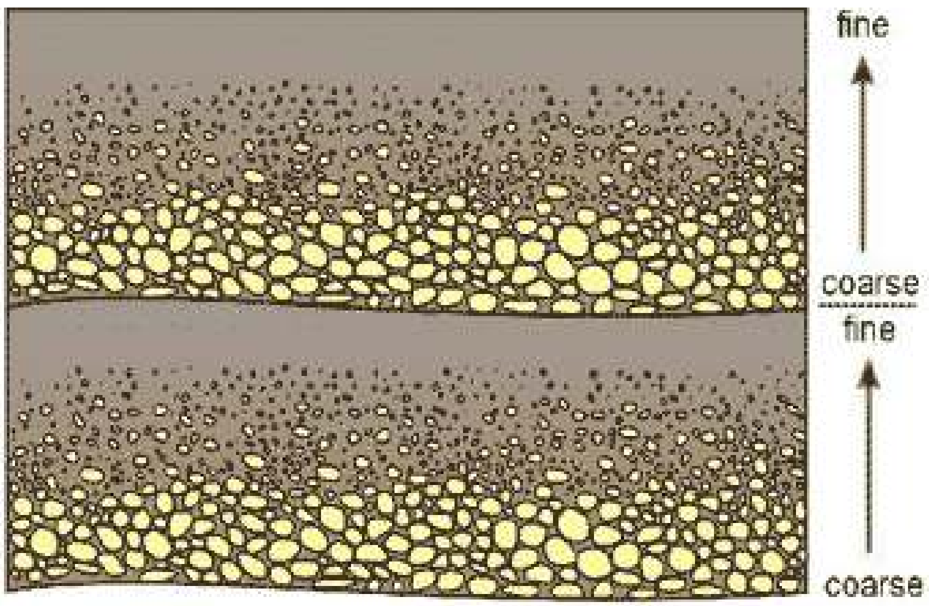
- Key to interpreting transport history of sediments and rocks

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

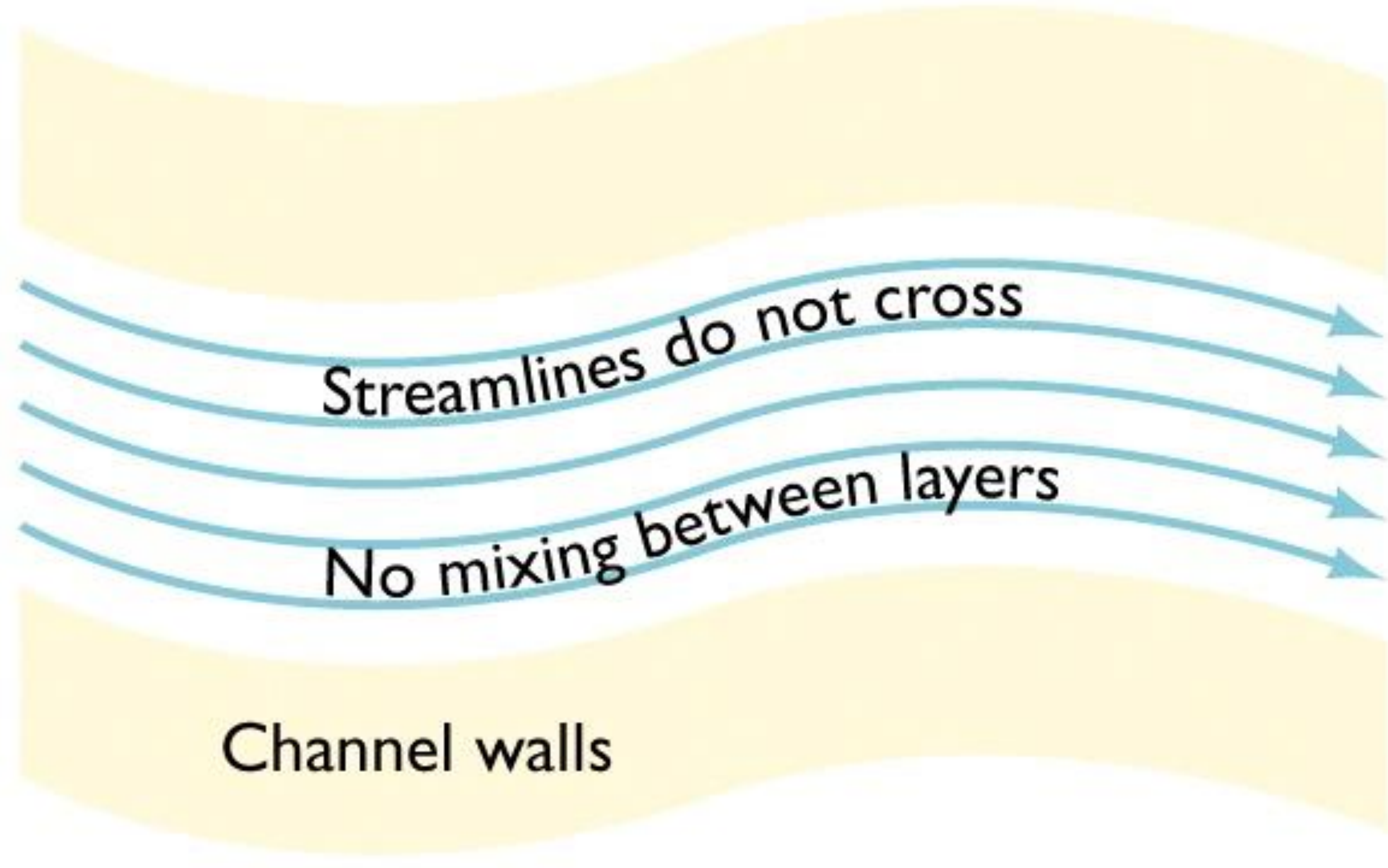
TURBULENT FLOW

Irregular swirling flow

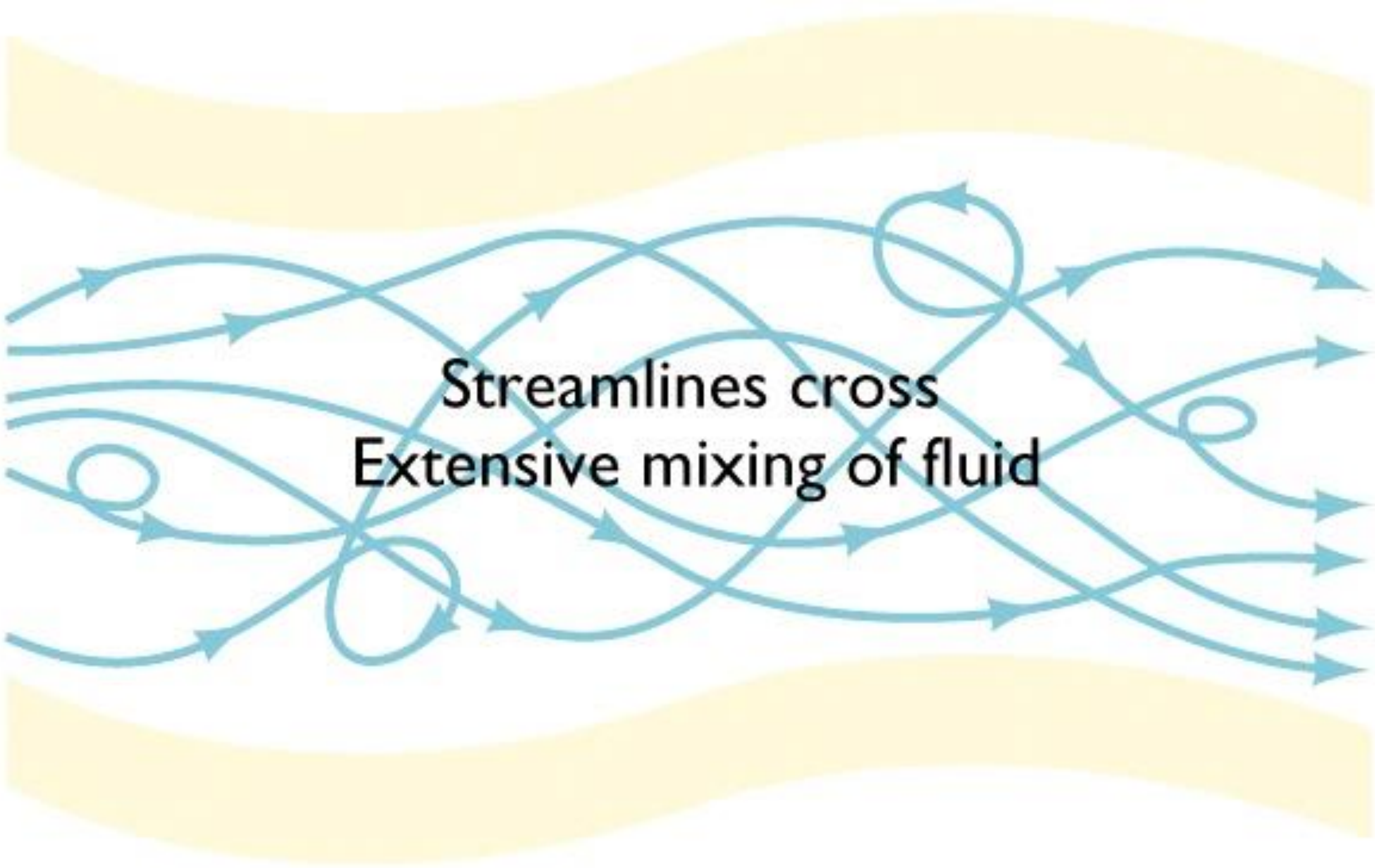
Occurs at most rates of stream flow

Keeps particles in suspension

LAMINAR FLOW



TURBULENT FLOW



LAMINAR TO TURBULENT TRANSITION

Laminar flow **Turbulent flow**

ONERA

Fig. 13.1c

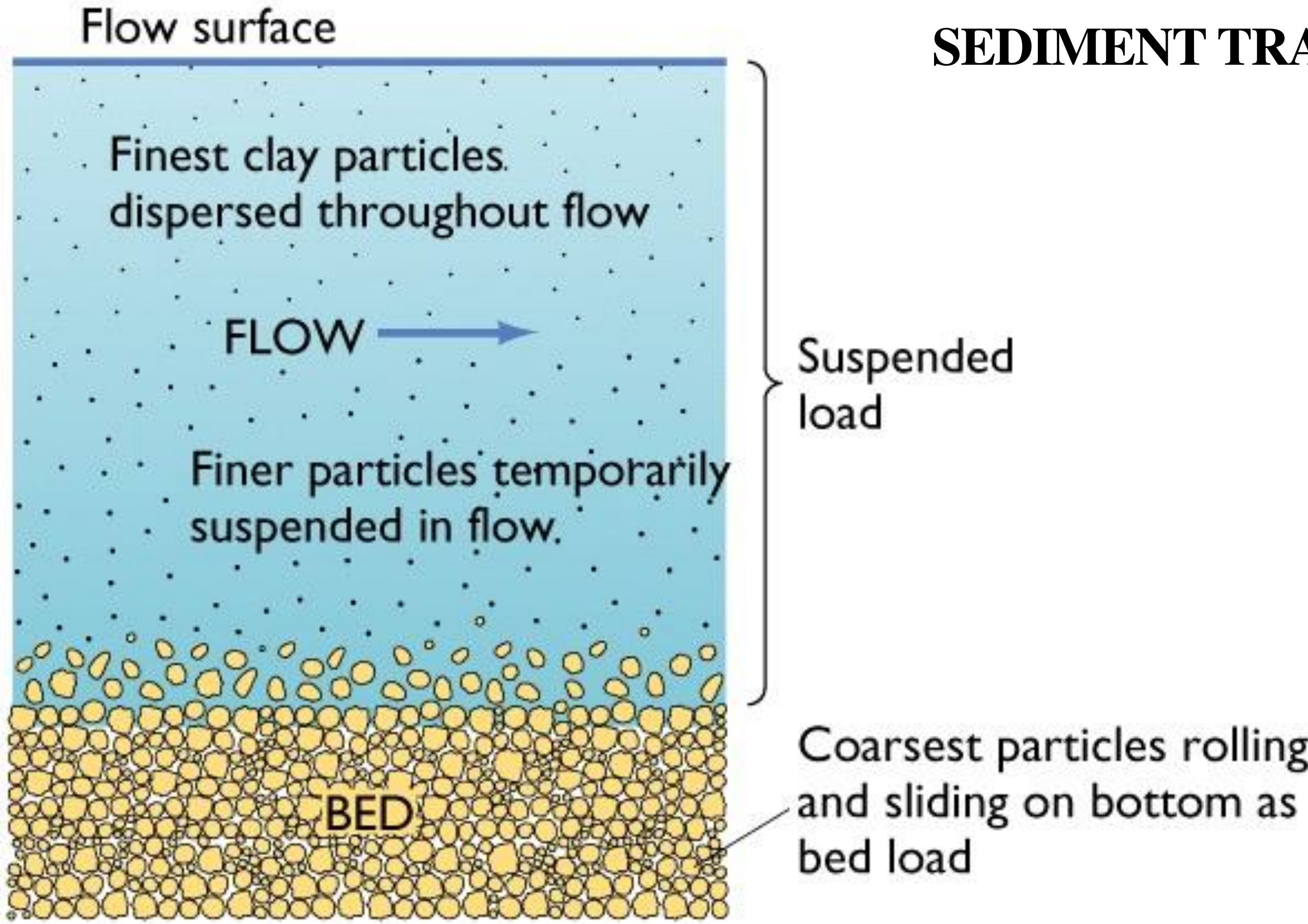
STREAMS MOVE MATERIAL IN THREE FORMS

Dissolved load

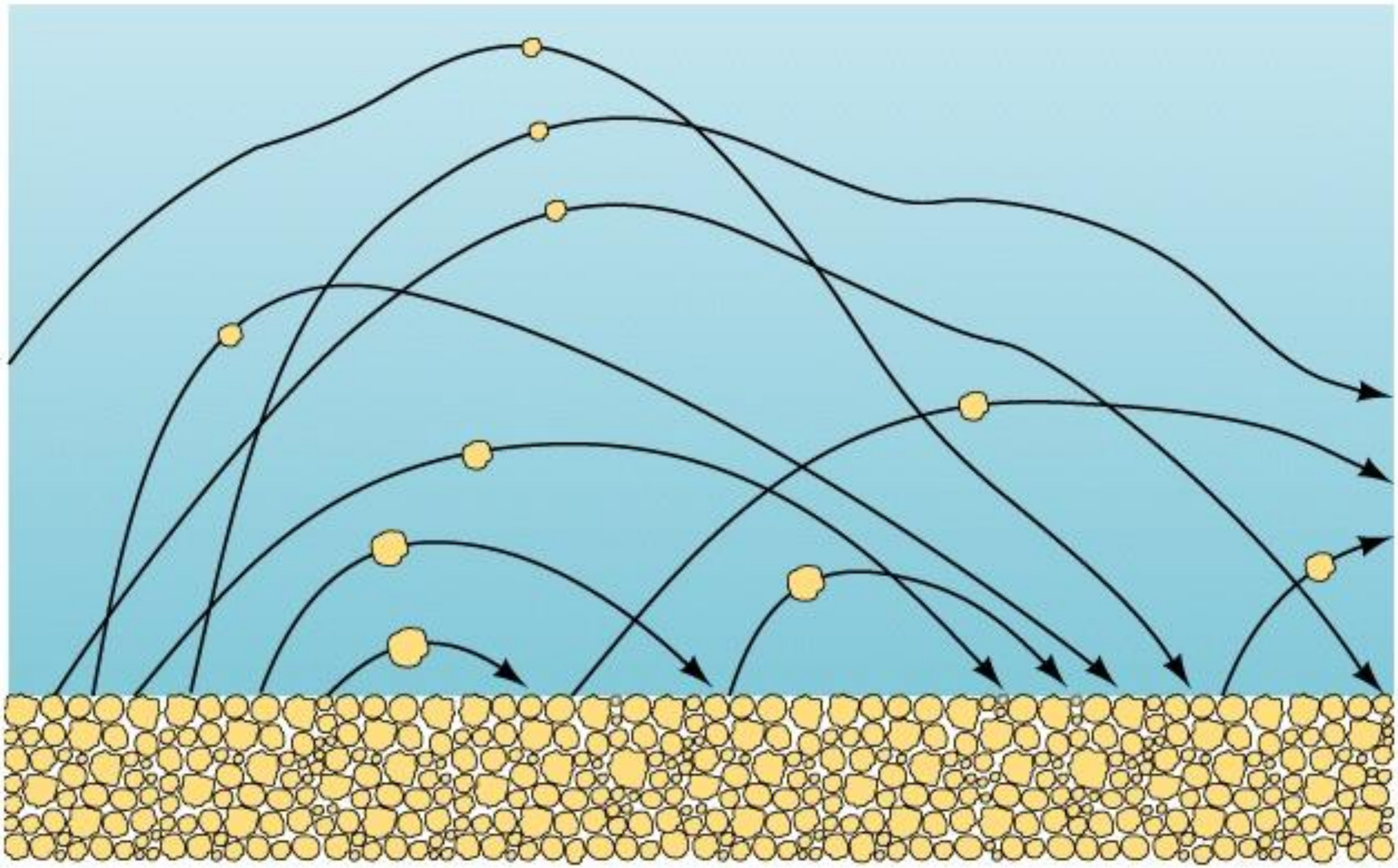
Suspended load

Bed load (traction and saltation)

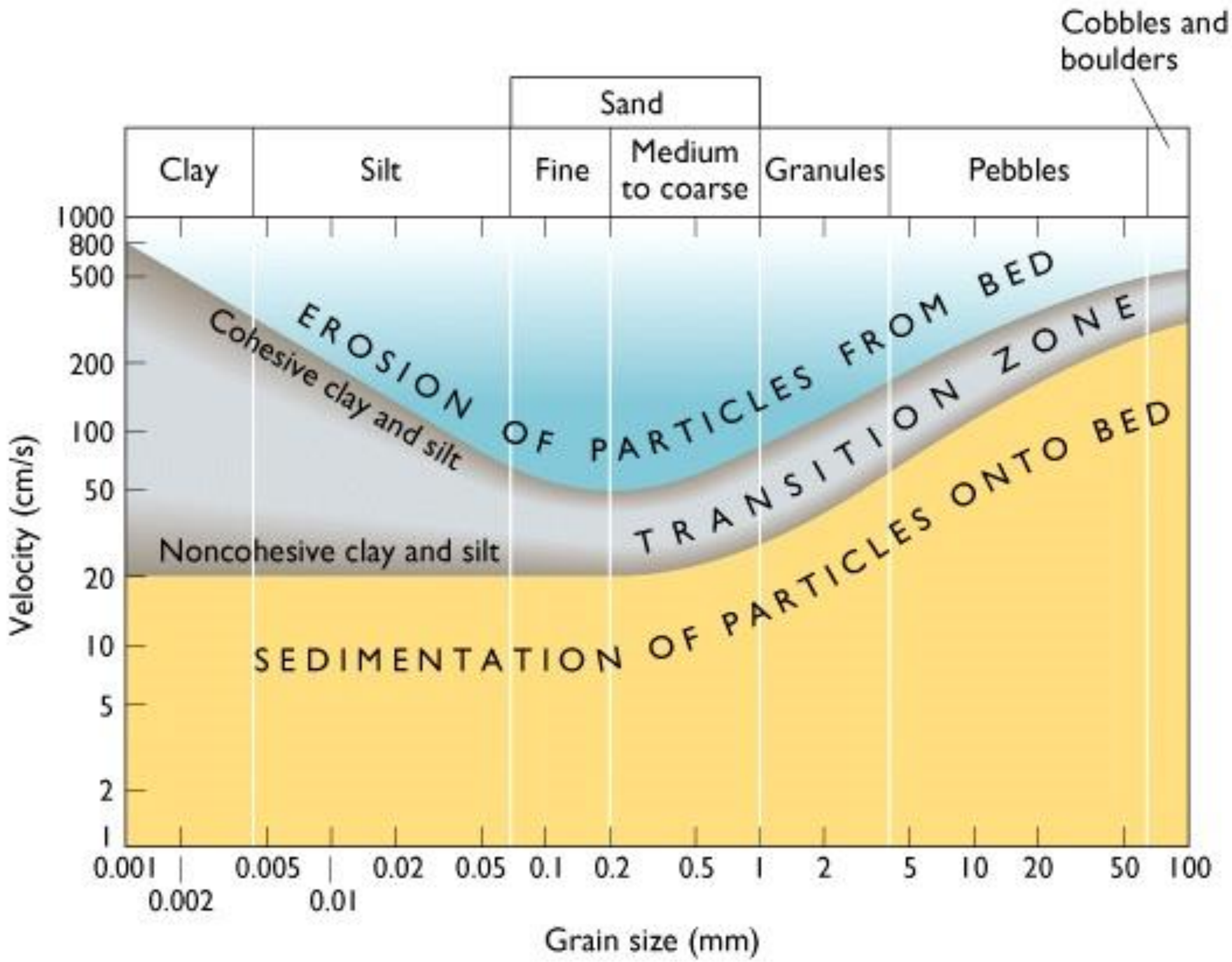
SEDIMENT TRANSPORT



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***

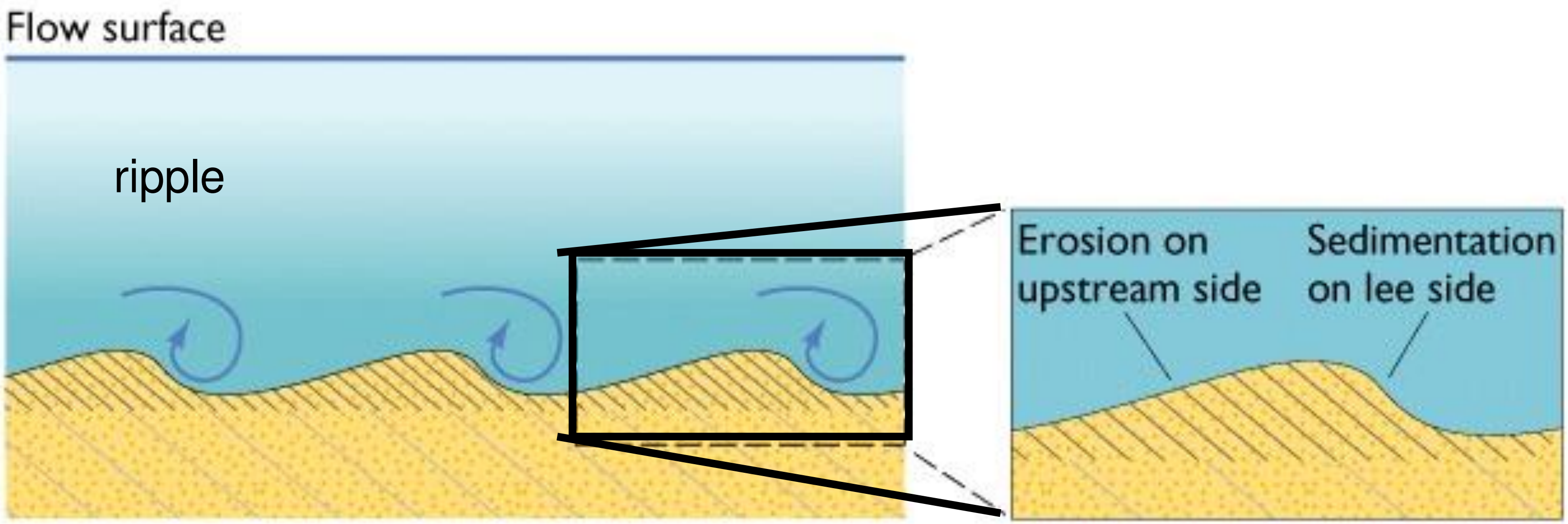
DISCHARGE

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

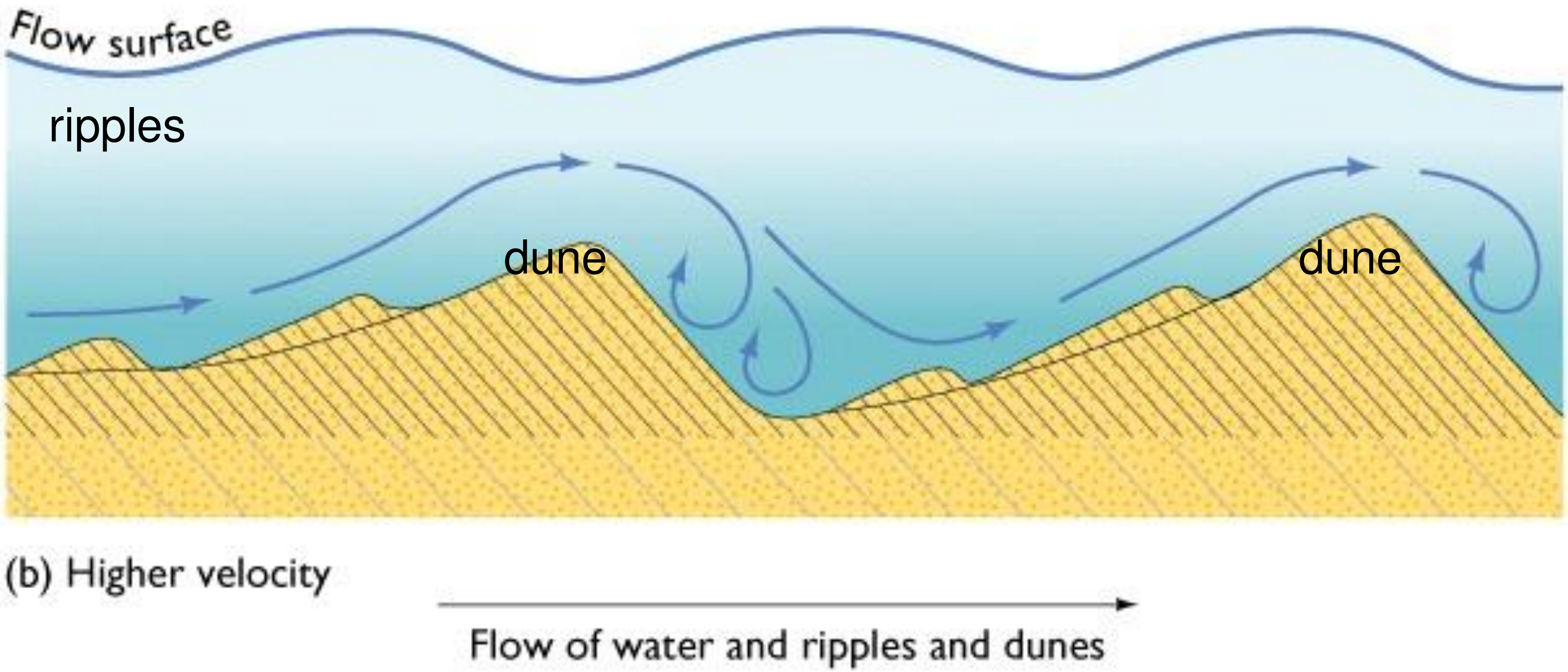
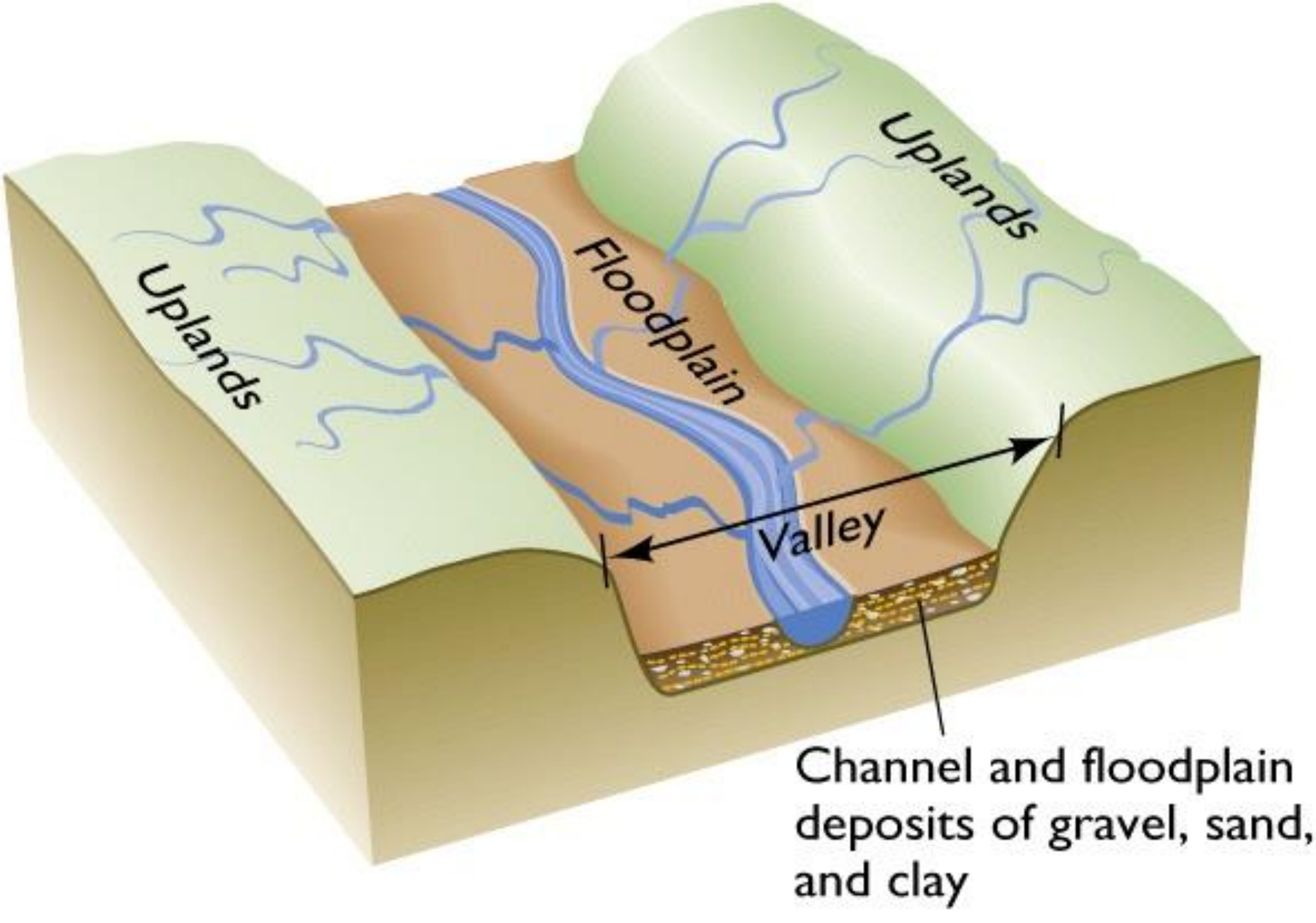


Fig. 13.5b

ATERFALL RETREATING
PRIVER

PARTS OF A RIVER SYSTEM



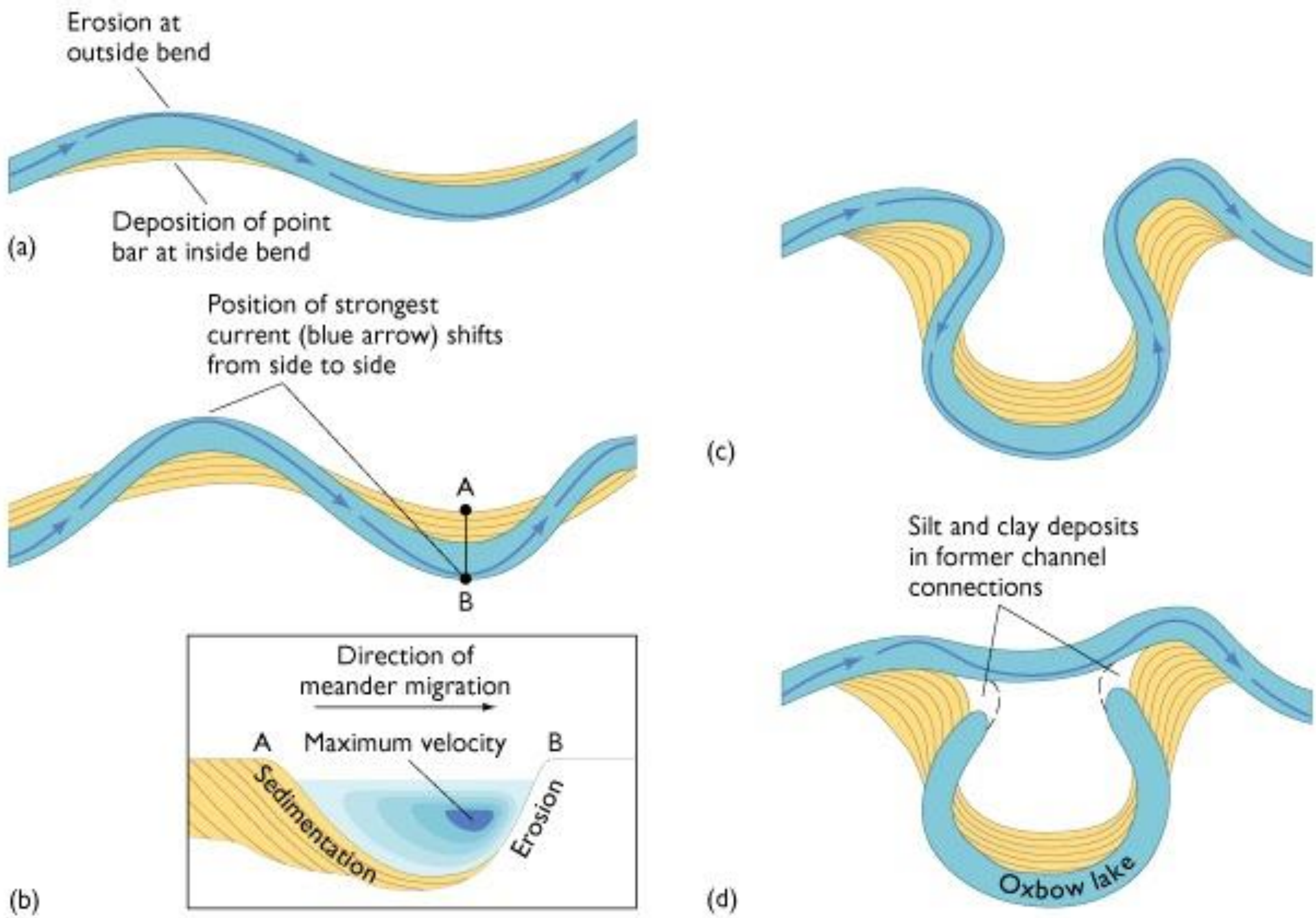
TWO IMPORTANT STREAM TYPES

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

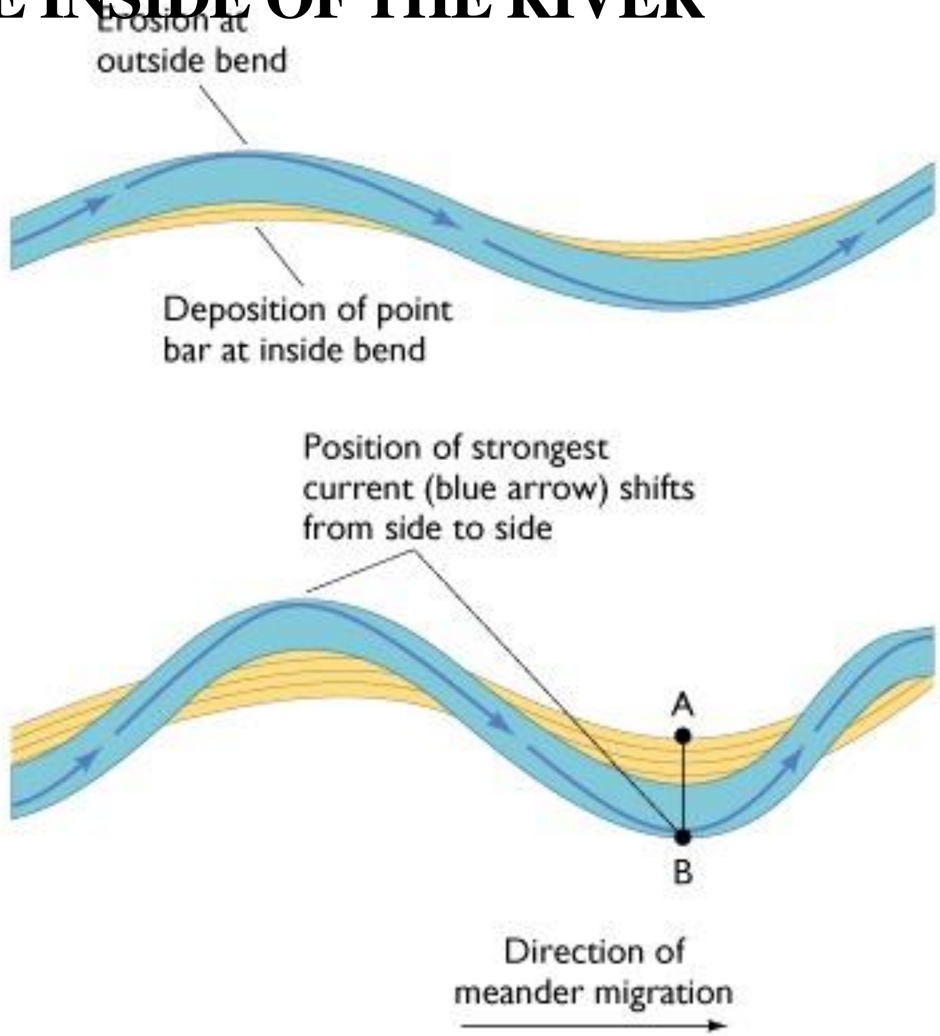
2. Braided Streams

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.

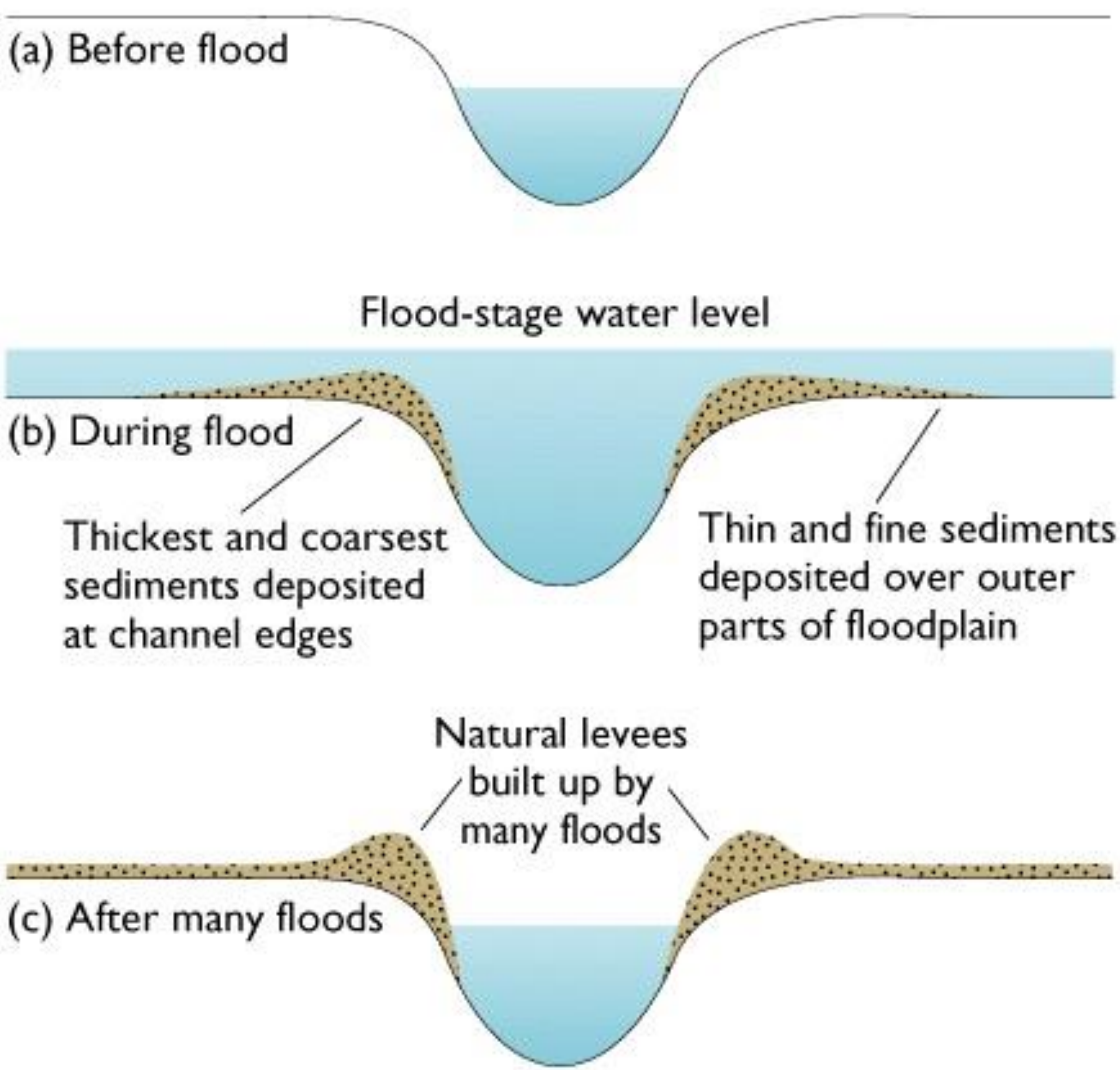
LATERAL MIGRATION BY EROSION AT THE OUTSIDE & DEPOSITION ON THE INSIDE OF THE RIVER



(a)

BRAIDED RIVER

FORMATION OF NATURAL LEVEES



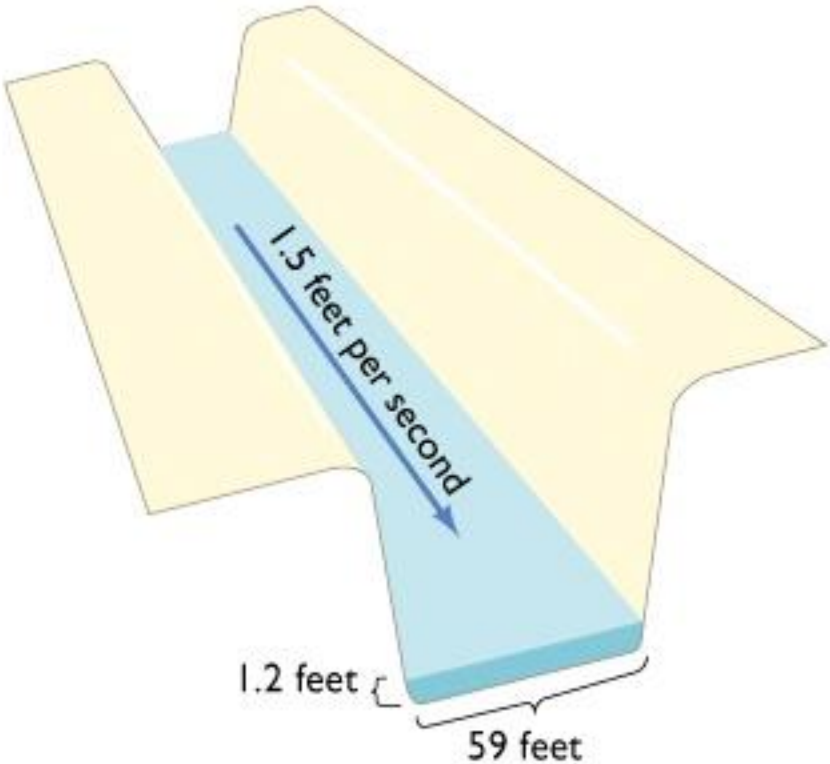
DISCHARGE

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



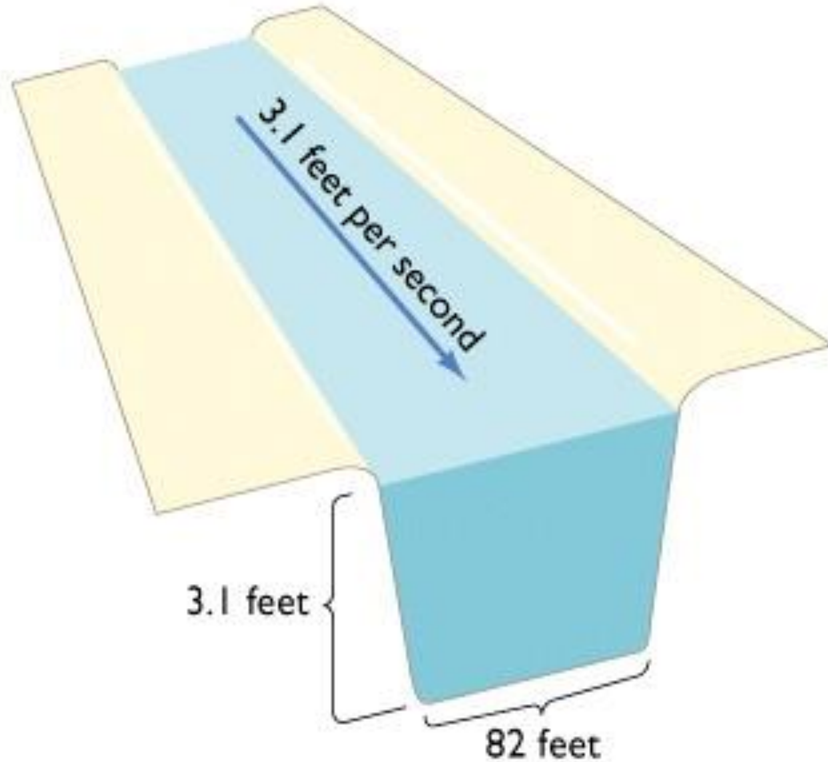
(a) River at average level

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 feet × 82 feet = 254.2 feet^3

Velocity high: 3.1 feet/s

Discharge high:
254.2 feet^2 × 3.1 feet/s = 788.02 feet^3/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

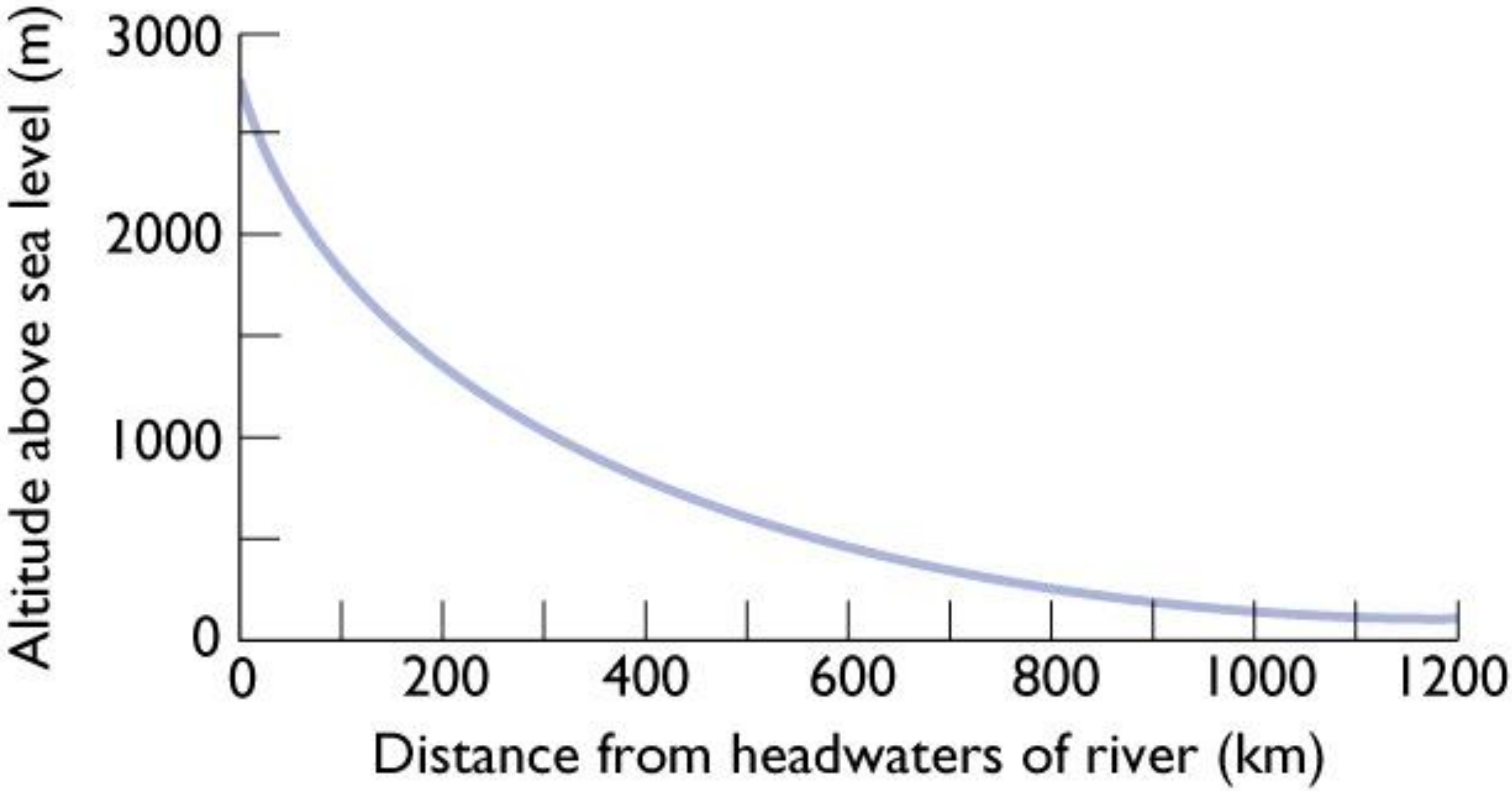
RECURRENCE INTERVAL

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

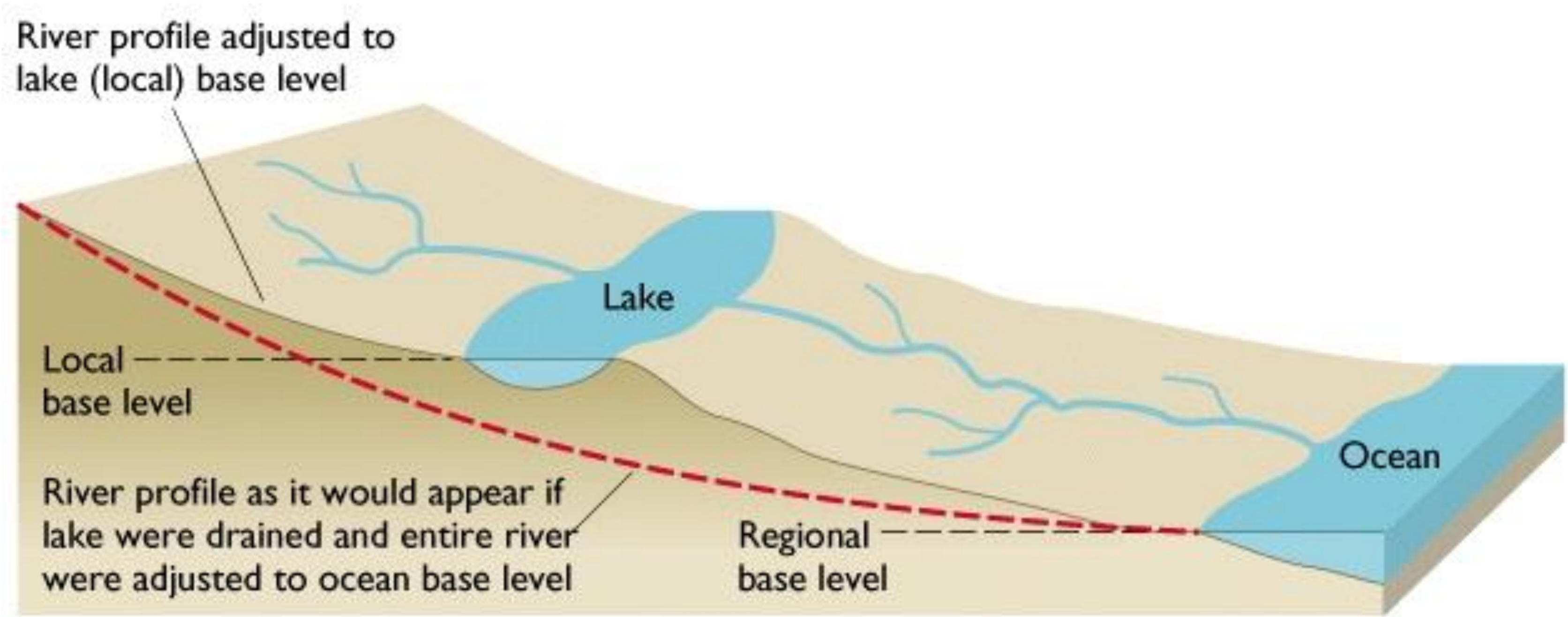
The recurrence interval of a flood of a given size at a given place depends on:

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

LONGITUDINAL STREAM PROFILE OF THE PLATT AND SOUTH PLATT RIVERS



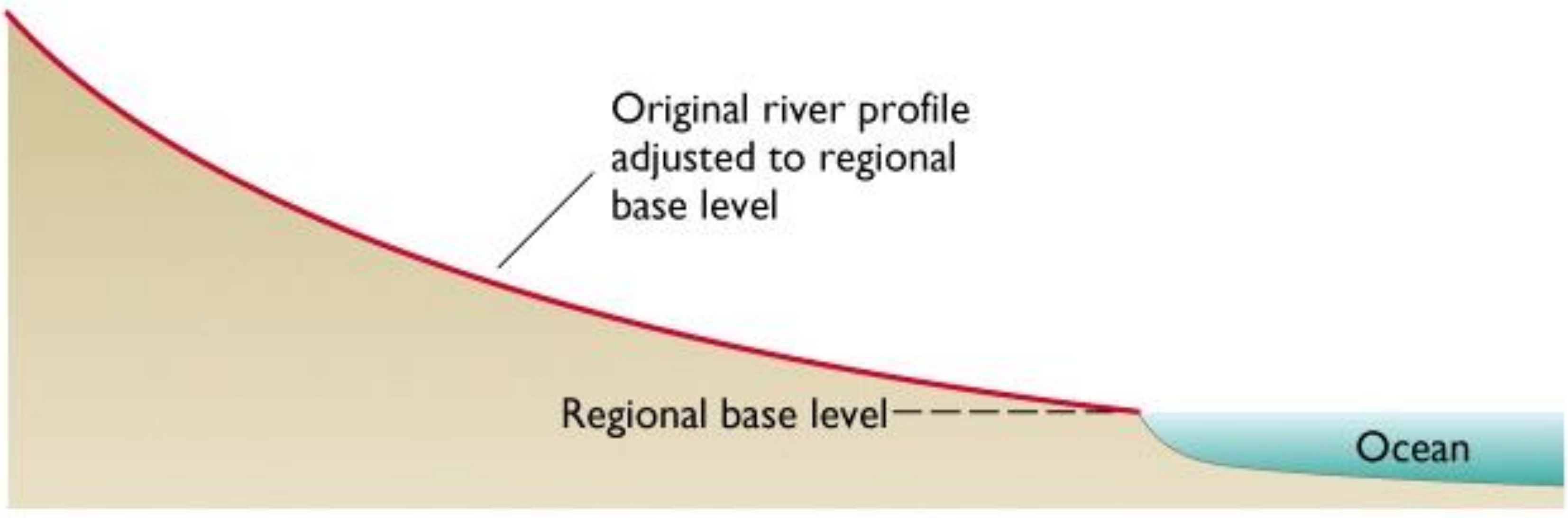
ROLE OF BASE LEVEL IN CONTROLLING LONGITUDINAL PROFILE OF RIVERS



BASE LEVEL

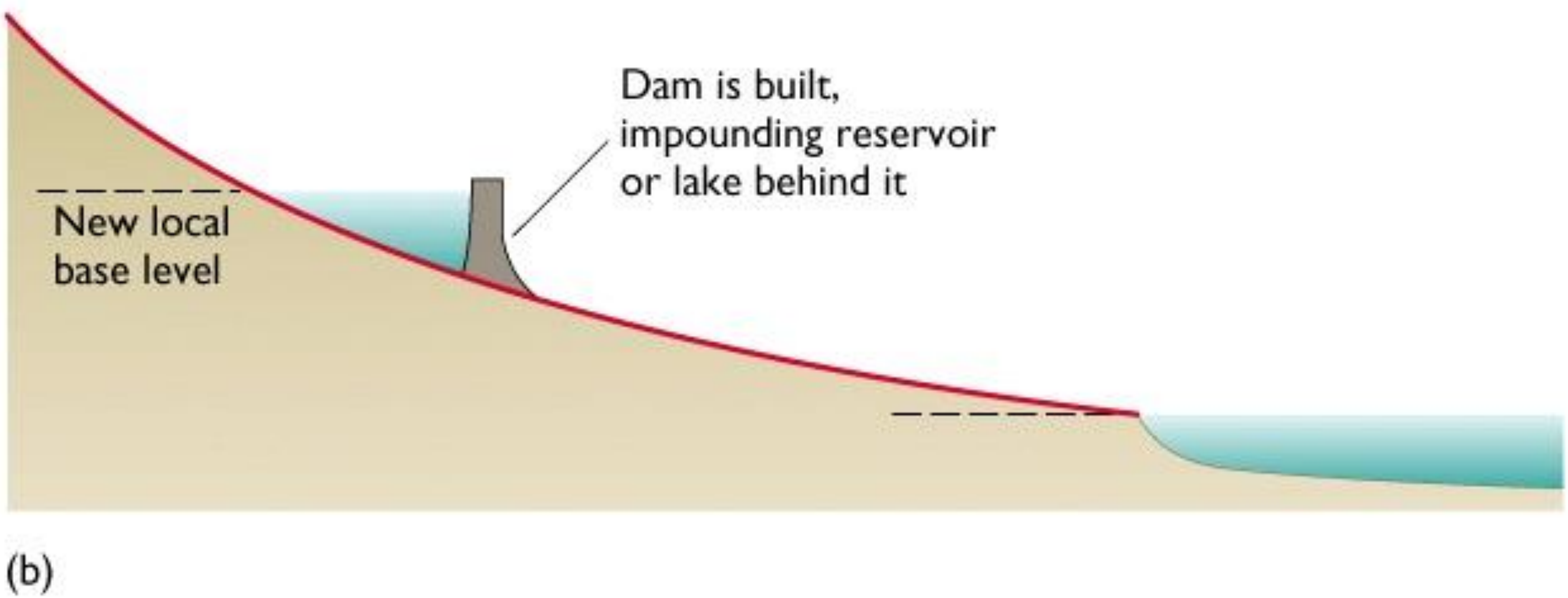
Elevation at which a stream enters a large body of water such as a lake or ocean

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

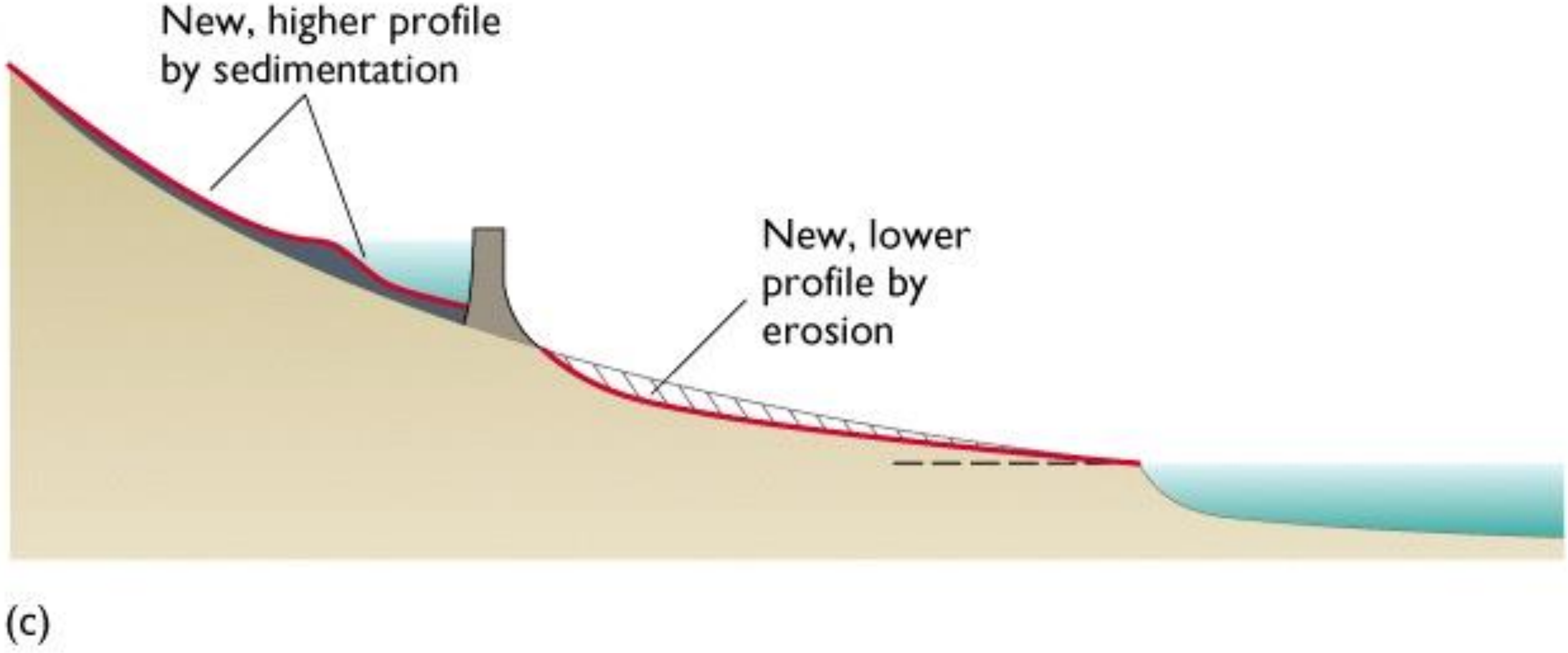


(a)

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



EFFECTS OF BUILDING A DAM DEPOSITION UPSTREAM AND EROSION DOWNSTREAM



GRADED STREAM

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

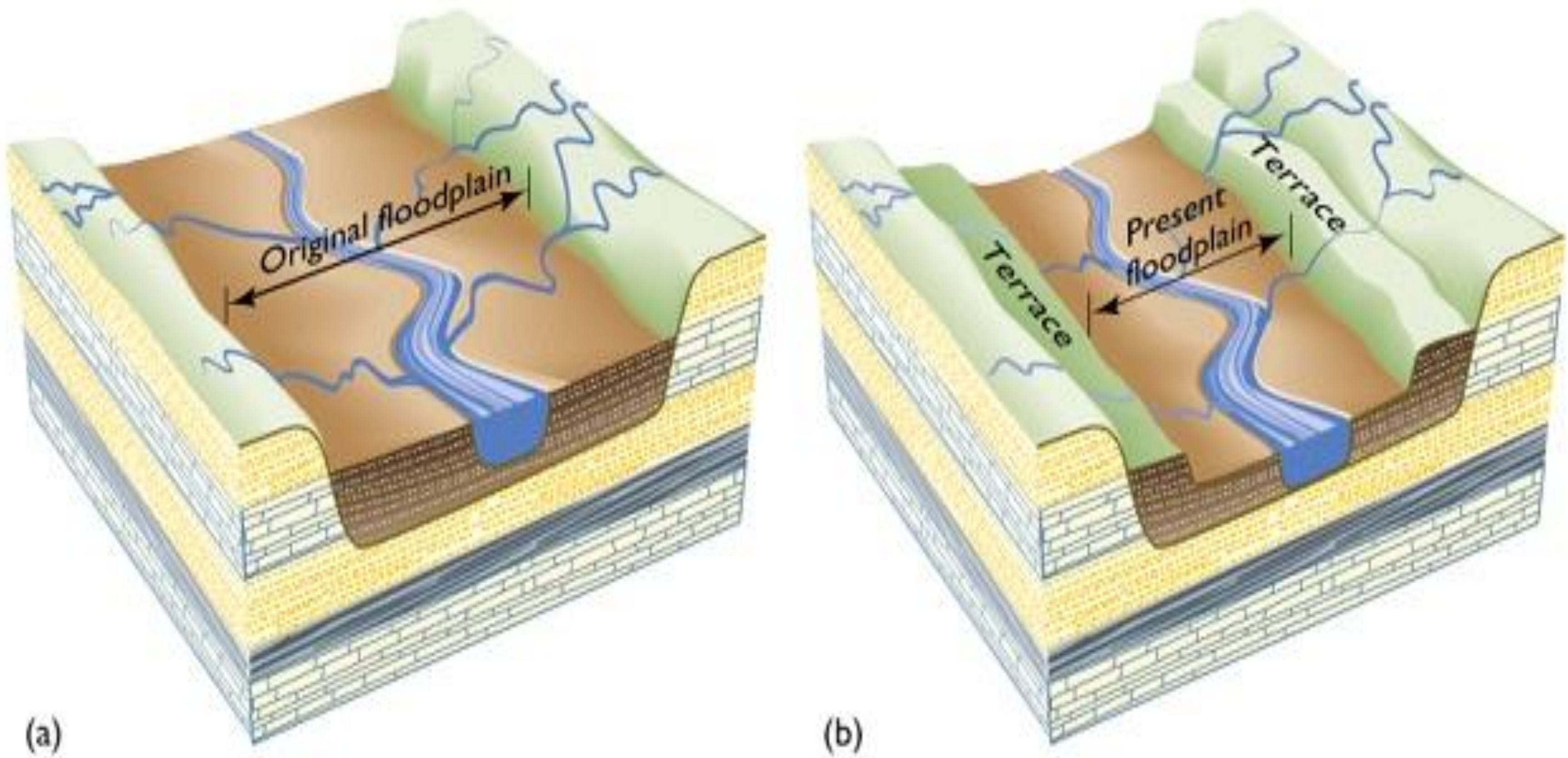
GEOLOGIC EVIDENCE OF CHANGES IN STREAM EQUILIBRIUM

Alluvial fans

Terraces: erosional remnants of former floodplains

Alluvial fans

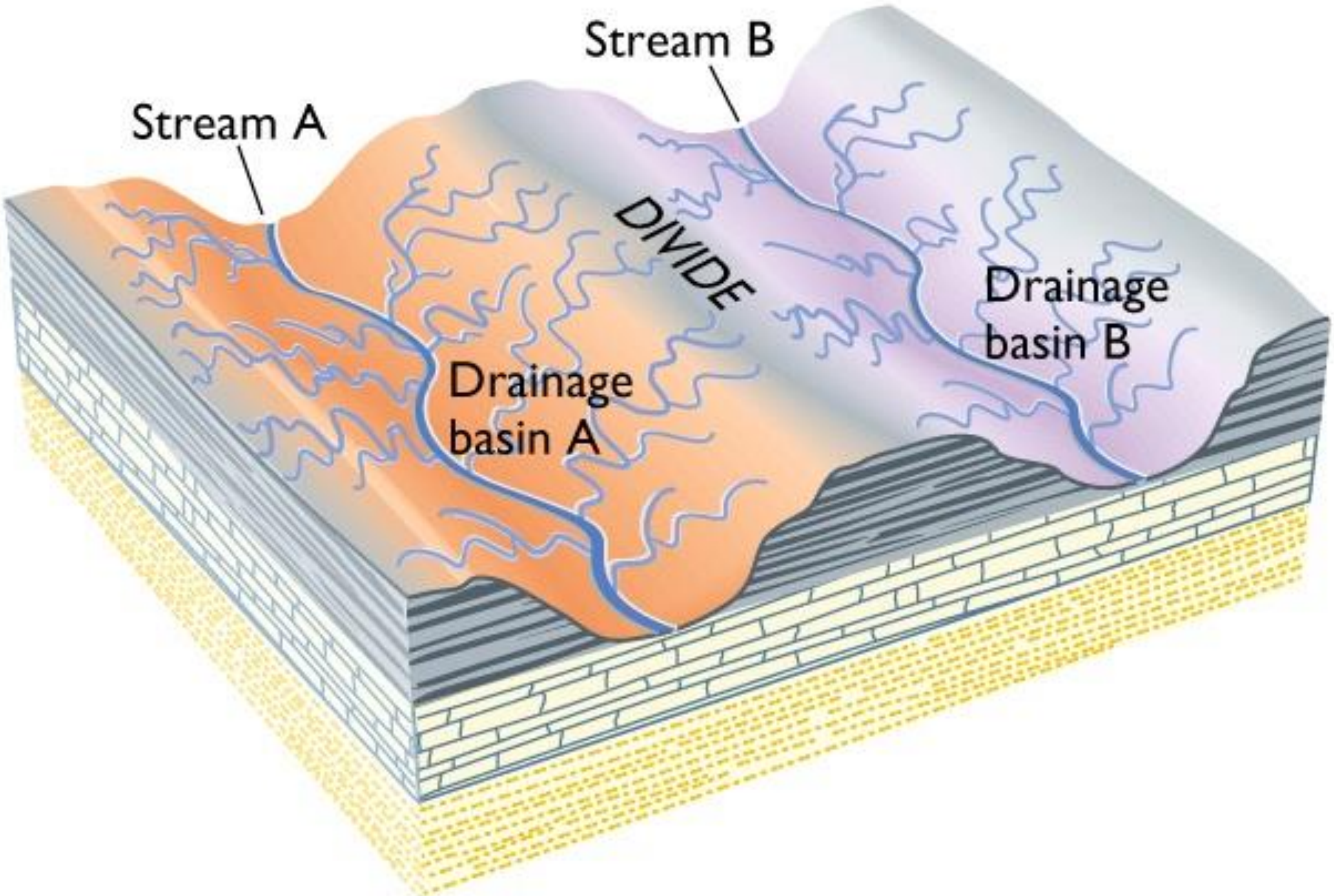
FORMATION OF RIVER TERRACES



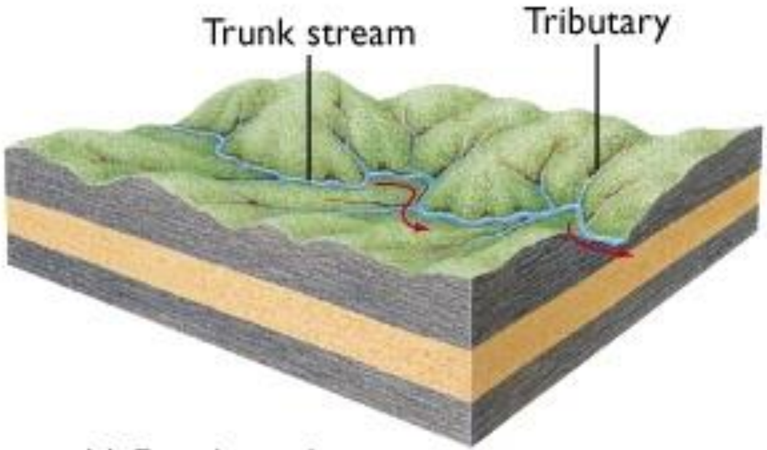
DRAINAGE BASIN

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

GE DIVIDES SEPARATE ADJACENT DRAINAGE BASINS

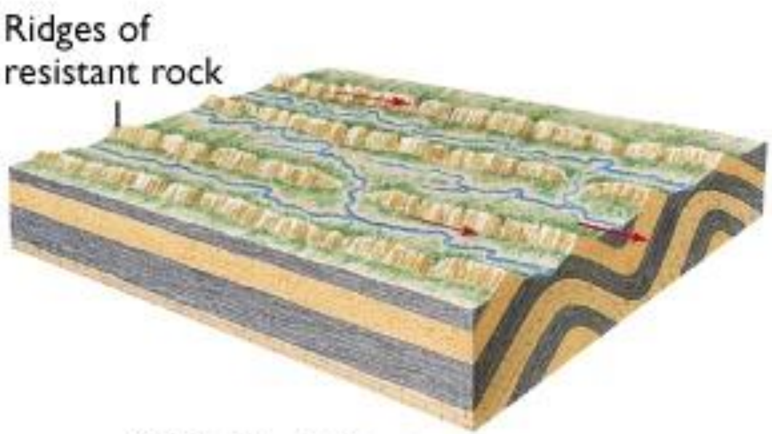


TYPICAL DRAINAGE NETWORKS

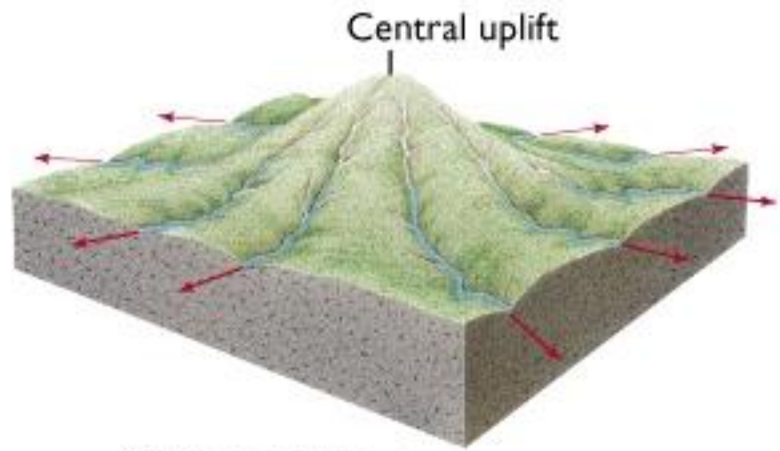


(a) Dendritic drainage


(b) Rectangular drainage



(c) Trellis drainage



(d) Radial drainage

DELTA

Location of significant sedimentation where a river meet the sea.

TYPICAL LARGE MARINE DELTA

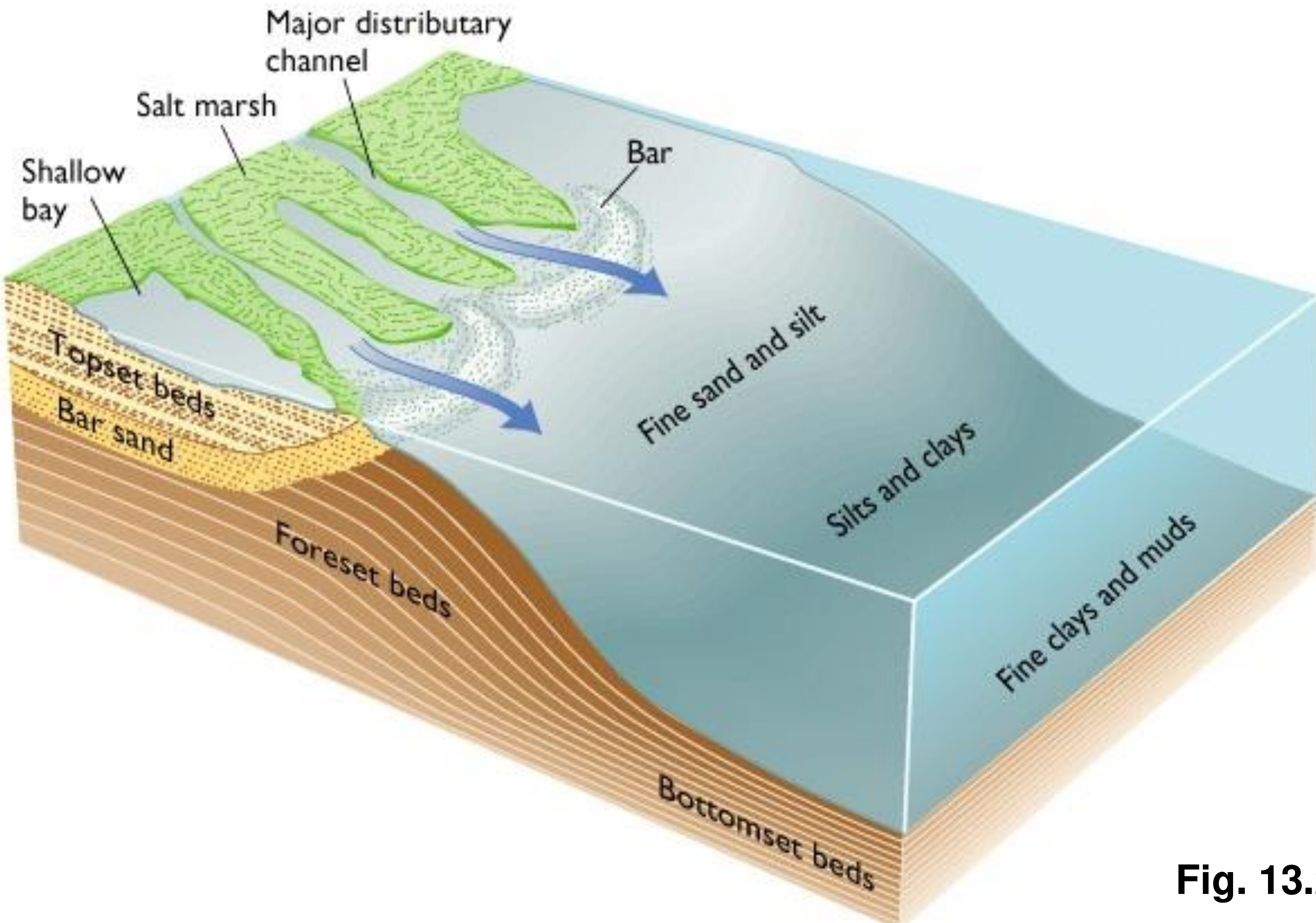
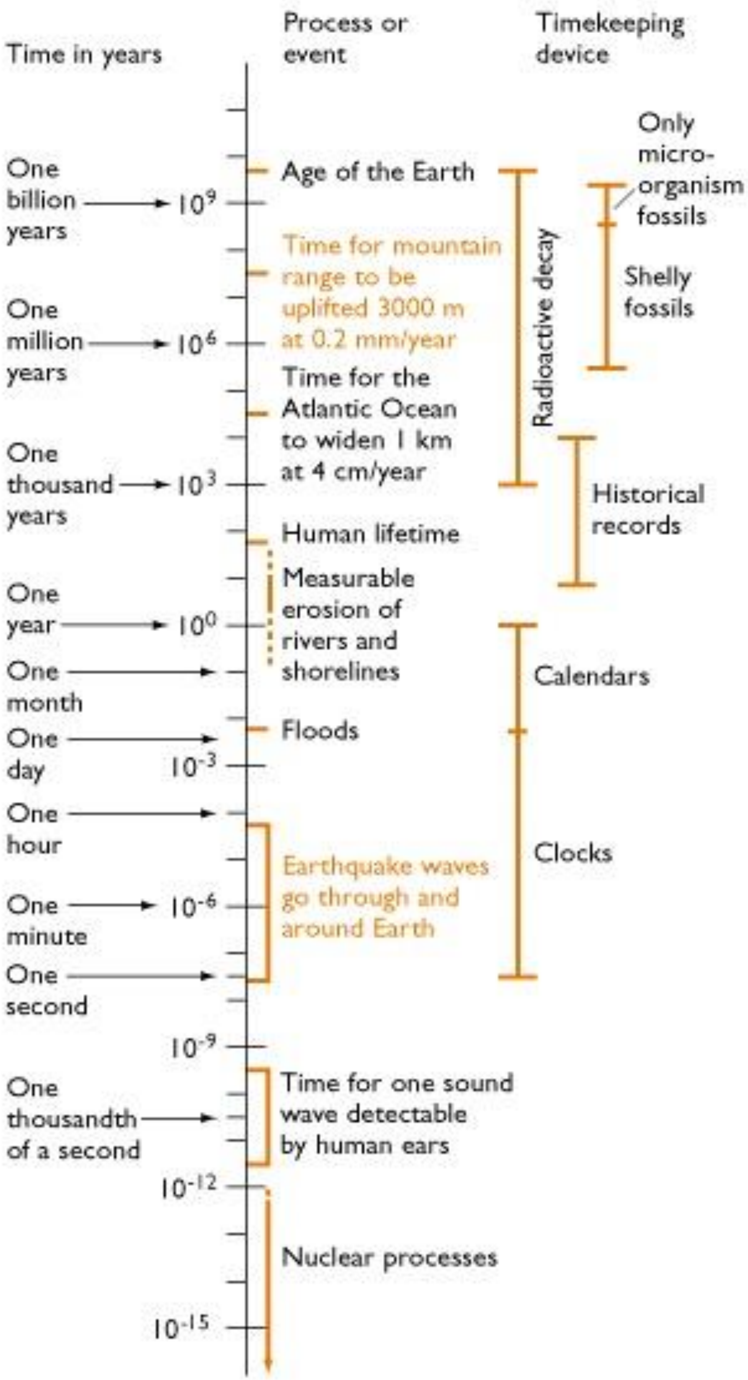


Fig. 13.27

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)

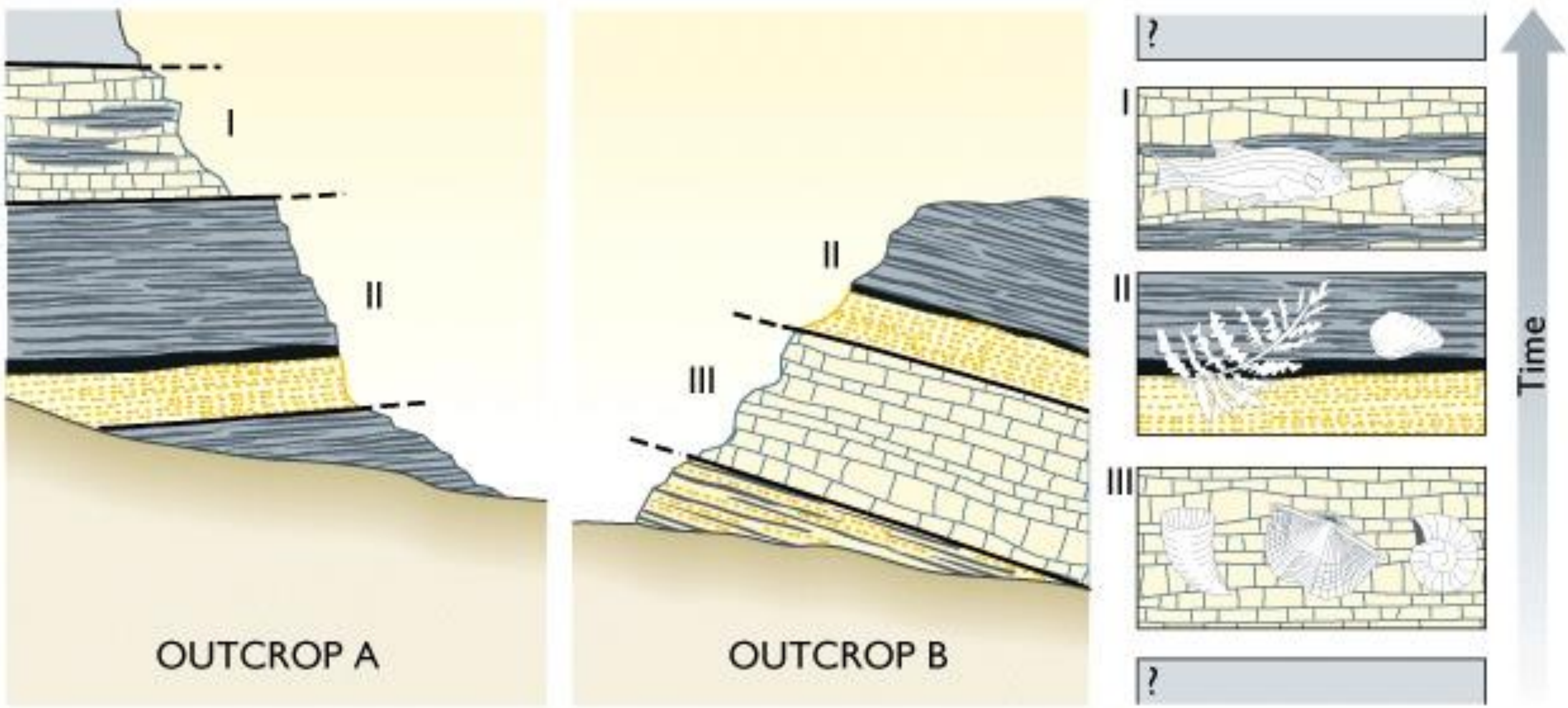
2) Absolute dating (isotopic, radioactive dating)

Ammonite Fossils

Fig. 9.4

Petrified Wood

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

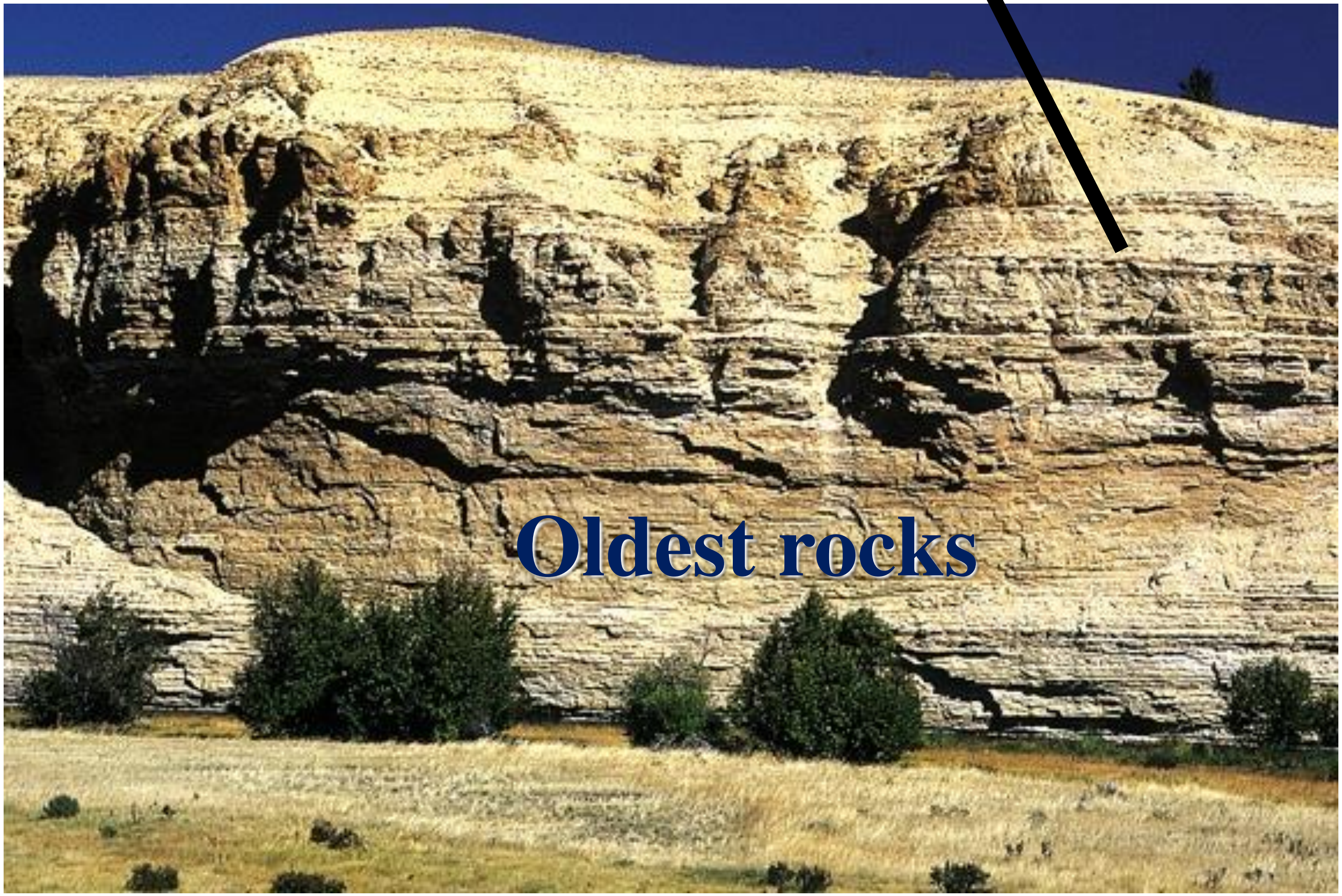
Laws apply to both sedimentary and volcanic rocks.

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

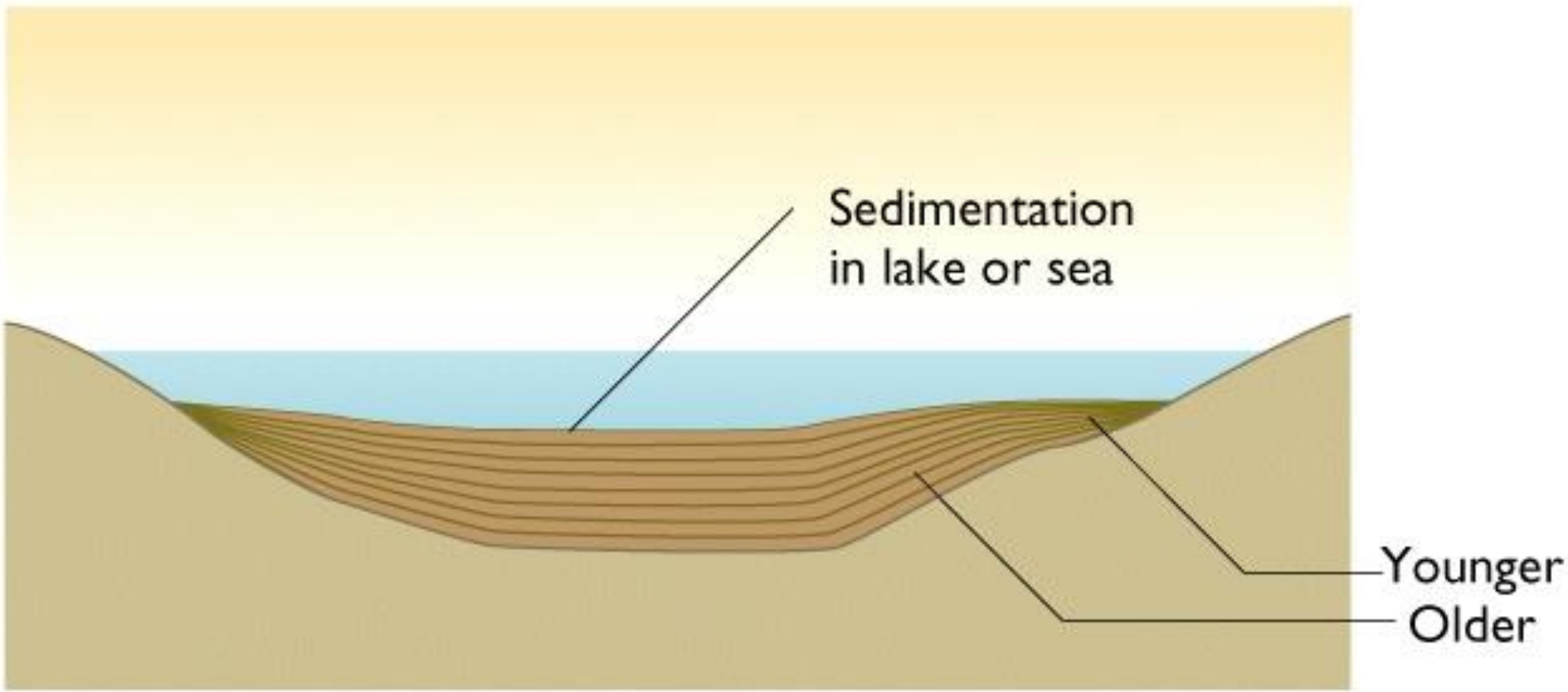
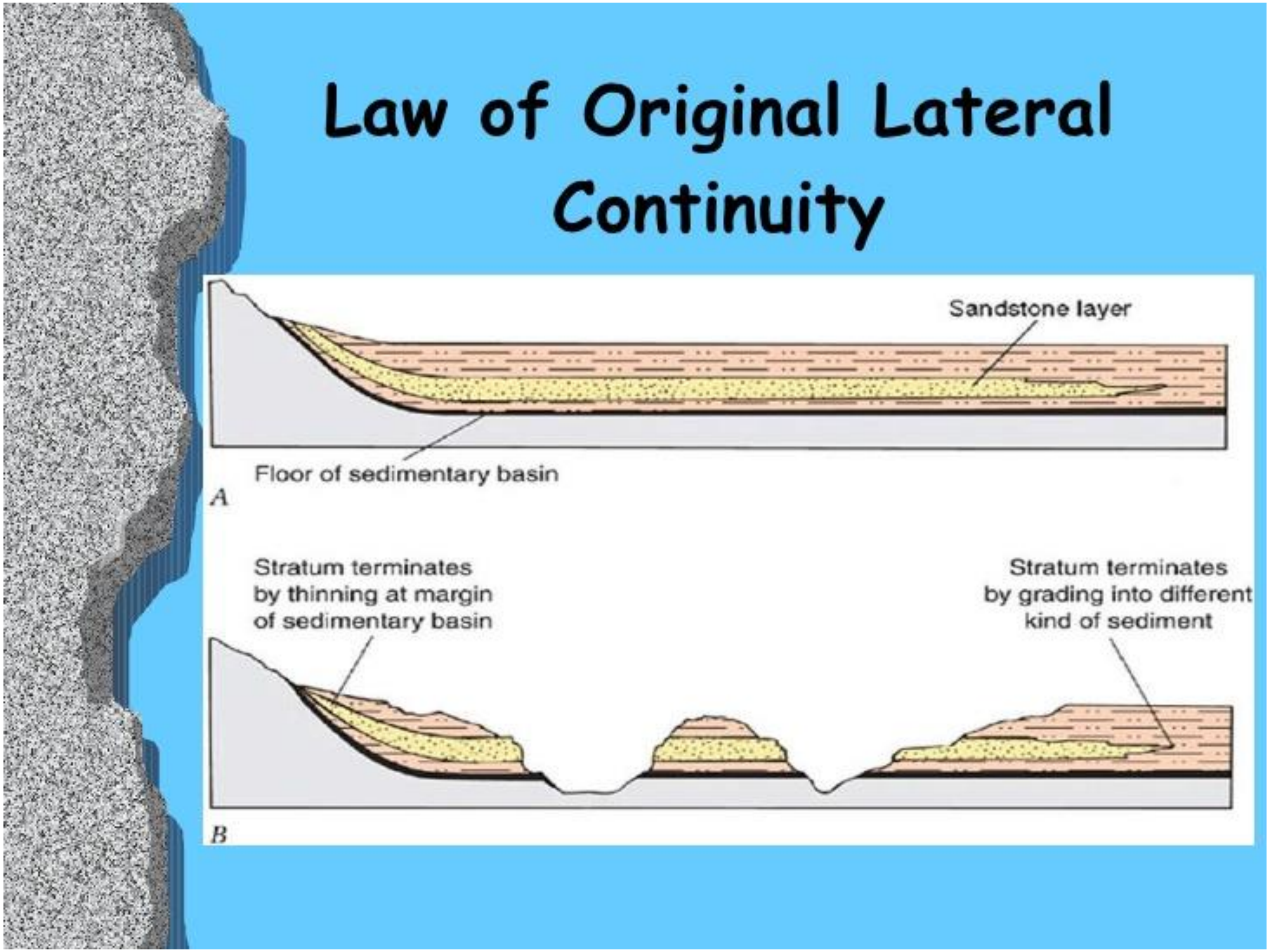


Fig. 9.3a

Principle of lateral continuity

Layered rocks are deposited in continuous contact.

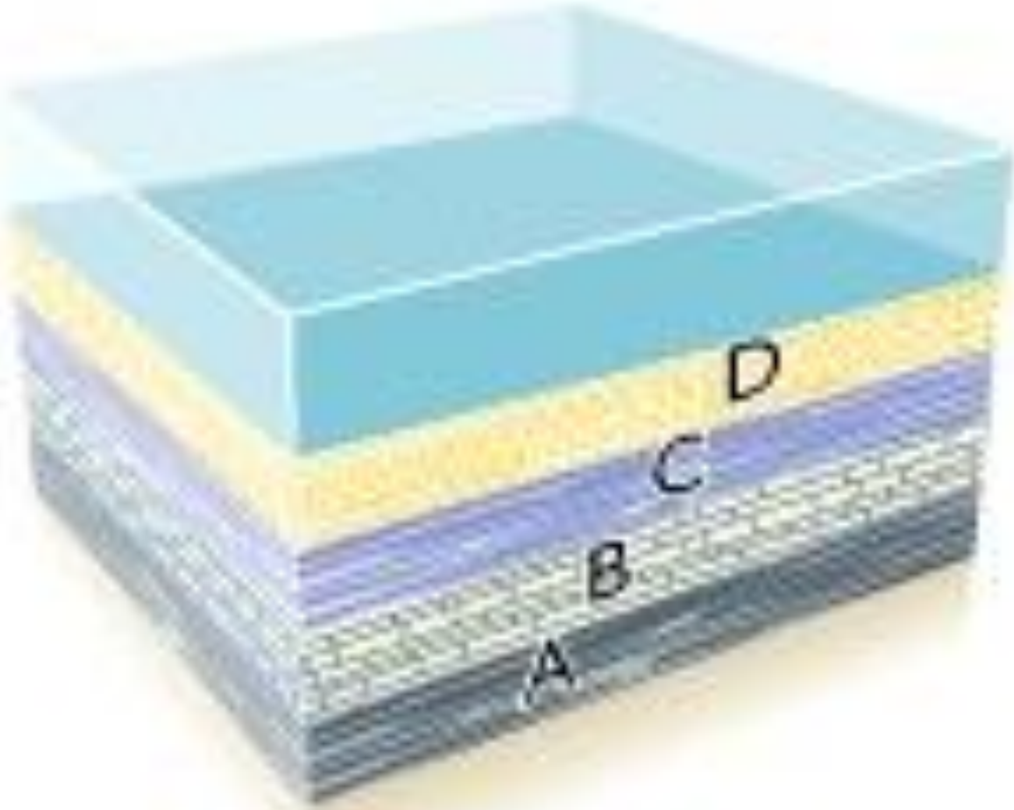
Principle of lateral continuity



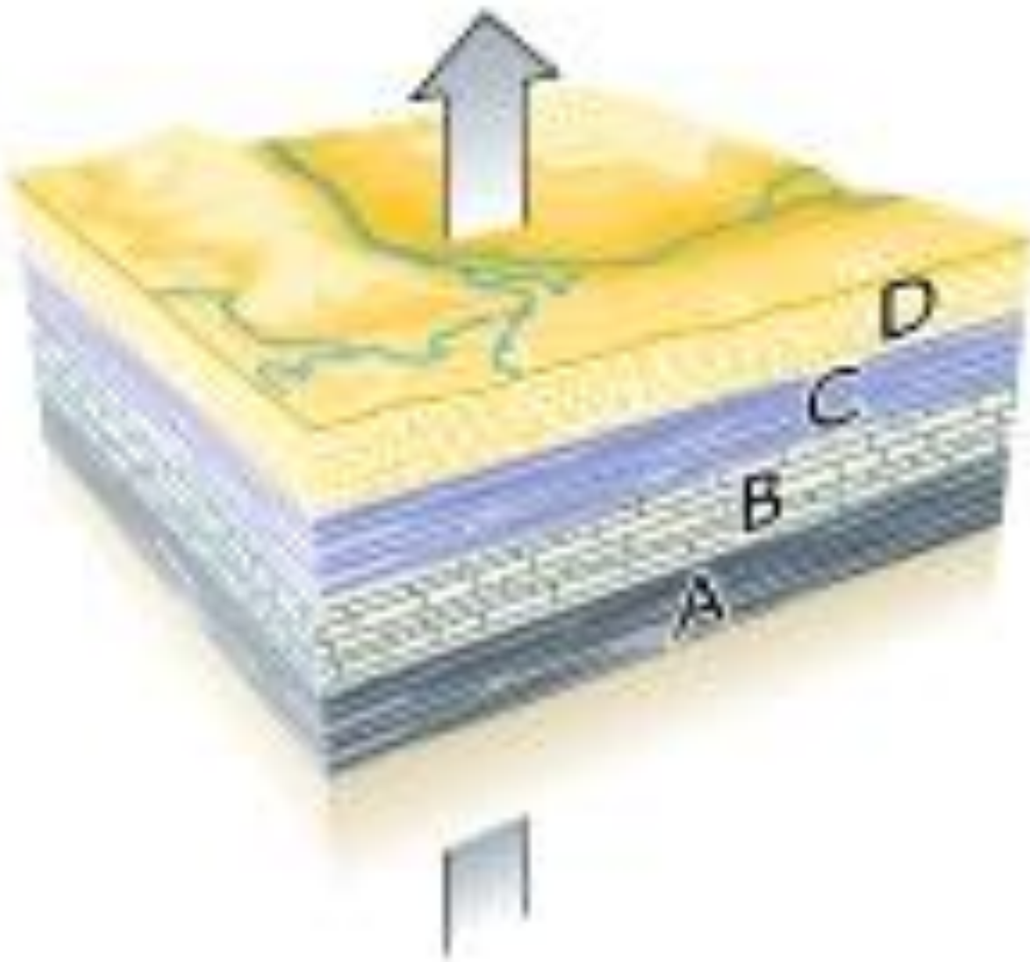
Unconformity

Buried surface of erosion

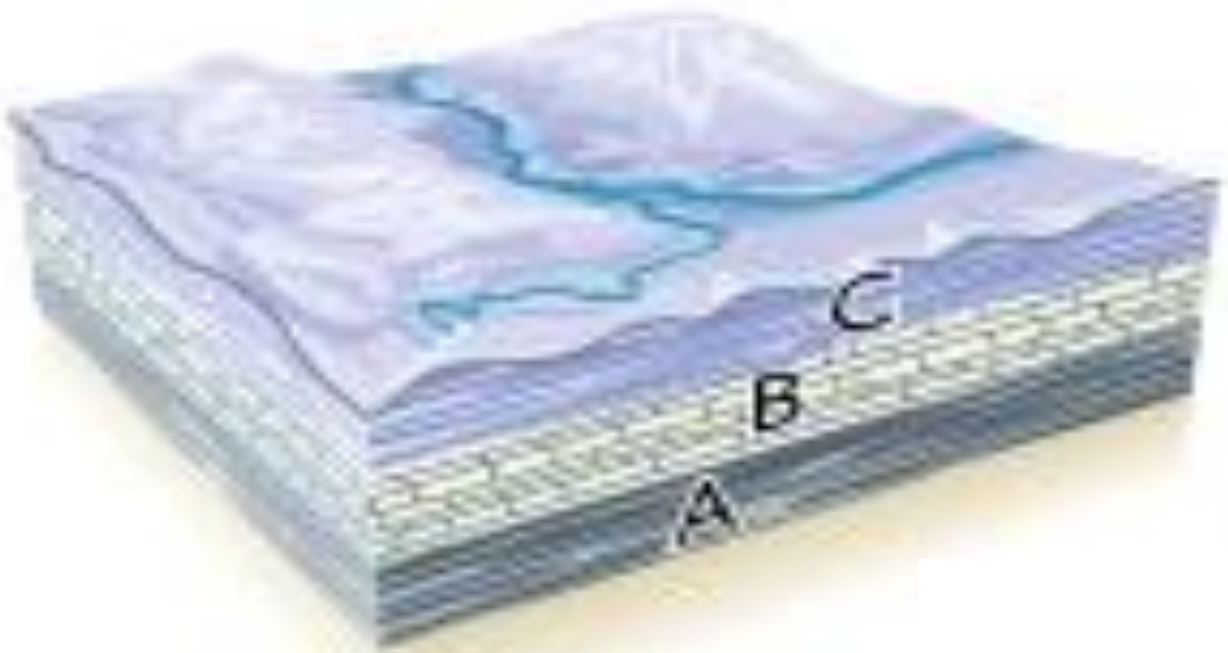
Sedimentation of beds A-D beneath the sea



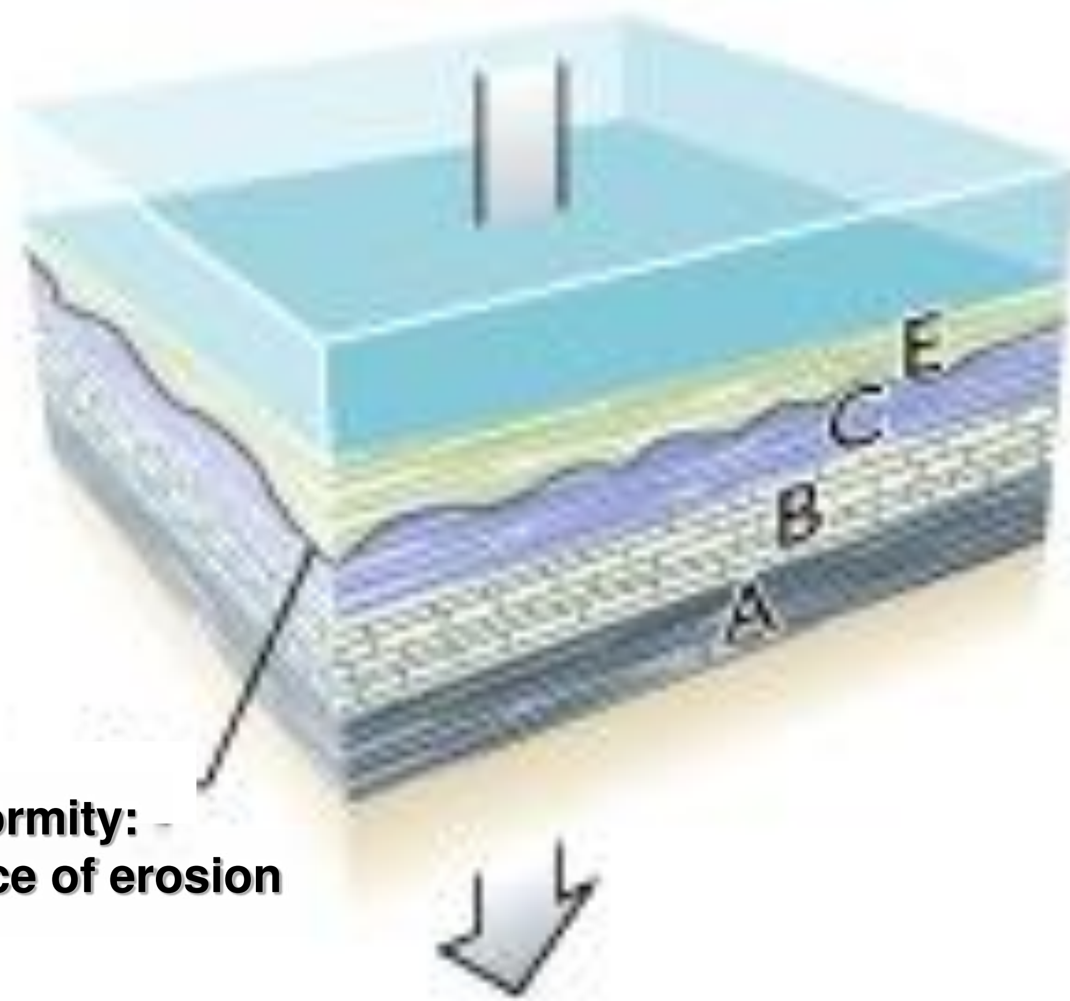
Uplift and exposure of D to erosion



Continued erosion removes D and exposes C to erosion



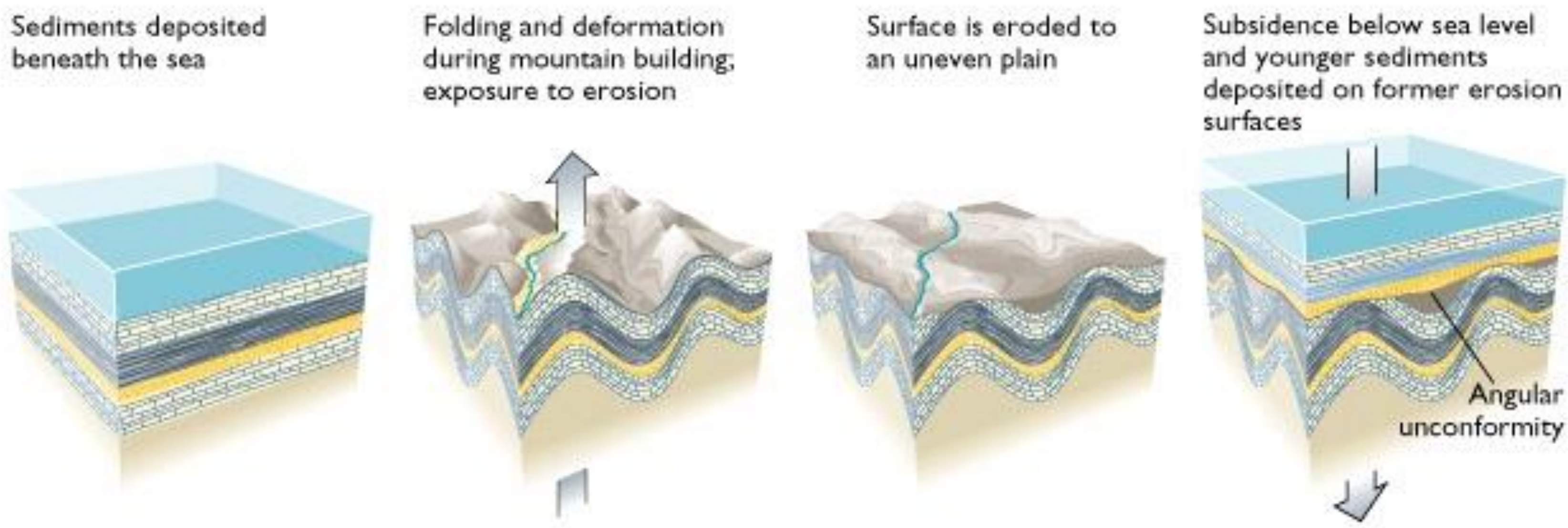
Subsidence and sedimentation of E over C



Unconformity:
a buried surface of erosion

The Great Unconformity of the Grand Canyon

Formation of an angular unconformity



Formation of a disconformity

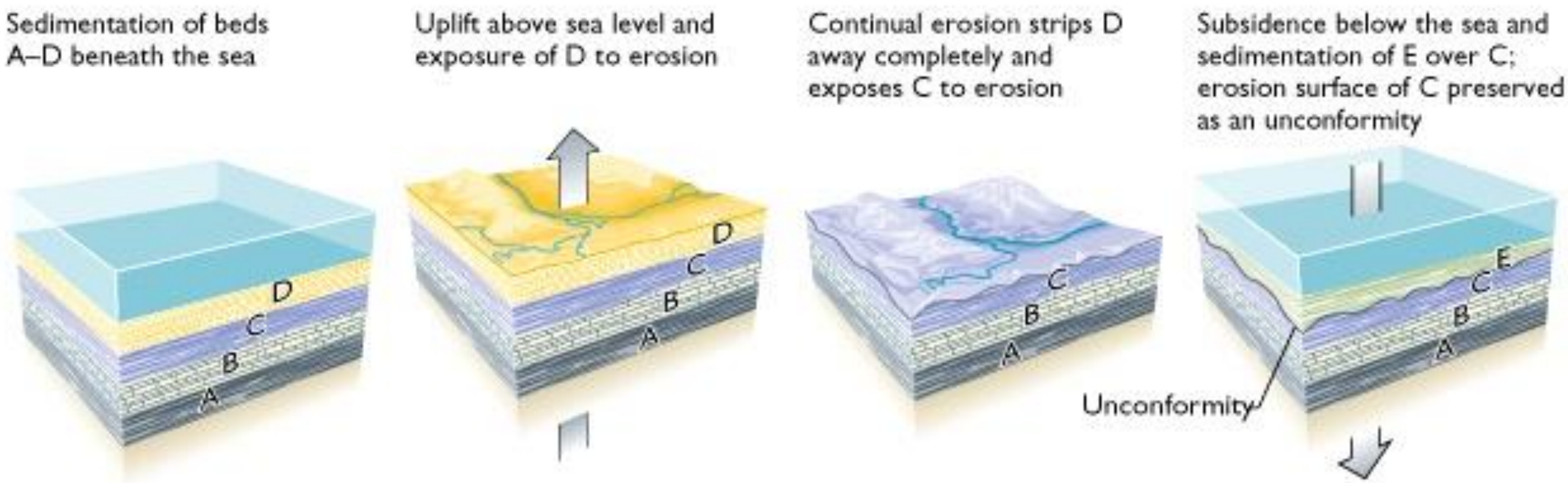
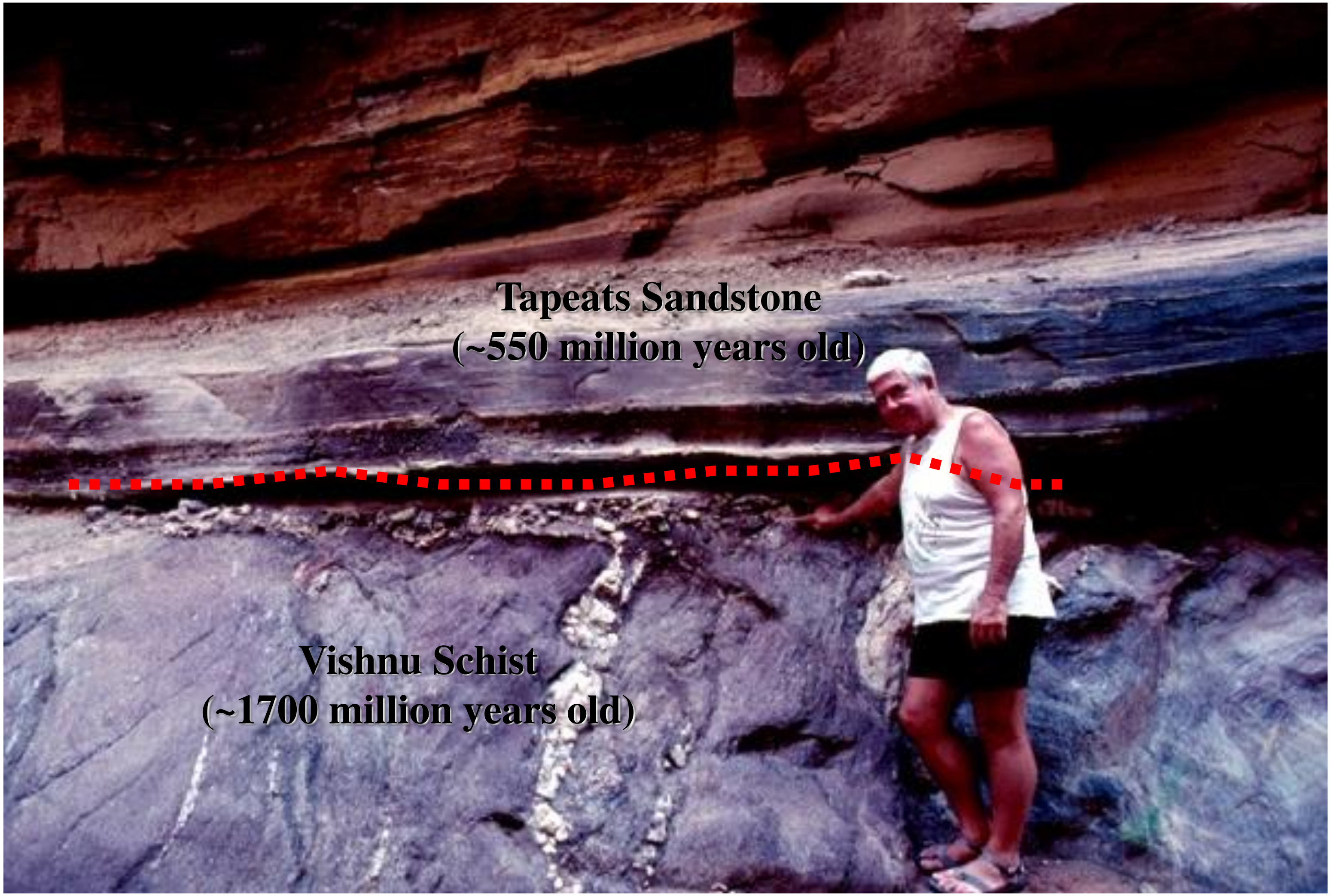


Fig. 9.6

Angular unconformity, grand canyon

Nonconformity in the grand canyon



Symmetrical ripples