Stratigrafie

Stratigrafie je geologický vědní obor, který studuje stáří sedimentárních vrstev hornin. Stratigrafie určuje staří těchto vrstev a to provádí absolutně (číselné datování) nebo relativně (vzhledem k ostatním vrstvám). Řídí se třemi stratigrafickými zákony:

zákonem **superpozice** (překrývání vrstev)

zákonem stejných zkamenělin

zákonem ireverzibility

I. Geologic time

Radiometric Dating – geochronologic units

B. Absolute Dating

-Absolute dating give an age of the sample in years
- Technique used is Radiometric dating
- Involves measuring the amount of unstable radioactive isotope (parent) and the amount of isotope that the parent decays into (daughter)
- Rate at which parent isotopes decay into daughter isotopes is constant
- The amount of time it takes for **half of the parent to decay into daughter isotopes is a half life**
- Graph to determine age and number of half lives, Fig. 2.5 p. 15 lab manual and Fig. 8.12

Use different isotopes with different kinds of rocks and also depends on approximate age of the sample , Table 8.1

Geochronologic units (time units) - time intervals in the history of Earth (e.g., Late Devonian Epoch). Also, time intevals during which corresponding time-rock units (i.e., chronostratigraphic units) formed

a. isotope: same number of protons, different number of neutrons
b. radioactive isotopes disinegrate & radiate particles at a fixed rate
c. half life: time it takes to disintegrate half of original amount

Selecting a dating method

- duration of half life
- chemical composition
- closed system

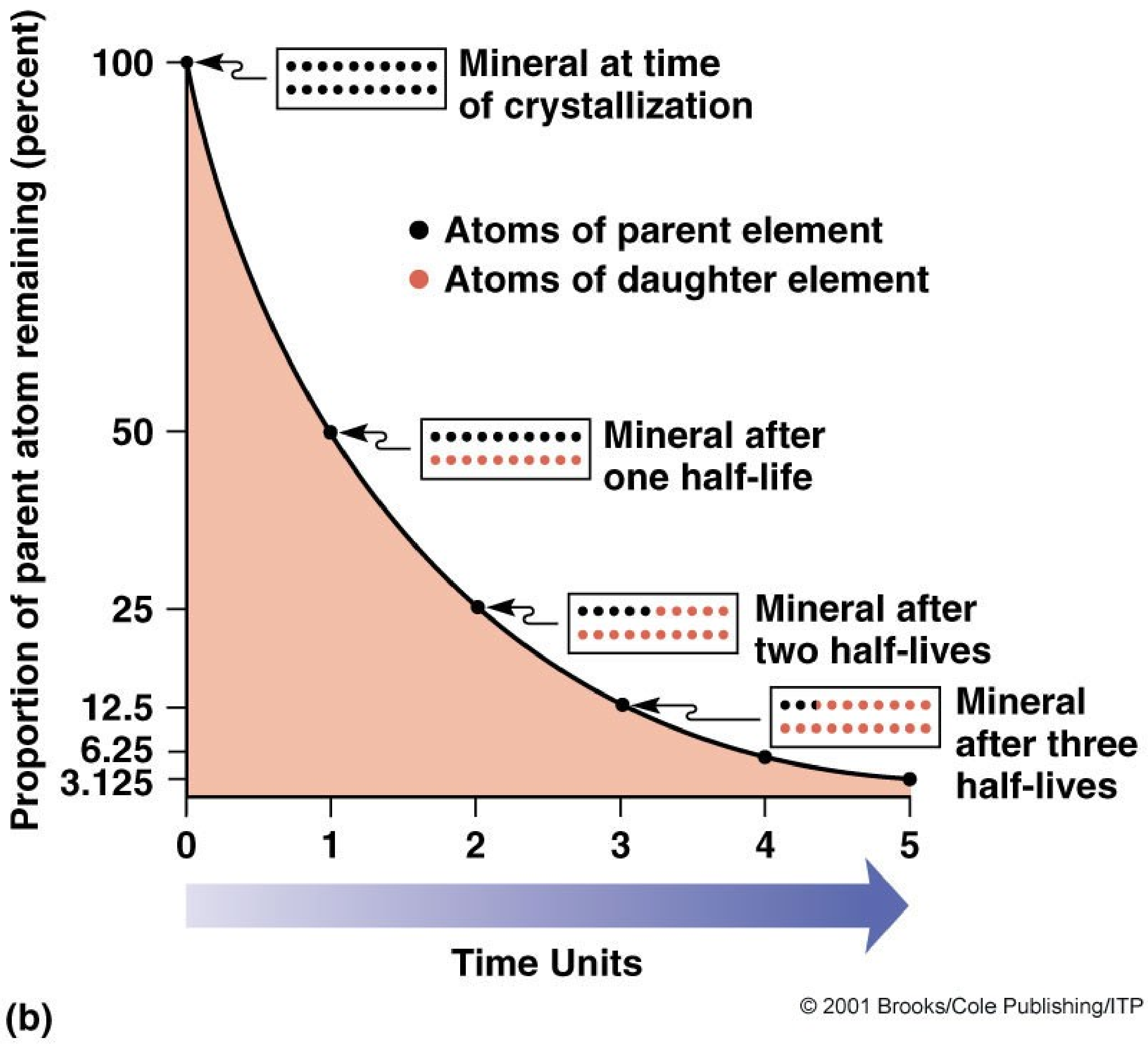
Age Dating with Half-Lives

- Half-life of a radioactive isotope is the time it takes for one half of the atoms of the original unstable parent isotope to decay to atoms of a new more stable daughter isotope
- The half-life of a specific radioactive isotope is constant and can be precisely measured

Radiometric Dating

- One Half Life = 50% of the isotope has decayed
- Half Life differs for each isotope.
- Two Half Lives = 25% remains (75% decayed).
- Three Half Lives = 12.5% remains (87.5% decayed).

Geometric Radioactive Decay



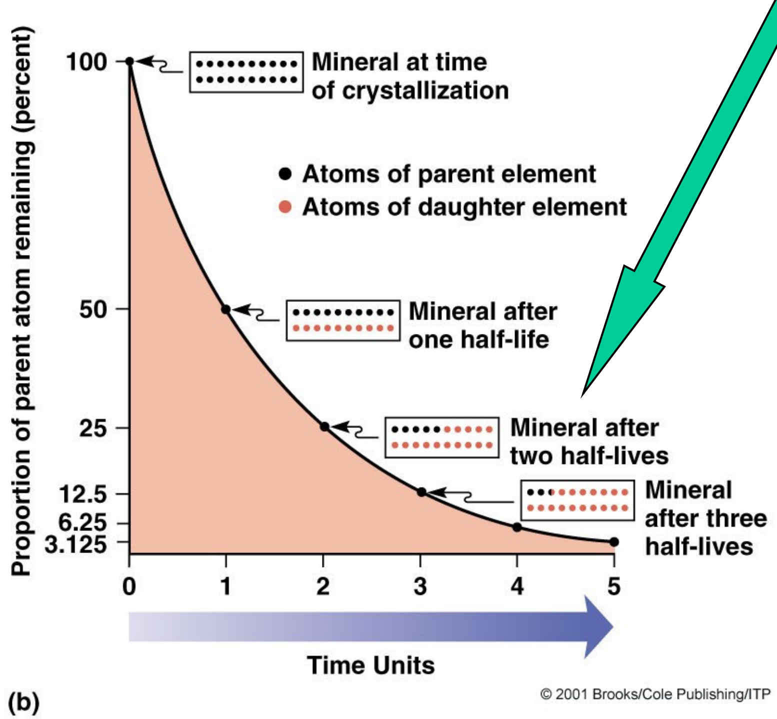
During each half-life, the proportion of parent atoms decreases by 1/2

Determining Age

- By measuring the parent/daughter ratio and knowing the half-life of the parent, geologists can calculate the age of a sample containing the radioactive element
- The parent/daughter ratio is usually determined by a mass spectrometer
  - an instrument that measures the proportions of atoms with different masses

Determining Age

- For example:
  - If a rock has a parent/daughter ratio of 1:3 , the remaining parent proportion is 25%
  - 25% = 2 half lives



- If half life is 57 million years then the rock is 57 million years x 2 =

  114 million years old

What Materials Can Be Dated?

- Most radiometric dates are obtained from igneous rocks
- As magma cools and crystallizes, radioactive parent atoms separate from daughter atoms
  - Parent and daughter fit differently into the crystal structure of certain minerals
- Geologists can use the crystals containing the parent atoms to date the time of crystallization

TABLE 1–3 Some of the More Useful Nuclides for Radioisotopic Dating

Parent Nuclide*	Half-Life†	Daughter Nuclide	Source Materials
Carbon-14	5730 years	Nitrogen-14	Organic matter
Uranium-238	4.5 billion years	Lead-296	Zircon, uraninite, pitchblende
Uranium-235	704 million years	Lead-207	
Thorium-232	14 billion years	Lead-208	
Rubidium-87	48.8 billion years	Strontium-87	Potassium mica, potassium feldspar, biotite, glauconite, whole metamorphic or igneous rock
Potassium-40	1251 million years (1.251 billion years)	Argon-40 (and calcium-40)‡	Muscovite, biotite, hornblende, whole volcanic rock, glauconite, and potassium feldspar†‡

**Nuclide* is a convenient term for any particular atom (recognized by its particular combination of neutrons and protons).

†Half-life data from Steiger, R. H., and Jäger, E. 1977. Subcommission on geochronology: Convention on the use of decay constants in geo- and cosmochronology. *Earth and Planetary Science Letters* 36:359–362.

‡Although potassium-40 decays to argon-40 and calcium-40, only argon is used in the dating method because most minerals contain considerable calcium-40, even before decay has begun.

IZOTOP	DCEŘINNÝ IZOTOP	POLOČAS ROZPADU (10^9 LET)	ROZSAH DATOVÁNÍ (MA)	MATERIÁL POUŽÍVANÝ K DATOVÁNÍ
^{40}K	^{40}Ar	1,250	1 až > 4500	muskovit, biotit, K-živce ap.
^{87}Rb	^{87}Sr	48,8	10 až > 4500	muskovit, biotit ap.
^{147}Sm	^{143}Nd	1,06	> 200	muskovit, biotit ap.
^{176}Lu	^{176}Hf	3,5	> 200	muskovit, biotit ap.
^{232}Th	^{208}Pb	14,01	10 až > 4500	monazit, apatit
^{235}U	^{207}Pb	0,704	10 až > 4500	zirkon, monazit, apatit
^{238}U	^{206}Pb	4,468	10 až > 4500	zirkon, monazit, apatit
^{14}C	^{14}N	5730 let	< 80 000 let	tkáň rostlin a živočichů, jejich schránky, zuby, kosti, voda, led

Relative dating

A. Relative Dating

- One unit is older than the other

1. Law of Superposition

2. Law of crosscutting relationships

- The crosscutting unit is younger

3. Law of faunal succession

- Each fauna or flora is succeeded by a different species through time

a) - Fossil

- The preserved remains, impressions or casts of plants and animals

b) - Index fossil

- Fossil that has a distinct morphology, wide ranging, the species was present for a short period of time.

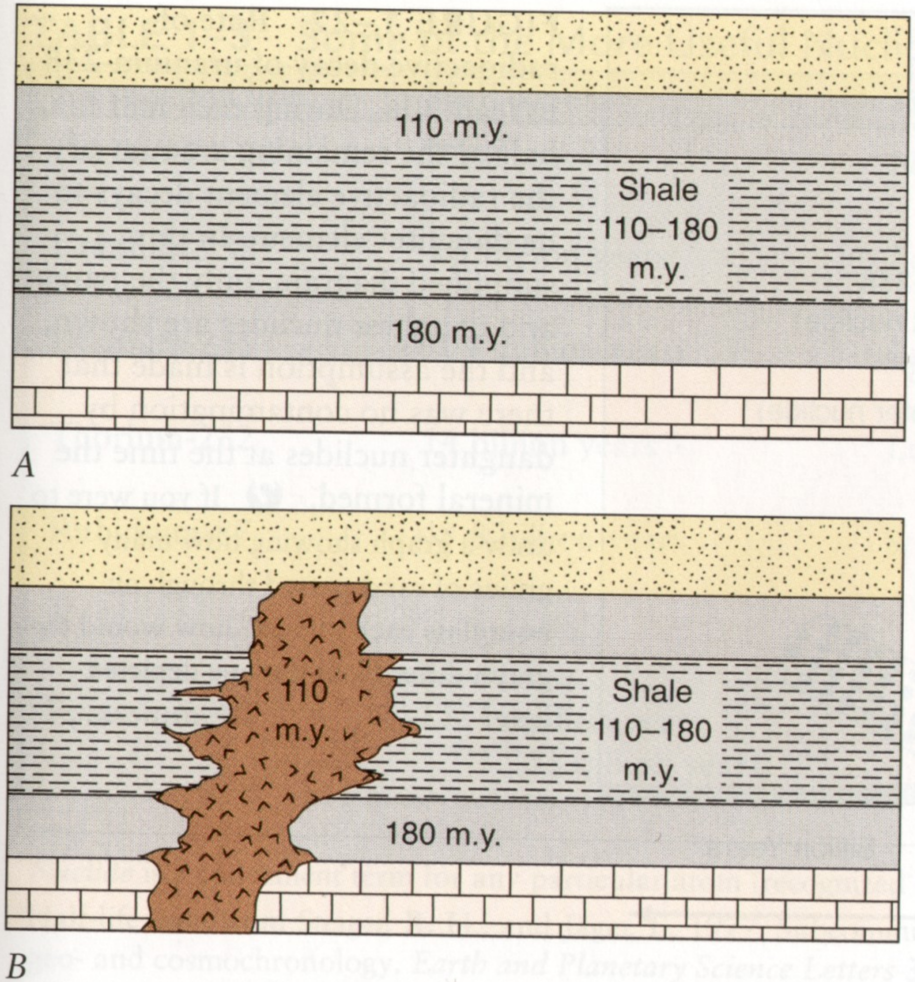


FIGURE 1–20 Igneous rocks that have provided absolute radiogenic ages can often be used to date sedimentary layers. (A) The shale is bracketed by two lava flows. (B) The shale lies above the older flow and is intruded by a younger igneous body. (Note: m.y. = million years.)

Relative dating

Stratigraphic record can be subdivided according to a variety of criteria including lithology (lithostratigraphy), fossils (biostratigraphy, ecostratigraphy), seismic profiles (sequence stratigraphy), magnetic polarity (magnetostratigraphy), event deposits (event stratigraphy).

Types of Rock units

1. Chronostratigraphic units (time-rock units) - all strata in the world deposited during a given time interval (example: Upper Devonian Series)

2. Biostratigraphic units - stratigraphic units of rocks defined by their fossil content

3. Lithostratigraphic units - stratigraphic units (usually spatio-temporally restricted, three dimensional rock bodies) defined by lithology and/or physical and chemical characteristics of rocks (Group, Formation, Member, Tongue, Bed)

(*Event Stratigraphic Units* **-** Units based on short-term events that had widespread depositional effects, that is,events that produced an isochronous event deposit; useful in regional (basin-wide) stratigraphic correlations)

4. Magnetostratigraphic units (polarity time units) - stratigraphic units based on magnetic reversals of the Earth's poles

5. Sequences (Sequence Stratigraphy) - basin wide stratigraphic sequences that are separated by regional unconformities or their correlative conformities

Table 1

Summary of Categories and Unit-Terms in Stratigraphic Classification*

Stratigraphic Categories	Principal Stratigraphic Unit-terms	
Lithostratigraphic	Group Formation Member Bed(s), Flow(s)	
Unconformity-bounded	Synthem	
Biostratigraphic	Biozones: Range zones Interval zones Lineage zones Assemblage zones Abundance zones Other kinds of biozones	
Magnetostratigraphic polarity	Polarity zone	
Other (informal) stratigraphic categories (mineralogic, stable isotope, environmental, seismic, etc.)	-zone (with appropriate prefix)	
		Equivalent Geochronologic Units
Chronostratigraphic	Eonothem Erathem System Series Stage Substage (Chronozone)	Eon Era Period Epoch Age Subage (or Age) (Chron)

* *If additional ranks are needed, prefixes Sub and Super may be used with unit-terms when appropriate, although restraint is recommended to avoid complicating the nomenclature unnecessarily.*

1. Lithostratigraphy

a. description of unit properties (e.g. color, texture, particle shape, stratification, lithology)
b. named after dominant grain size fraction
c. hierarchy of lithostratigraphic units
(1) group: consists of 2 or more formations
(2) formation: a main unit that has considerable lateral extent
(3) member: a named unit within a formation; names are geographical
d. lithostratigraphic units of Wisconsin (WGNHS handout)

Formální (tj. nomenklatoricky pevné a hierarchicky uspořádané podle Zásad české stratigrafické klasifikace 1997) litostratigrafické jednotky ve zvrstvených sledech jsou
souvrství - základní pojmenovaná jednotka zahrnující soubor hornin s typickými litologicko-faciálními znaky a zaujímající určitou stratigrafickou pozici (např. macošské souvrství),
člen (vrstvy) - nižší pojmenovaná jednotka než souvrství, jejíž litologicko-faciální znaky ji odlišují od ostatních částí souvrství (např. josefovské vápence),
vrstva - nejnižší jednotka sedimentárních hornin deskovitého tvaru vymezená vrstevními plochami. U hornin výlevných tvoří její analogon lávový proud nebo výlev.
Souvrství jsou někdy spojována do jednotek vysokého ranku označovaných jako **skupiny.** Ty představují vnitřně složité soubory více souvrství nebo též soubory obtížně vnitřně členitelné omezené většinou výraznými hranicemi (např. vrbenská skupina). Jednotky nižší než souvrství hrají roli především při sestavování místních litostratigrafických škál (např. dílčí části pánví).

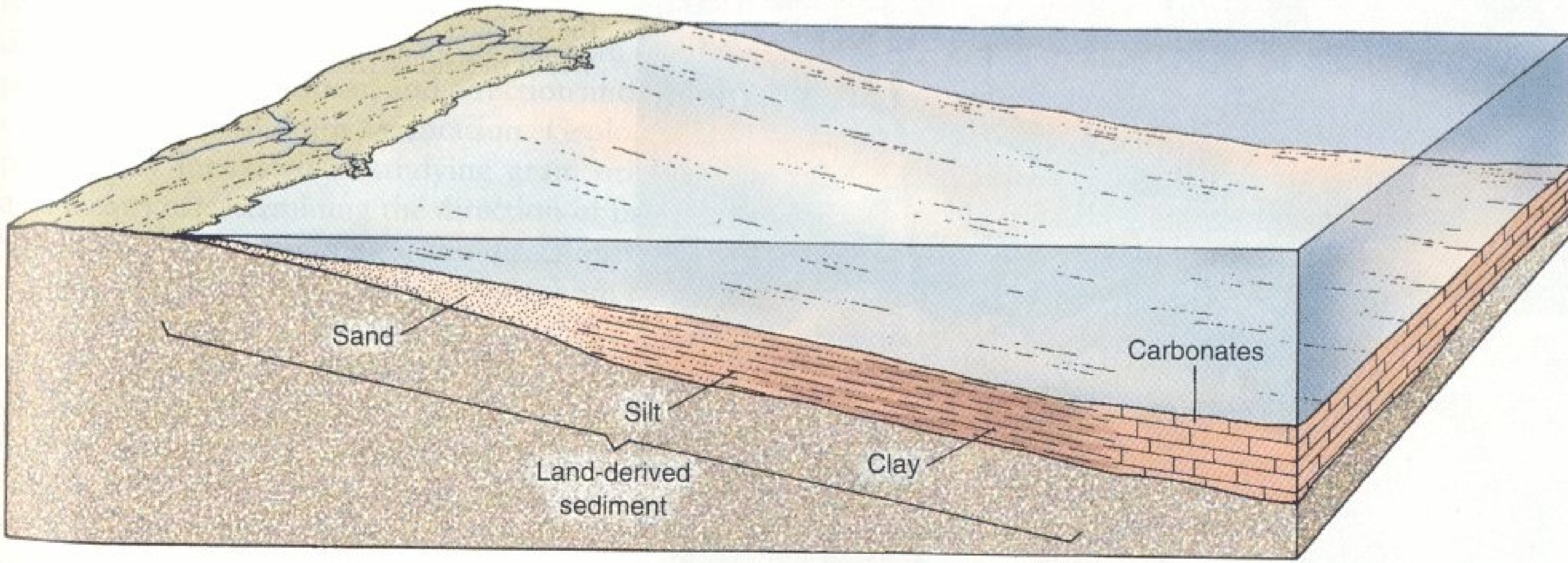


FIGURE 3–10 Idealized gradation of coarser nearshore sediments to finer offshore deposits.

Biostratigraphic Zones **Biozones -** the most fundamental biostratigraphic units. A zone is a body of rock whose lower and upper boundaries are based on the ranges of one or more taxa (usually species or phena) (see this Figure for graphic examples of the major types of biostratigraphic zones)

Index Fossils Guide Fossils (other terms used: Zone Fossil, Index Fossil)

A good index fossil must be:

1. Independent of environment
2. Fast to evolve
3. Geographically widespread
4. Abundant
5. Readily preserved
6. Easily recognised

Examples: Graptolites, Ammonites, Foraminiferans, Pollen, Nannoplankton

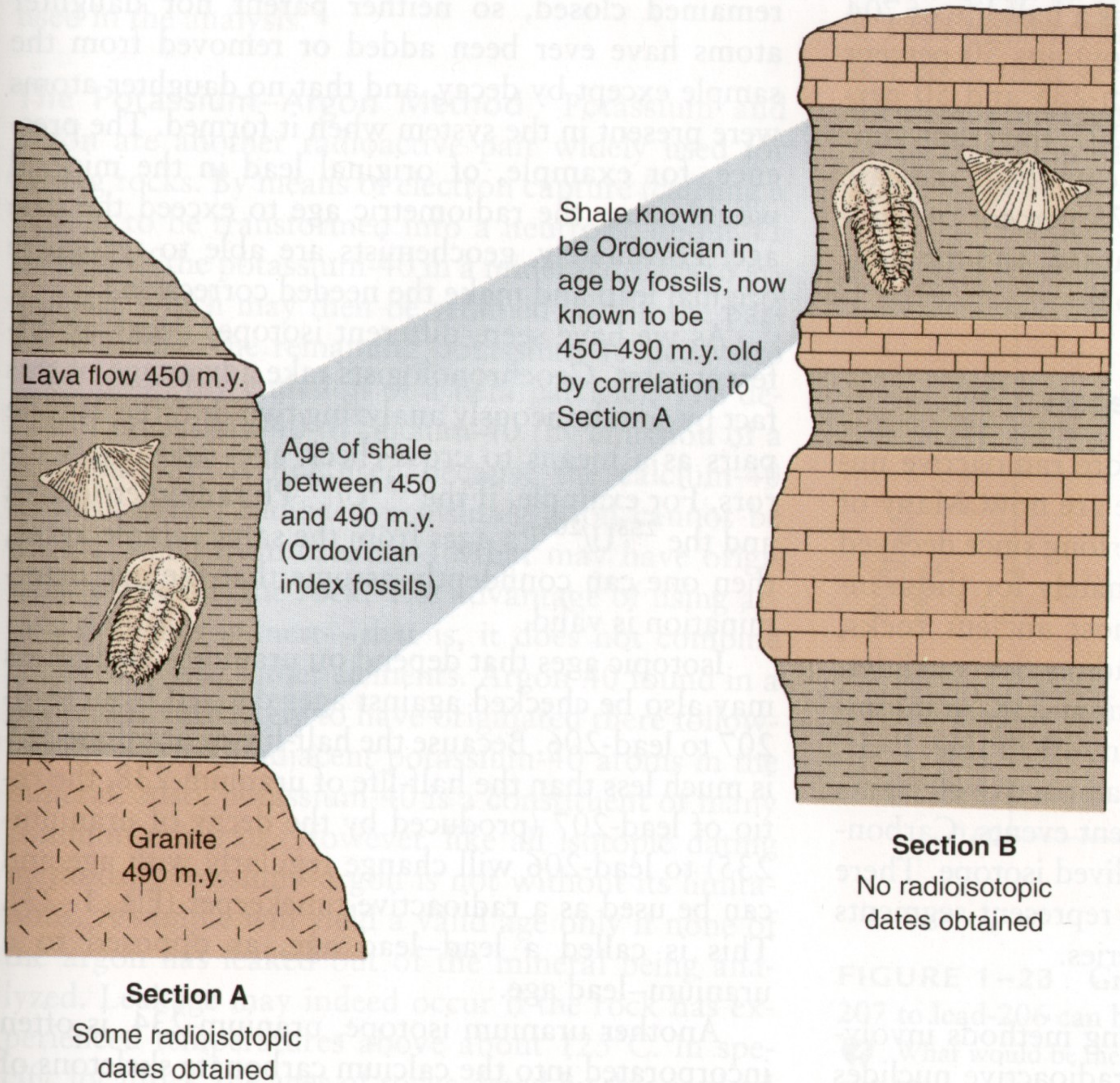


FIGURE 1–21 The actual age of rocks that cannot be dated isotopically can sometimes be ascertained by correlation.

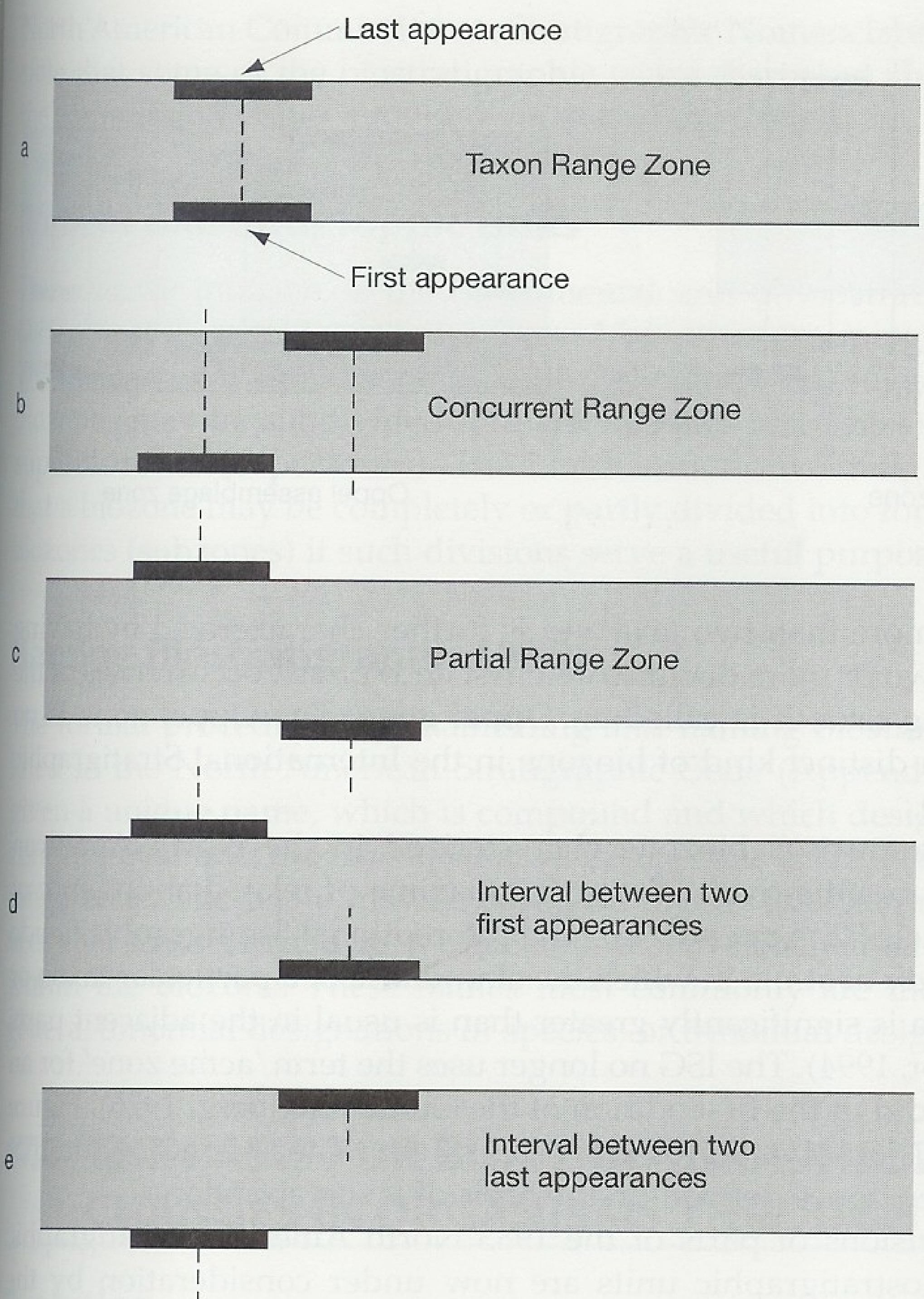
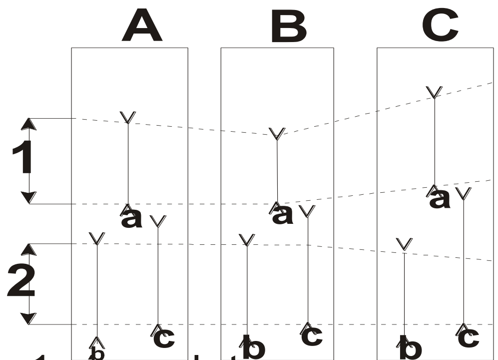
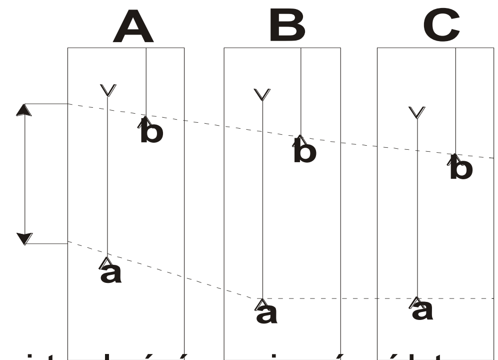


Figure 17.3
Diagram illustrating the principal kinds of interval zones as defined by the North American Stratigraphic Code (1983) and the International Stratigraphic Guide (1994).

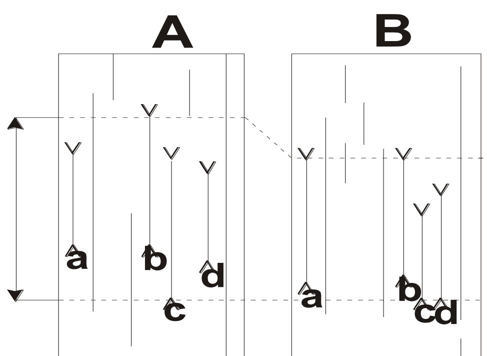
Grafické znázornění příkladů biozón
(upraveno dle Chlupáč & Štorch 1997)



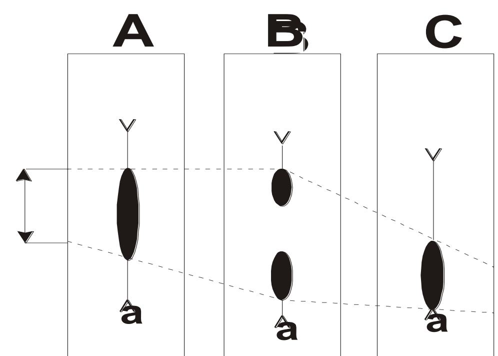
1 - zóna rozsahu taxonu **a**
2 - zóna společného rozsahu taxonů **b, c**



intervalová zóna mezi prvním výskytem taxonů **a, b**



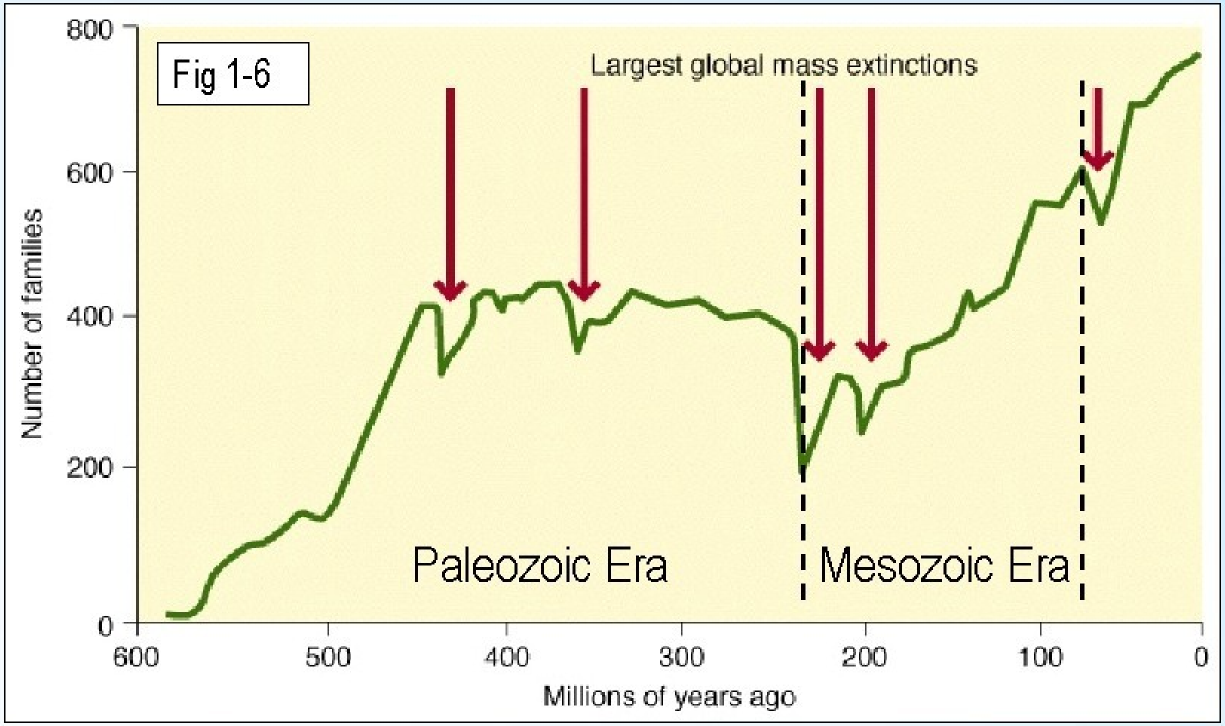
zóna rozsahu společenstva se čtyřmi vůdčími taxony (**a, b, c, d**)



zóna hojného výskytu taxonu **a**

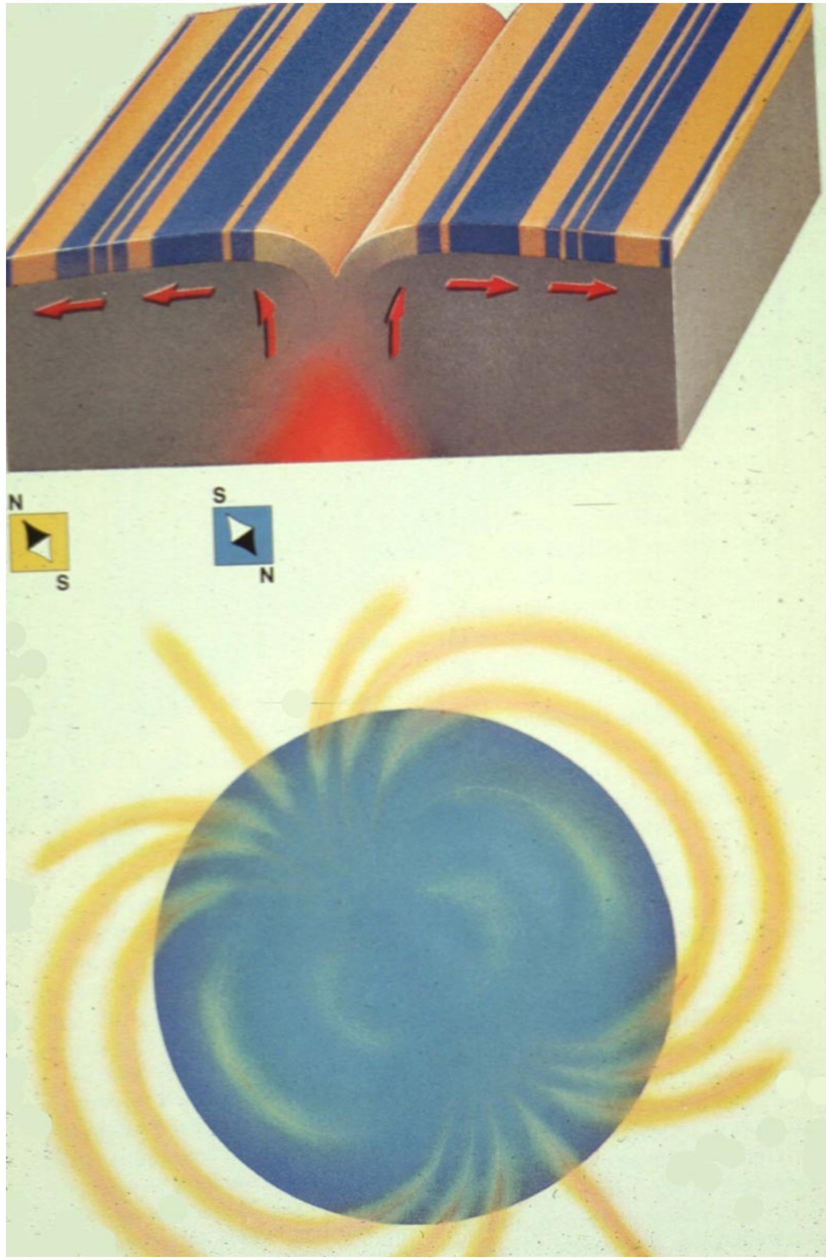
Vysvětlivky:
A, B, C - stratigrafické profily
a, b, c, d - vůdčí taxony (znaky)
Y - nejvyšší výskyt taxonu (znaku)
^ - nejnižší výskyt taxonu (znaku)
⬮ - hojný výskyt taxonu
- - - - hranice biozón

Mass Extinctions Punctuate Geologic Record



- Mass extinctions mark the end of Paleozoic and Mesozoic Eras, Ordovician, Devonian, & Triassic Periods

Magnetostratigraphy is a geophysical correlation technique used to date sedimentary and volcanic sequences. The method works by collecting oriented samples at measured intervals throughout the section. The samples are analyzed to determine their *characteristic remanent magnetization* (ChRM), that is, the polarity of Earth's magnetic field at the time a stratum was deposited.


N
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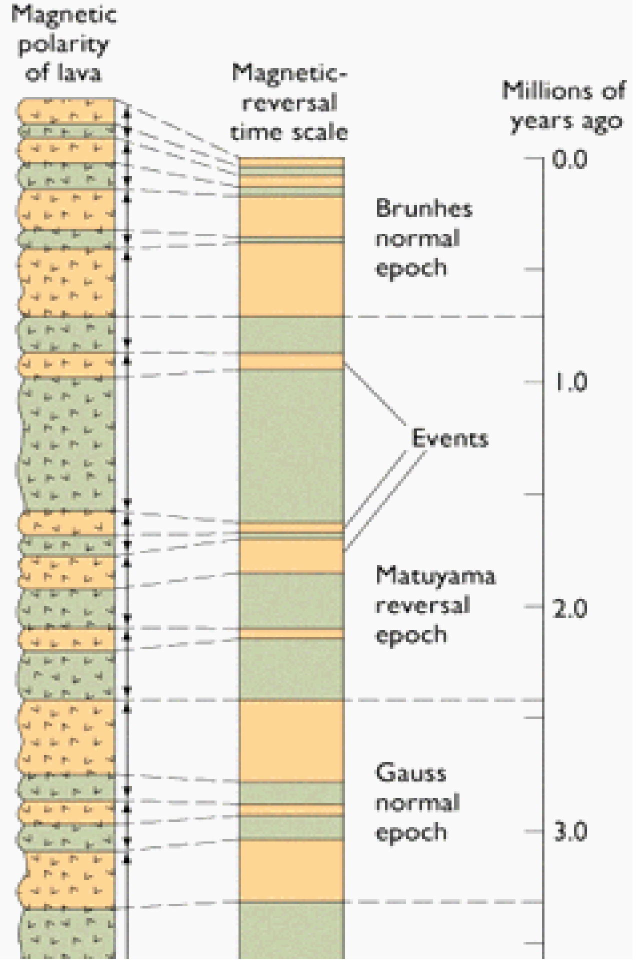
Uvedená metoda se uplatňuje především v mladších obdobích historie Země (od svrchní jury do recentu). Pracuje s jednotkami **magnetostratigrafické polarizace**. Základní jednotkou škály je **zóna**



Sequence Stratigraphy

Metoda sekvenční stratigrafie. Vychází z myšlenky, že kolísání hladiny světového oceánu (eustatické pohyby) v geologické historii zanechává v sedimentech zemské kůry záznam, který může být využit i pro globální celosvětové korelace. Zvyšování a následný

Během jednoho cyklu dochází

k uložení nejméně jednoho tělesa sedimentů označovaného jako **sekvence**

Any package of sedimentary strata bounded above and below by an unconformity (of any kind) is a *sequence*.

Sequence stratigraphy makes sequences the fundamental units of the rock record, and hence emphasizes periods of deposition and nondeposition (closely related to episodes of rising and falling sea level) as the essential information. Sequence stratigraphy grew out of **seismic stratigraphy**; unconformities are easily distinguished in seismic records, but lithology is often unknown.

The second and often co-incident step in the interpretation of well logs and cores is the use of parasequence stacking patterns (the vertical occurrence of repeated cycles of coarsening or fining upwards sediment) of to identify the lowstand system tracts (LST), transgressive system tracts (TST) and highstand system tracts (HST) that are enveloped by the mfs, TS and SB. These parasequence cyclic stacking patterns are commonly identified on the basis of variations in grain size and when these fine upwards are indicated by triangles whose apex is up while those that coarsen upwards are indicated by inverted triangles whose apex is down.

The repeated stacking patterns for LST cycles are: -

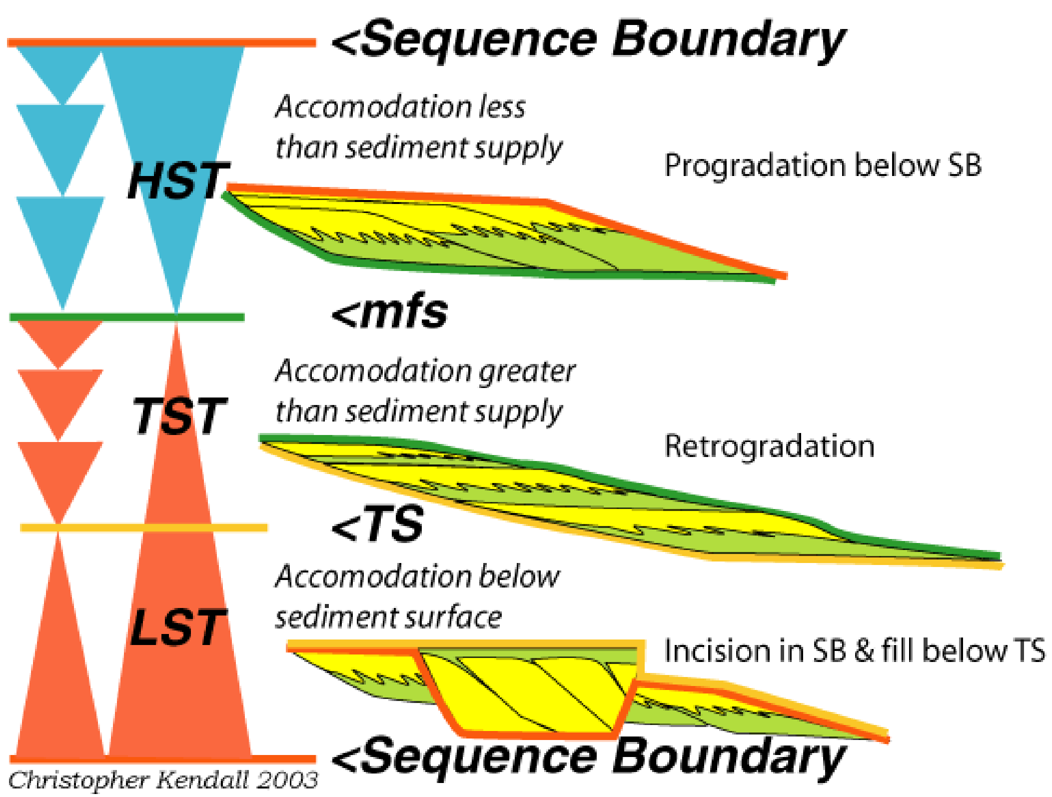
•Cyclic fill of incised depressions that tend to fine upward.

•Cyclic sand to shale bodies of basin floor fans that tend to fine and **thin** upward.

•Cyclic sand to shale bodies of shelf margin clinoforms that tend to coarsen and **thicken** upward.

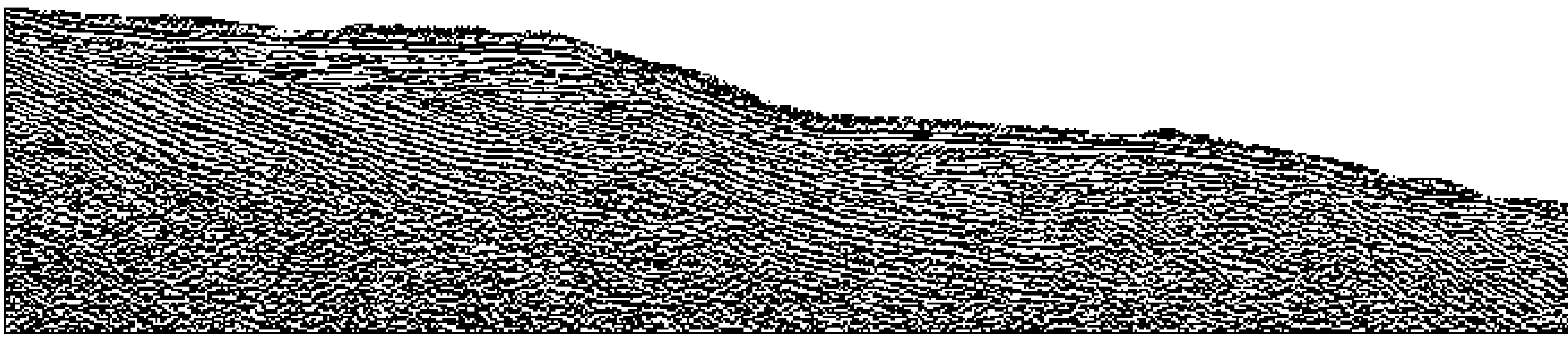
The repeated stacking patterns for TST cycles are: -

•Regressive cyclic shale to sand bodies of that tend to coarsen and **thin** upward.



Seismic stratigraphy

Interpreting how the Earth's sedimentary layers have formed, is difficult. Cores taken on land and from the ocean are not only expensive to retrieve, but represent a small percentage of the Earth's surface. Methods using **seismic waves** developed in the 1960's help to observe the crust's layers in detail**. Seismic stratigraphy** is when energy waves are used to bounce off the different layers of the Earth. These layers provide us with data that a seismic stratigrapher can then interpret. For example, in the seismic profile below we show the results of waves bouncing off the different layers and then recorded on the surface of the Earth. These "wavy" images can then be used to reconstruct the area in rock units, as shown in the interpretation of the **seismic profile**. These advances have allowed geologists to map more area than ever before. Prior to these advances, only **outcrops** and geologists walking and recording on their maps could be used.



Chemostratigraphy

. Oxygen Isotopes

1. 3 Oxygen Isotopes; ^{16}O and ^{18}O most common
2. Fractionation
a. ^{16}O lighter so evaporates preferentially; ^{18}O heavier so condenses preferentially
b. ratio at which these isotopes enter chemical compounds is temperature dependent
c. most widely used proxy for:

- **changes in global ice sheet volume**
- **changes in global temperatures**

3. Measurement
a. measure how much $^{18}O/^{16}O$ ratio deviates from isotope proportions found in modern oceans

b. $\delta^{18}O$ ‰ is zero for standard marine ocean water
4. During Glacials:

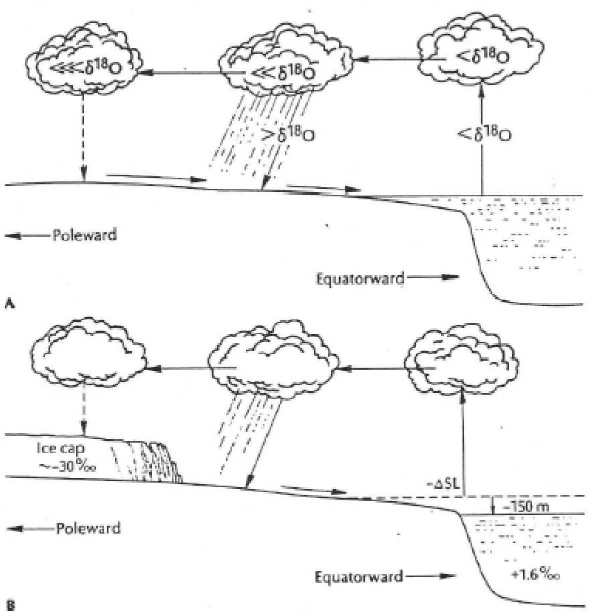
- **^{16}O preferentially evaporated from oceans**
- **^{16}O deposited on ice sheets & concentrated there**
- **ice sheets relatively depleted in ^{18}O so $\delta^{18}O$ is negative**
- **^{18}O concentrated in seawater; ice age oceans have $\delta^{18}O$ values of about +5**
- **marine shells also enriched in ^{18}O during glacials**

1. Different isotopes of an element have different atomic masses (because they have different numbers of neutrons)

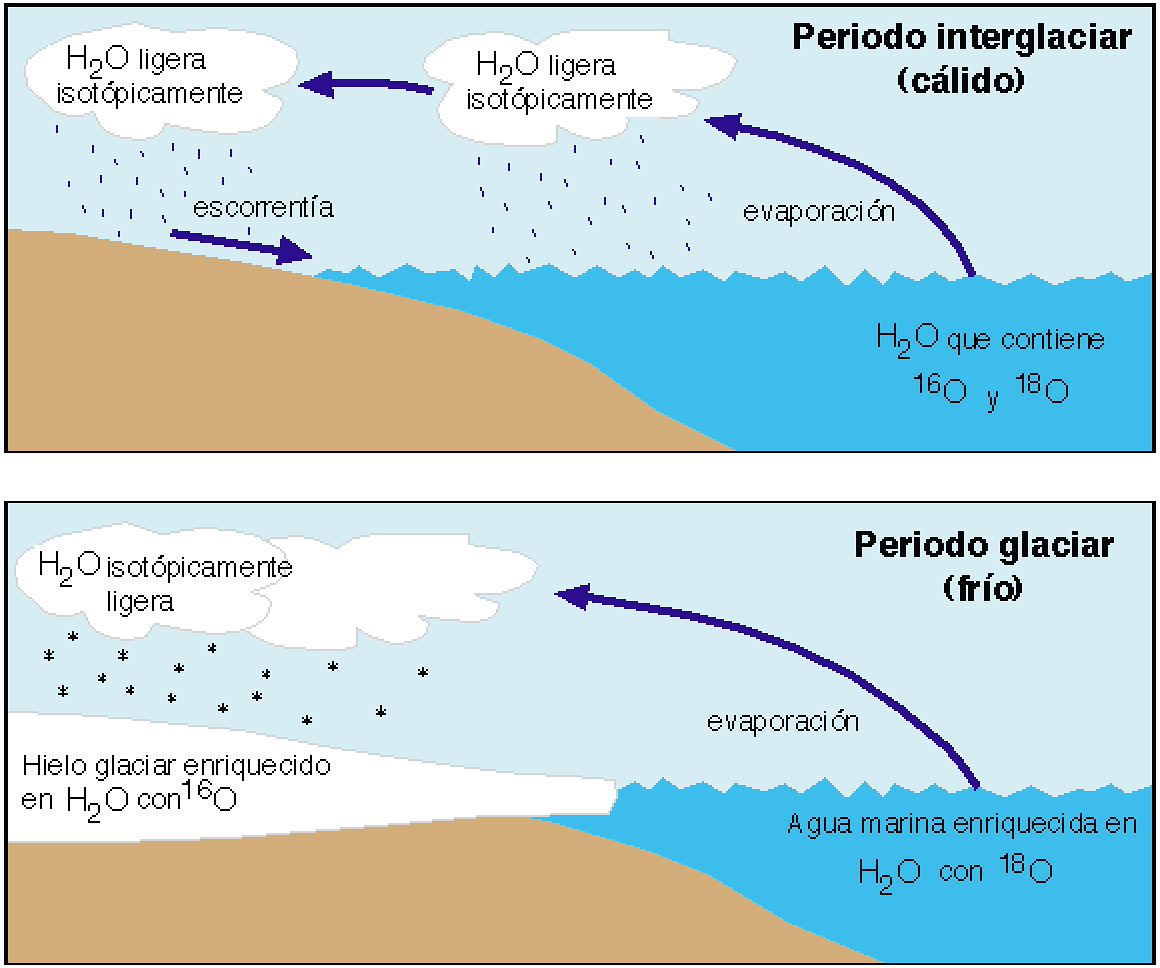
2. Oxygen is made up of two isotopes:
   Oxygen - 16 (also known as ^{16}O)
   Oxygen - 18 (also known as ^{18}O)

3. The relative amounts of these two isotopes in a sample of water, ice, rock, plant, human, etc. is a function of climate/environment

4. The relative amounts are expressed as either
   $^{18}O/^{16}O$ or $\delta^{18}O$



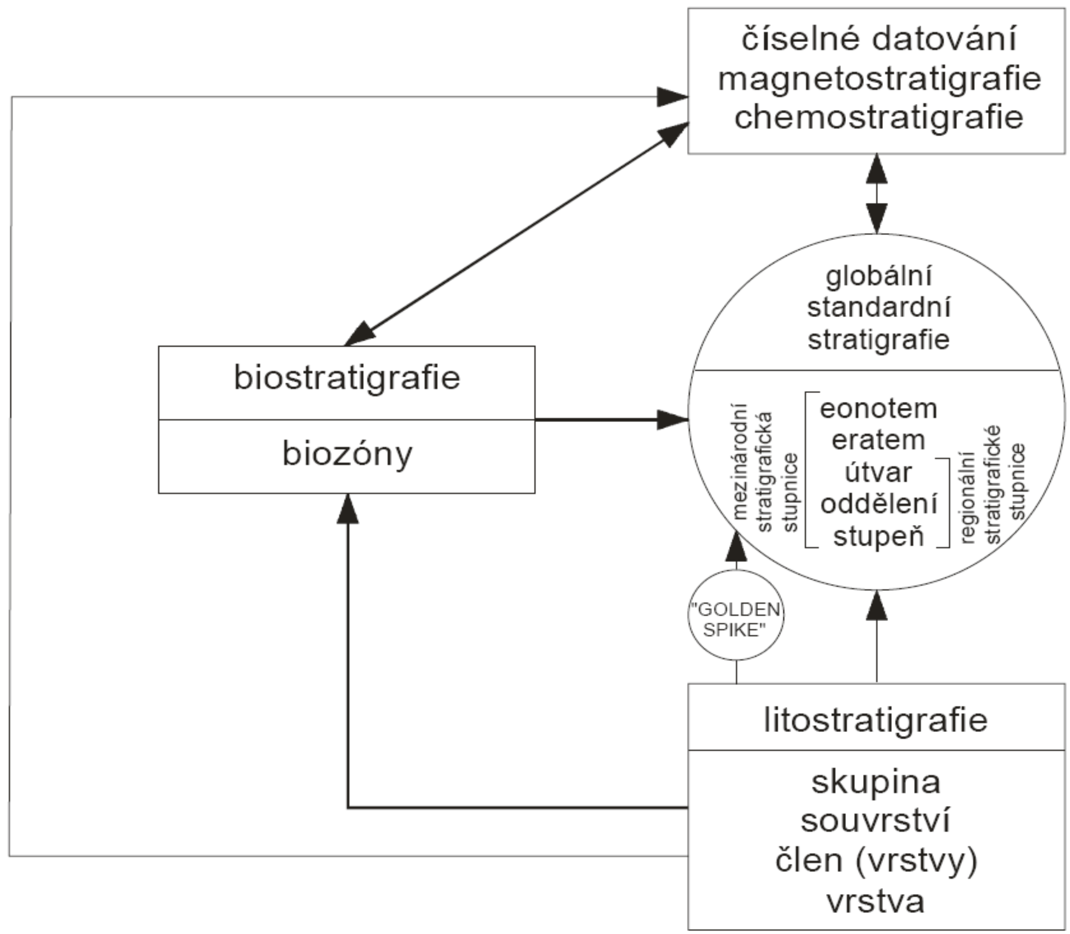
Oxygen isotope fractionation during glacial-interglacial cycles. In **A** water carrying the lighter isotope ^{16}O is preferentially evaporated to form clouds. As the clouds move landward and rain out, they become even more ^{18}O-depleted. During interglacial periods, however, this ^{18}O-poor waters returns to sea, and there is no net change. In B, during glacial periods, the ^{18}O-depleted water is trapped in the ice caps, which have $^{18}O/^{16}O$ ratios of -30 parts per thousand (‰). The ocean as a consequence, is relatively enriched in ^{18}O (+1.6‰)



Periodo interglaciar
(cálido)
H2O ligera
isotópicamente
H2O ligera
isotópicamente
escorrentía
evaporación
H2O que contiene
16O y 18O
Periodo glaciar
(frío)
H2O isotópicamente
ligera
evaporación
Hielo glaciar enriquecido
en H2O con 16O
Agua marina enriquecida en
H2O con 18O

Chronostratigraphy

Lithostratigraphy – only local lithostratigraphic units. To compare the strata of the same age deposited in different regions **biostratigraphy** is used. Its use enables to determine **chronostratigraphic units** (time-rock units) - all strata in the world deposited during a given time interval (example: Upper Devonian Series)



Obr. 5. Vztahy stratigrafických metod a vznik Mezinárodní stratigrafické stupnice (upraveno podle Hollanda 1992).

Ze shrnutí nejrůznějších dat z profilů (místní stupnice) a jejich korelací se vynořuje syntéza významných etap vývoje zemské kůry ve formě **chronostratigrafických jednotek a Globální stratigrafické standardní stupnice**. Tyto jednotky jsou založené na horninách vznikajících během určitého intervalu geologické historie a jejich hranice jsou odvislé od vybraných konkrétních bodů na spodních hranicích stratotypových profilů. Slouží k sjednocování a řazení událostí a jevů v historii planety a představují členění této historie podle mezinárodně dohodnuté hierarchie.

Základní jednotkou je **stupeň**, který v dnešní etapě stratigrafického poznání má často jen regionální platnost a proto korelace stupňů v celosvětovém měřítku skýtají těžkosti. Jeho rozsah je dán stratotypy spodní a svrchní hranice (mají mít co nejvýraznější a na velké vzdálenosti sledovatelnou charakteristiku), jeho jméno většinou geografickým názvem typické oblasti (např. givet, baden). Vyšší jednotkou je **oddělení**, jehož hranice jsou definovány spodní hranicí jeho nejstaršího stupně a horní hranicí nejmladšího stupně. Jeho znaky přesahují většinou již hranice oblastí a mají interregionální ráz. Názvy jsou dány pozicí uvnitř útvaru (např. spodní, střední, svrchní devon) nebo vzácněji geografickým jménem. Oddělení skládají vyšší jednotku - **útvar**. Útvary mají většinou již značný časový rozsah, celosvětovou platnost a jsou odrazem celosvětově sledovatelných evolučních kroků. Jejich hranice jsou analogicky dány hranicemi nejstarší a nejmladší nižší jednotky. Jejich názvy jsou v literatuře tradovány mnohdy již od úsvitu geologie a vyjadřují vztahy etnografické (např. silur), geografické (např. perm), litologické (křída), či pozici ve stratigrafickém sledu (např. kvartér). Jednotkou vyšší je **eratem**, který vymezuje velmi významné etapy života na naší planetě (např. paleozoikum) a nejvyšší pak **eonotem** odrážející nejvýznamnější kroky historie Země (např. fanerozoikum).

Spodní hranice **mezinárodních stratotypů** (vybraných typických, co nejúplnějších a chráněných profilů) je definována jedinečným (standardním) bodem v profilu (tzv. „golden spike“), který zaujímá jistou konkrétní polohu v geologické historii vyjádřenou např. stupněm vývoje organického světa, radiometrickým stářím, polaritou etc.

Príklad:	Chronostratigrafické jednotky	Geochronologické jednotky	Oblastné litostratigrafické jednotky	Rýdzo biostratigrafické jednotky
fanerozoikum	eonotem	eon		
mezozoikum	eratem	era		
jura	útvar	perioda	skupina	
lias	oddelenie	epocha	súvrstvie	rôzne druhy biostratigrafických zón
toark	stupeň	věk	člen	
Hildoceras bifrons	chronozóna	chron		(subzóna)
			vrstva (horizont)	(biohorizont)

Obr. 23a. Prehľad hlavných stratigrafických jednotiek. Chronostratigrafické a geochronologické jednotky si vzájomne zodpovedajú a ich obsah je presne stanovený. Oblastné litostratigrafické a biostratigrafické jednotky sú nezávislé od iných stupníc a hierarchické usporiadanie je relatívne

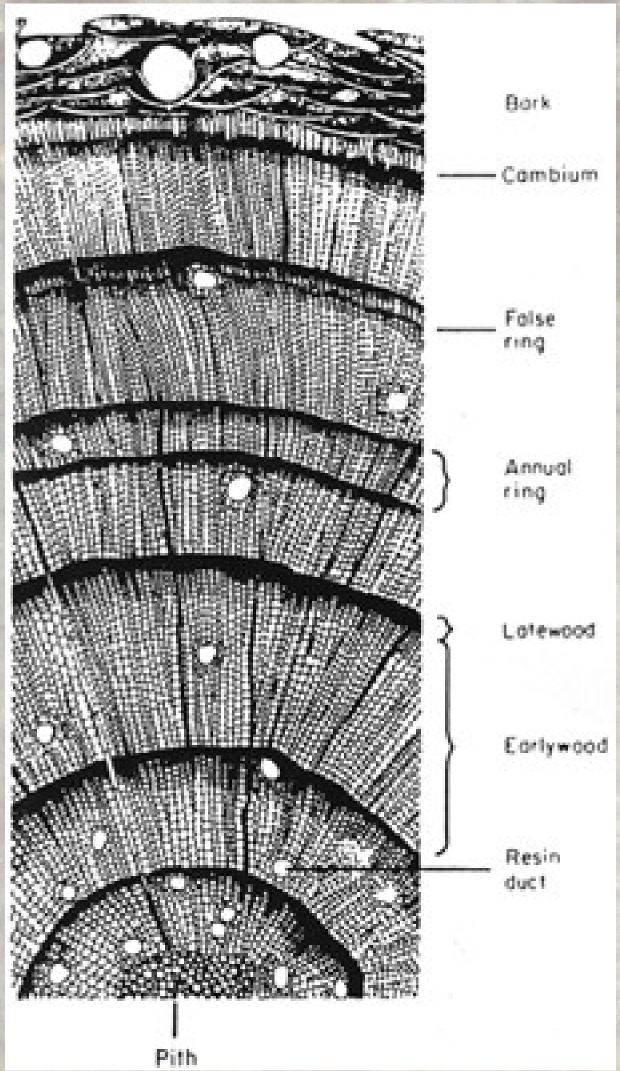
Chronostratigrafie

zkoumá a řadí horninové jednotky na základě jejich radiometrického i relativního stáří. Je tedy také vztažena k horninovým jednotkám narozdíl od geochronologie, která vymezuje etapy ve vývoji Země v "absolutním" čase

5H. Other Dating Methods

1. Dendrochronology
2. Lacustrine Sediments - varvites
3. Lichenometry

INSIDE THE TREE



Tree ring width

Variability of tree ring width and climatic conditions

Seasonal patterns:

Early wood Large, thick-walled cells

Late wood Small, densely-packed, thin-walled cells

Together = an annual growth ring

Mean width of rings dependant on:

tree species

tree age

availability of stored food

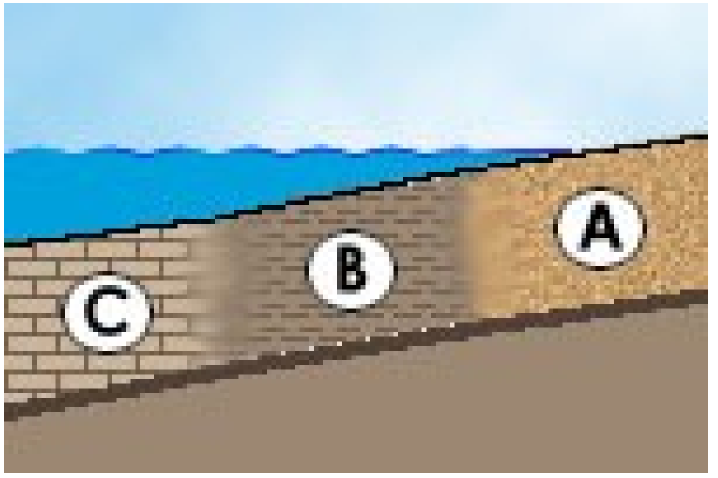
climate (precipitation, temperature, humidity, sunshine,

windspeed, humidity)

Trees as filters and sources of palaeoclimatic data

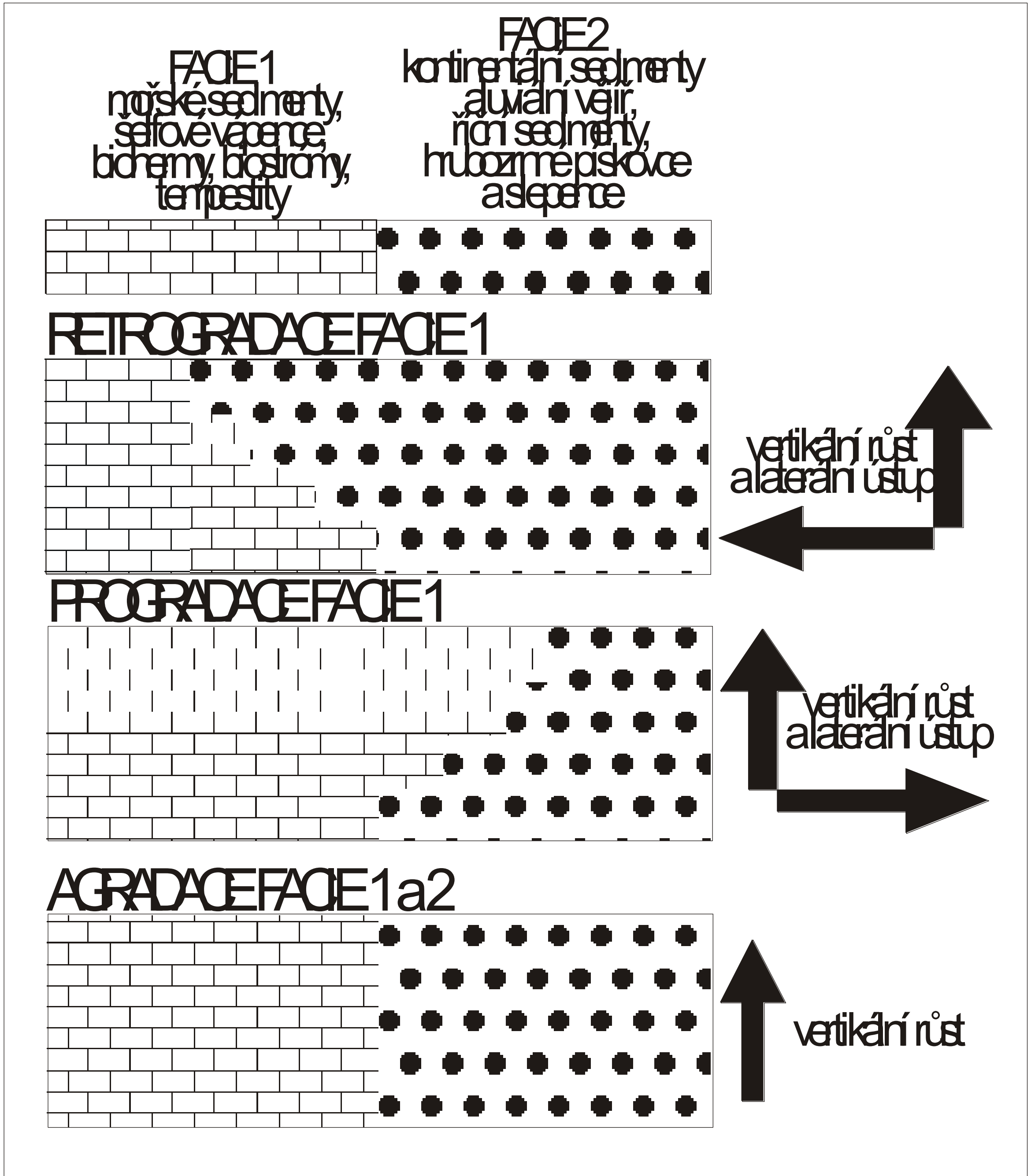
Facies

Facies - The set of characteristics of a body of rock that represents a particular processes.
Sedimentary Facies Stratigraphic units distinguished by lithologic, structural and organic characteristics reflecting the processes of the depositional environment.
example
facies description
beach Sandstone, white, fine grained, rounded, well sorted, slightly muddy at base (<5% mud), laminated at top, burrowed, at base, 15'6" thick **Lithofacies** - the set of lithological characteristics of a body of rock that represents a particular depositional environment or can be interpreted in terms of depositional processes
Biofacies - the set of biological characteristics of a body of rock that represents a particular depositional environment and ecosystem or can be interpreted in terms of depositional and biological processes ***(Biofacies and Biozones are not synonimous terms!)***
Ichnofacies - facies delineated on the basis of trace fossils
Taphofacies - facies delinated on the basis of preservational charecteristics of fossils

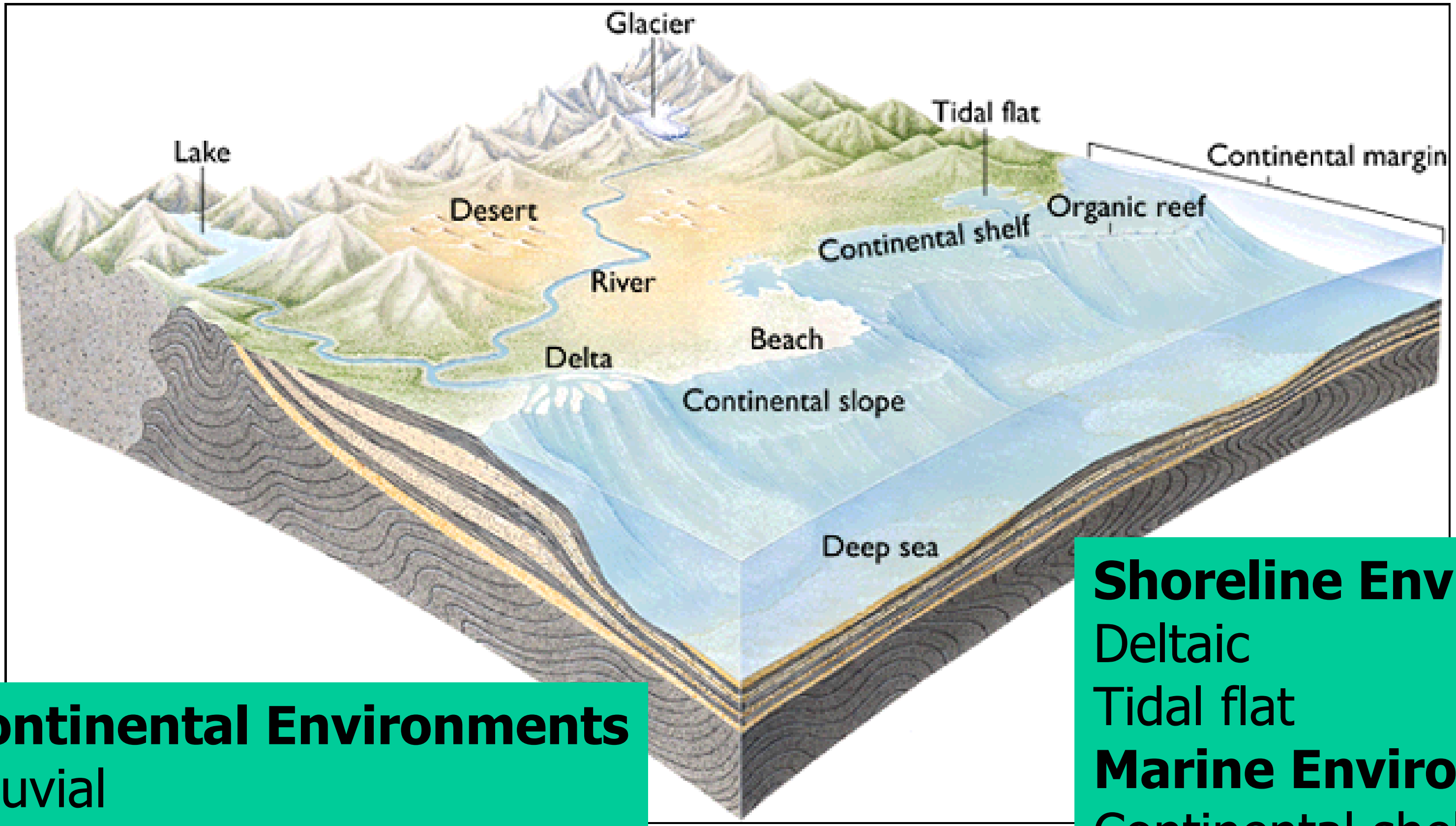


A = Sandstone facies (beach environment)
B = Shale facies (offshore marine environment)
C = Limestone facies (far from sources of terrigenous input)

Each depositional environment grades laterally into other environments. We call this **facies change** when dealing with the rock record

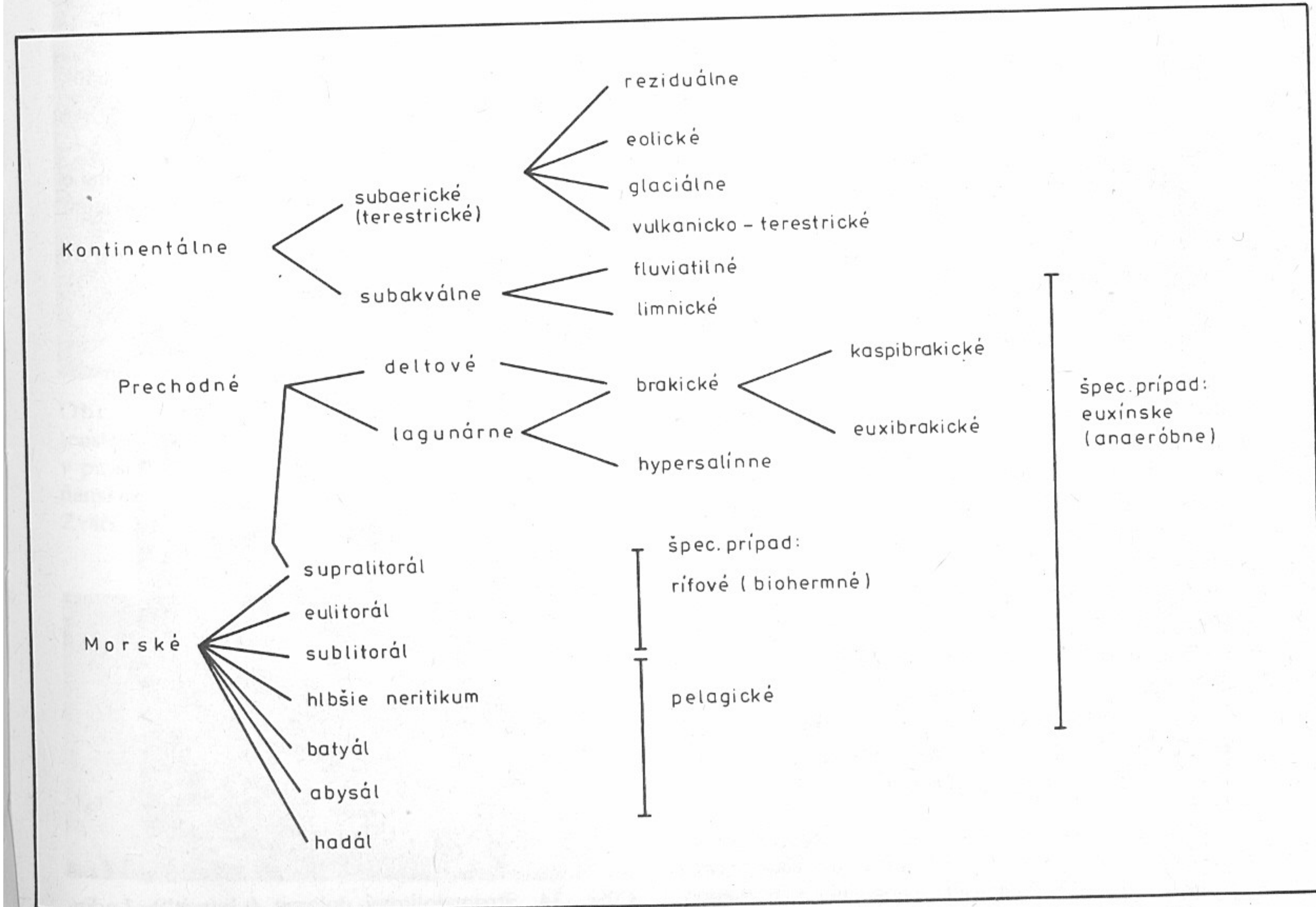

FACIE 1
mořské sedimenty,
šelfové vápence,
biohermy, biostromy,
tempestity
FACIE 2
kontinentální sedimenty
aluviální vějíř,
říční sedimenty,
hrubozrnné pískovce
a slepence
RETROGRADACE FACIE 1
vertikální růst
a laterální ústup
PROGRADACE FACIE 1
vertikální růst
a laterální ústup
AGRADACE FACIE 1 a 2
vertikální růst

Sedimentary Environments



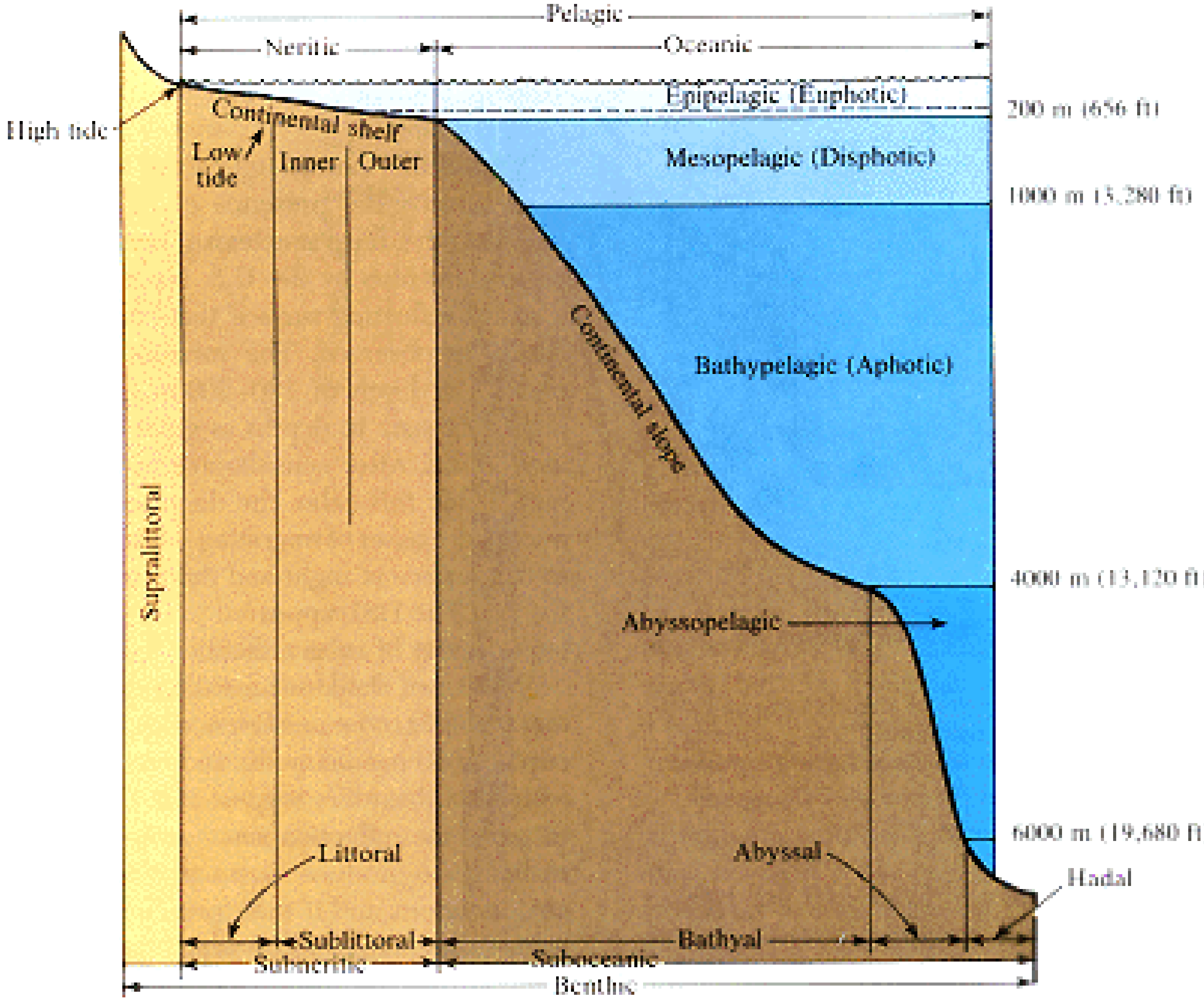
Continental Environments
Alluvial
Desert
Lake
Glacial

Shoreline Environments
Deltaic
Tidal flat
Marine Environments
Continental shelf
Continental slope
Organic reefs
Deep-sea



reziduálne
eolické
glaciálne
vulkanicko – terestrické
subaerické (terestrické)
Kontinentálne
fluviatilné
subakválne
limnické
kaspibrakické
deltové
Prechodné
brakické
lagunárne
euxibrakické
hypersalínne
špec. prípad: euxínske (anaeróbne)
špec. prípad:
supralitorál
rífové (biohermné)
eulitorál
Morské
sublitorál
hlbšie neritikum
pelagické
batyál
abysál
hadál

Marine environments


Pelagic
Neritic
Oceanic
Epipelagic (Euphotic)
200 m (656 ft)
High tide
Continental shelf
Low tide
Inner
Outer
Mesopelagic (Disphotic)
1000 m (3,280 ft)
Continental slope
Bathypelagic (Aphotic)
Supralittoral
4000 m (13,120 ft)
Abyssopelagic
6000 m (19,680 ft)
Littoral
Abyssal
Hadal
Sublittoral
Bathyal
Subneritic
Suboceanic
Benthic

TEXTURE (SIZE).

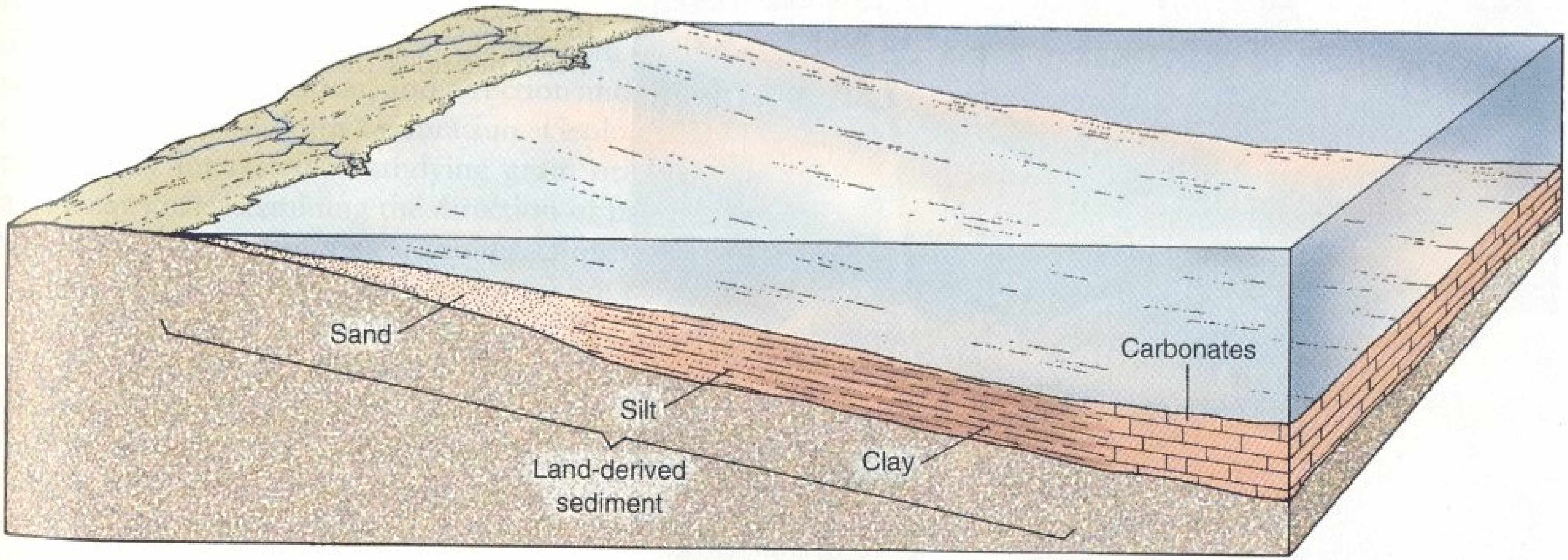
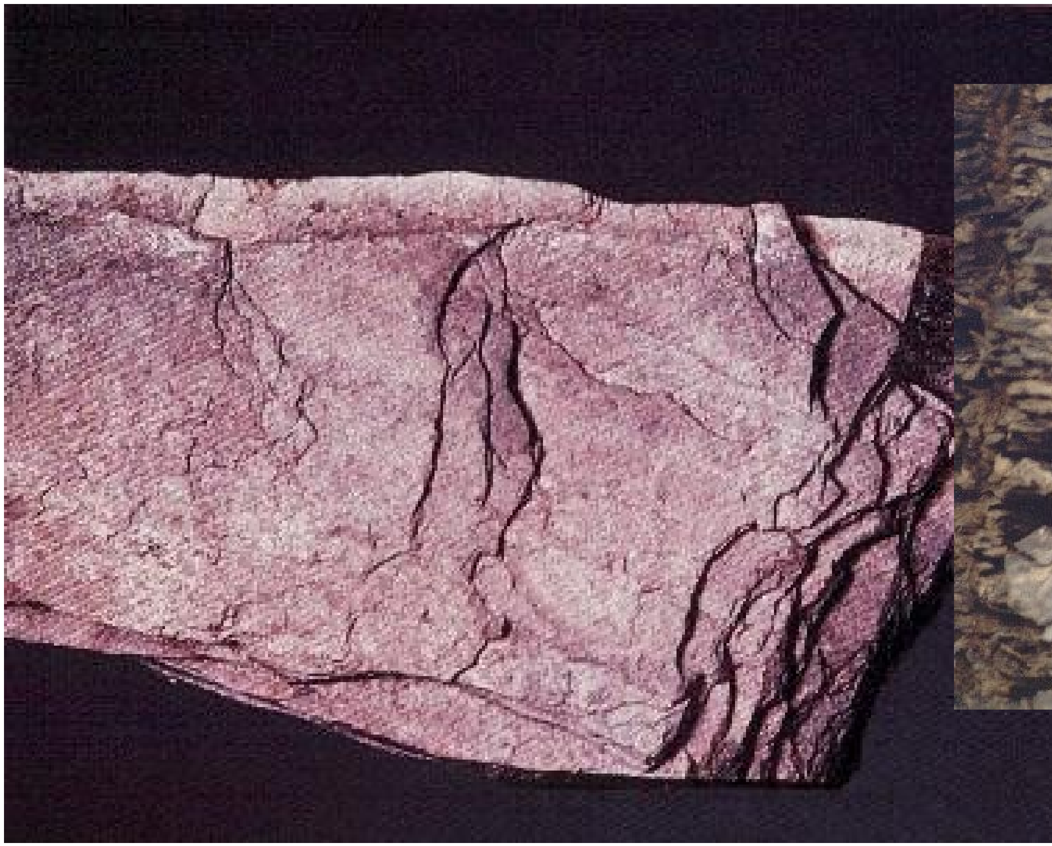
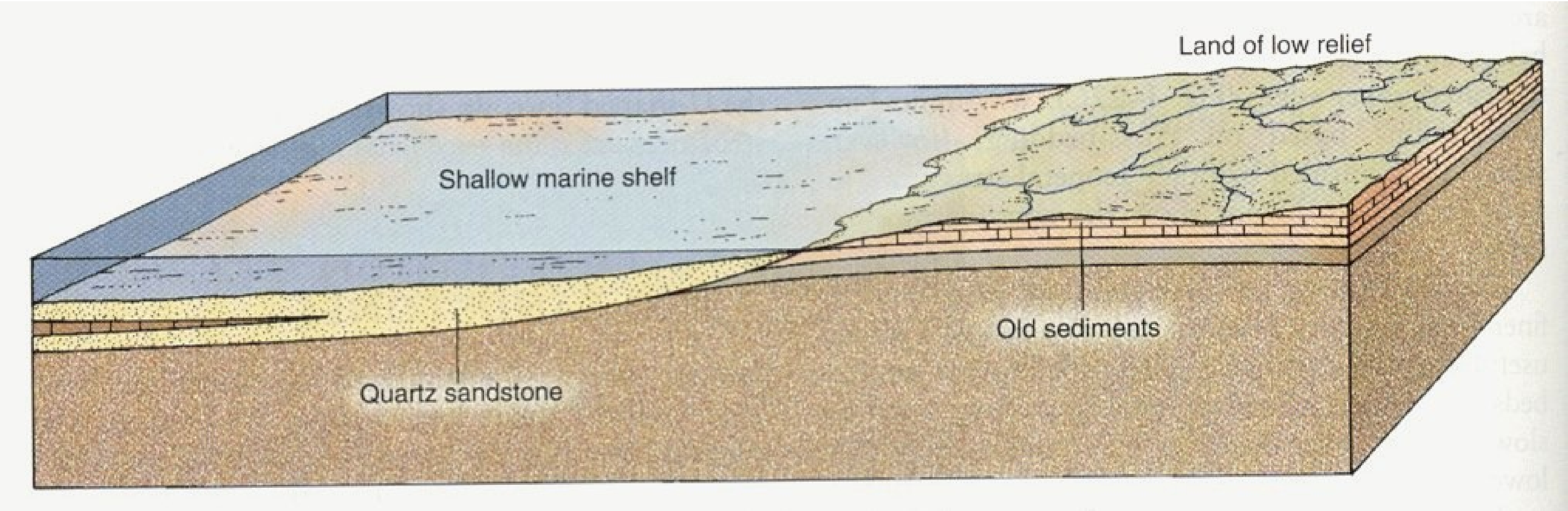


FIGURE 3–10 Idealized gradation of coarser nearshore sediments to finer offshore deposits.

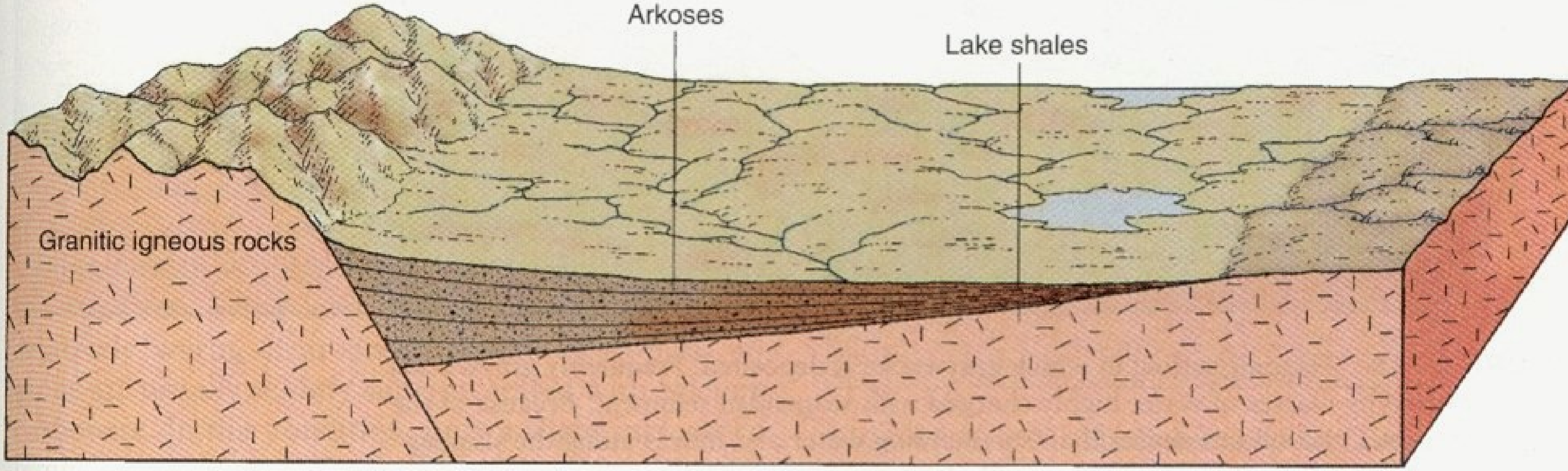
Particle size in clastic sedimentary rocks reflects the ENERGY of the depositional environment. E.g. (above) Nearshore - waves crashing on beaches -> fairly high energy -> coarse textured deposits (pebbles/sand); offshore -> progressively lower energy environments -> progressively finer textured deposits - medium sand - fine sand - silt/mud - clay - carbonates (beyond land-derived sedimentation in shallow tropical oceans).

SHALES: Form in similar environments to sandstones, only deposited under lower energy conditions (i.e. "quieter" locations) -> finer particles (clay, silt). Shallow marine, marshes, lakes, lower energy coastal plains and floodplains. Finely layered, often fissile. Common fossils.

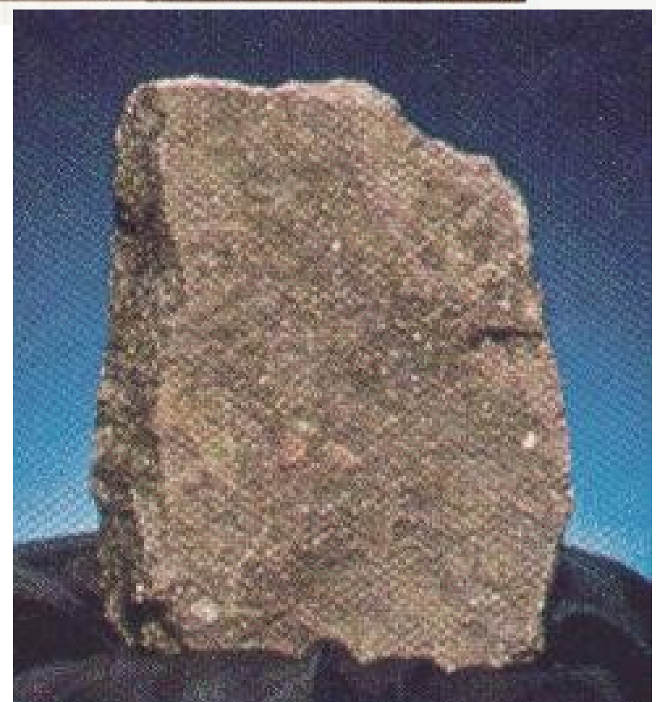




a) Quartz sandstone - predominantly quartz grains ("clean sandstone"). Long transportation (quartz survives long transportation because it is relatively hard). Distant from mountainous regions, tectonically stable. Often form at coastlines, in deserts, on higher energy coastal plains and river floodplains (e.g. Padre Island). Quartz grains make up 90%+ of rock and the grains are well rounded. Cross beds and ripples are common.



b) Arkose - terrestrial; derived from granitic highlands, contain > 25% feldspar grains (implies fairly short transportation, because feldspar is relatively soft and erodes over long distances). Commonly pink-red color.



CARBONATES: Most common = limestone (calcium carbonate). Formed by abundant marine organisms and the precipitation of calcium carbonate from sea water. Warm, clear, shallow tropical oceans - particularly common in platform areas.

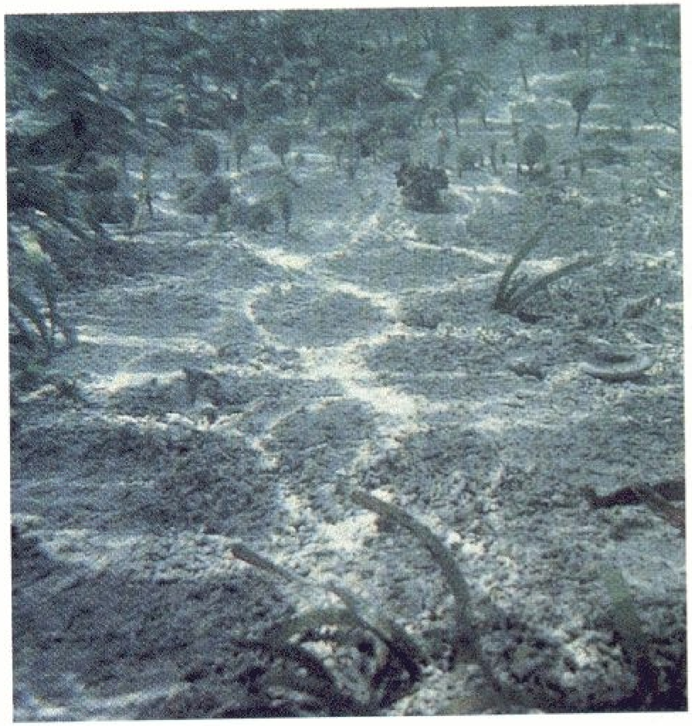
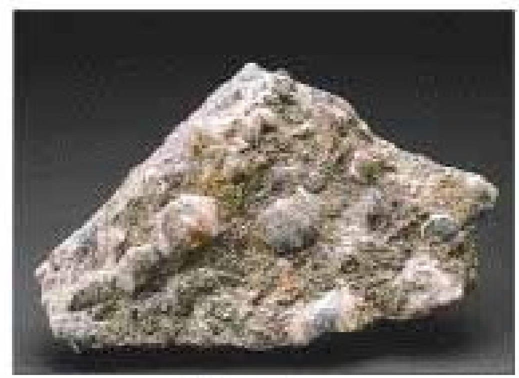


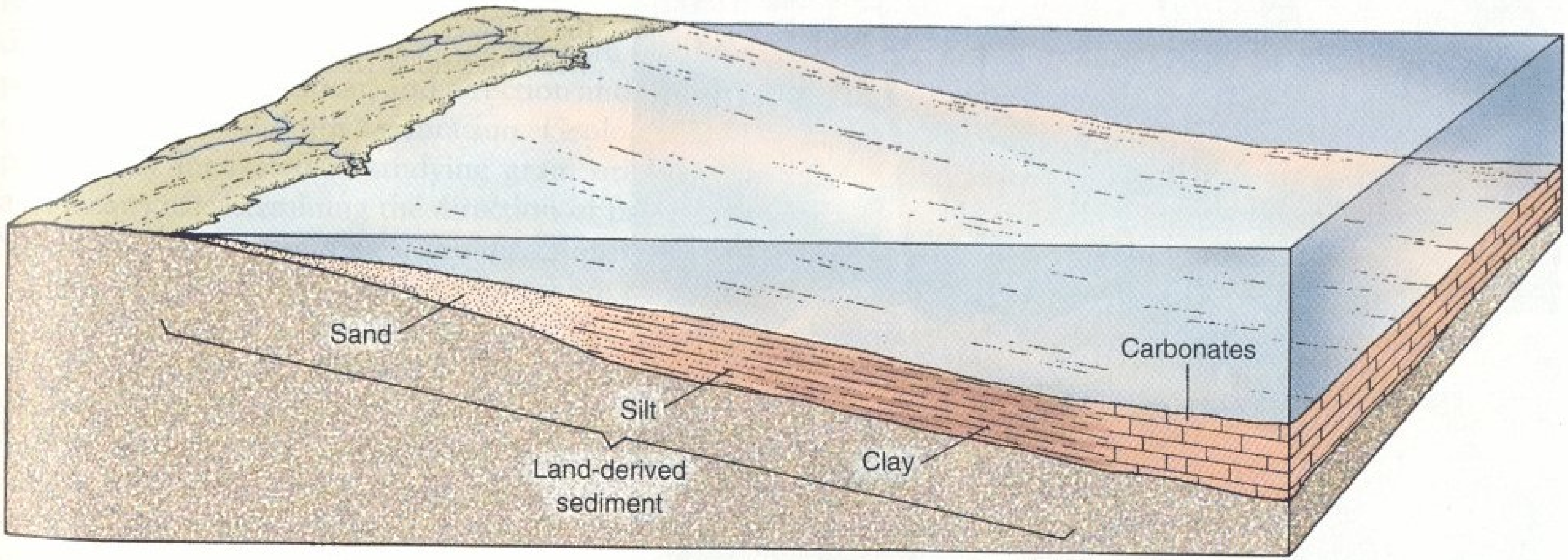
FIGURE 3–31 Carbonate mud accumulating on the sea floor in the shallow warm waters of the Bahama Banks carbonate platform. Green algae of the genus *Penicillus* form the tuftlike growths in the background. These algae produce fine, needlelike crystallites of calcium carbonate (aragonite) that contribute to the production of carbonate sediment. Other algae, such as *Halimeda*, produce similar calcium carbonate particles. *(Courtesy of*

(b)



Limestone

TEXTURE (SIZE).



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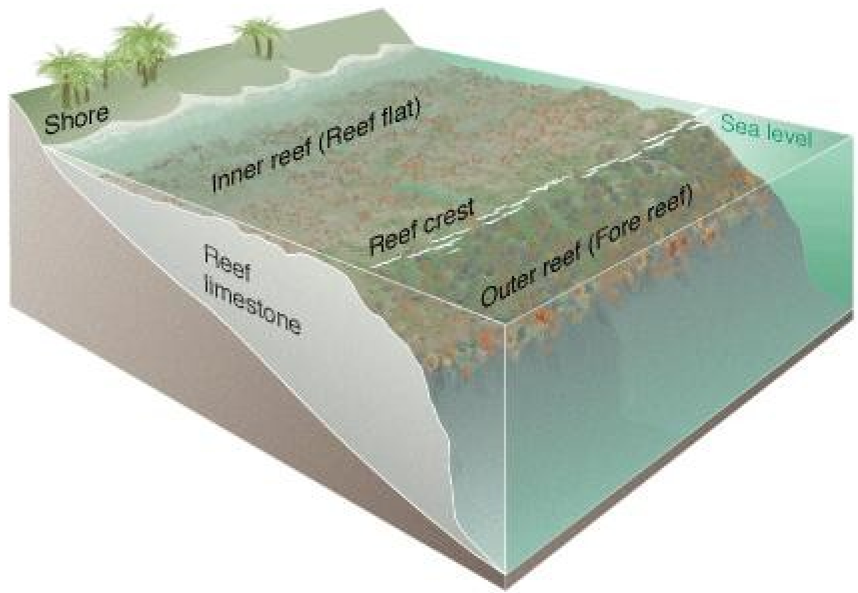
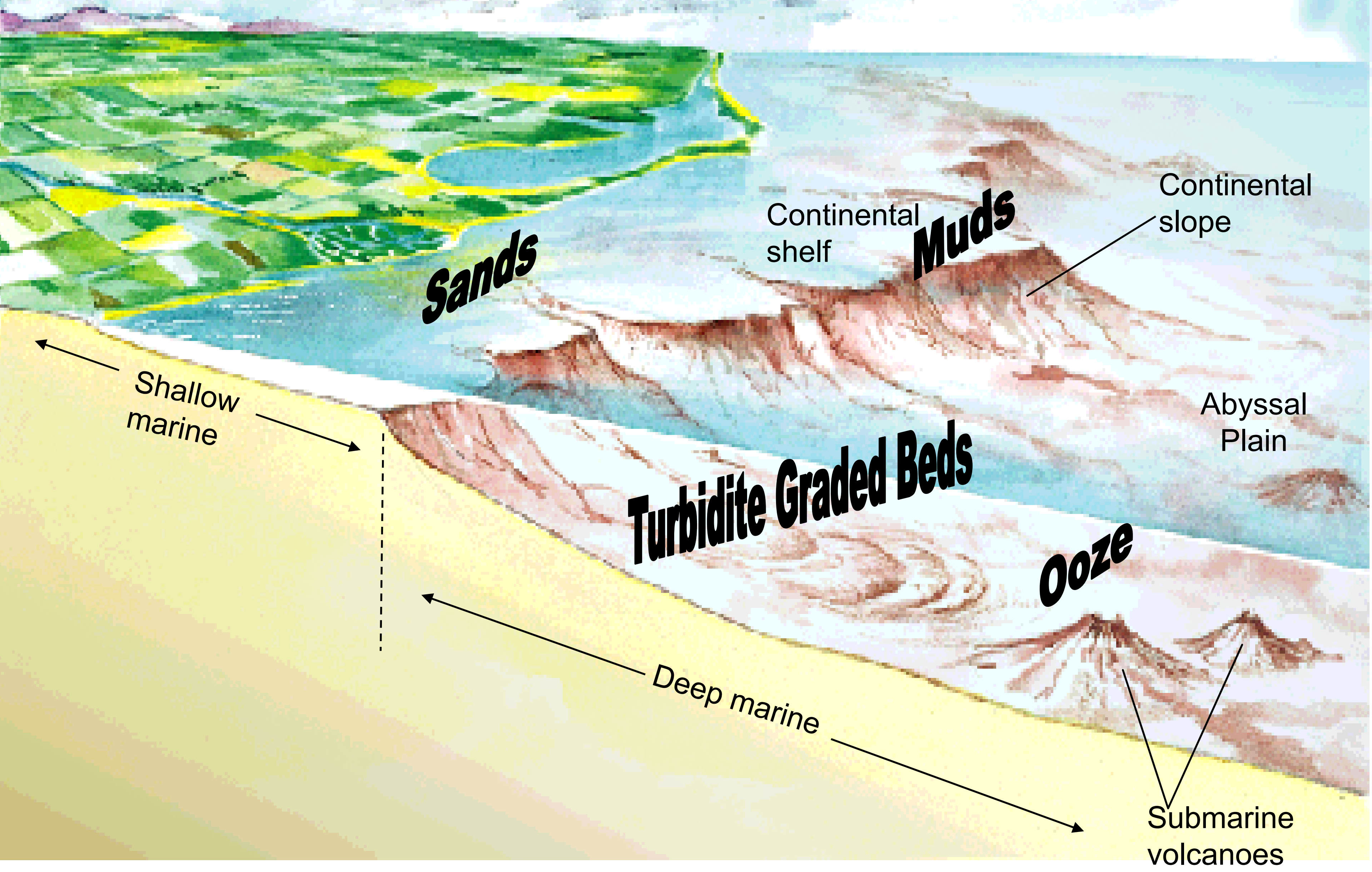
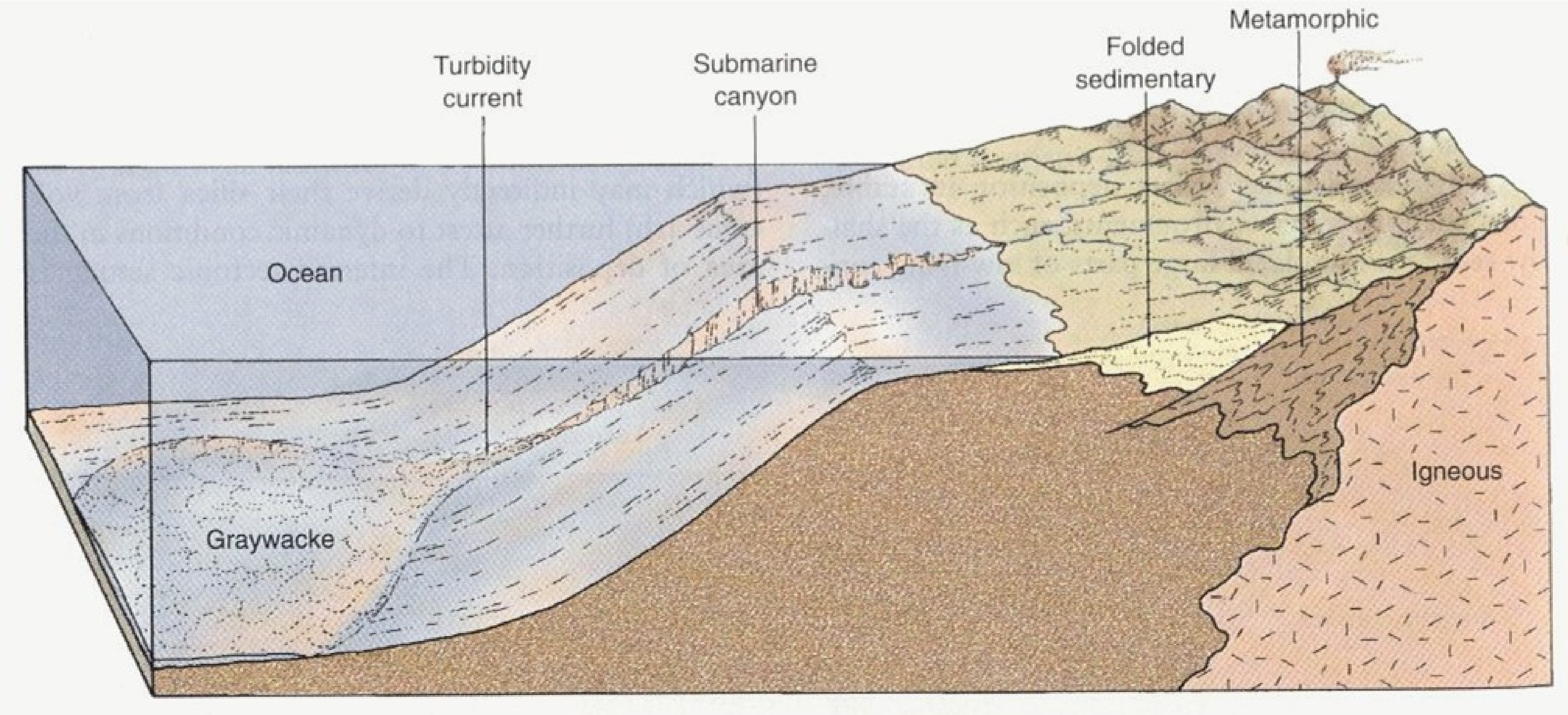
Reefs are held up by a macroscopic skeletal framework



Terms for Marine (i.e. Ocean) Environments and some characteristic sediment facies

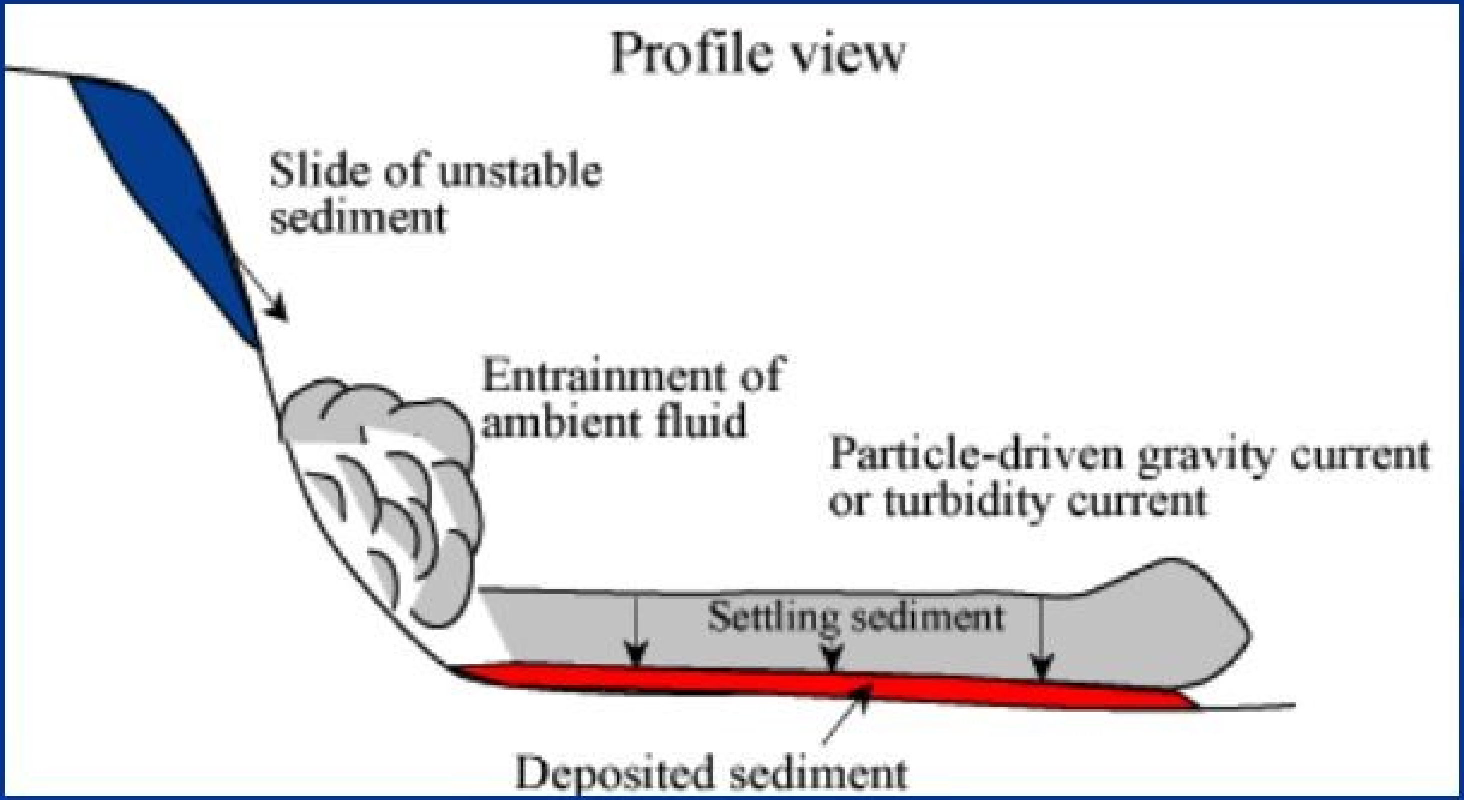


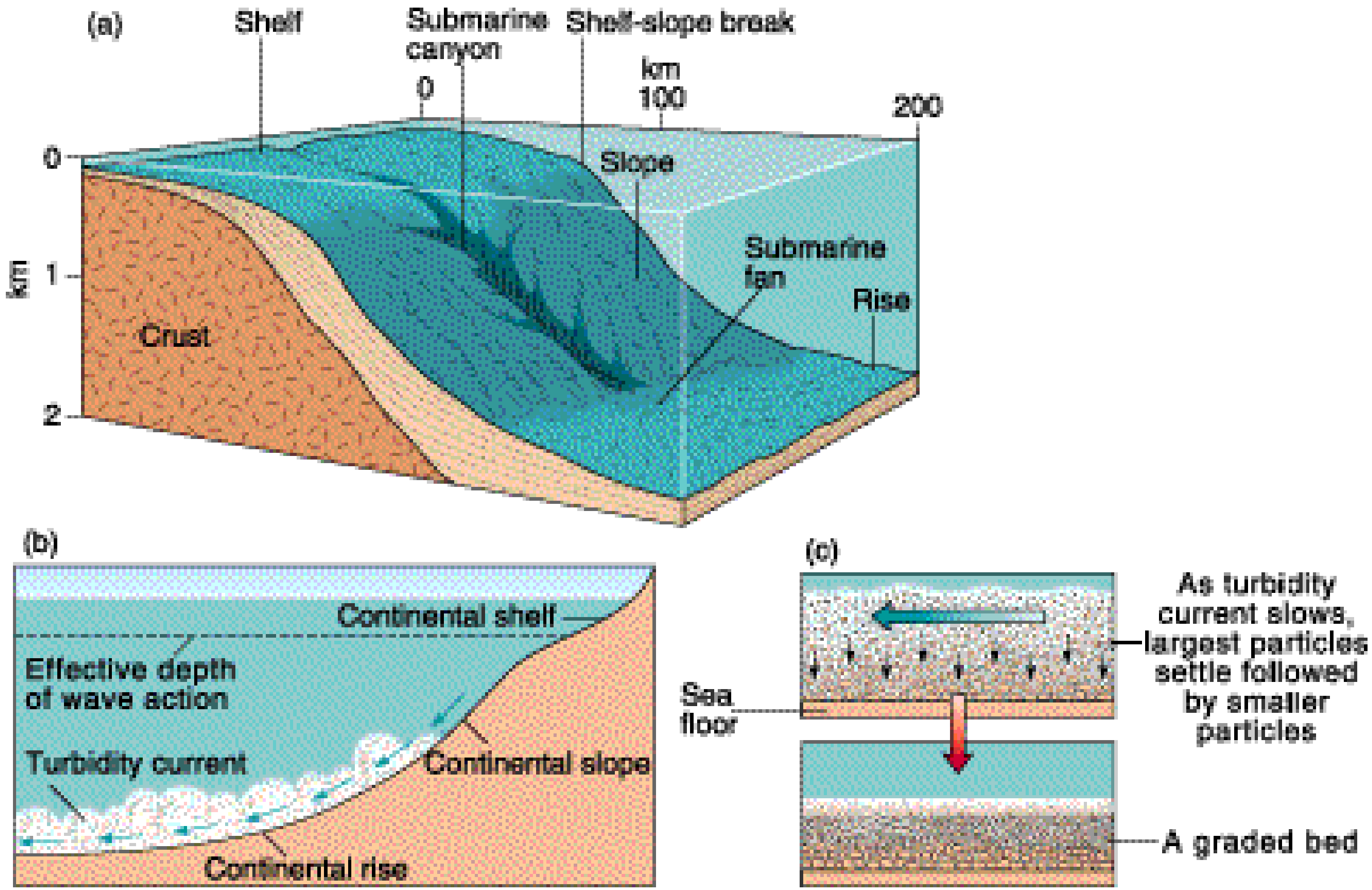


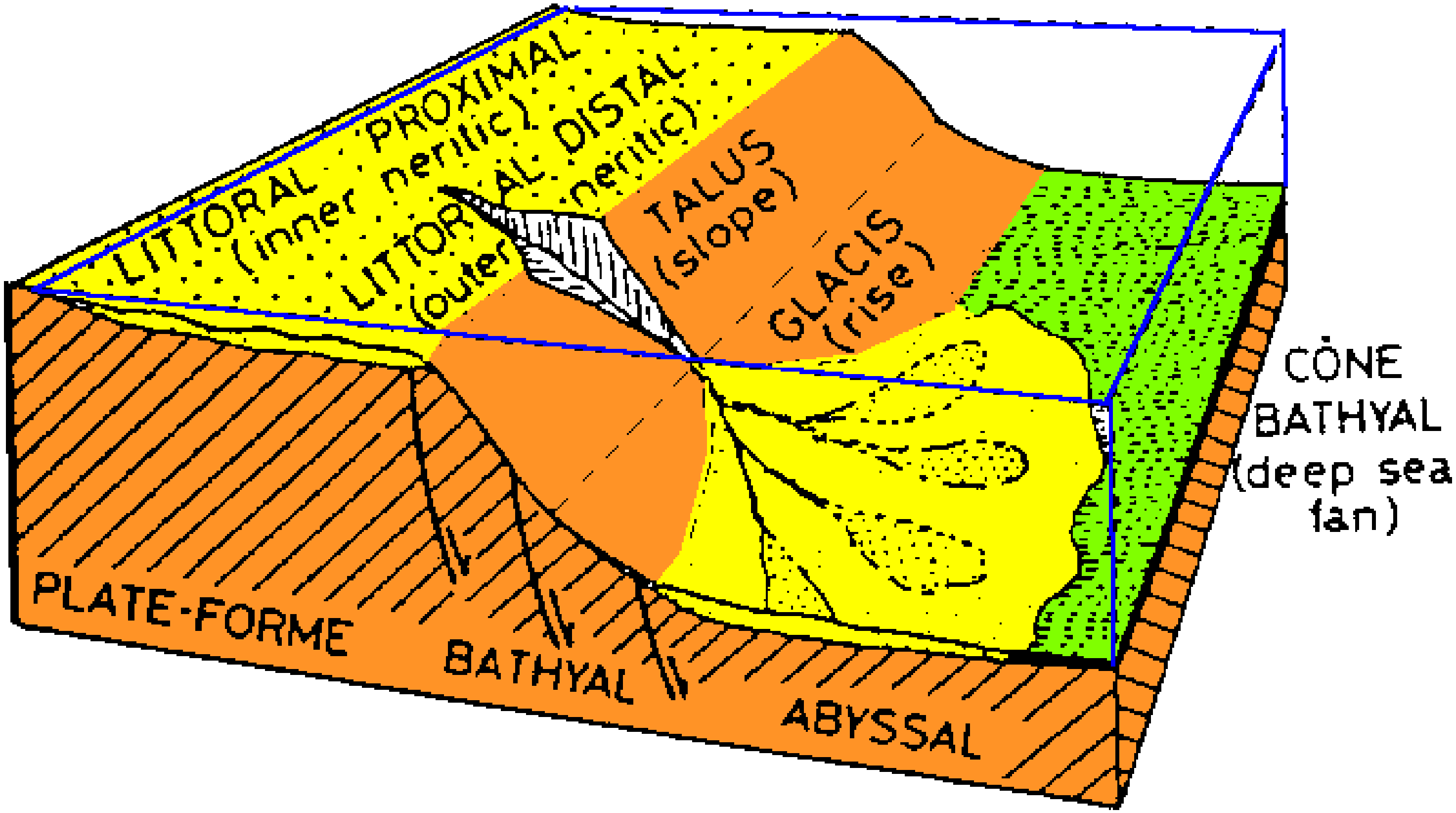
c) Graywacke – mixture of sand, clay and rock fragments ("dirty sandstone"). Indicates tectonic activity, rapid erosion/sediment accumulation, short transportation. Often deposited as <u>turbidites</u> (submarine landslide deposits). Matrix is usually 30%. Beds are often graded (sorted by size - coarse at the base, finer at the top).

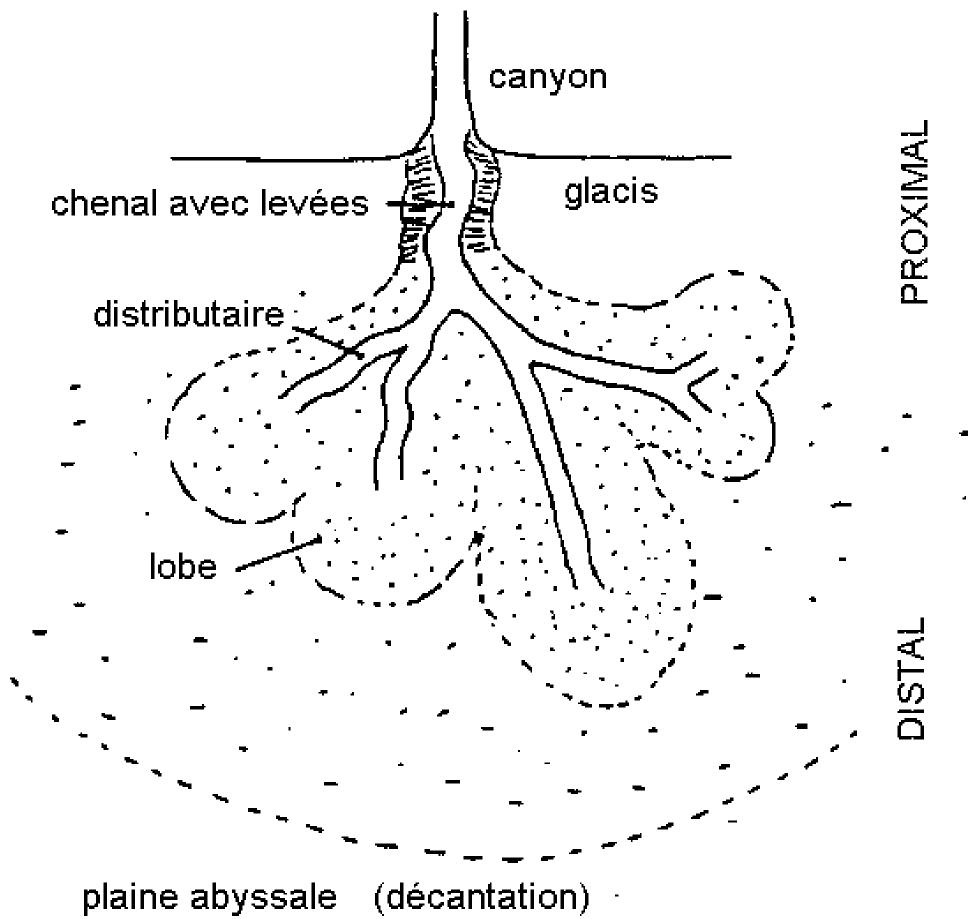
Turbidity currents

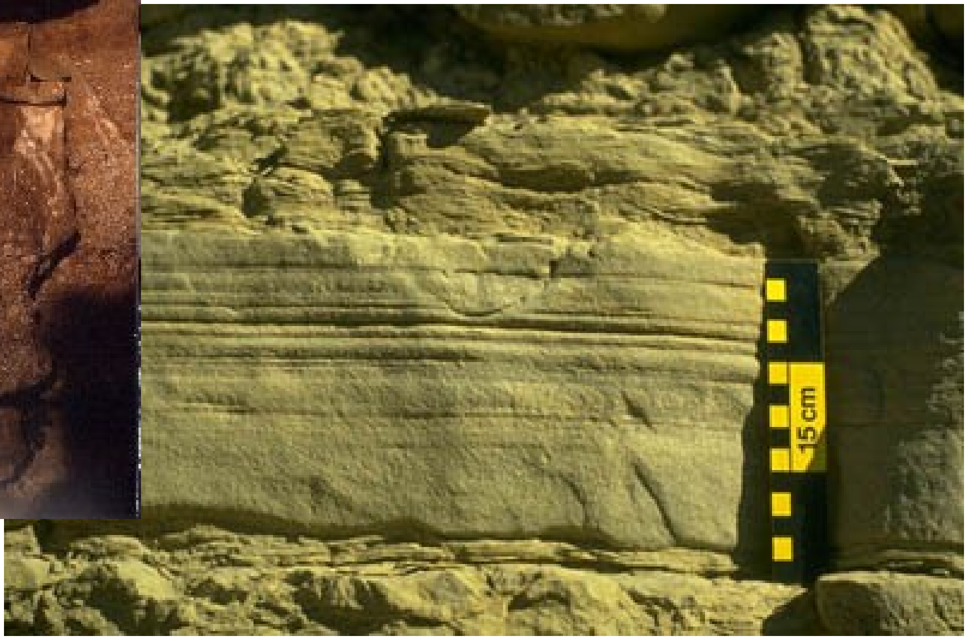
- Suspension of water, sand, and mud that moves downslope (often very rapidly) due to its greater density than that of the surrounding water (often triggered by earthquakes)
- Speed of turbidity currents first appreciated in 1920 — breaking of phone lines in the Atlantic; also gave indication of distance traveled by a single deposit



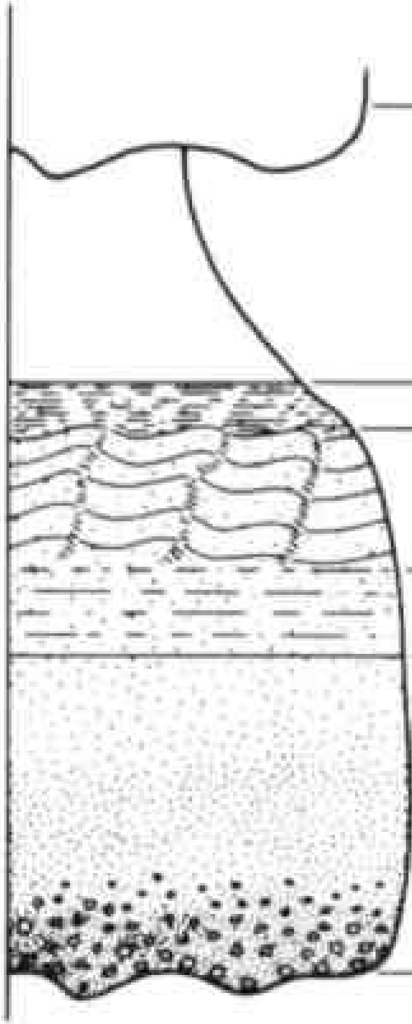

(a)
Shelf
Submarine canyon
Shelf-slope break
km
0
100
200
0
1
2
km
Slope
Submarine fan
Rise
Crust
(b)
Continental shelf
Effective depth of wave action
Turbidity current
Continental slope
Continental rise
(c)
As turbidity current slows, largest particles settle followed by smaller particles
Sea floor
A graded bed


LITTORAL PROXIMAL
(inner neritic)
LITTORAL DISTAL
(outer neritic)
TALUS
(slope)
GLACIS
(rise)
CÔNE
BATHYAL
(deep sea
fan)
PLATE-FORME
BATHYAL
ABYSSAL


canyon
glacis
chenal avec levées
distributaire
lobe
PROXIMAL
DISTAL
plaine abyssale (décantation)

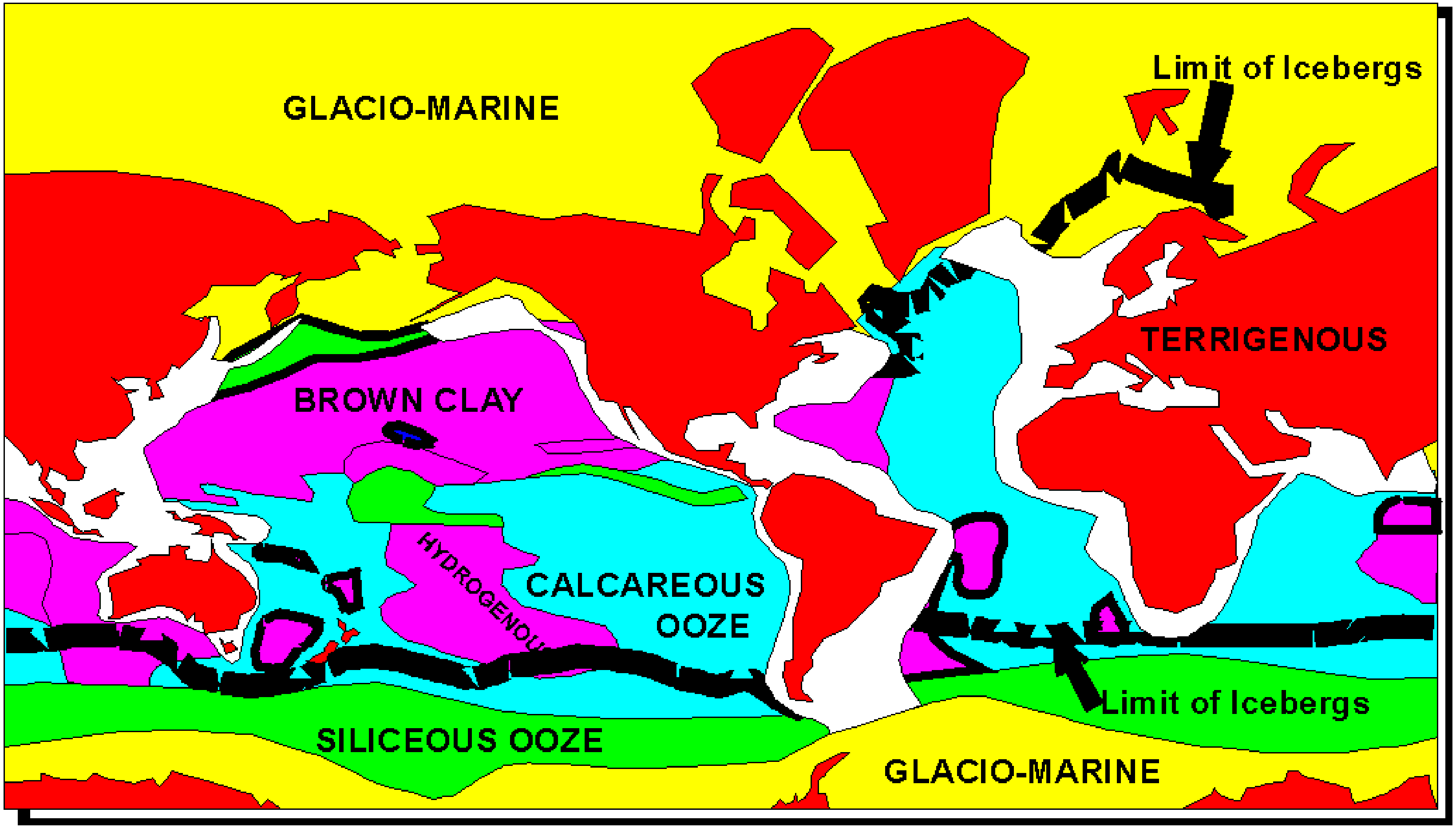

15 cm

CLASSICAL TURBIDITE

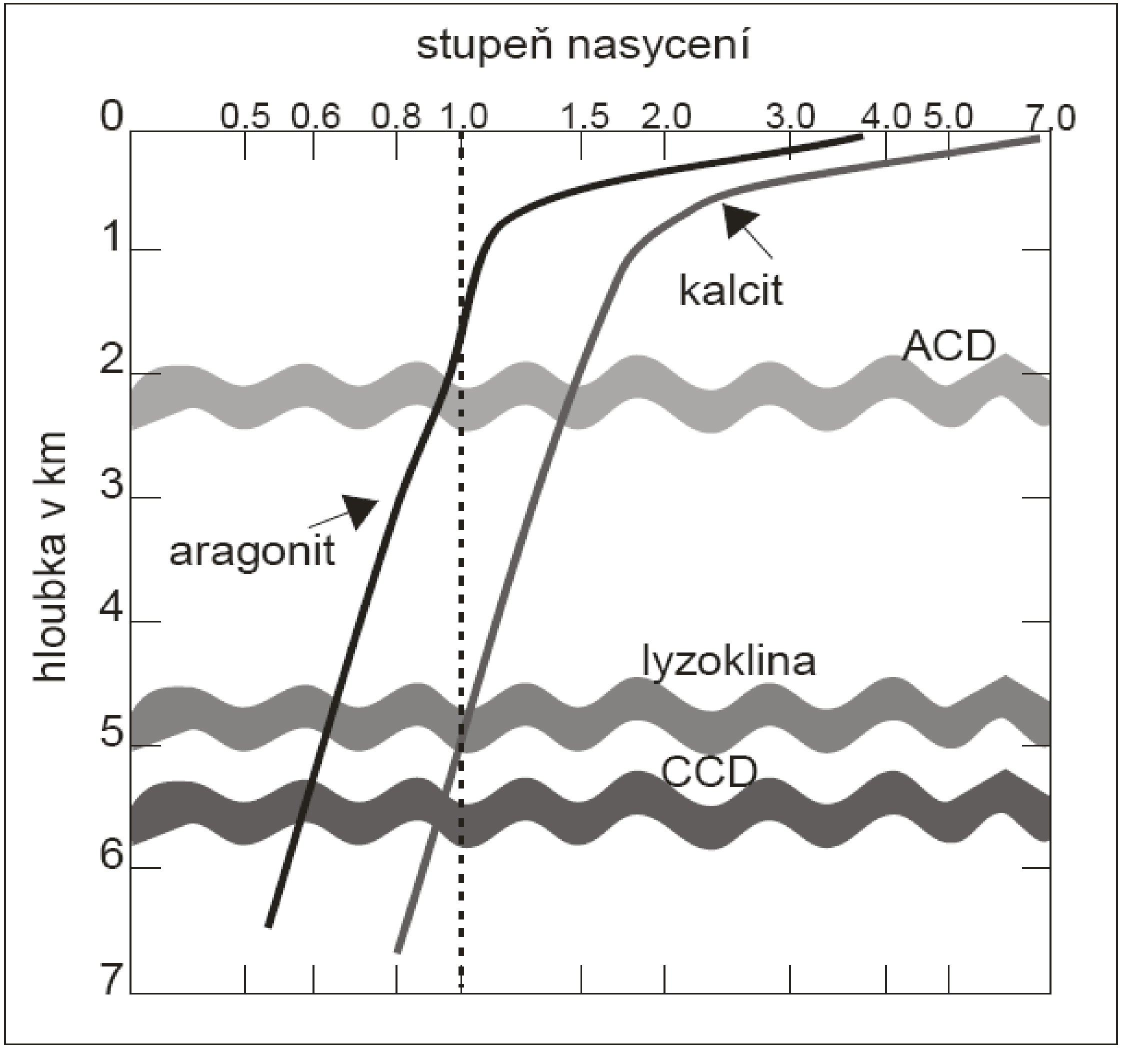


Grain Size		Bouma (1962) Divisions	Interpretation
Mud	T_{ep}	Pelite	Pelagic sedimentation
	T_{et}	Massive or graded Turbidite	fine grained, low density turbidity current deposition
Sand-Silt	T_d	Upper parallel laminae	? ? ?
	T_c	Ripples, wavy or convoluted laminae	Lower part of Lower Flow Regime
Sand (to granule at base)	T_b	Plane parallel laminae	Upper Flow Regime Plane Bed
	T_a	Massive, graded	? Upper Flow Regime Rapid deposition and Quick bed (?)

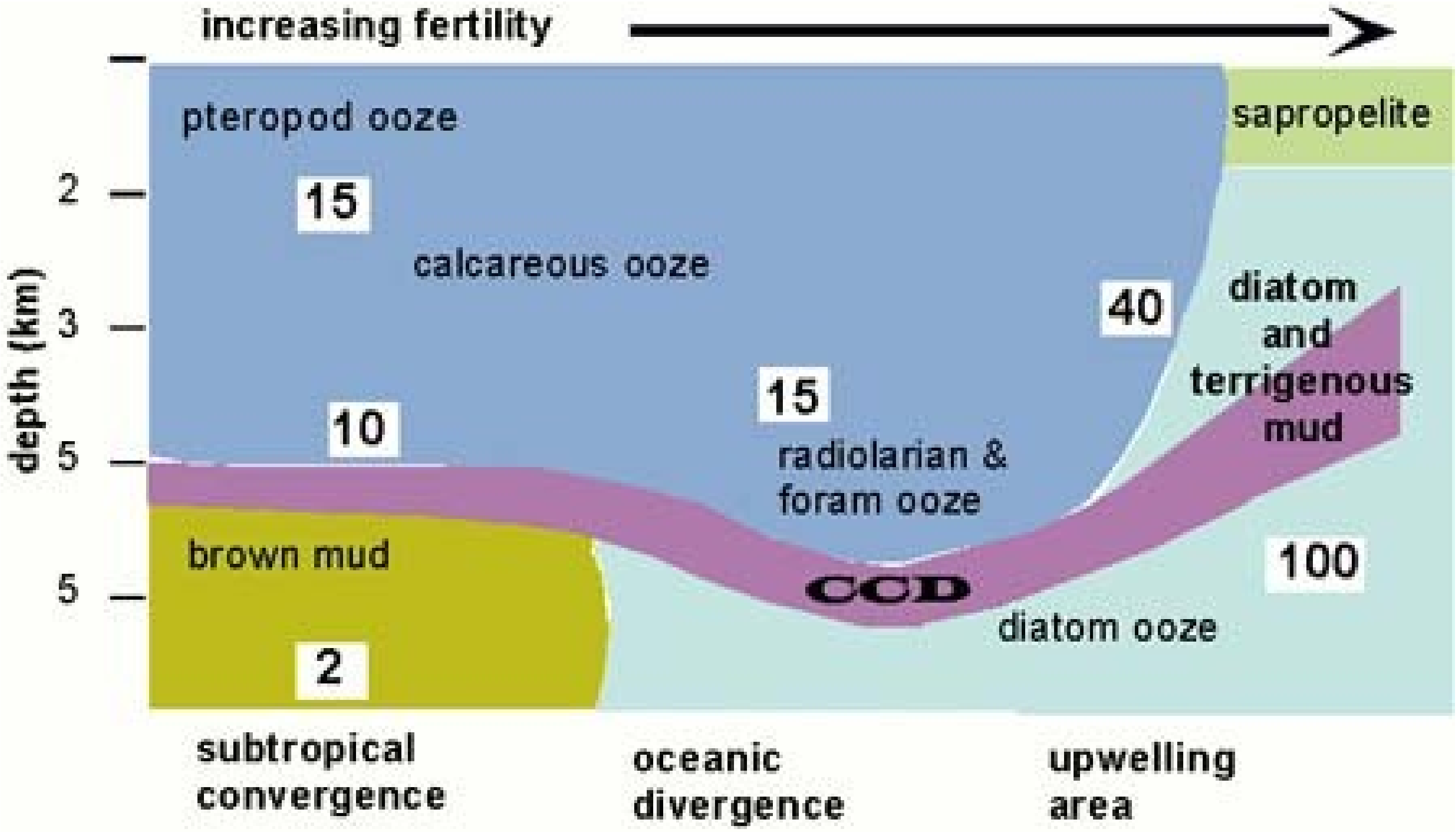
DISTRIBUTION OF DEEP-SEA SEDIMENTS



sedimentaci vápnitých nebo křemitých bahen je karbonátová kompenzační hloubka (**CCD**).



Obr. 21. Křivky závislosti nasycení mořské vody vzhledem k aragonitu a kalcitu na hloubce mořské vody pro současný Atlantik. Vlnovkou jsou vyznačeny kompenzační hloubka aragonitu (ACD) a kalcitu (CCD), lyzoklina je hloubková úroveň, ve které rychle vzrůstá rychlost rozpouštění kalcitu ale ve které se ještě vyskytují pelagické karbonáty. Upraveno podle Broecker (1974).



Distribution of modern sediment facies in the context of depth and ocean fertility, based on sediment patterns in the eastern central Pacific. Numbers are typical sedimentation rates in mm/1000 yrs

•Marine

•- Continental Shelf
- Continental Slope
- Continental Rise

•Turbidite Deposits

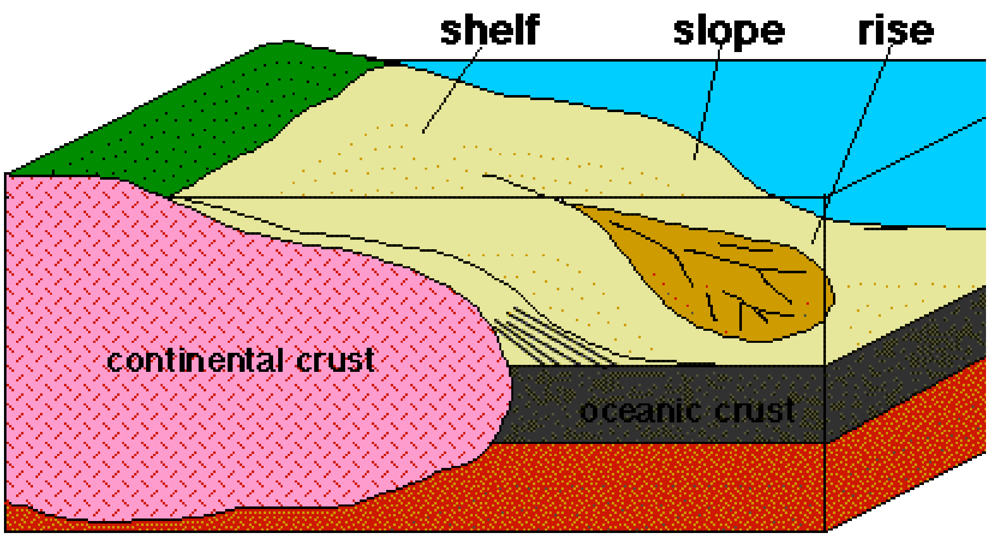
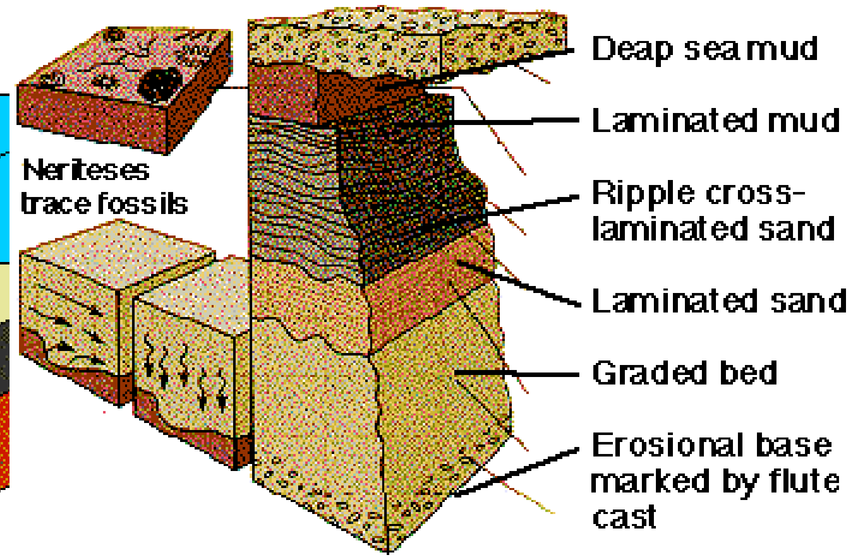
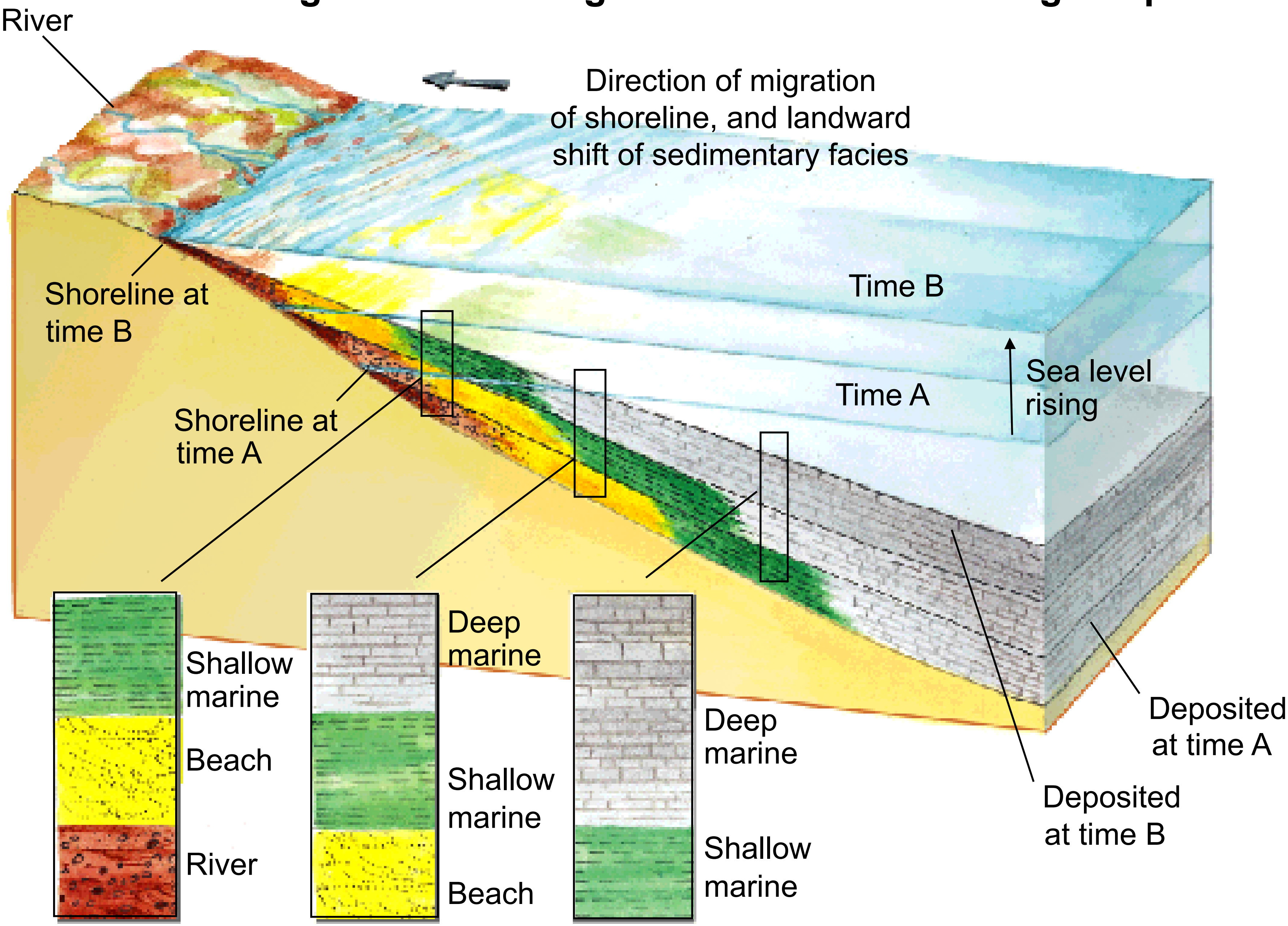


Figure 5.11, p. 115



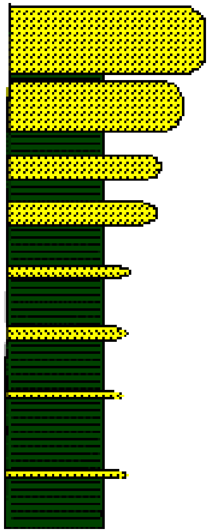
Facies changes due to rising sea level - Water Getting Deeper

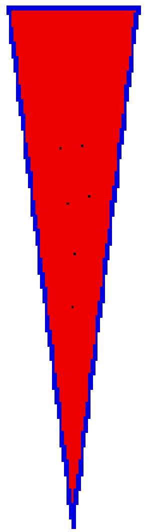


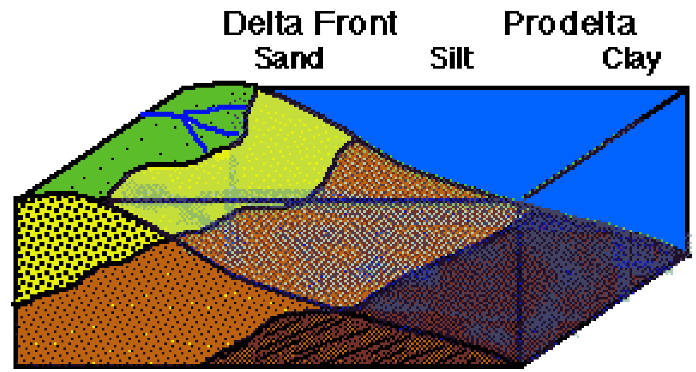
Comparison of sediments deposited

•Delta

•Progradation
Coarsening Upwards Sequence







•Mississippi Delta