INTEGRATED STRATIGRAPHY

Amalia Spina

Correlation in stratigraphy is usually concerned with considering rocks in a **temporal framework**, that is, we want to know the time relationships between different rock units – which ones are older, which are younger and which are the same age.

Correlation on the basis of lithostratigraphy alone is difficult because, as discussed before, **lithostratigraphic units are likely to be diachronous**. In the example of the lithofacies deposited in a beach environment during a period of rising sea level the lithofacies has different ages in different places. **Therefore the upper and lower boundaries of this lithofacies will cross time-lines**.

If we can draw a time-line across our rock units, we would be able to reconstruct the distribution of palaeoenvironments at that time across that area.

To carry out this exercise of making a palaeogeographic reconstruction **we need to have some means of determining the age of rock units.**

Biostratigraphy is the branch of stratigraphy which focuses on correlating and assigning **relative ages** of rock strata by using the **fossil assemblages** contained within them. It can assign a **numerical age** to rock strata by correlation to a geochronologically calibrated reference **time scale**.

Magnetostratigraphy is the branch of stratigraphy which focuses on correlating and assigning **relative ages** of rock strata by using the sequence of normal and reverse polarity reversals of the Earth's magnetic field registered within them by magnetic minerals. It can assign a **numerical age** to rock strata by correlation to a geochronologically calibrated reference **time scale (**that includes marine magnetic anomalies).

Chemostratigraphy is the branch of stratigraphy which focuses on the changes in the relative proportions of trace elements and isotopes (mainly carbon and oxygen) within and between lithologic units. It can be used for correlating and assigning **relative ages** of rock strata, demonstrating that a particular horizon in one geological section containing a particular isotopic excursion represents the same period of time as another horizon at some other section containing a similar isotopic excursion.

Cyclostratigraphy is the branch of stratigraphy which focuses on astronomically forced climate cycles within sedimentary successions due to the gravitational interaction of the Earth's orbit with other masses within the solar system. Due these interactions, solar irradiation differs through time on different hemispheres, and these insolation variations have influence on Earth's climate and on the deposition of sedimentary rocks. It can be used to assign a **numerical age** to rock strata when used in conjunction with geochronology.

Geochronology is the science of determining the **numerical age** of rocks, fossils, and sediments by measuring the amount of decay of a radioactive isotope with a known half-life.

Formal Units

Table 2. Categories and Ranks of Units Defined in This Code*

I. MATERIAL CATEGORIES BASED ON CONTENT OR PHYSICAL LIMITS

LITHOSTRATIGRAPHIC	LITHODEMIC	MAGNETOPOLARITY	BIOSTRATIGRAPHIC	PEDOSTRATIGRAPHIC	ALLOSTRATIGRAPHIC
Supergroup	Supersuite Complex				
Group	Suite	Polarity Superzone			Allogroup
Formation	*Lithodeme*	*Polarity Zone*	*Biozone* (Range, Interval, Linneage, Assemblage or Abundance)	*Geosol*	*Alloformation*
Member (or Lens, or Tongue)		Polarity Subzone	Subbiozone		Allomember
Bed(s) or Flow(s)					

IIA. MATERIAL CATEGORIES USED TO DEFINE TEMPORAL SPANS

CHRONO-STRATIGRAPHIC	POLARITY CHRONO-STRATIGRAPHIC
Eonothem	Polarity Superchronozone
Erathem (Supersystem)	
System (Subsystem)	*Polarity Chronozone*
Series	
Stage (Substage)	Polarity Subchronozone
Chronozone	

IIB. NON-MATERIAL CATEGORIES RELATED TO GEOLOGIC AGE

GEOCHRONOLOGIC	POLARITY CHRONOLOGIC	DIACHRONIC	GEOCHRONOMETRIC
Eon	Polarity Superchron		Eon
Era (Superperiod)			Era (Superperiod)
Period (Subperiod)	*Polarity Chron*	*Episode*	*Period* (Subperiod)
Epoch		Diachron Phase	Epoch
Age (Subage)	Polarity Subchron	Span	Age (Subage)
Chron		Cline	Chron

*Fundamental units are italicized.

- **Biostratigraphy:** is the classification of bodies of rock or rock material into biostratigraphic units based on their contained fossils.
- Good biostratigraphy requires:
  - Common fossils
  - Good taxonomy
  - Accurate location of these fossils in carefully measured sections. This requires:
    - The vertical changes in fossils can be noted at one place and convenient boundaries chosen.
    - These changes and boundaries must be recognized at other places.

Biostratigraphy and fossils. A (very) little bit of history!

Leonardo Da Vinci (1452-1519) postulated that the deluge - a mythical story of a great flood sent by a deity to destroy civilization as an act of divine retribution - could not have caused the presence of fossils in the Italian Apennines: *Della stoltizia e semplicità di quelli che vogliono che tali animali fussin in tal lochi distanti dai mari portati dal diluvio. Come altra setta d'ignoranti affermano la natura o i celi averli in tali lochi creati per influssi celesti....E se tu dirai che li nichi [le conchiglie] che per li confini d'Italia, lontano da li mari, in tanta altezza si vegghino alli nostri tempi, sia stato per causa del diluvio che lì li lasciò, io ti rispondo che credendo che tal diluvio superassi il più alto monte di 7 cubiti - come scrisse chi 'l misurò! - tali nichi, che sempre stanno vicini a' liti del mare, doveano stare sopra tali montagne, e non sì poco sopra la radice de' monti...*

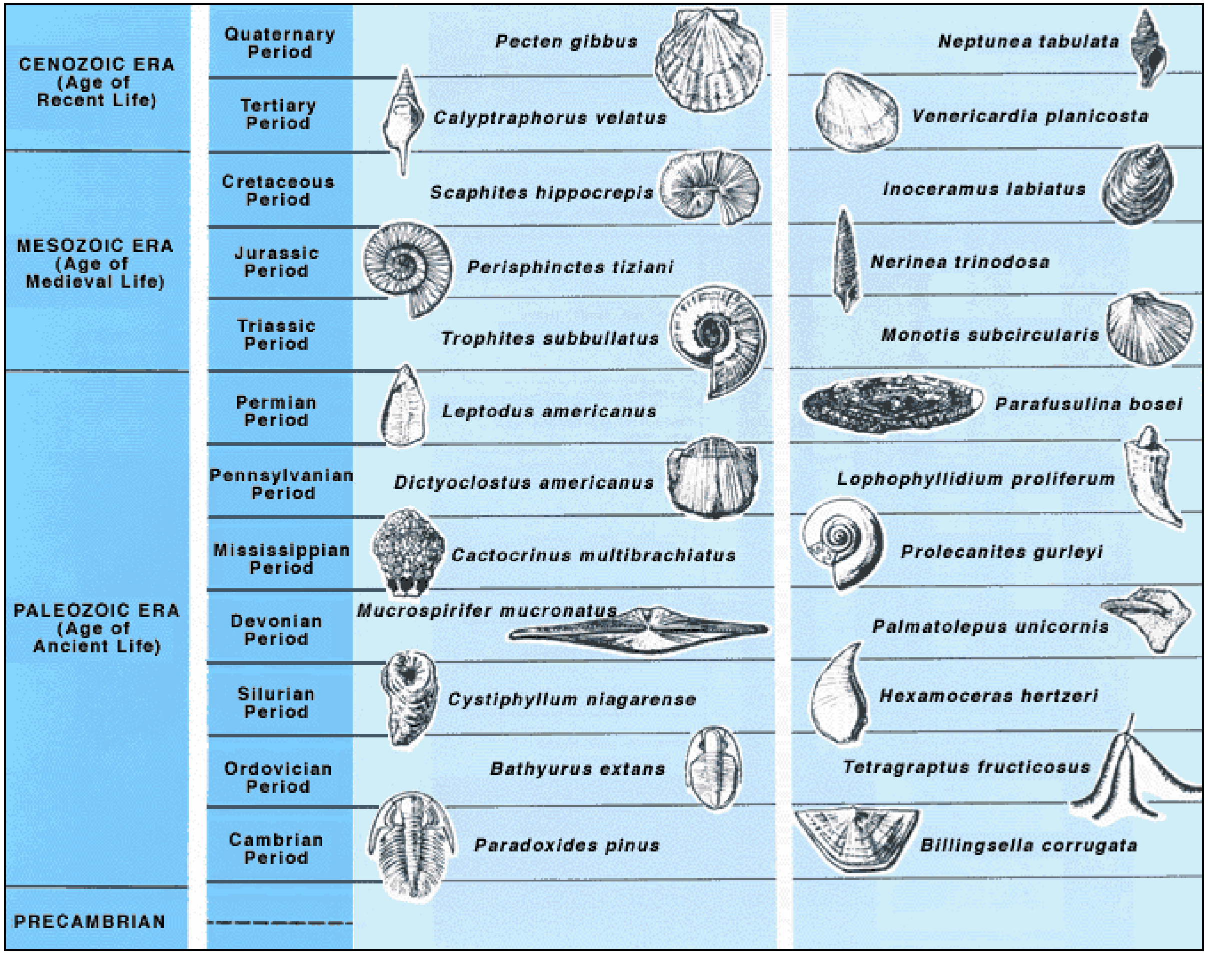
William Smith (1769-1839) formulated the principle of faunal succession based on the observation that sedimentary rock strata contain fossilized flora and fauna, and that these fossils succeed each other vertically in a specific, reliable order that can be identified over wide horizontal distances: *...each stratum contained organized fossils peculiar to itself, and might, in cases otherwise doubtful, be recognized and discriminated from others like it, but in a different part of the series, by examination of them.*

Biostratigraphy uses fossils for correlating and dating sediments

"Sediments of the same age can look completely different because of local variations in the sedimentary environment. For example, one section might have been made up of clays and marls while another has more chalky limestones, but if the **fossil species** recorded are similar, the two sediments are likely to have been laid down at the same time. Different fossils work well for sediments of different ages."

Ammonites, graptolites, archeocyathids, and trilobites are index fossils that are widely used in biostratigraphy. Microfossils such as acritarchs, chitinozoans, conodonts, dinoflagellate cysts, pollen, spores and foraminiferans are also frequently used.

Refer to the Paleontology class you took!!



Facies Fossils vs. Zone Fossils

Facies Fossils

- Some fossils can be found only in certain environments, and they allow us to learn about the environmental conditions in the period when the covering layer was deposited.

Zone Fossils

- The fossil space may appear completely independent to the rock units.

In 1856 **Albert Oppel** introduced the concept of **biozone** to describe strata characterised by the overlapping range of fossils. A biozone represents the interval between the **appearance** of species at the base of the zone and the appearance of other species at the base of the next zone. Oppel's zones are named after a particular distinctive fossil species, called an **index fossil**.

Biostratigraphic units or biozones exist only where the particular diagnostic feature or attribute on which they are based has been identified.

Biostratigraphic units, therefore, are objective units based on the identification of fossil taxa. Their recognition depends on the identification of either their defining or characterizing attributes.

Biostratigraphic units may be enlarged to include more of the stratigraphic record, both vertically and geographically, when additional data are obtained. In addition, since they depend on taxonomic practice, changes in their taxonomic base may enlarge or reduce the body of strata included in a particular biostratigraphic unit.

A biostratigraphic unit may be based on:
- a single taxon;
- combinations of taxa;
- relative abundances;
- specified morphological features;
- or variations in any of the many other features related to the content and distribution of fossils in strata.

The same interval of strata may be zoned differently depending on the diagnostic criteria or fossil group chosen.

Thus, there may be several kinds of biostratigraphic units in the same interval of strata that may have gaps between them or overlaps of their vertical and horizontal ranges.

Biostratigraphic units are distinct from other kinds of stratigraphic units in that the organisms whose fossil remains establish them show evolutionary changes through geologic time that are not repeated in the stratigraphic record.

This makes the fossil assemblages of any one age distinctive from any other.

There exist different types of biozones:

Range biozone:

Taxon range biozone representing the range of occurrence of a single taxon (**A**).

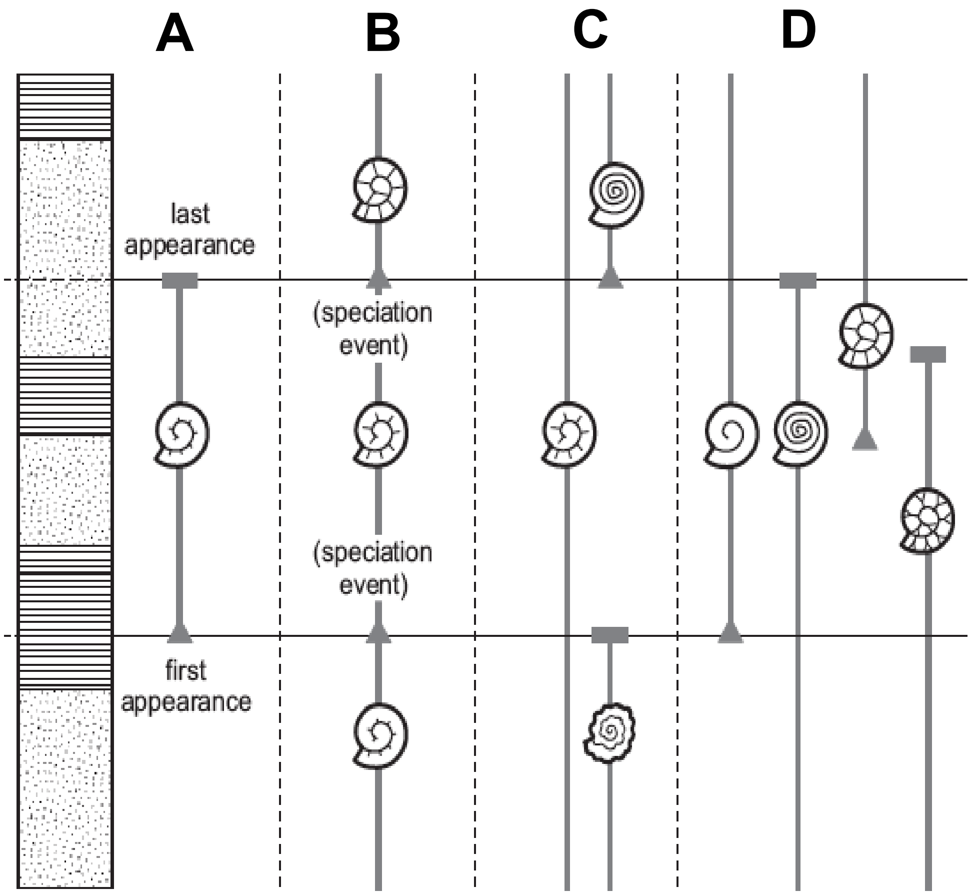
Concurrent range biozone representing the concurrent range of two taxa (**C**).

Lineage biozone representing a specific segment of an evolutionary lineage (**B**).

Assemblage biozone representing a unique association of three or more taxa (**D**).

Interval biozone

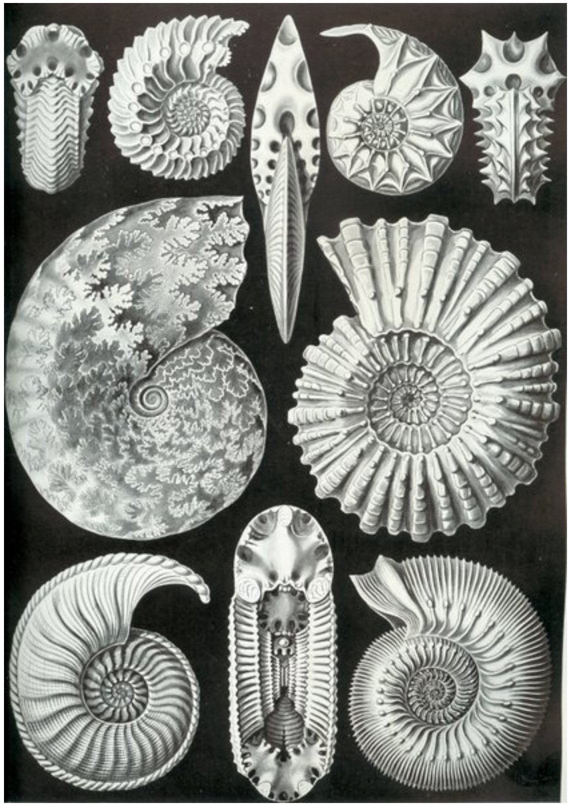
Abundance biozone



Biozones are based on **index fossils**.

Although different sediments may look different depending on the conditions under which they were laid down, they may include the remains of the same species of fossil. **If the species concerned were short-lived** (in geological terms!), **then it is certain that the sediments in question were deposited within that narrow time period**. The shorter the lifespan of a species, the more precisely different sediments can be correlated, and so rapidly evolving types of fossils are particularly valuable.

Ammonites



To be useful in biostratigraphy index fossils should be:

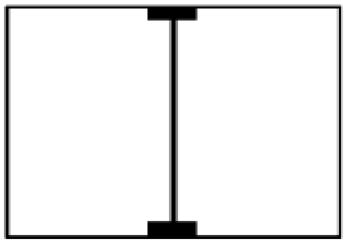
*Rapidly evolving (short-lived)
* Independent of their environment
* Geographically widespread
* Abundant (easy to find in the rock record)
* Easy to preserve in the rock record
* Easy to identify

Range Zone (*taxon range zone*)

- **Range Biozone:** is a body of rock representing the known stratigraphic and geographic range of occurrence of any selected element or elements of the chosen fossil taxon, or taxa, present in the rock record.
- There are two kinds of range biozones:

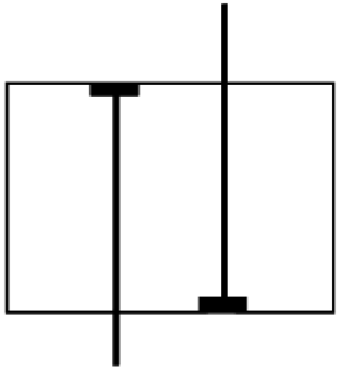
Types of Range Zones

- **1- A taxon-range biozone:** is a body of rock representing the known stratigraphic and geographic range of a chosen taxon.



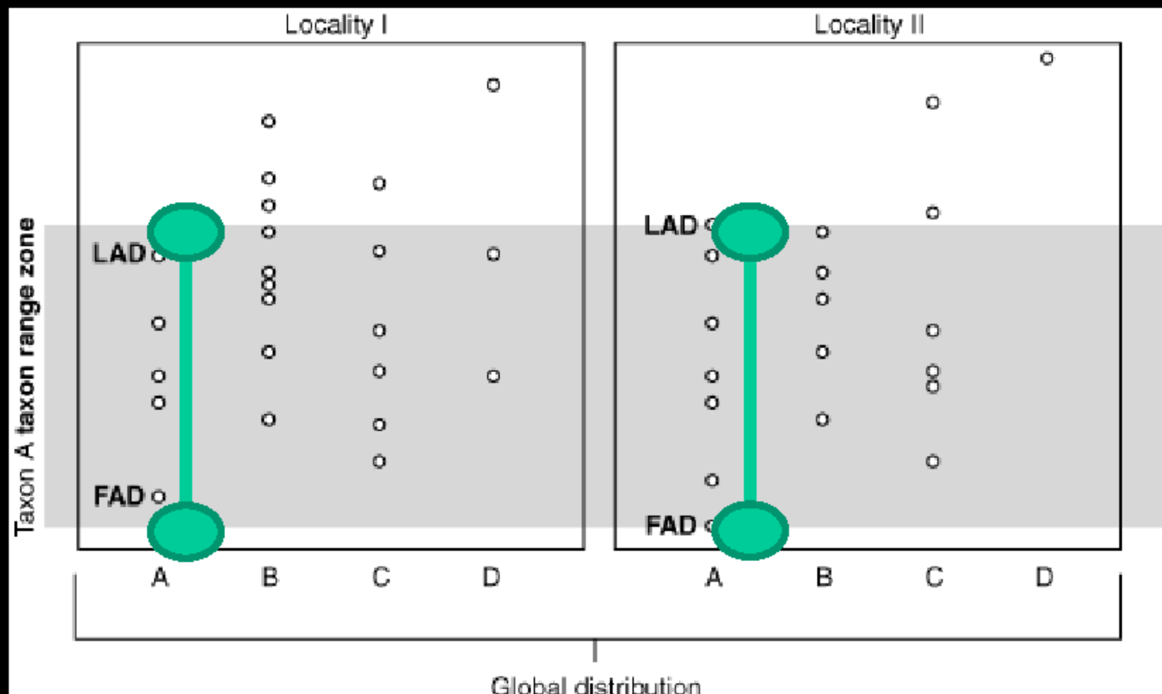
A. Taxon-range Biozone (based the range of a taxon).

- **2- A concurrent-range biozone:** is a body of rock including the concurrent, coincident, or overlapping part of the ranges of two specified taxa.



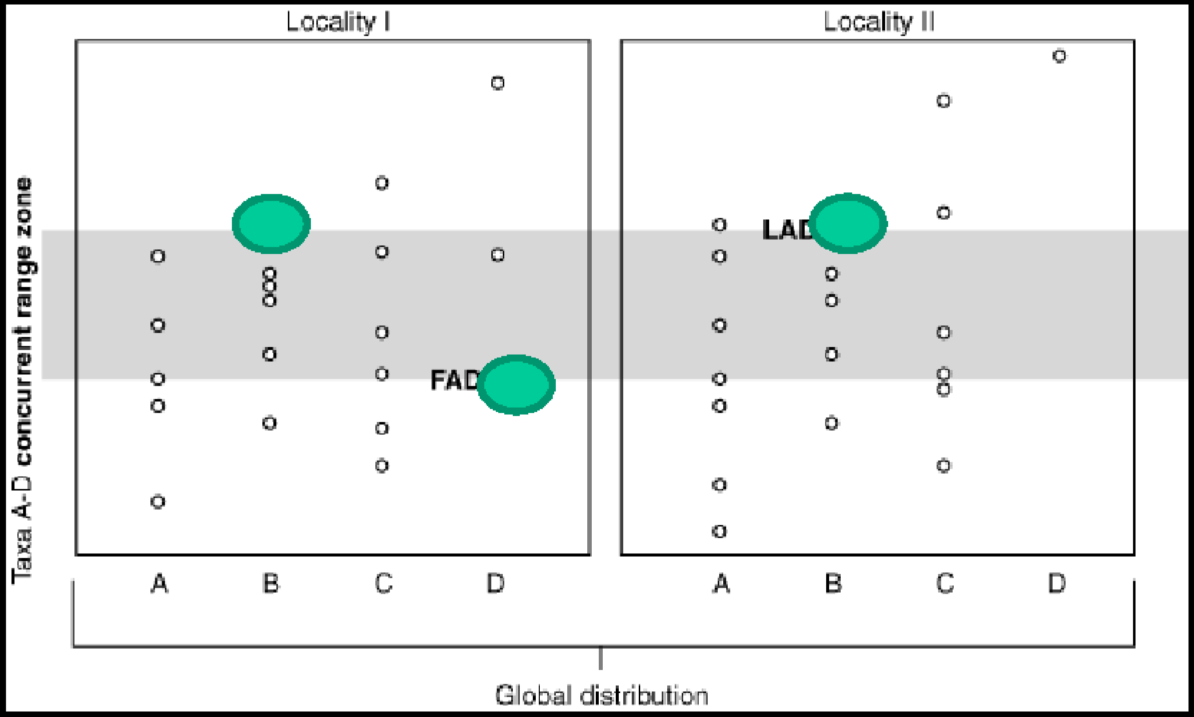
B. Concurrent-range Biozone (based on range of concurrent occurrences of two taxa).

Taxon Range Zone:
Between a FAD and a LAD for a given species



http://www.geol.umd.edu/~tholtz/G331/lectures/331strat.html

Concurrent Range Zone: FAD on Sp. D, LAD on Sp. B



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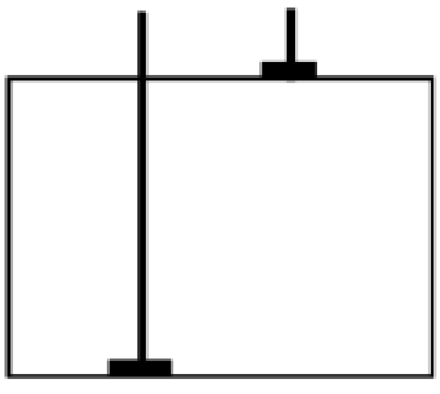
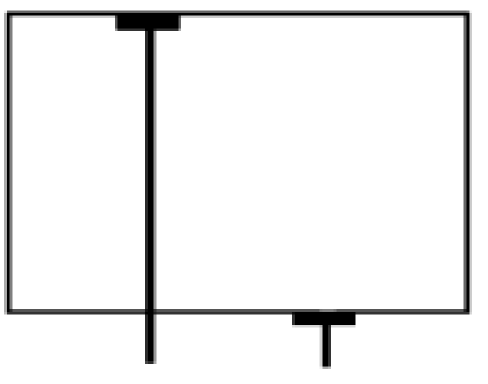
Interval Zone

- **An interval biozone** is a body of rock between two specified biostratigraphic surfaces (biohorizons). The features on which biohorizons are commonly based include lowest occurrences, highest occurrences, distinctive occurrences, or changes in the character of individual taxa (e.g., changes in the direction of coiling in foraminifera or in number of septa in corals).

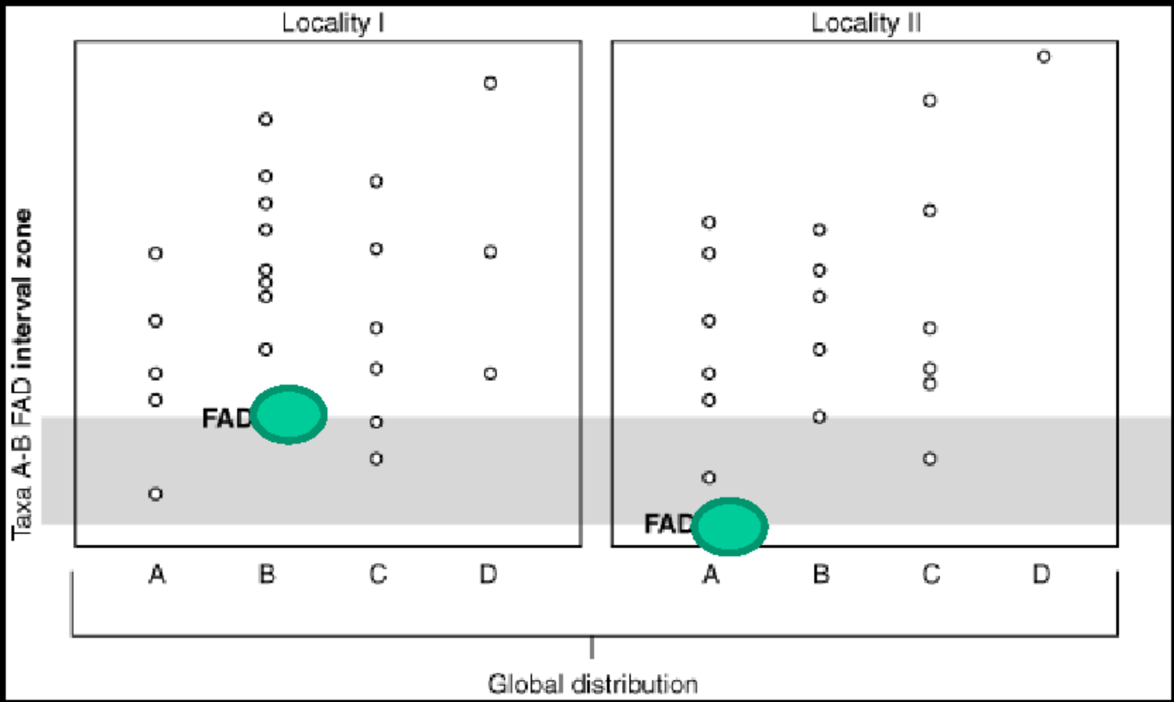


C. Interval Biozone (based on lowest occurrences).



D. Interval Biozone (based on highest occurrences).

Interval Zone:
Between two successive FADs or LADs



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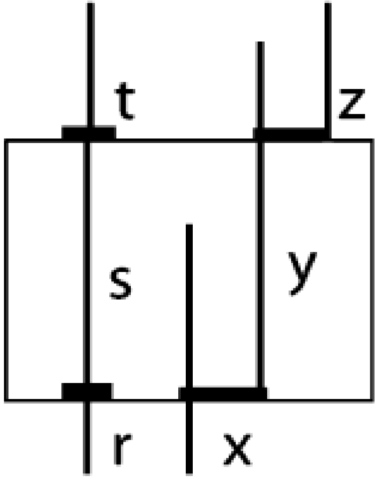
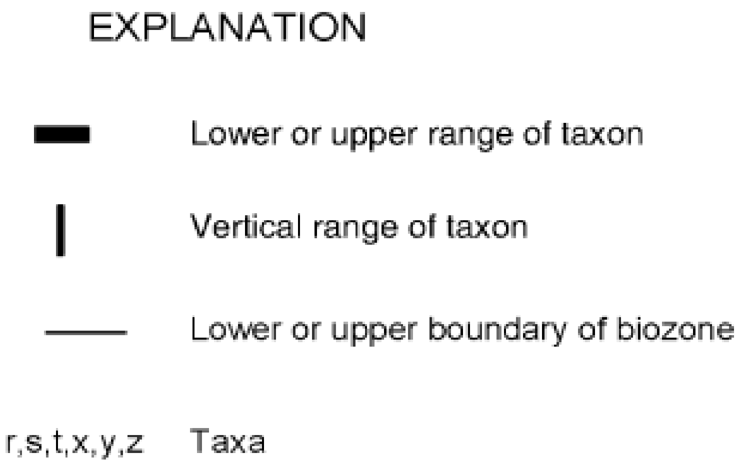
Lineage Biozone

- **A lineage biozone** is a body of rock containing species representing a specific segment of an evolutionary lineage.

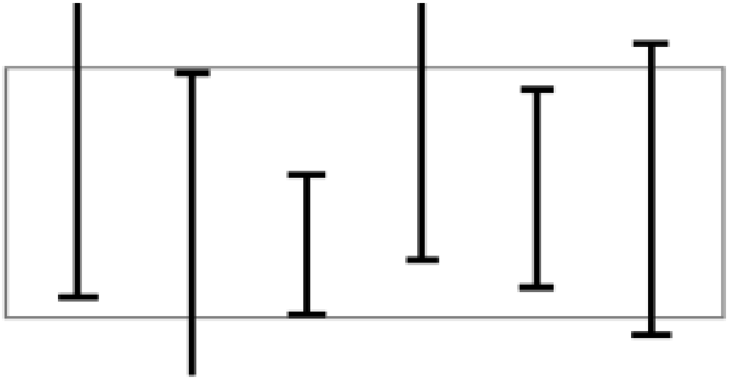


E. Lineage Biozone (based on successive elements in a segment of an evolutionary lineage).



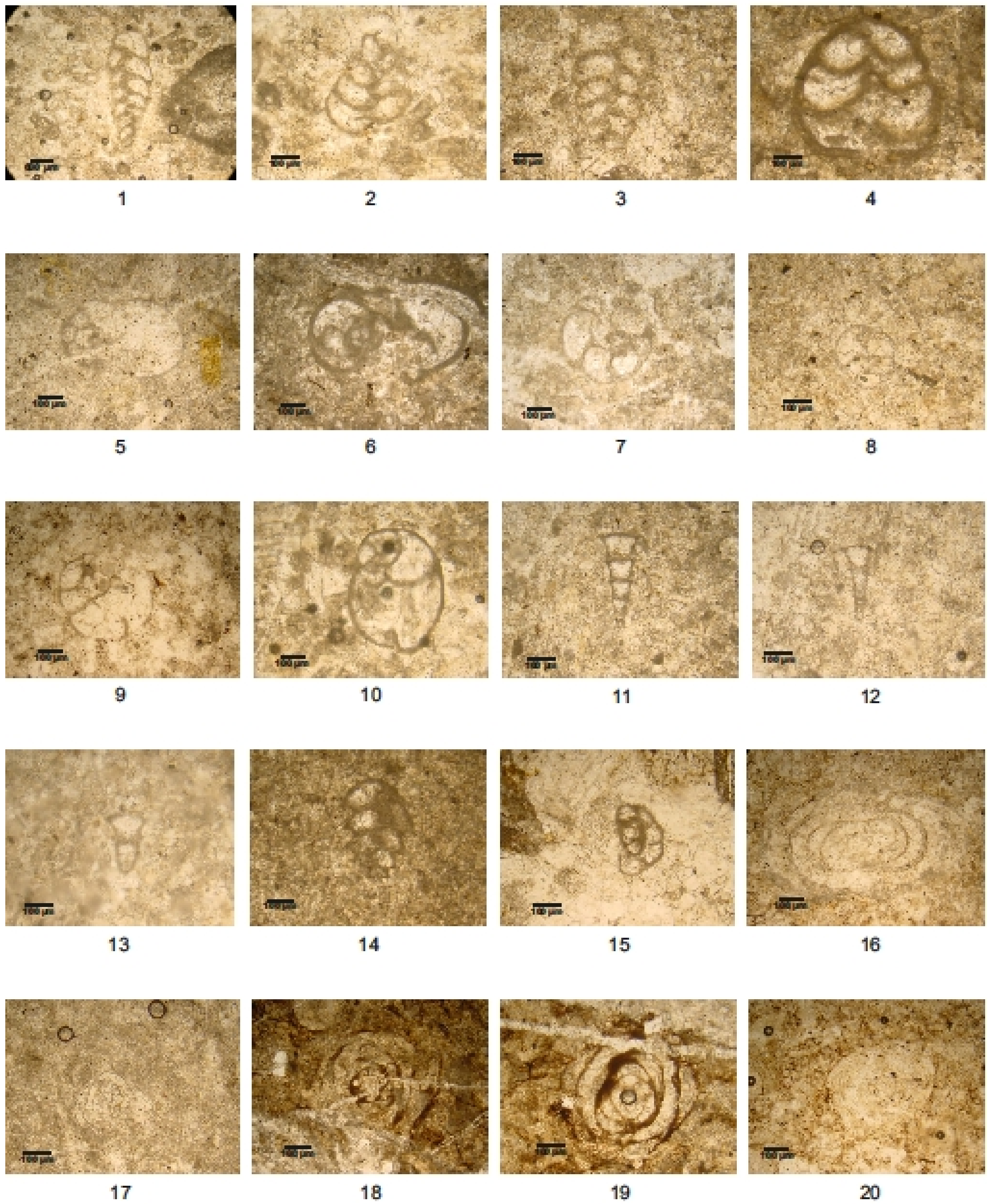
Assemblage Biozone

- **An assemblage biozone** is a body of rock characterized by a unique association of three or more taxa, the association of which distinguishes it in biostratigraphic character from adjacent strata. An assemblage biozone may be based on a single taxonomic group, for example, trilobites, or on more than one group, such as acritarchs and chitinozoans.



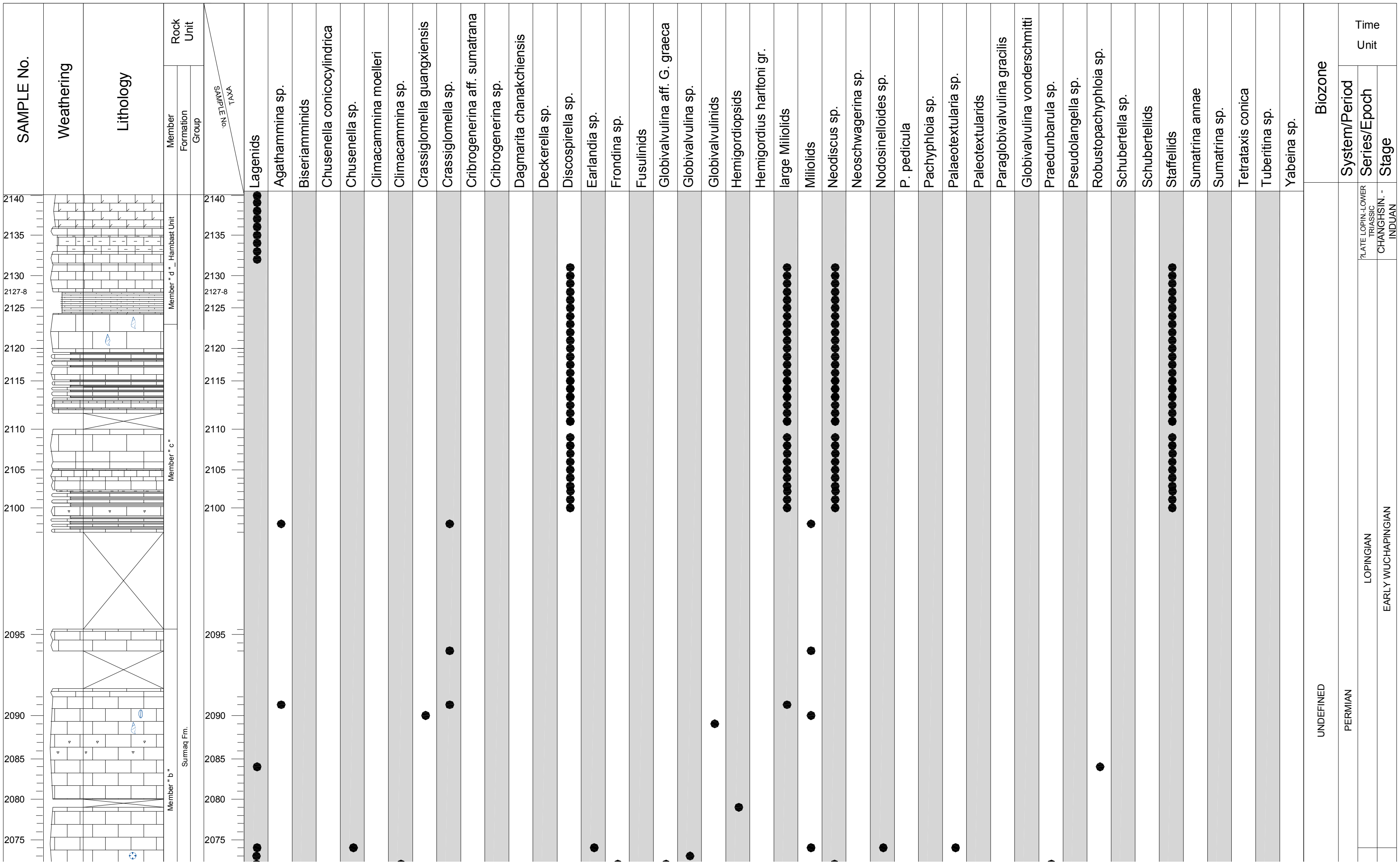
A. Assemblage Biozone (based on the overlapping ranges of an assemblage of co-occurring taxa).

Plate 4



Shareza succession, Central Iran, courtesy of R. Rettori

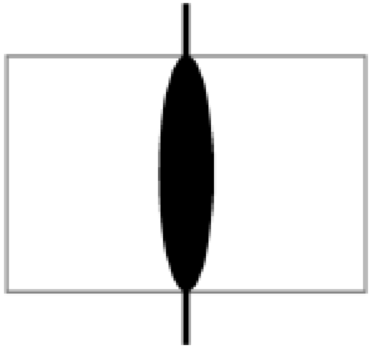
example



Shareza succession, Central Iran, courtesy of R. Rettori

Abundance Biozone

- **An abundance biozone** is a body of rock in which the abundance of a particular taxon or specified group of taxa is significantly greater than in adjacent parts of the section.
- *Abundance zones may be of limited, local utility because abundances of taxa in the geologic record are largely controlled by paleoecology, taphonomy, and diagenesis. The only unequivocal way to identify a particular abundance zone is to trace it laterally.*



B. Abundance Biozone (thickened line denotes range of increased abundance of the taxon).

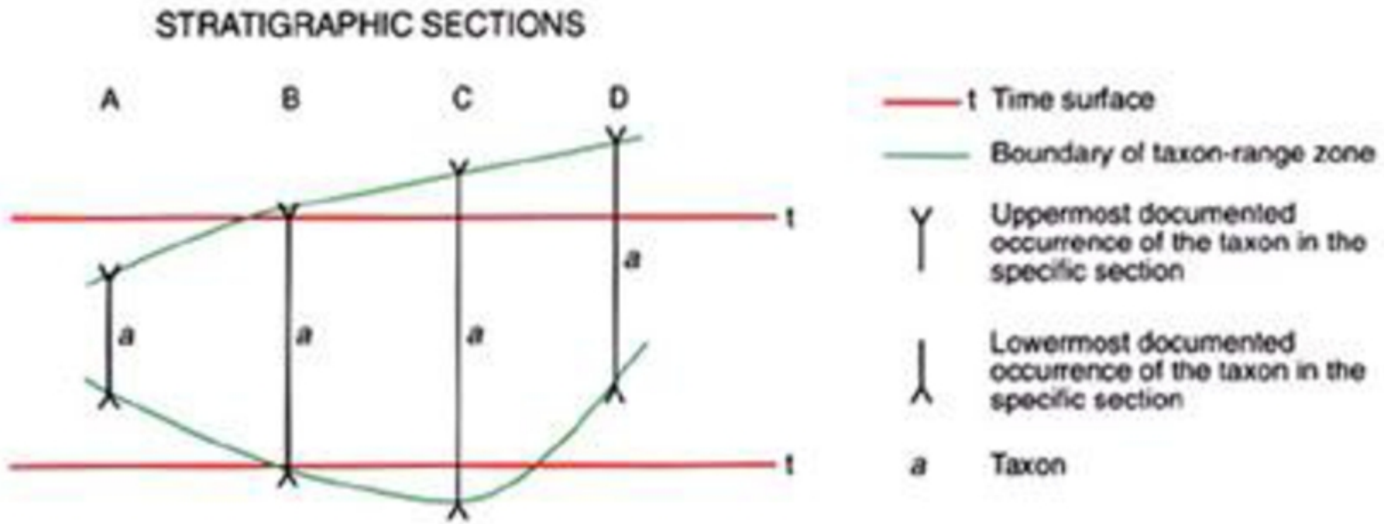


Figure 1: Taxon-range Zone. The lower, upper, and lateral limits of this zone are determined by the range of occurrence of taxon *a*.

Hedberg and Salvador, 1994

http://www.stratigraphy.org/upload/bak/bio.htm

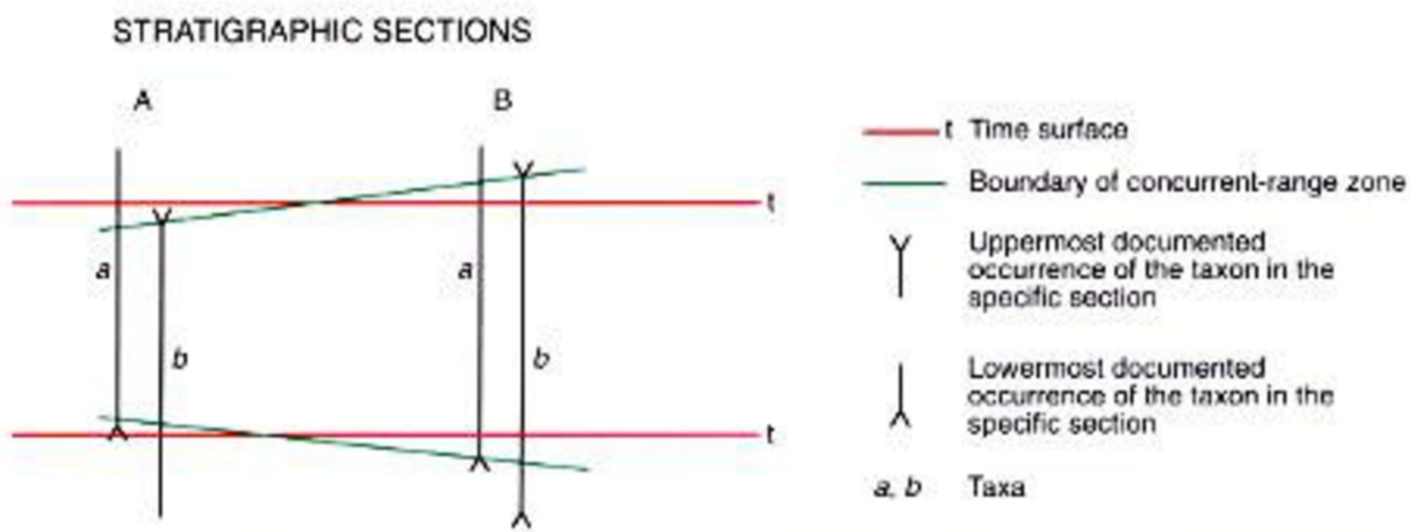


Figure 2: Concurrent-range Zone. The lower, upper, and lateral limits of this zone are determined by the range of concurrent occurrence of taxa *a* and *b*.

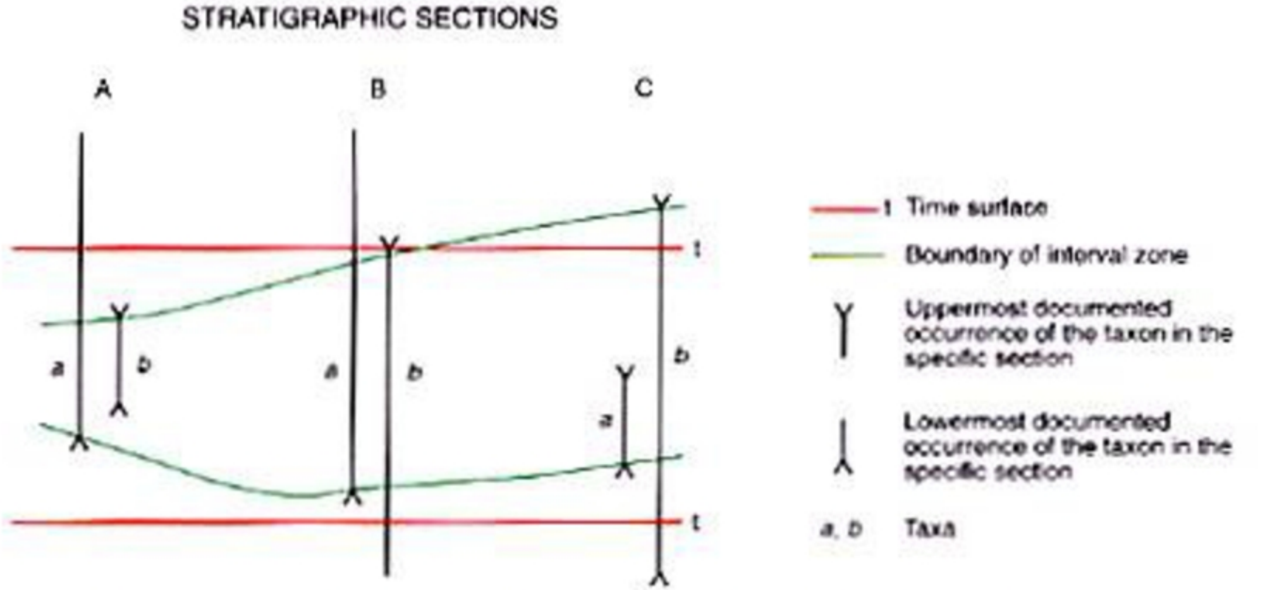


Figure 3: Interval Zone. In this example, the lower limit of the zone is the lowermost known occurrence of taxon *a*, and the upper limit is the highest known occurrence of taxon *b*. The zone extends laterally as far as both of the defining biohorizons can be recognized.

Hedberg and Salvador, 1994

http://www.stratigraphy.org/upload/bak/bio.htm

Ranges may or may not be concurrent.

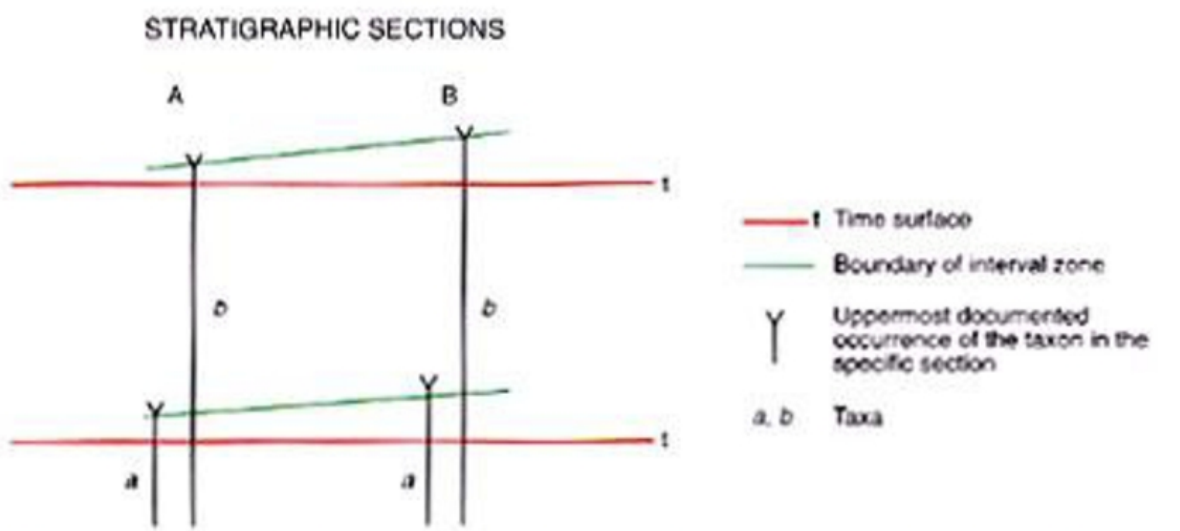


Figure 4: Interval Zone (Highest-occurrence Zone). This kind of interval zone is particularly useful in subsurface work.

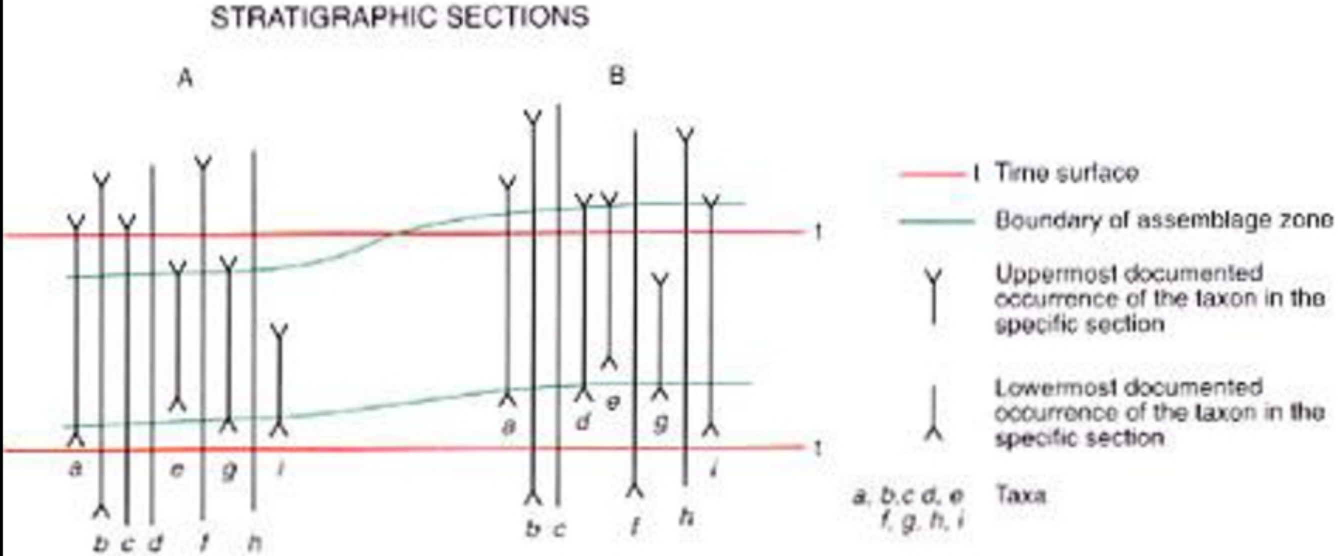


Figure 6: Assemblage Zone. In this example, the assemblage diagnostic of the zone includes nine taxa with diverse stratigraphic ranges. For this assemblage zone to be useful, it may be necessary to provide some explicit description of its boundaries: for example, the lower boundary can be said to be placed at the lowermost occurrence of taxa *a* and *g* and the upper boundary at the highest occurrence of taxon *e*. Most of the taxa of the assemblage characteristic of the zone should, however, be present.

Hedberg and Salvador, 1994

http://www.stratigraphy.org/upload/bak/bio.htm

Not commonly used.

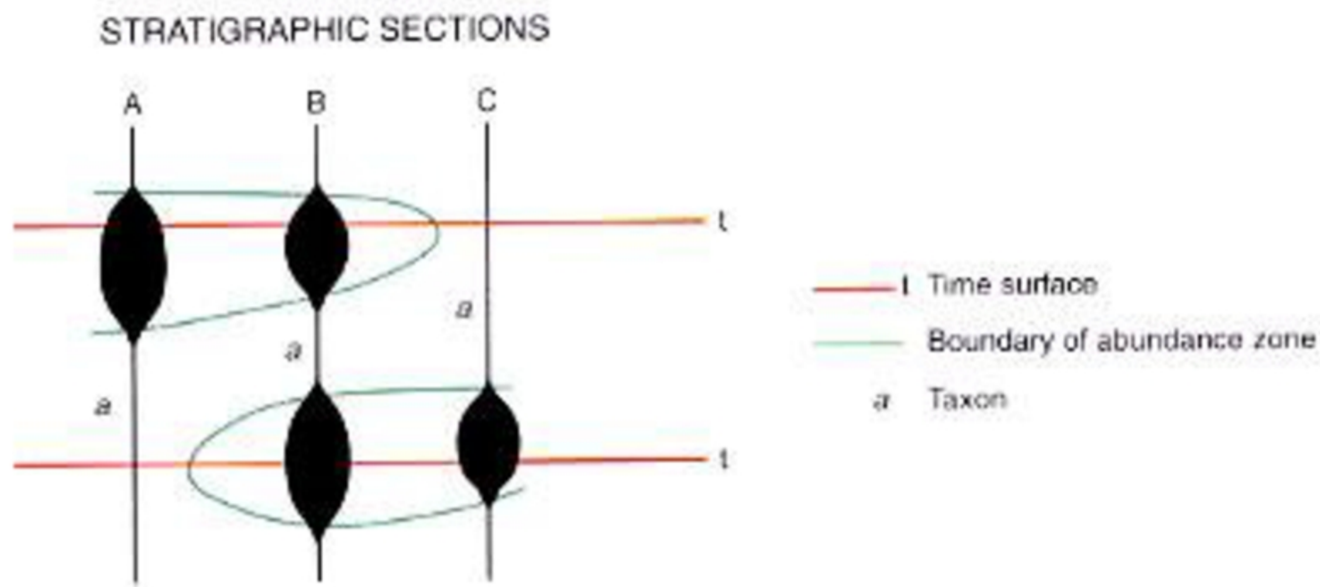


Figure 7: Abundance zones.

Can be diachronous.

Boundaries (Biohorizones)

- The boundaries of a biozone are drawn at surfaces that mark the lowest occurrence, highest occurrence, limit, increase in abundance, or decrease in abundance of one or more components of the fauna or flora.
- Note// the base or top of one kind of biozone may not, or need not, coincide with the base or top of another kind of biozone.

Name of Biozone

- **The name of a biozone** consists of the name of one or more distinctive taxa or parataxa (for trace fossils) found in the biozone, followed by the word ‵‵Biozone.”
- (e.g., *Turborotalia cerrozaulensis* Biozone or *Cyrtograptus lundgreni-Testograptus testis* Biozone).

- The name of the species whose lowest occurrence defines the base of the zone is the most common choice for the biozone name.
- Note// names of the nominate taxa, and hence the names of the biozones, conform to the rules of the international codes of zoological or botanical nomenclature or, in the case of trace fossils, internationally accepted standard practice.

Good Zone Fossils

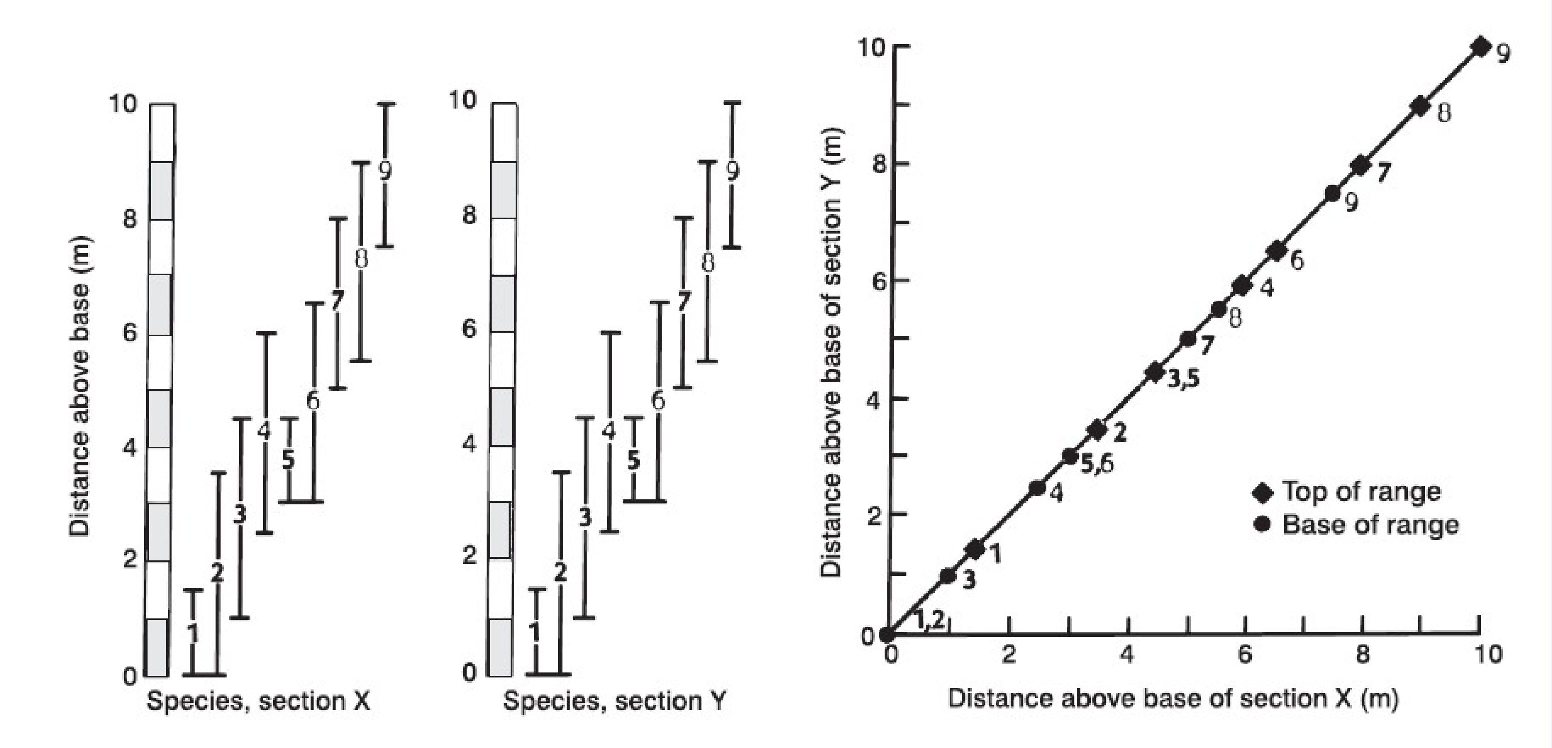
- Any fossil group can be used for zoning. But since the aim is to recognize the smallest time intervals over the widest area, zone fossils should ideally have the following characteristics:
  - 1- A relatively wide paleogeographic range, usually marking wide ecological tolerances.
  - 2- Limited vertical time range of species.
  - 3- Easily recognized changes of taxonomic features on the skeleton.
  - 4- Floating, swimming, or flying forms.
  - 5- Capable to being preserved.
  - 6- Relatively abundant.

Graphic correlation with fossils

Alan Shaw's (1964) methods

➢ **Perfect 45° correlation line:**

- If the two sections have the same rang of fossil species
- the section must have accumulated at the same rate.



Base and tops of ranges ploton a stright line at 45° correlation in two identical sections (Prothero, 1990 in Brookfiled, 2004)

One of the most commonly used biozones in biostratigraphy is the **Taxon range biozone** representing the range of occurrence of a single taxon.

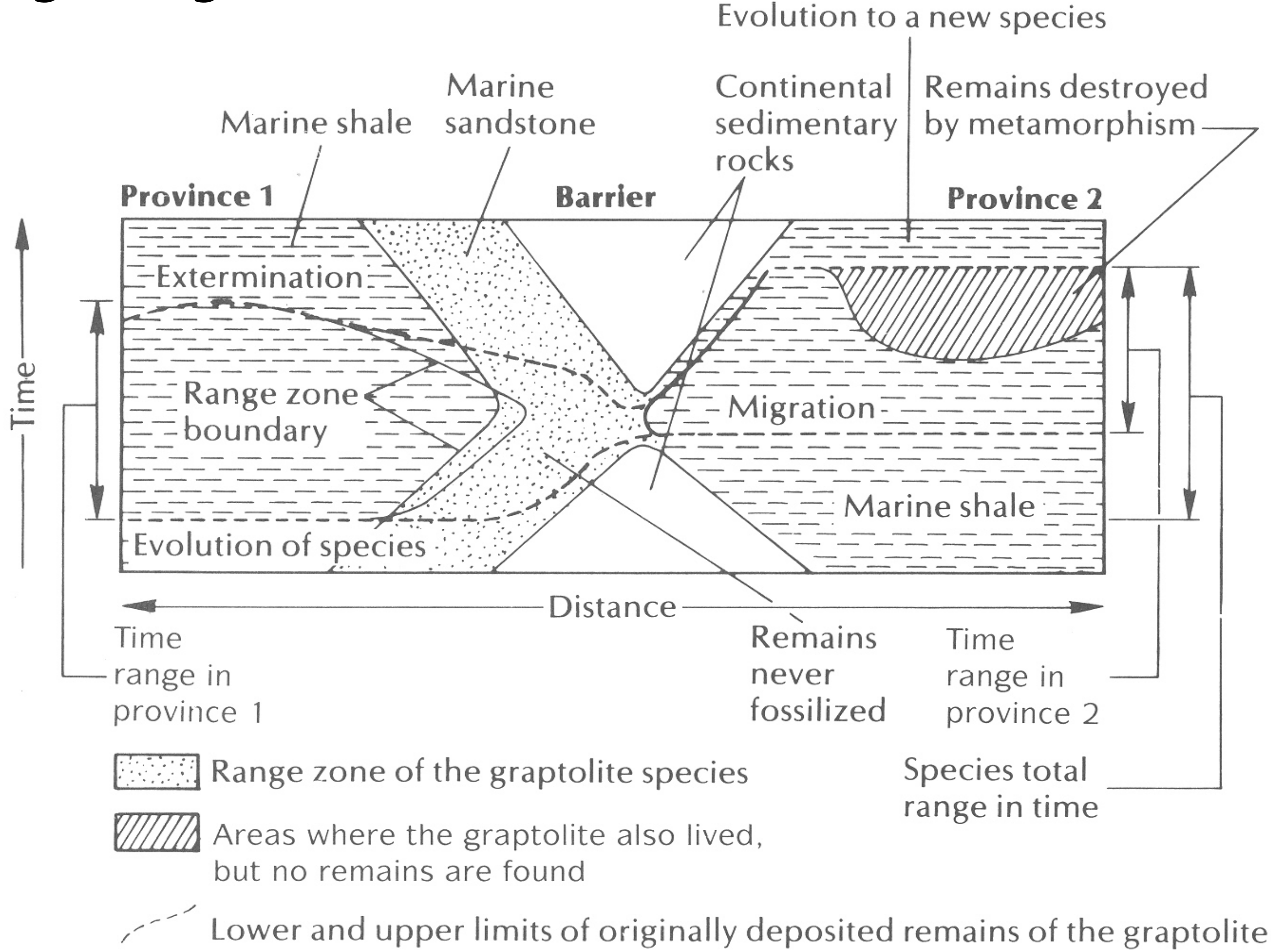
This range is comprised between the **First Appearance Datum (FAD)**, which designates the first (oldest) **appearance on Earth** (**speciation event**) of the taxon, and the **Last Appearance Datum (LAD)**, which designates the last (youngest) presence on Earth of that taxon and consequently its disappearance from Earth (**extinction event**).

However, the fossil record is inherently imperfect (only a very small fraction of organisms become fossilized) and sediments do not always register faithfully speciation events that occur through time because sediments may contain hiata (absence of deposition, erosion) or be affected by changing environmental conditions that are variably favorable to that particular taxon. Therefore, the appearance or disappearance of a zone fossil in the rock record may be due to **changes in environment rather than be true speciation or extinction events**.

Hence, when dealing with rocks, biostratigraphers use the terms **First Occurrence (FO)** and **Last Occurrence (LO)** of a taxon to **approximate** its FAD (speciation) and LAD (extinction).

Reason why FAD&LAD ≠ FO&LO: Biogeography.

If the depositional environment has remained the same, the appearance of a taxon may be due to a speciation event. However, species may have already existed for a period of time in a different geographical location before **migrating** to the area of the studied section.



Reason why FAD&LAD ≠ FO&LO: Lazarus Effect

A Lazarus taxon is a taxon that disappears from one or more periods of the fossil record, only to appear again later. Lazarus taxa are **observational artifacts**: they disappear from the geologic record to reappear later in the geologic record because of **locally changing environmental conditions**, for example a regression that superposes continental sediments above marine sediments, followed by a transgression that re-establishes marine sedimentation. Lazarus taxa may also be **sampling artifacts** due to incomplete sampling of a rock succession or changing preservation efficiency of organisms during fossilization.

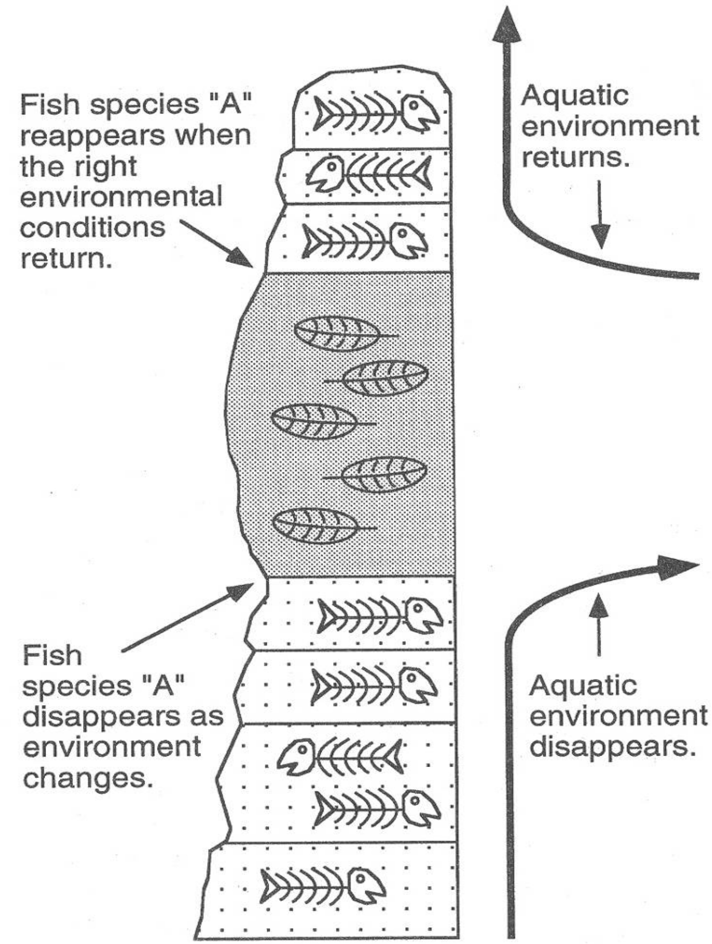


figure 10.12 The Lazarus effect. When a taxon disappears from the record, it is not necessarily its final extinction. It may have simply migrated out of the local region, or may be restricted to a refugium where it is not fossilized. It can then reappear higher in the section when the appropriate conditions return, like Lazarus rising from the dead. This is particularly critical for studies that focus on the taxa that disappear at a mass extinction level, and do not look higher in the section to see if the "extinct" taxon later reappears. (From Archibald, 1996a.)

Reason why FAD&LAD ≠ FO&LO: Zombie Effect!

A Zombie taxon refers to a fossil that was washed out of old sediments (by erosion) and re-deposited in sediments millions of years younger.

When this occurs the fossil is described as **reworked,** meaning that it comes from older sediments and from an evolutionary viewpoint, it has **nothing to do** with the age of the sediment where it is actually found.

Zombie taxa, if not understood for what they really are (i.e., reworked), can lead to huge mistakes in the interpretation of the age of the sediment.

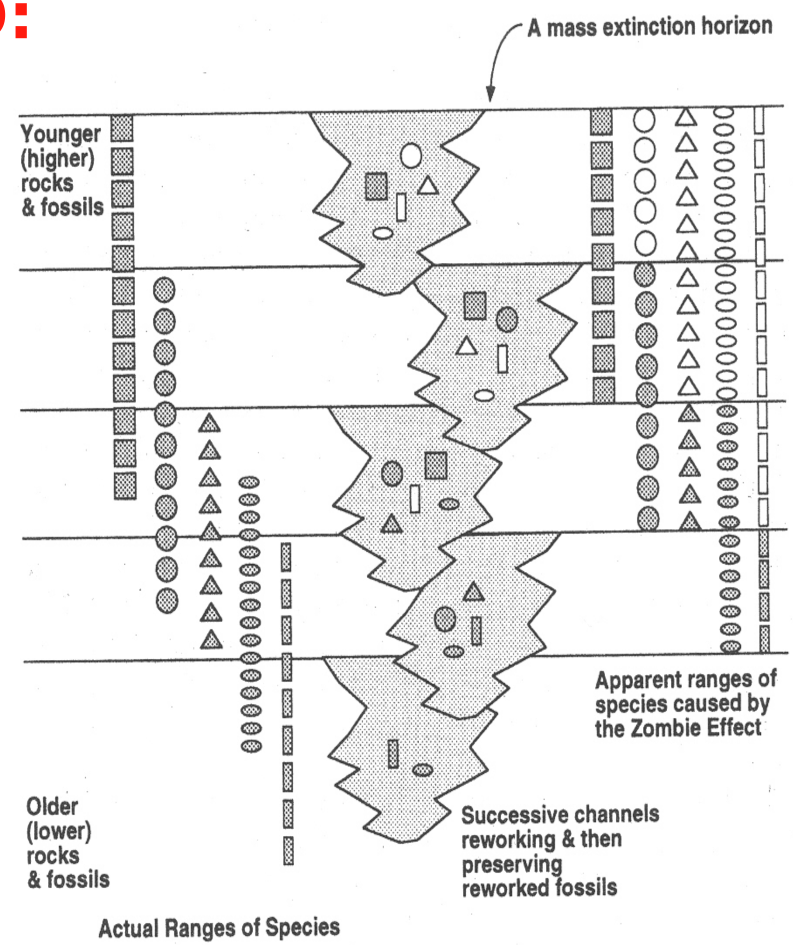


figure 10.13 The Zombie effect. Some fossils are remarkably durable when eroded out of older deposits, so that they can be redeposited into younger beds long after the original organism is extinct. This gives the false impression that they survived longer than they actually did. Fossils deposited during the time the organism lived are shown with the filled shapes in the channels; those reworked from older beds are indicated by unfilled shapes. (From Archibald, 1996a.)

Reason why FAD&LAD ≠ FO&LO: Infiltration Effect

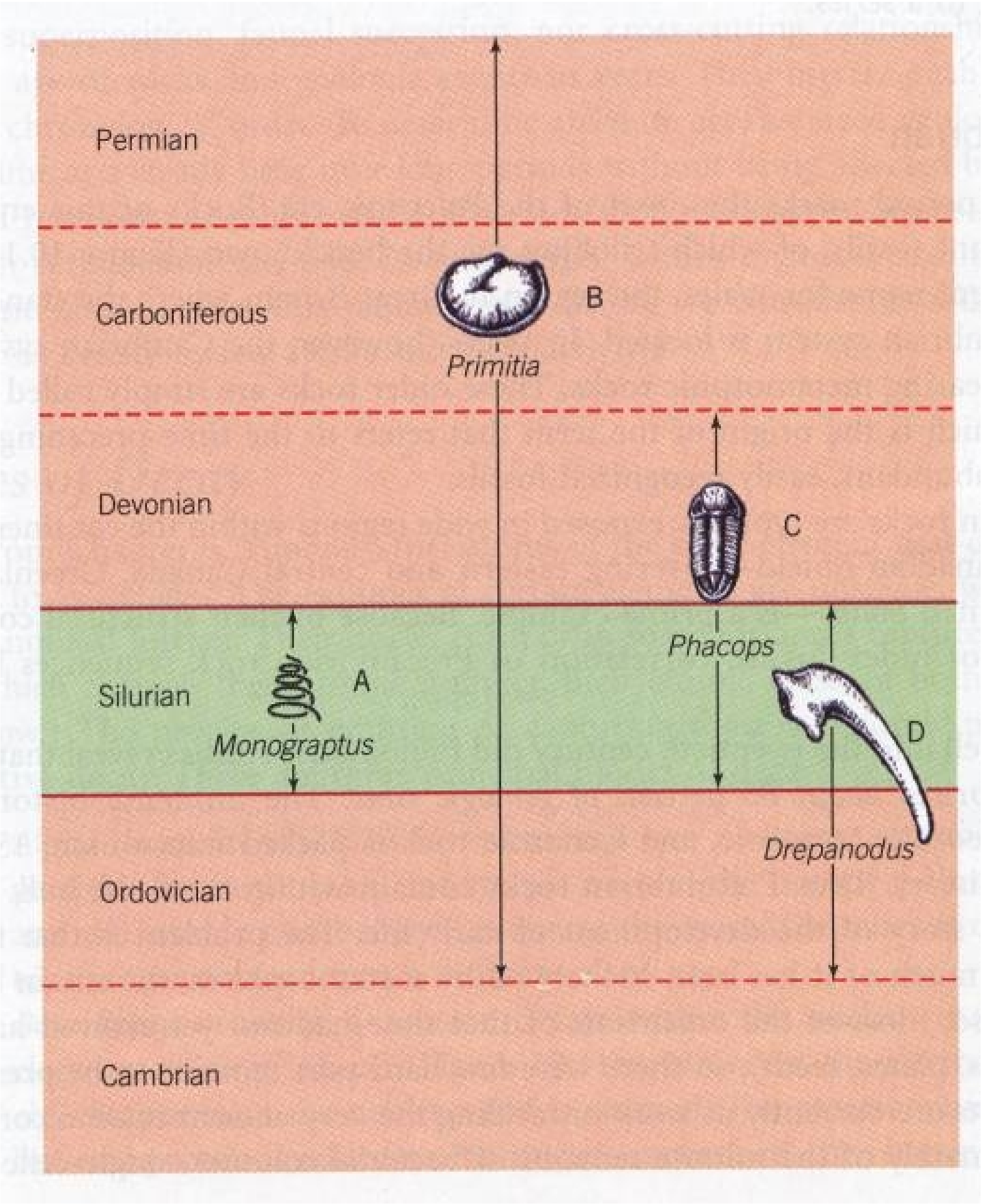
Introduced or infiltrated fossils are younger fossils introduced into older rocks by fluids, through animal burrows or root cavities, or by sedimentary dikes or diapirs. They should be distinguished from indigenous fossils in biostratigraphic zonation.

Reason why FAD&LAD ≠ FO&LO: Condensation

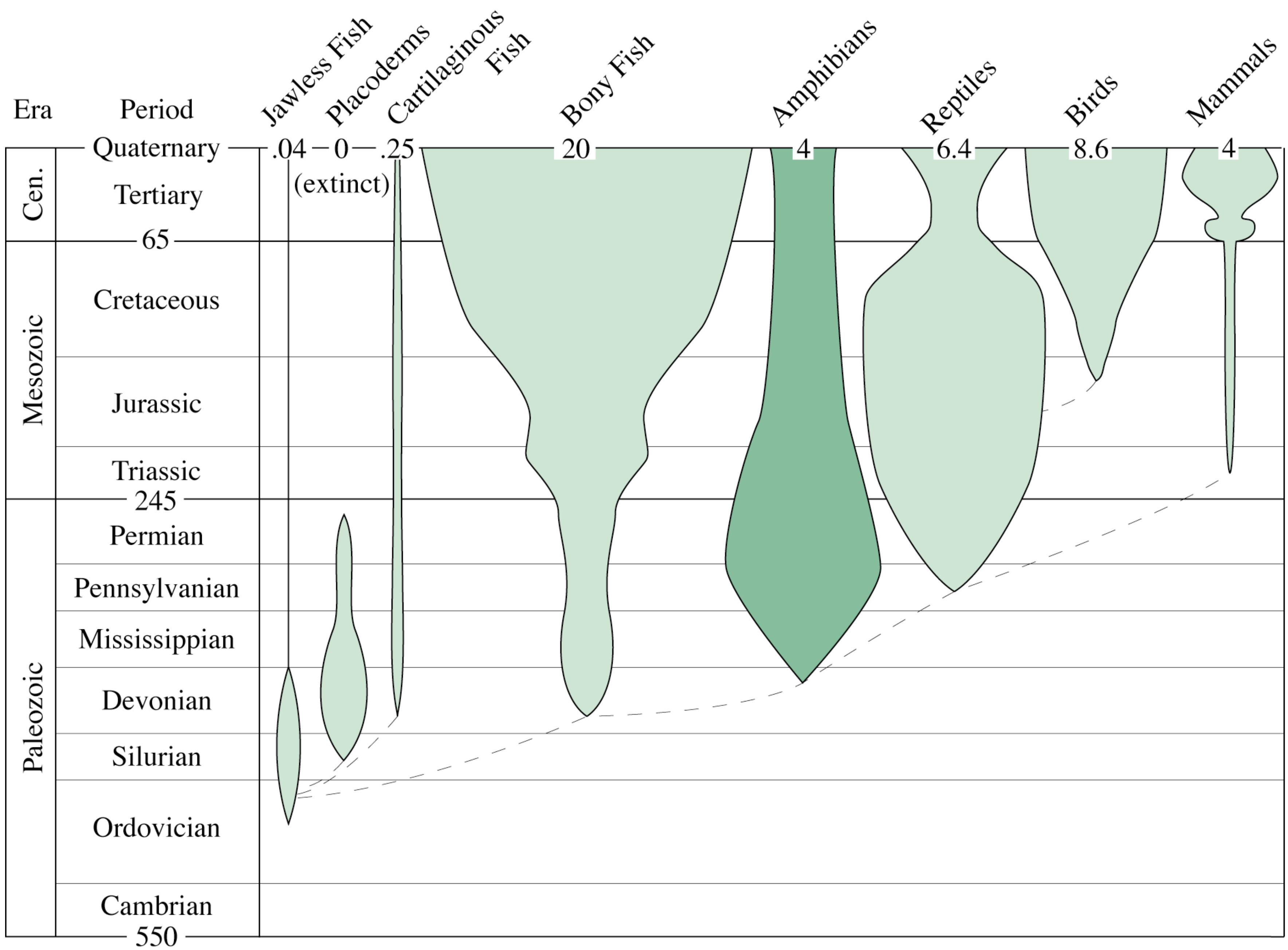
Effects of stratigraphic condensation. Extremely low rates of sedimentation may result in fossils of different ages and different environments being mingled or very intimately associated in a very thin stratigraphic interval, even in a single bed.

Biozones

- Taxon Range Zone?
- Concurrent Range Zone?
- Assemblage Zone?



Biozones



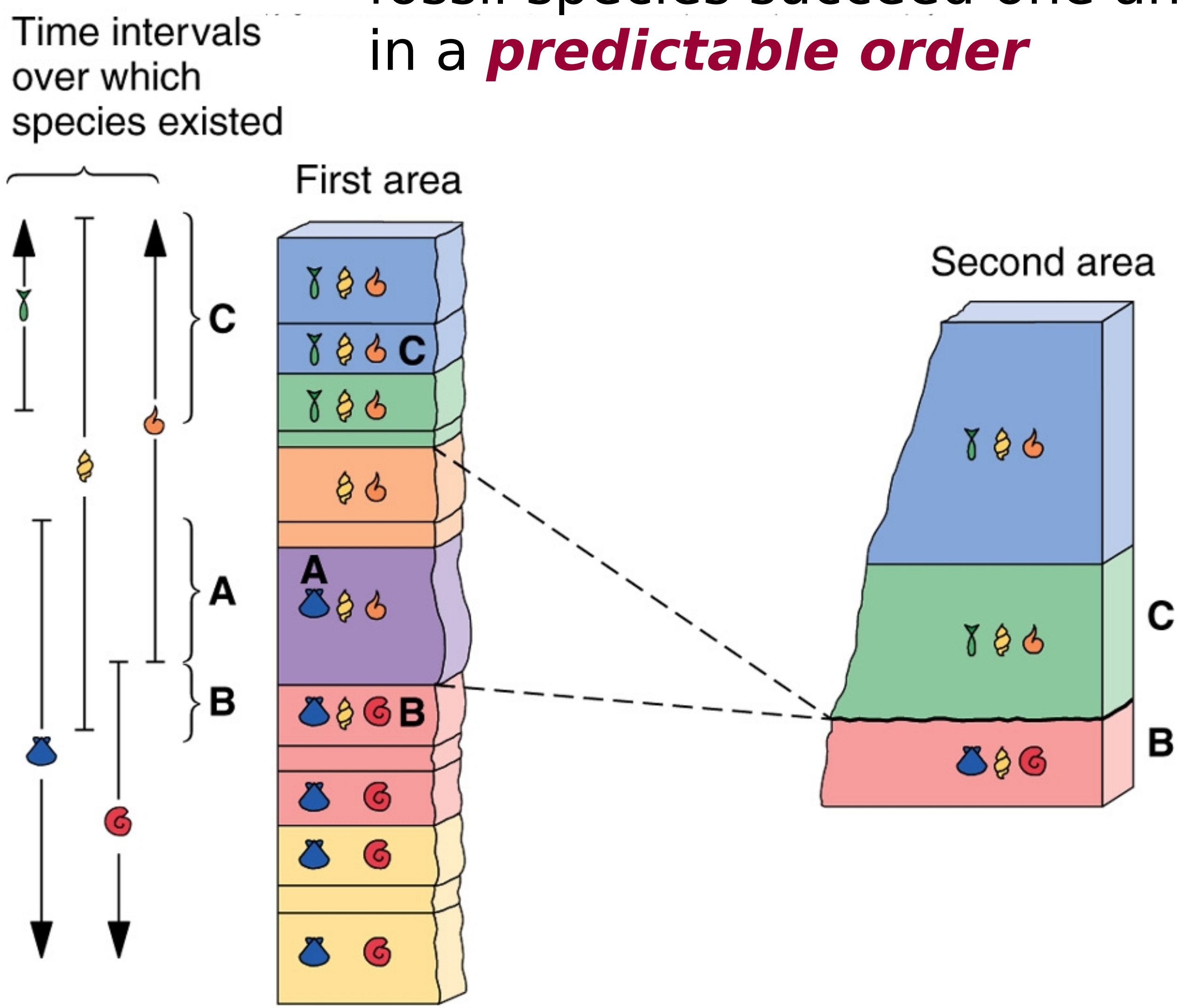
Era
Period
Jawless Fish
Placoderms
Cartilaginous Fish
Bony Fish
Amphibians
Reptiles
Birds
Mammals
Quaternary
.04
0
.25
20
4
6.4
8.6
4
(extinct)
Cen.
Tertiary
65
Mesozoic
Cretaceous
Jurassic
Triassic
245
Paleozoic
Permian
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
550

relative age: correlation

how is this done?

faunal succession (correlation by fossils)

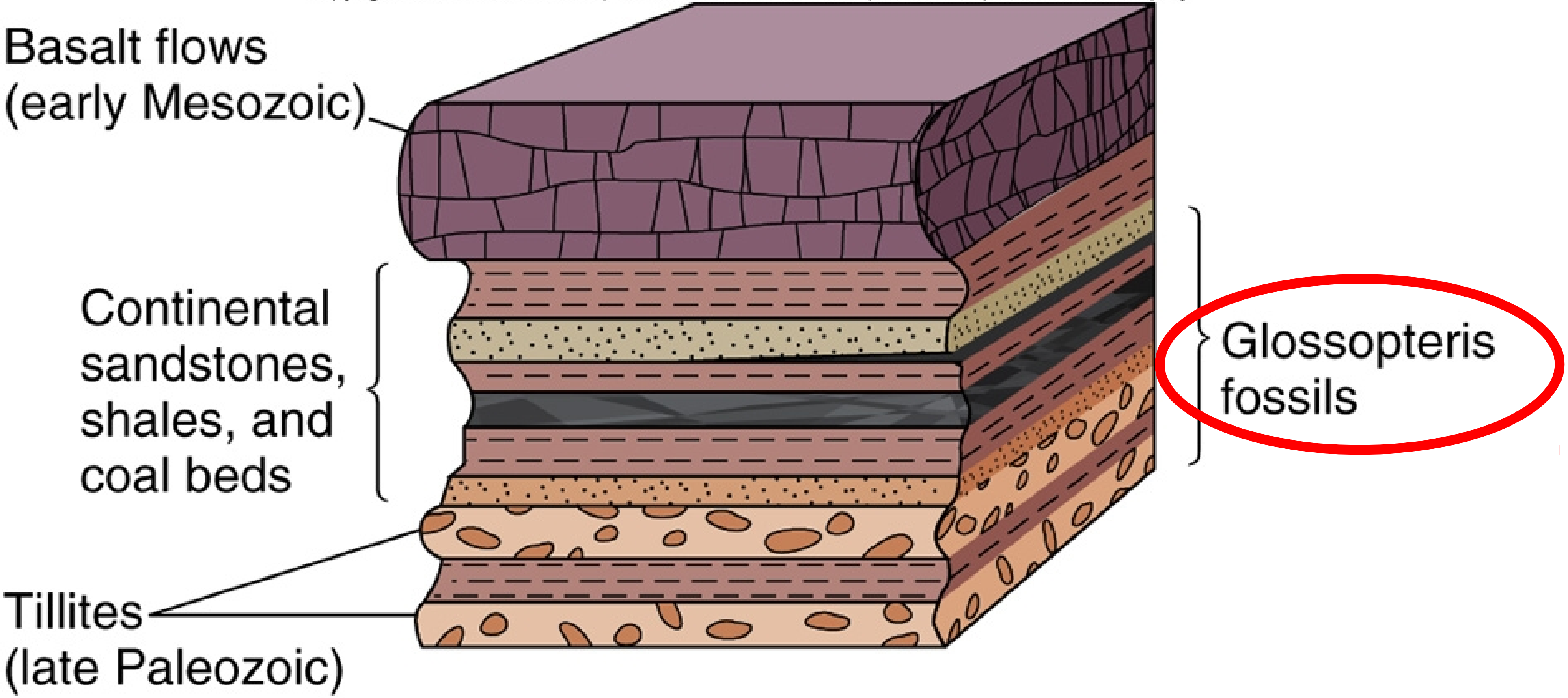
fossil species succeed one another through the layers in a ***predictable order***



index fossil
short-lived organism; points to narrow range of geologic time

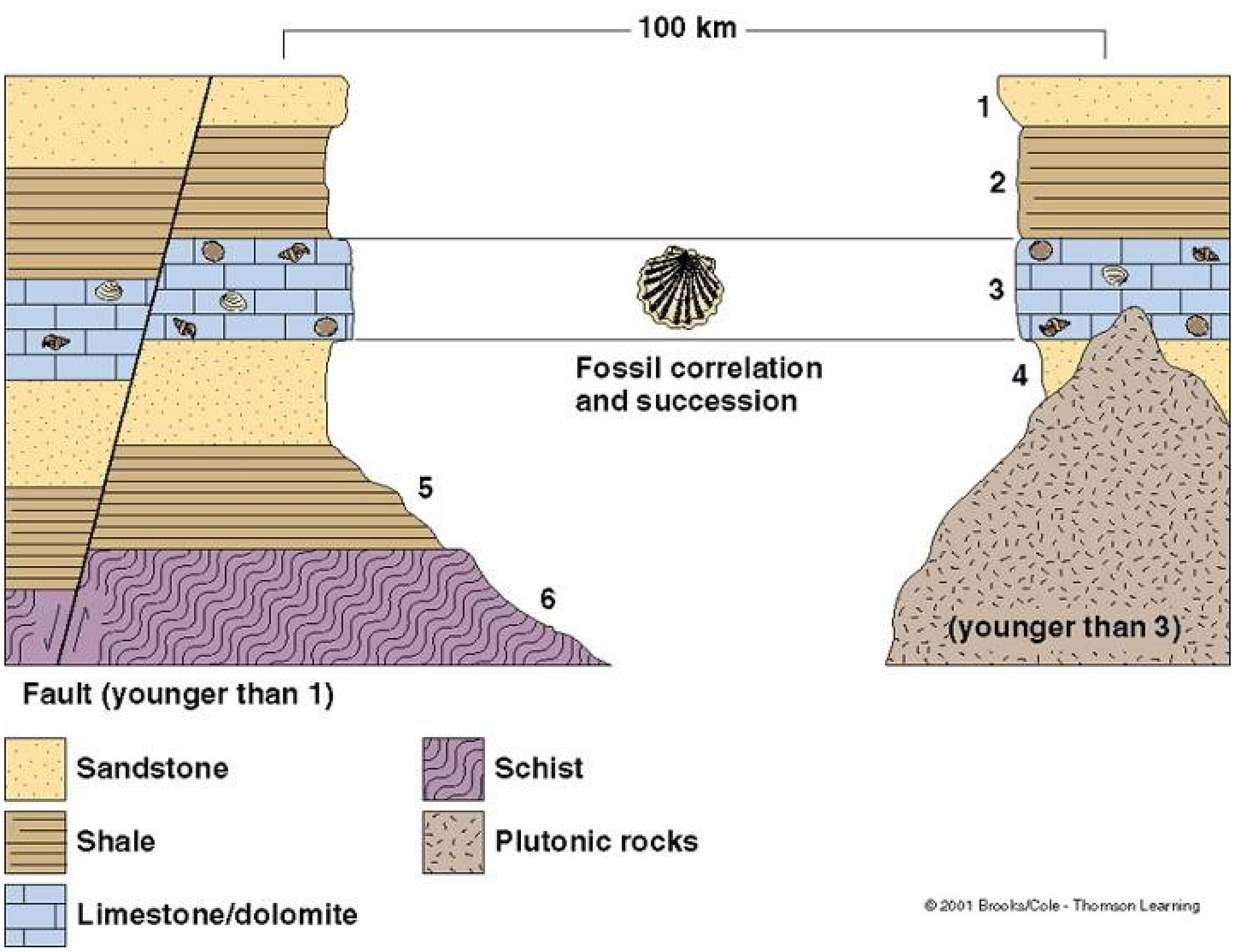
fossil assemblage
group of fossils associated together

use of index fossils/fossil assemblages permits global correlation

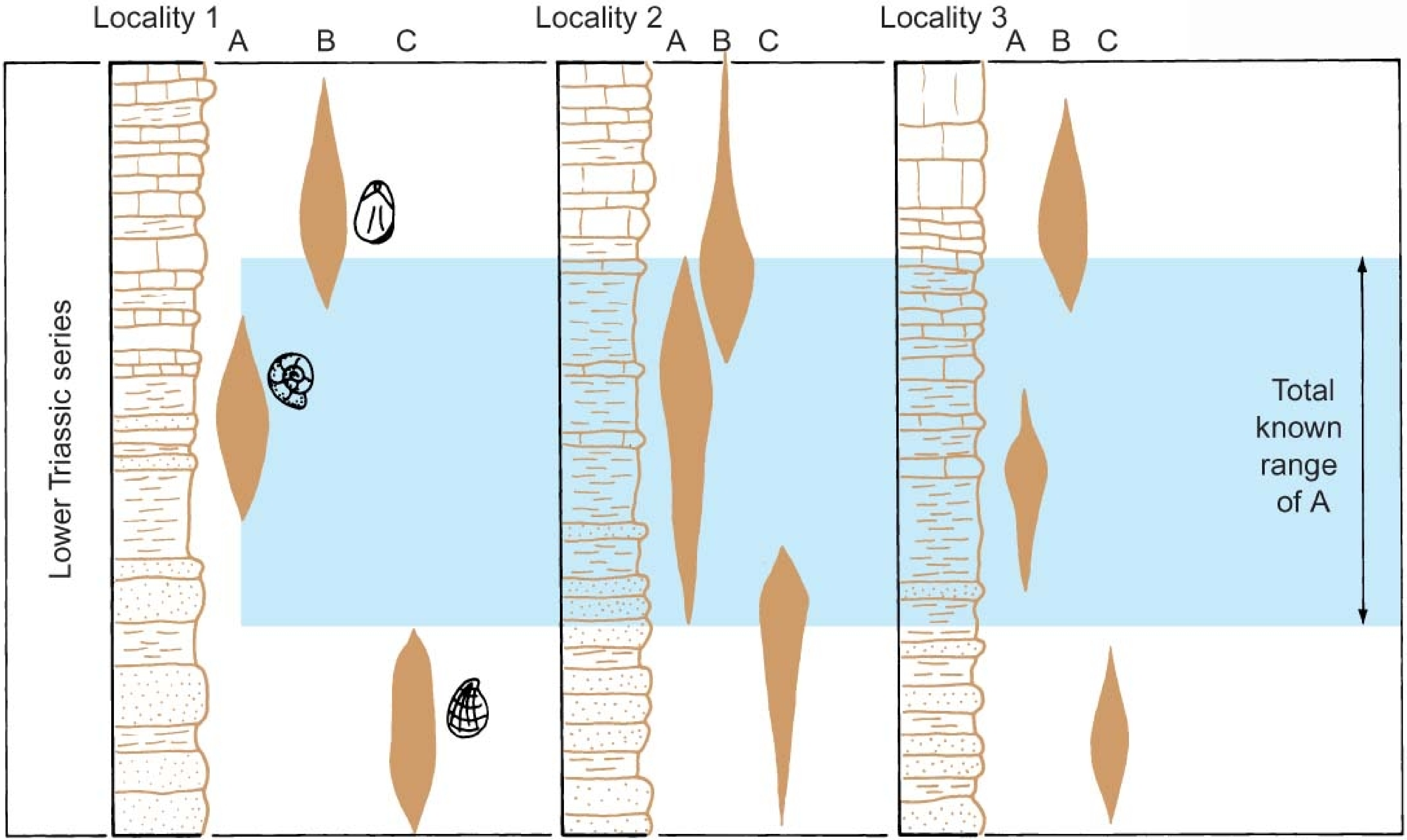


similar units found in India, Africa, S. America, Australia, Antarctica.

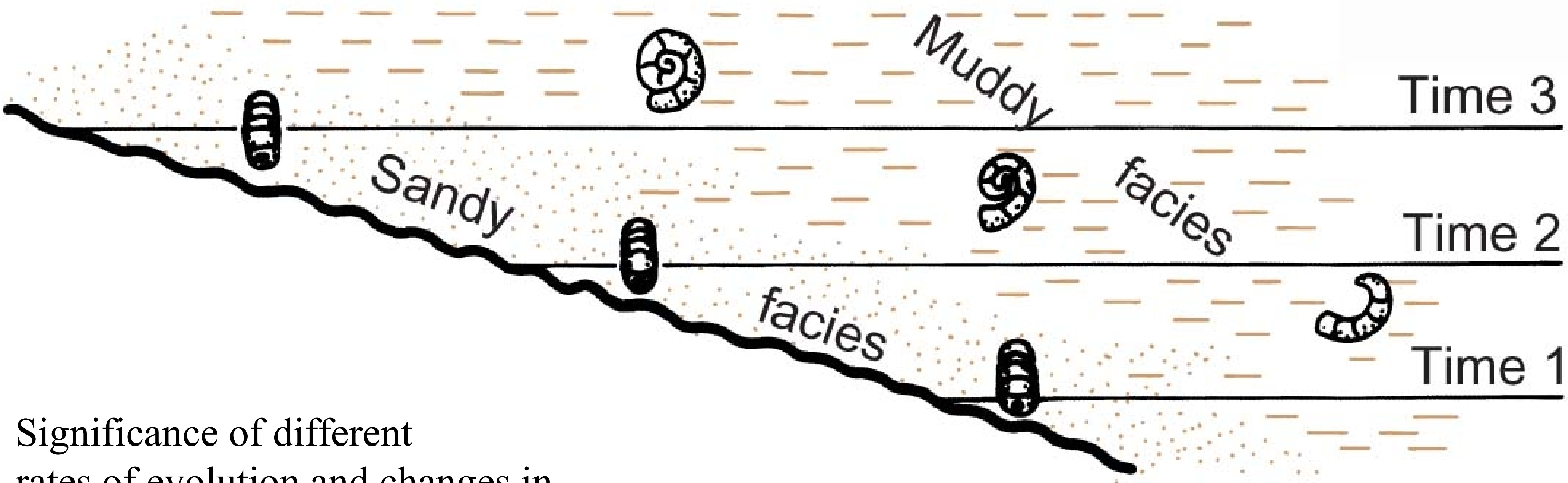
Correlation



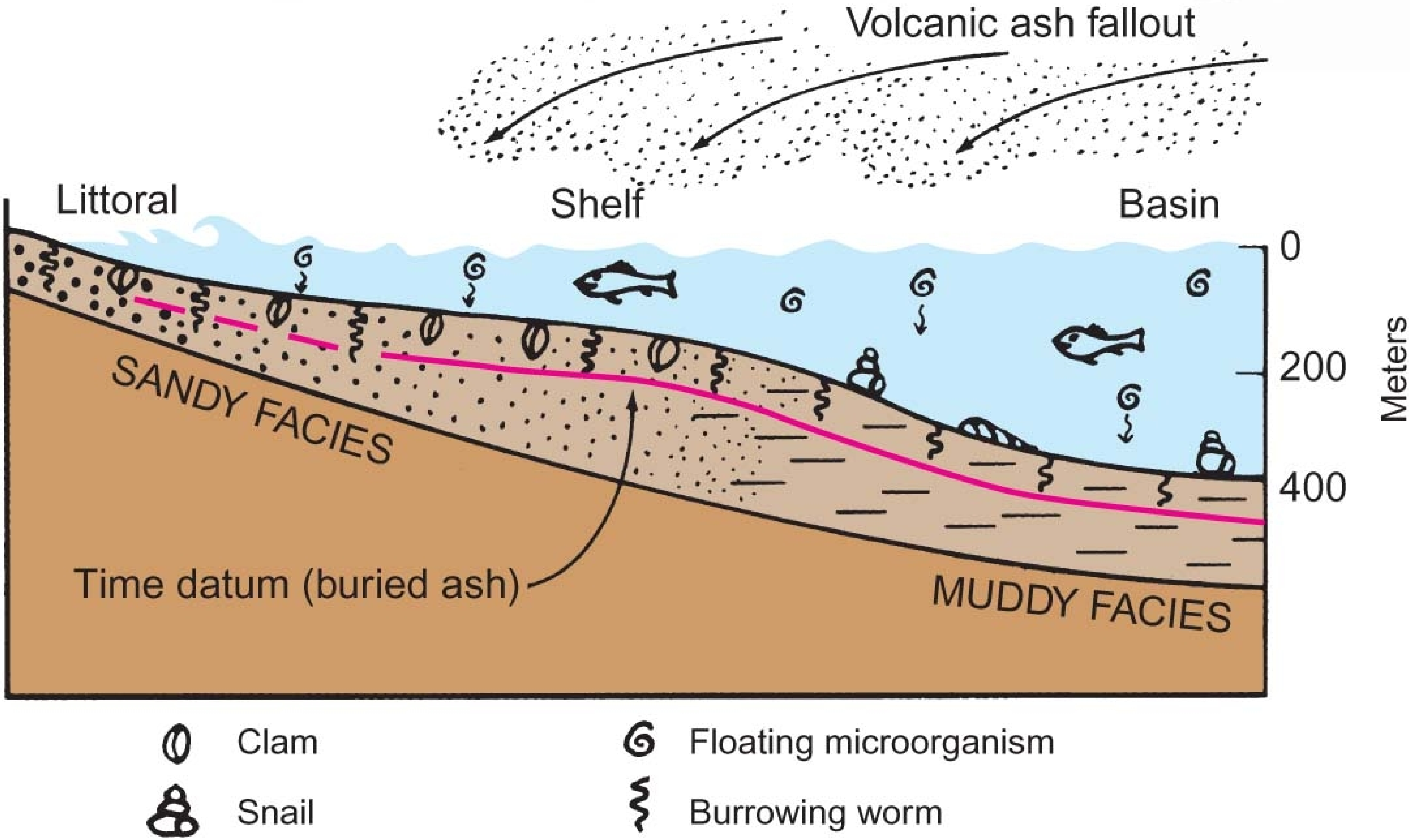
http://www.uwsp.edu/geo/faculty/ozsvath/images/stratigraphy.jpg



Correlation using three different index fossils. A single fossil zone is shown in blue. Note that range and maximum development (indicated by pattern width) vary from place to place.



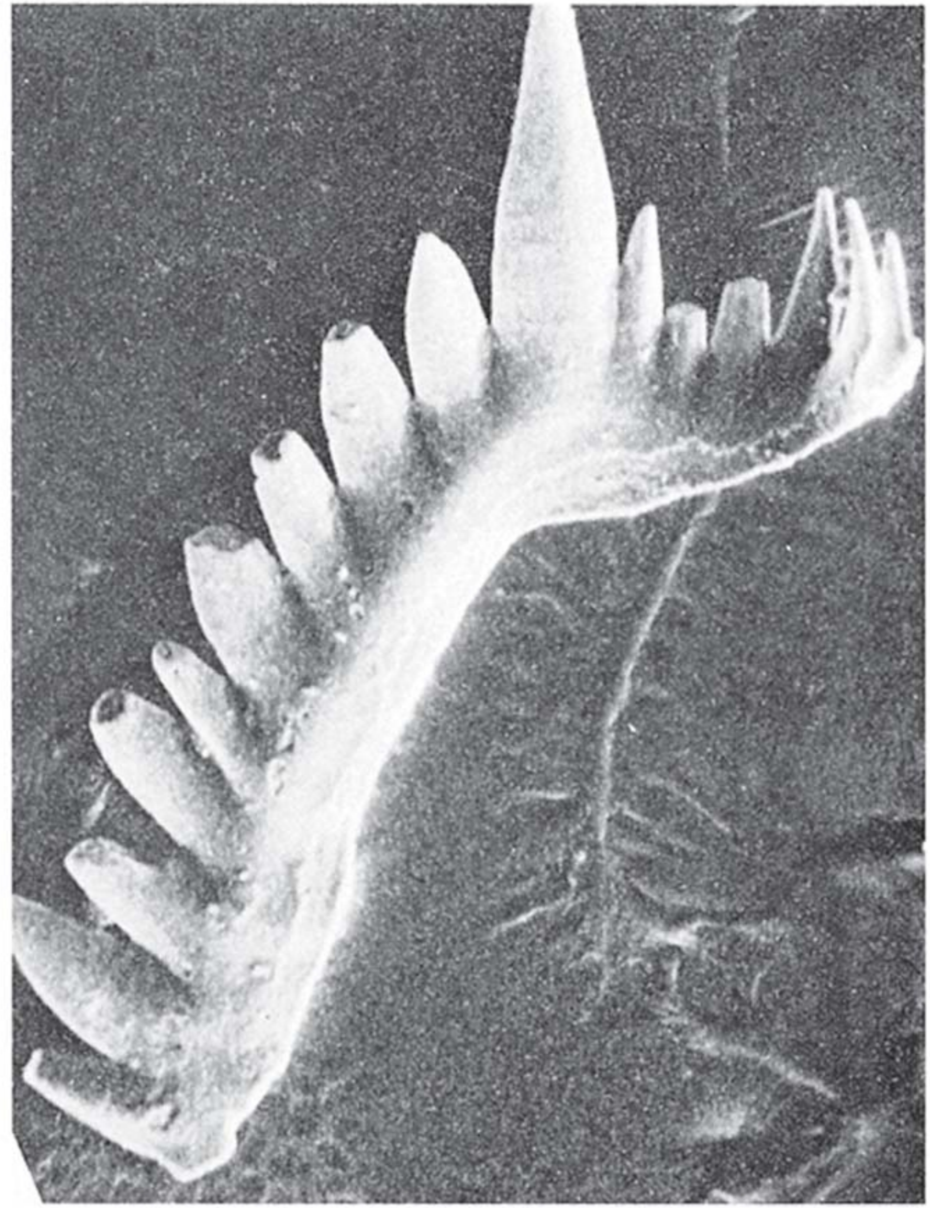
Significance of different
rates of evolution and changes in
environment (due to transgression). The
brachiopod evolved slowly and stayed in/on sand facies. The cephalopods evolved rapidly
and are free swimmers. They were changing and widely distributed and thus excellent
index fossils.



Volcanic ash layers (bentonites) make excellent time markers and permit correlations between facies (provided the ash layer is preserved).

Conodont.

A conodont is a preserved bony part of an extinct eel. It evolved rapidly and is widely distributed across many facies types. They are excellent index fossils and can be used to determine maximum burial temperatures as well. Conodont specialists were once highly sought after by oil companies.



Application of biostratigraphic studies

USING MICROFOSSILS IN PETROLEUM EXPLORATION

Microfossils have many applications to petroleum geology. The two most common uses are: biostratigraphy and paleoenvironmental analyses.

Biostratigraphy (as we saw before) is the differentiation of rock units based upon the fossils which they contain.

Paleoenvironmental analysis is the interpretation of the depositional environment in which the rock unit formed, based upon the fossils found within the unit.

There are many other uses of fossils besides these, including: paleoclimatology, biogeography, and thermal maturation.

There are a great number of different types of microfossils available for use. There are three groups which are of particular importance to hydrocarbon exploration. The three microfossil groups most commonly used are:

- foraminifera (attending the Micropaleontology course in your second year is kindly suggested);
- calcareous nannofossils;
- palynomorphs.

Foraminifera are protists that make a shell (called a "test") by secreting calcium carbonate or gluing together grains of sand or silt.
Most species of "forams" are bottom- dwellers (benthic), but during the Mesozoic Era a group of planktonic foraminifera arose.

Benthic foraminifera tend to be restricted to particular environments and as such provide information to the paleontologist about what the environment was like where the rock containing the fossils formed.

For example, certain species of foraminifera prefer the turbid waters near the mouths of rivers while others live only in areas of very clear water.
These preferences are recognized by two methods:

(1) studies of the distribution of modern foraminifera and

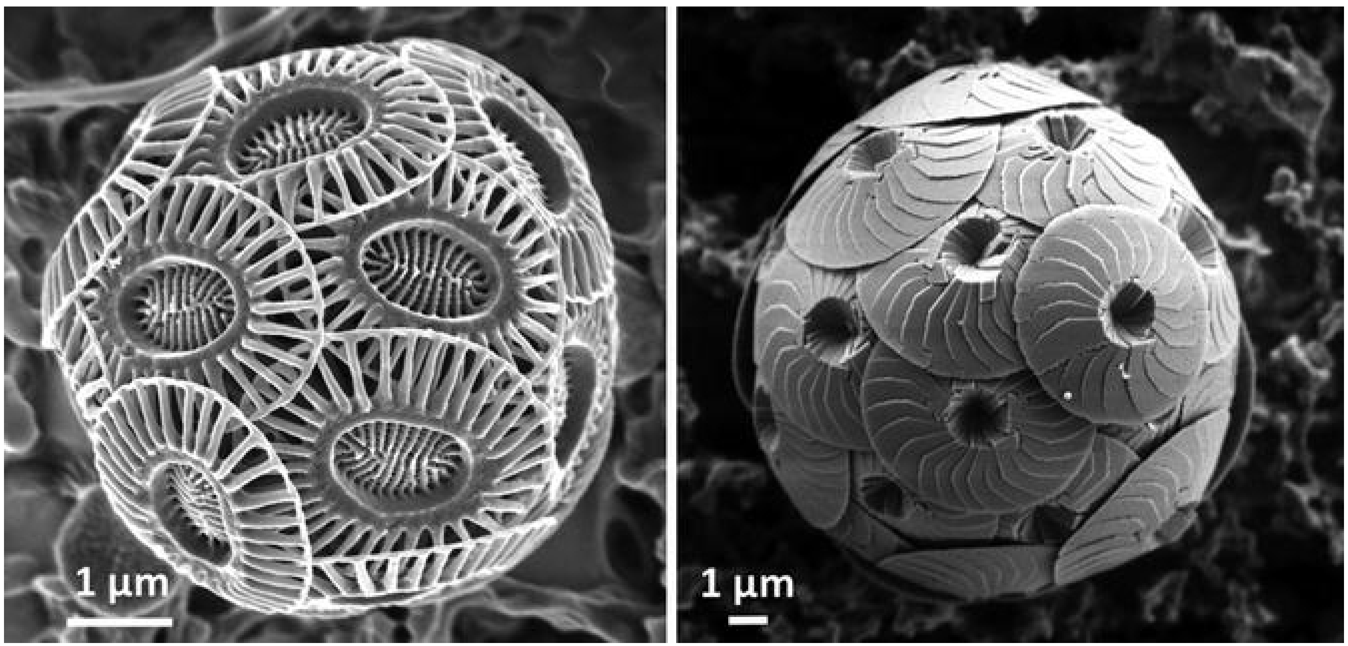
(2) analysis of the sediments containing ancient microfossils. In the first case, if the modern species has a fossil record, one can reasonably assume that the fossil ancestors had similar modes of life as the living organism. However if the species in question is extinct, then one examines modern forms, inferring that the fossil forms had similar environmental preferences. In the latter case, studies of the rock containing the fossils (sandstone, shale, limestone, etc.) give further clues to the environment of deposition.

If a given species is always found in sandstones deposited in river deltas, it is not too much of a guess to suggest that this species preferred to live in or near ancient river deltas.

If a company is drilling for oil in deltaic reservoirs, then such information can be very useful by helping to locate ancient deltas both in time and space.

For instance, the delta for the ancestral Mississippi River during the late Pliocene was not southeast of New Orleans as it is today, but rather far to the west, south of the Texas-Louisiana border (Galloway et al., 1991).

Calcareous nannofossils are extremely small objects (less than 25 microns) produced by planktonic unicellular algae. As the name implies, they are made of calcium carbonate.



From Thierstein (2014)

Introduction to Palynology: What is Palynology

What is Palynology?

Palynology is the study of non-mineralized 'organic' microfossils such as pollens and spores, acritarchs, dinoflagellates, chitinozoans and others and organic debris.

All microfossils are, of course, of organic composition.

Introduction to Palynology: What is Palynology

- **Palynofacies** (Combaz, 1964): the assemblage of phytoclasts found in a particular sediment, such as palynomorphs, wood fragments, cuticles, etc. Comment: The term is actually used in two senses, namely the palynolithofacies and palynobiofacies.
- **Palynomorph** (Tschudy, 1961): a general term for all entities found in palynological preparations. Comment: In addition to pollen grains and spores, the term encompasses acritarchs, dinoflagellates and scolecodonts, but not other microfossils, such as diatoms, that are dissolved by hydrofluoric acid.

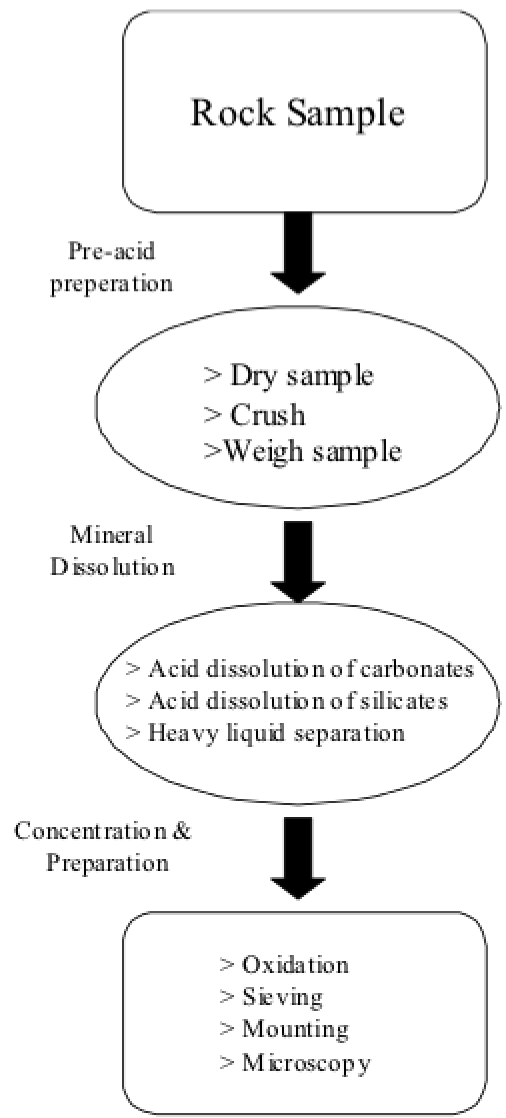
Introduction to Palynology: What is Palynology

- **Palynodebris** (Manum, 1976): all palynomorph-sized particles in a sediment excluding those that actually are palynomorphs but including, for example, wood fragments, cuticles and some animal remains.
- **Phytoclast** (pl. phytoclasts): a general term for plant-derived, more or less resistant-walled, particle occurring in a sediment.

Introduction to Palynology: Laboratory techniques

- Sample: 5-30 grams
- HCl 37%
- HF 50%
- HCl 30%
- $ZnBr_2$ or $ZnCl_2$
- HCl 30%
- Sieve 10 micron: slide
- Oxidation: Nitric acid
- Sieve 10 micron: slide

Introduction to Palynology: Laboratory techniques



Introduction to Palynology: General application of Palynology

Palynology: applications to geology

- *Biostratigraphy and geochronology.* Geologists use palynological studies in biostratigraphy to correlate strata and determine the relative age of a given bed, horizon, formation or stratigraphical sequence.
- *Palaeoecology and climate change.* Palynology can be used to reconstruct past vegetation (land plants) and marine and freshwater phytoplankton communities, and so infer past environmental (palaeoenvironmental) and palaeoclimatic conditions.

Introduction to Palynology: General application of Palynology

Palynology: applications to geology

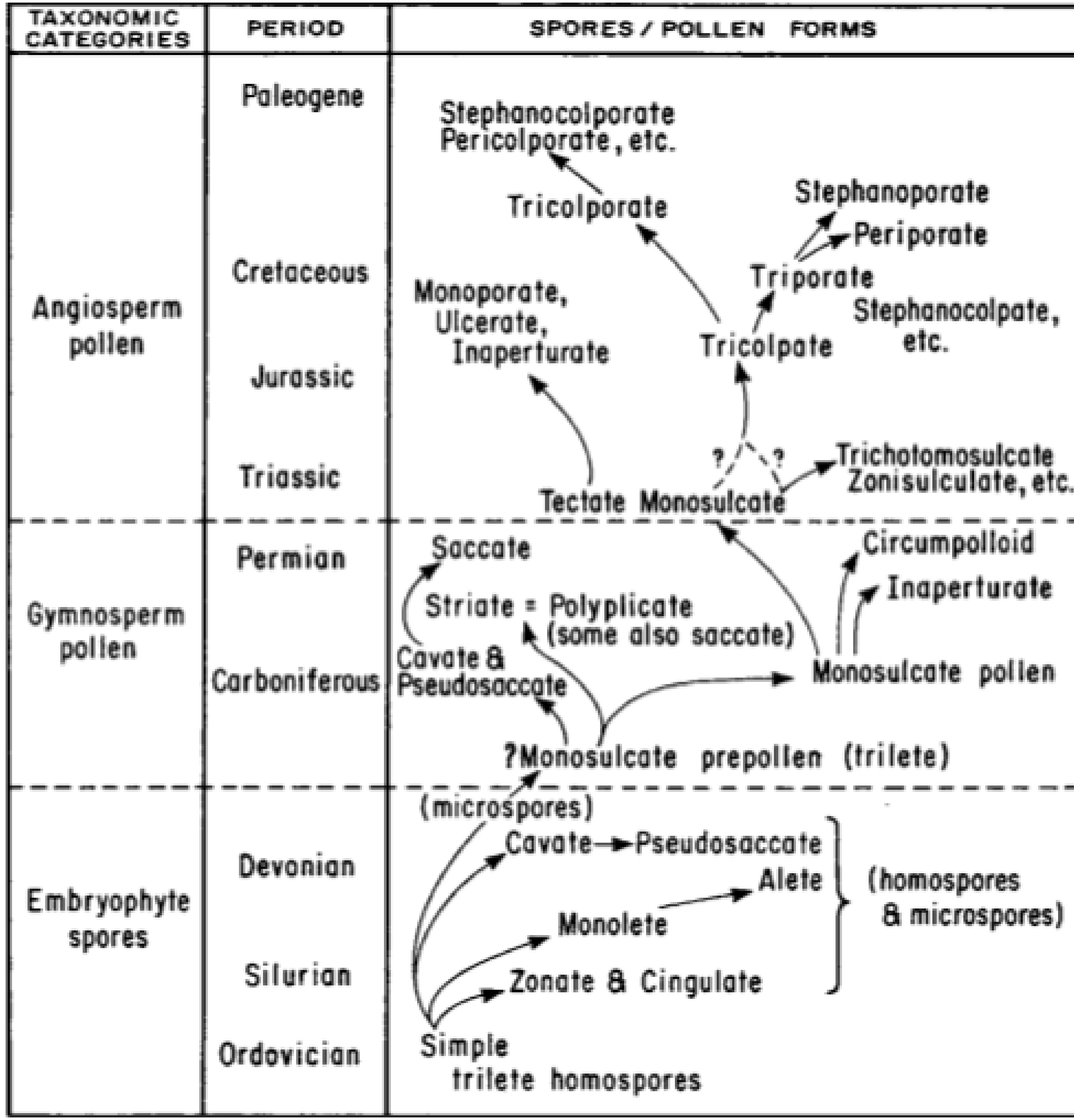
- *Organic palynofacies studies,* which examine the preservation of the particulate organic matter and palynomorphs provides information on the depositional environment of sediments and depositional palaeoenvironments of sedimentary rocks.
- *Geothermal alteration studies* examine the colour of palynomorphs extracted from rocks to give the thermal alteration and maturation of sedimentary sequences, which provides estimates of maximum palaeotemperatures.

Introduction to Palynology: General application of Palynology

Palynology: applications to geology

- *Limnology studies*. Freshwater palynomorphs and animal and plant fragments, including the prasinophytes and desmids (green algae) can be used to study past lake levels and long term climate change.
- *Taxonomy and evolutionary studies.*

Probable evolutionary pathways of major spores/pollen morphological types. Time periods not to scale. Spores/pollen of course do not evolve independently of the taxa producing them, but, for example, logic and the fossil record indicate that plants producing monolete homospores were derived from plants producing trilete spores, etc. (from Traverse, 2007).



Introduction to Palynology: Palaeozoic palynomorphs

Palaeozoic palynomorphs:
- Acritarchs
- Chitinozoans
- Scolecodonts
- Fungal or algal remains
- Cryptospores
- Trilete spores
- Pollens
- Foraminiferal linings
- Megaspores

Introduction to Palynology: Palaeozoic palynomorphs

Acritarchs:

- Range: from Proterozoic to present.
- The meaning of term “acritarchs” is “of undecided or doubtful origin” (Greek: ακριτοσ-αρχη).
- Size: from 10 to more than 1000 µm, although mostly 15-80 µm, well within the palynomorph size.
- Wall: sporopollenin or similar components.
- Ornamentation: psilate, scabrate, spiny, reticulate and other.
- Stratigraphic importance: Lower Palaeozoic.

Introduction to Palynology: Palaeozoic palynomorphs

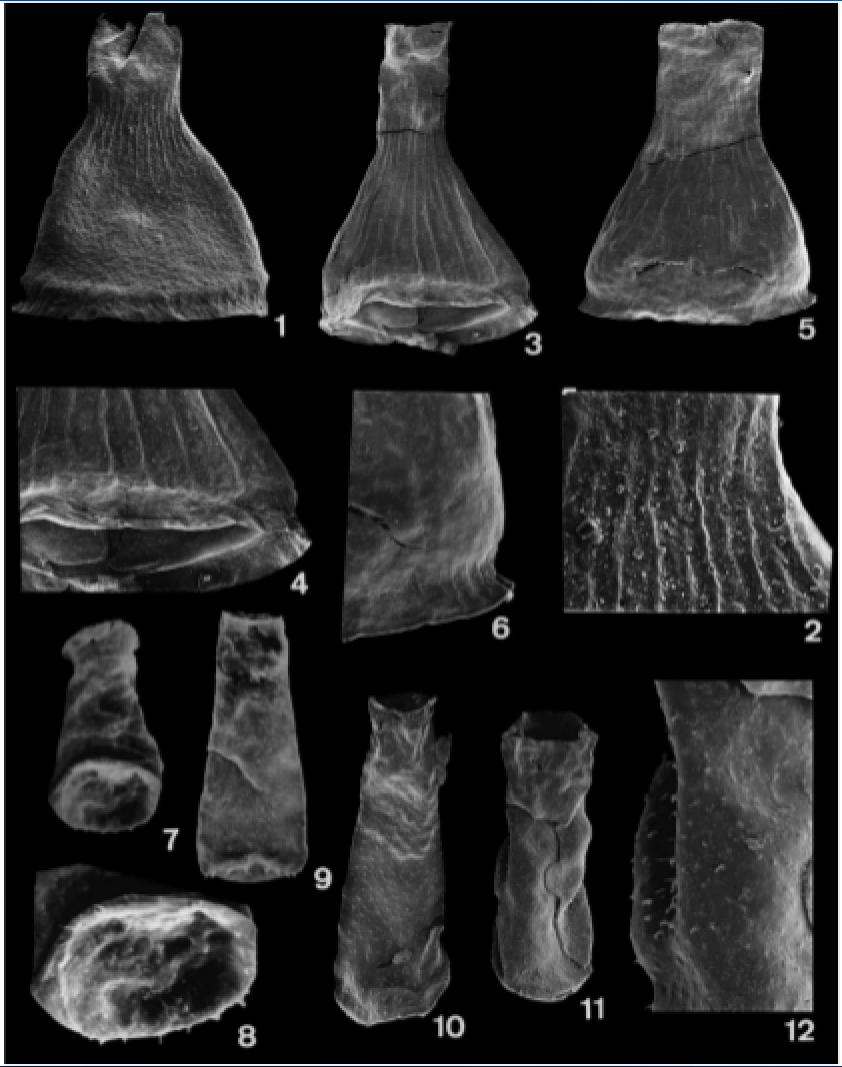





Introduction to Palynology: Palaeozoic palynomorphs

Chitinozoans
- Range from Late Cambrian to Latest Dovonian
- Uncertain origin: graptolites, fungal or meazoans.
- They are found only in marine sediments.
- Sometimes they could occur in chains, but usually as single individuals. Due to their thick, more or less opaque walls, thay are usually studied by the SEM.
- Because they are not present in abundance, larger quantitative of samples than for acritarchs or miospore, should be processed.

Introduction to Palynology: Palaeozoic palynomorphs



M. Ghavidel-syooki, T. Winchester-Seeto / Review of Palaeobotany and Palynology 118 (2002)

Introduction to Palynology: Palaeozoic palynomorphs

Cryptospores:
- Range from Cambrian or Ordovician to Devonian.
- Defined by Richardson et al. (1984) as "Non-marine sporomorphs (non-pollen grains) without those typical visible haptotypic features such as trilete marks or furrows which characterize tracheophyte spores and pollen grains. Single grains or monads, "permanent" dyads and tetrads are included as are sporomorphs separated from polyads which may or may not preserve contact areas".

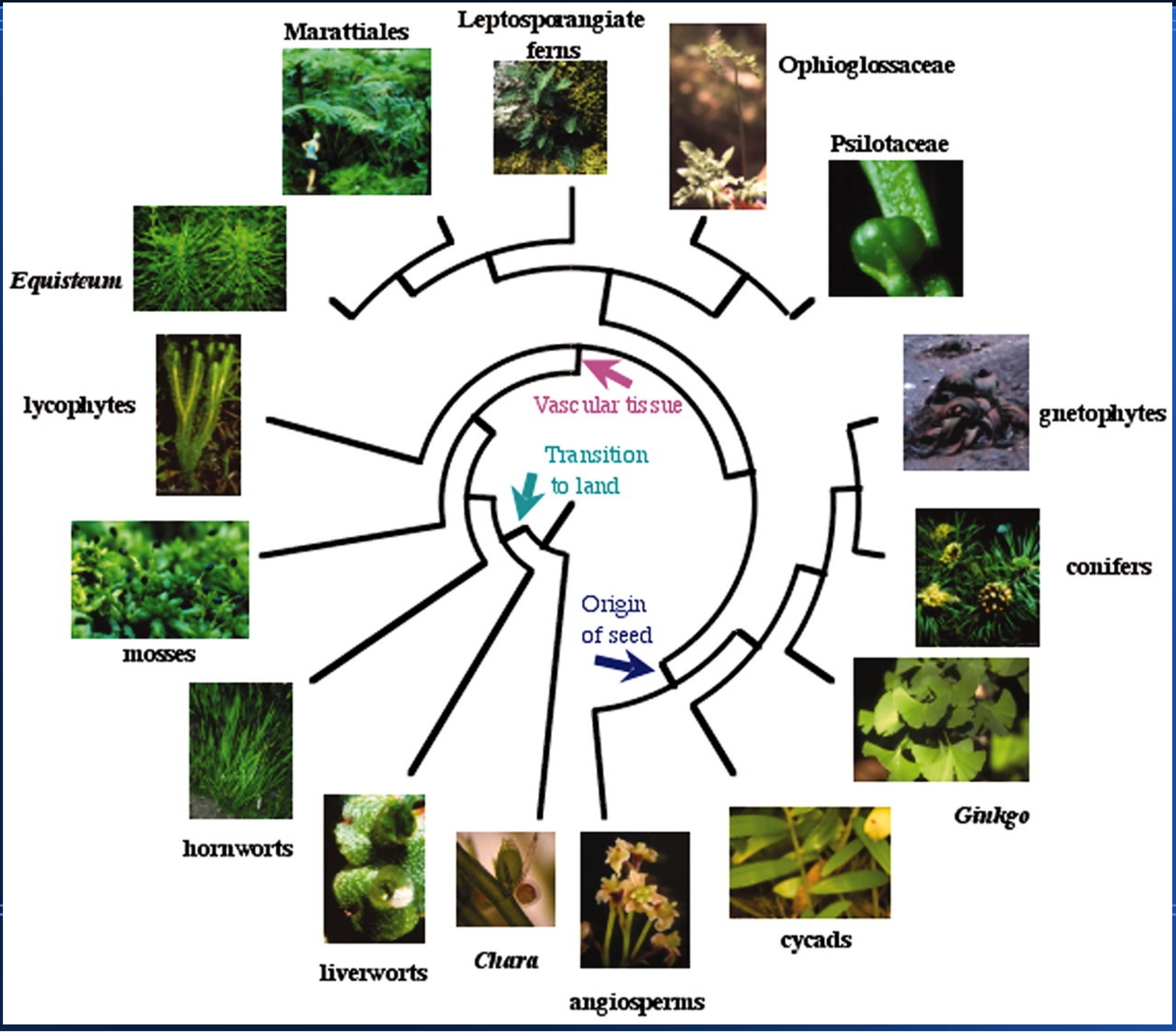
Anteturma Cryptosporites Richardson et al., 1984.

Introduction to Palynology: Palaeozoic palynomorphs

Trilete spores

- Range from Upper Ordovician to present.
- Embryophytes (land plants) include most familiar plants such as trees, grasses, herbs, ferns and mosses. They are very important organisms to supply the most part of production on land. Sizes are varied, from a few millimeters to a hundred meters.
- Most species are terrestrial, but there are many secondarily aquatic embryophytes.
- For palynologysts, “spore” as usually employed refers to sporopolleninous microspores and homospores (=isospores) of embryophytes.

Introduction to Palynology: Palaeozoic palynomorphs



Summary of phylogenetic relationships among major lineages of embryophytes (land plants). Charales are the sister group of the embryophytes. Within the embryophytes, liverworts, hornworts, and mosses are the basal most lineages; however, their precise branching order is uncertain. One of the best supported topologies is depicted with liverworts, hornworts, and mosses as successive sisters to the tracheophytes (vascular plants). Within tracheophytes, there are two clades: monilophytes and spermatophytes (seed plants).

http://www.plantphysiol.org/

Introduction to Palynology: Palaeozoic palynomorphs

Pollens:
- Range from latest Devonian to present
- Such classes are useful in identification keys and may be subdivided into more restrictive categories, pollen types and pollen groups. The definition of pollen is not morphological but functional: the microspore wall of seed plants, plus the microgametophyte that develops within the wall. Only the outer microspore wall survives as a fossil.

Introduction to Palynology: Palaeozoic palynomorphs

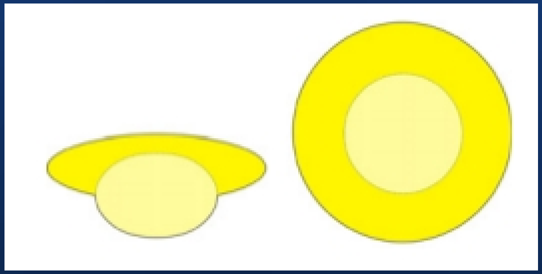
Megaspores:
- Range from latest Pragian to present
- They are the spores of heterosporous embryophytes, inside of the walls of which the megagametophytes develop
- The size is over than 200 μm;
- After the Cretaceous, they are rarely present in the palaeo-palynological preparations, but they can be common locally and palaeoecologically useful

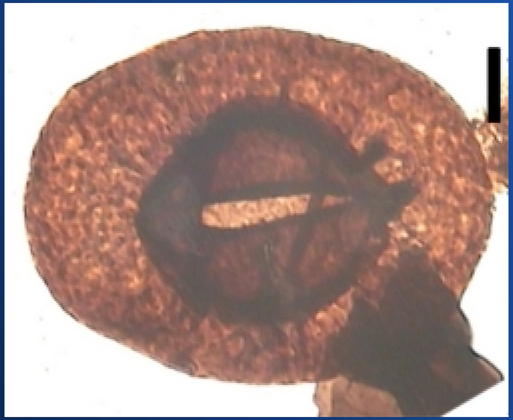
Introduction to Palynology: spores and pollen morphology

Palaeozoic pollens:
- monosaccate
- bisaccate
- sulcate

Introduction to Palynology: spores and pollen morphology

Monosaccate (Potonié and Kremp, 1954)
Describing a pollen grain with a single saccus.

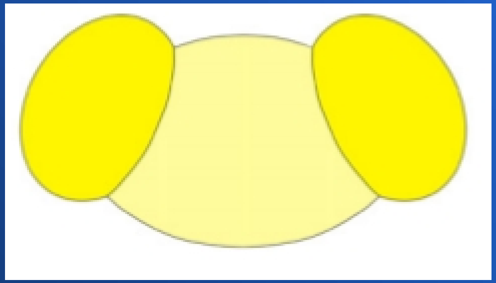




Potonieisporites novicus Bhardwaj 1954
from Finu-1 borehole, Iran

Introduction to Palynology: spores and pollen morphology

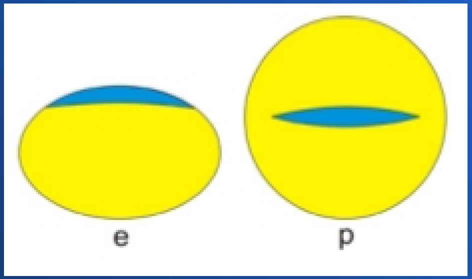
Bisaccate (Potonié and Kremp, 1954)
Describing pollen with two sacci.



Protohaploxypinus latissimus (Luber and Waltz) Samoilovich 1953
from Finu-1 borehole

Introduction to Palynology: spores and pollen morphology

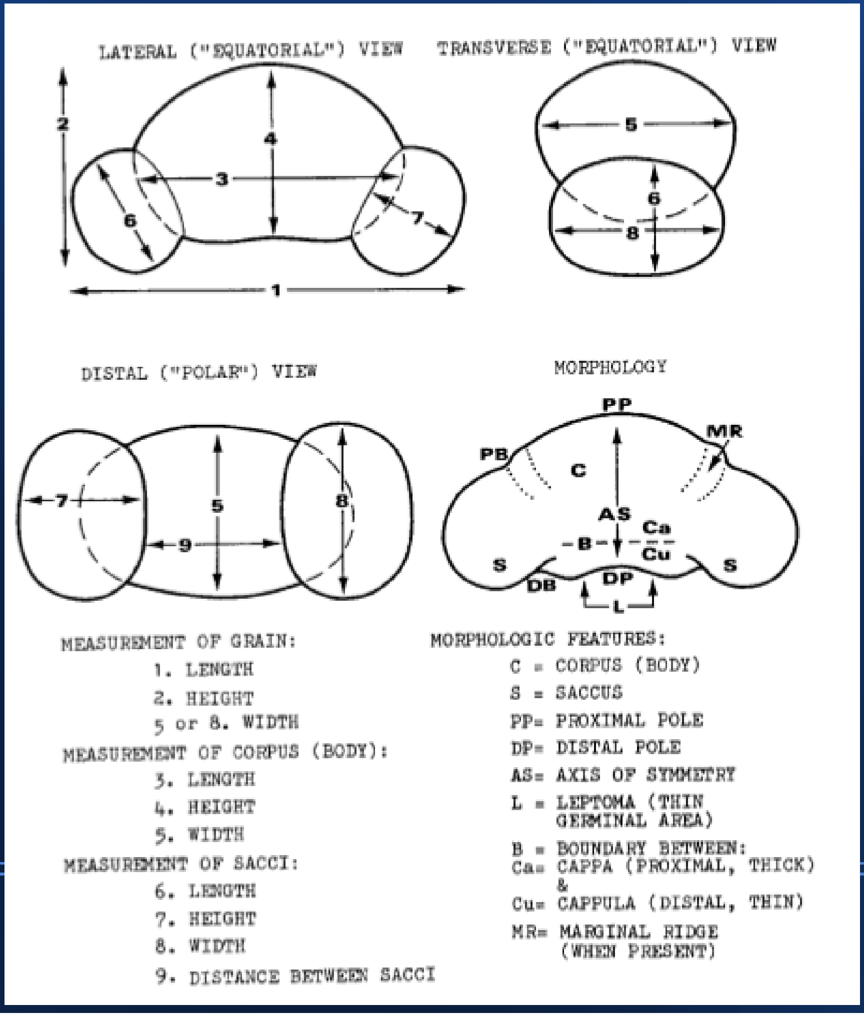
Sulcus (pl. sulci, adj. sulcate) (Erdtman, 1952)
An elongated latitudinal ectoaperture situated at the distal or proximal pole of a pollen grain.



Sverdrupollenites agluatus Utting 1994 from Utting (1994)

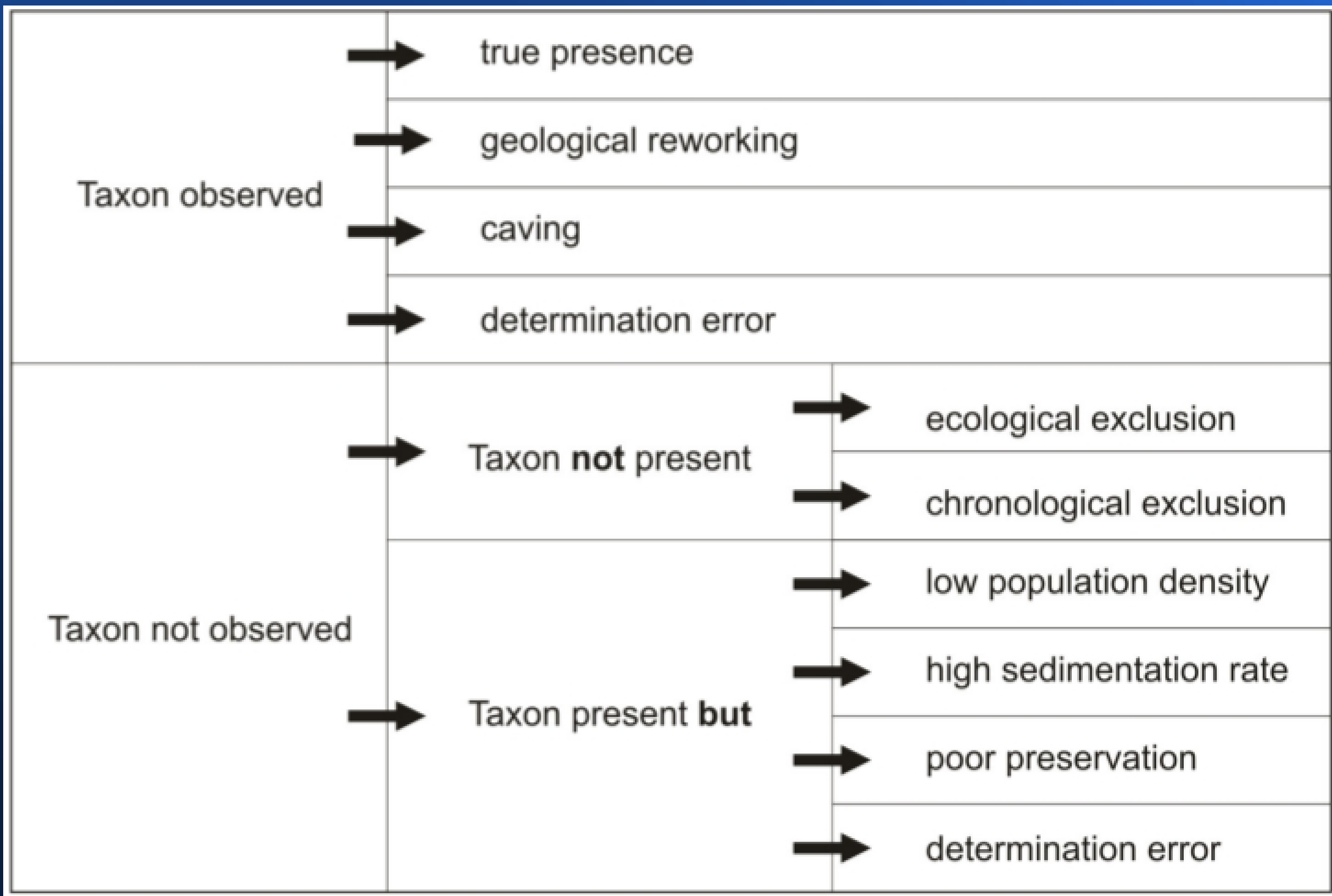
Introduction to Palynology: spores and pollen morphology

Morphological Types in Detail:
Palaeozoic bisaccate and monosaccate pollens



Bisaccate pollen present special problems in measurement because of their tri-partite structure.

Introduction to Palynology: quality of fossil record



modified after Gradstein et al., 1985. The presence or absence of a taxon depend on multiple factors.

Palynostratigraphy

The fossil sporomorphs (pollens and spores) are mainly a hollow, tough, variously ornamented and grooved bag, ball, or case, from which the contents (inner wall layers and protoplasm) have been removed through biodegradation by bacteria, fungi and probably non-biological lysis.

The bag consists of a wall (exine) of sporopollenin which retains considerable resilience until much of the hydrogen and oxygen has been removed during increase of rank (“coalification”=“carbonization”=“maturation”).

Therefore, during palynological processing of the enclosing rock, low-rank palynomorphs will often re-expand to some extant.

Palynostratigraphy

Technical aspects:

Collection of material

In order to determine which microfossils occur at specific stratigraphic levels and establish biostratigraphic zonations, the palynostratigrapher first needs ideally to collect outcrop material from localities with good stratigraphic control. Such outcrops should be:

- well exposed;
- contain macrofossils;
- be free from faulting;

Palynostratigraphy

a) contain suitable lithologies in which microfossils may be found. Lithologies most suitable for palynology are:

- grey mudstones/shales and siltstones
- grey argillaceous carbonates and sandstones

Unsuitable are:

- Red brown arkose, sandstones, siltstones and shales. Also very poor are mottled red and green beds or any sediments which have suffered much oxidation.

Coals may or may not contain abundant pollen and spores depending on the type of coal. For example, some coals are composed almost entirely of spores whereas others may be made up of woody material.

Palynostratigraphy

For micropalaeontology similar lithologies are suitable, but in addition carbonates may be ideal for some fossil groups, e.g. conodonts and larger foraminifera.

In offshore frontier areas where oil exploration takes place, the general stratigraphy may be unknown and there may be no accessible outcrops. The samples available for study would probably be:

i) Cuttings
ii) Slidewall cores
iii) Cores

Palynostratigraphy

i) Cuttings: are the broken bits of solid material removed from a borehole drilled by rotary, percussion, or auger methods. Boreholes drilled in this way include oil or gas wells, water wells, and holes drilled for geotechnical investigations or mineral exploration.

The small size of the fossils studied by micropalaeontologists and palynologysts is a distinct advantage when studying cuttings. Any macrofossils in the rock are ground up into small fragments and virtually useless.

The main problem with cuttings is contamination especially by caving. For this reason, the biostratigraoher uses “tops” of fossil ranges to determine ages. This is the opposite to studying outcrop samples where the first appearance of fossils is important.

http://www.fossiloil.com/glossary-of-oil-gas-terms

Palynostratigraphy

ii) Sidewall cores: a core or rock sample extracted from the wall of a drill hole, either by shooting a retractable hollow projectile, or by mechanically removing a sample.

Sidewall cores have a distinct advantage over cuttings in that:

- exact location of the sample is known
- there is no problem from caving

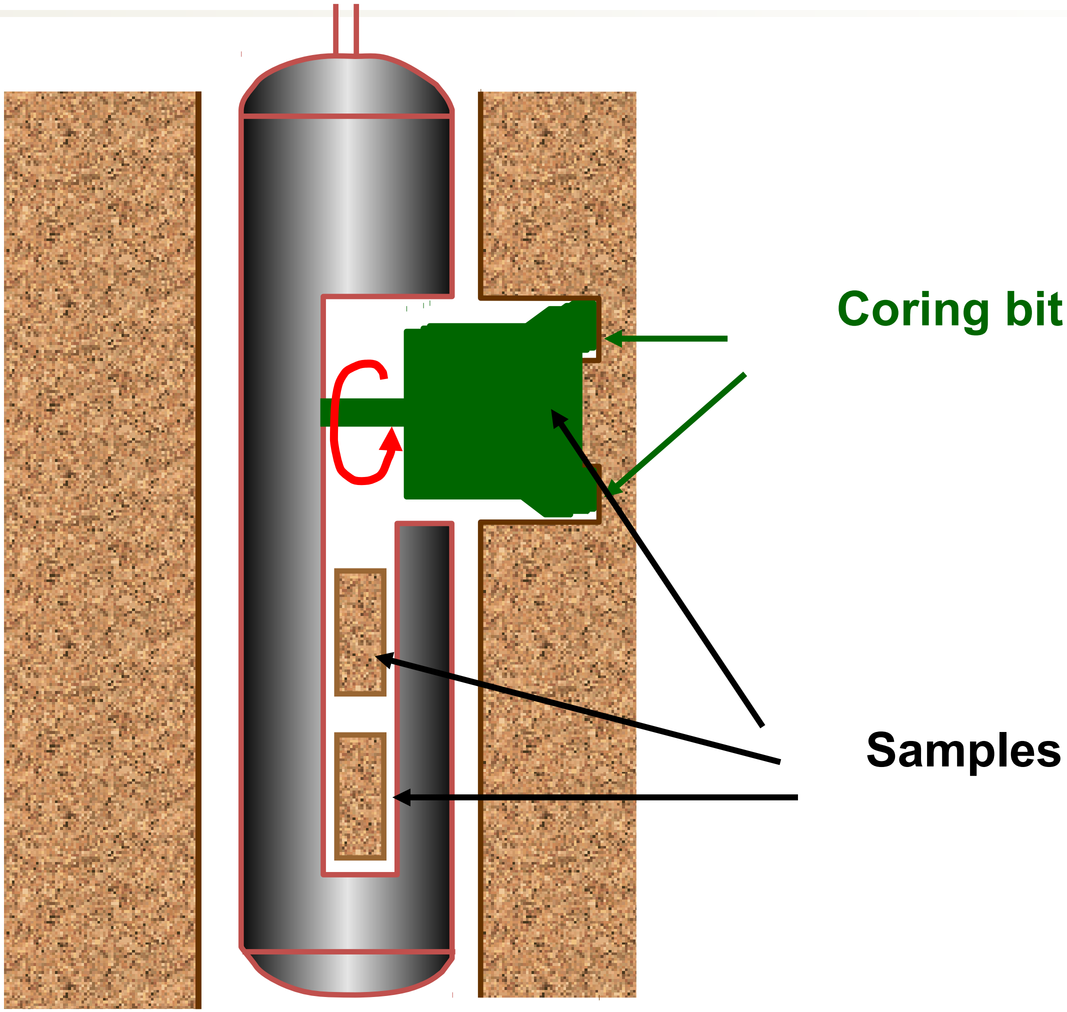
The disadvantages however are:

- sample size small
- much of sample may consist of filter cake on side of borehole
- in beds where lithology rapidly alternates, the sidewall core may be of unsuitable lithology for micropalaleontology or palynology

SIDEWALL CORING TOOL

A newer wireline tool actually drills a plug out of the borehole wall, thus avoiding crushing of the sample.

Up to 20 samples can be individually cut and are stored inside the tool.



Palynostratigraphy

iii) Core

Core is often taken at the bottom of a borehole and is ideal for sampling purposes.
Sampling should take place as soon as possible as core tends to be moved around frequently.

The person sampling should:
- verify that the core has been placed in core boxes correctly and is not upside down
- verify that there is no obvious contamination
- make sure that only part of the core is sampled, if possible leaving material for other workers.

It is essential that all samples are clearly numbered with indelible markers!

http://www.aramcoexpats.com/articles/2007/03/cutting-cores-and-mixing-mud
/

Palynostratigraphy

b) Analysis of samples

Fundamental to both micropalaeontology and palynology is the accurate identification of specimens.

When this has been done:

- vertical distribution charts may be drawn up
- zones may be recognized
- age determination made

In some project where detailed correlation is required, quantitative analysis may be necessary. e.g. correlation of coal seams using palynology, such projects may involve the use of other disciplines such as coal petrography.

Palynostratigraphy

Biostratigraphic analysis should not be carried out in isolation, but in close contact with other specialities. Also the biostratigrapher must be cognisant of the **general geology** in the are in which he/she is working!

Palynostratigraphy

Limitation and problems

a) Caving

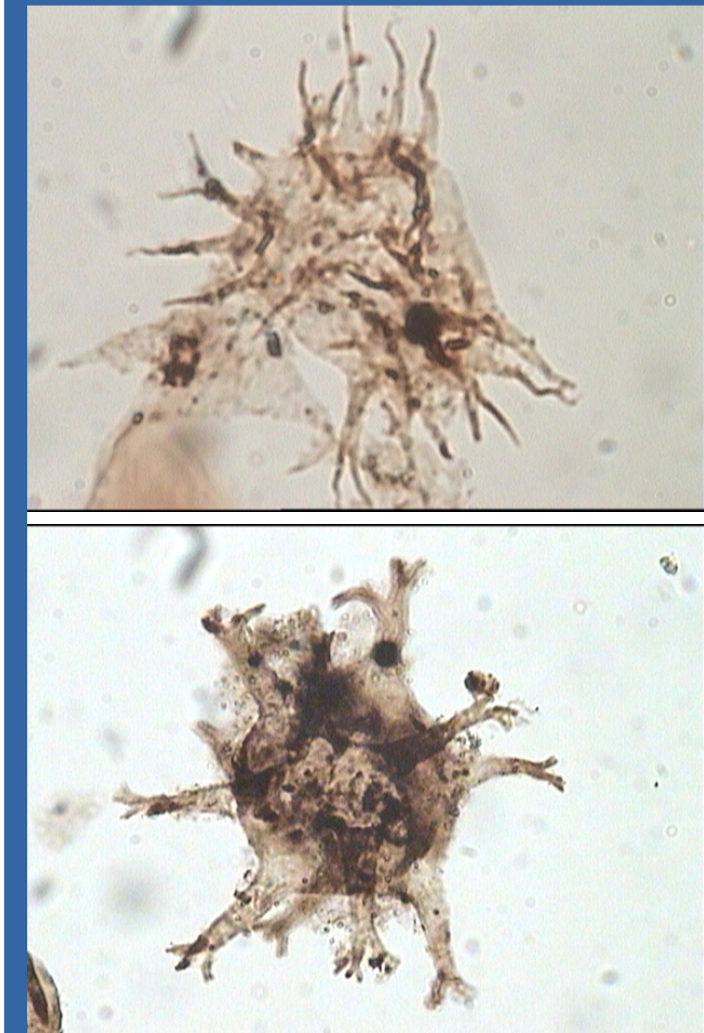
In most wells some indication of caving is found in the micropaleontological and palynological data. Thus it is especially important to use the “tops” of the fossil ranges in the vertical distribution charts as anomalous occurrences further down the well may be the result of caving.
In some instances wrong ages can be obtained when caving is not recognized.
This may be especially true of single spot samples when the biostratigrapher is giving the correct age for the fossil found, although these fossils may have been caved from above.

Palynostratigraphy

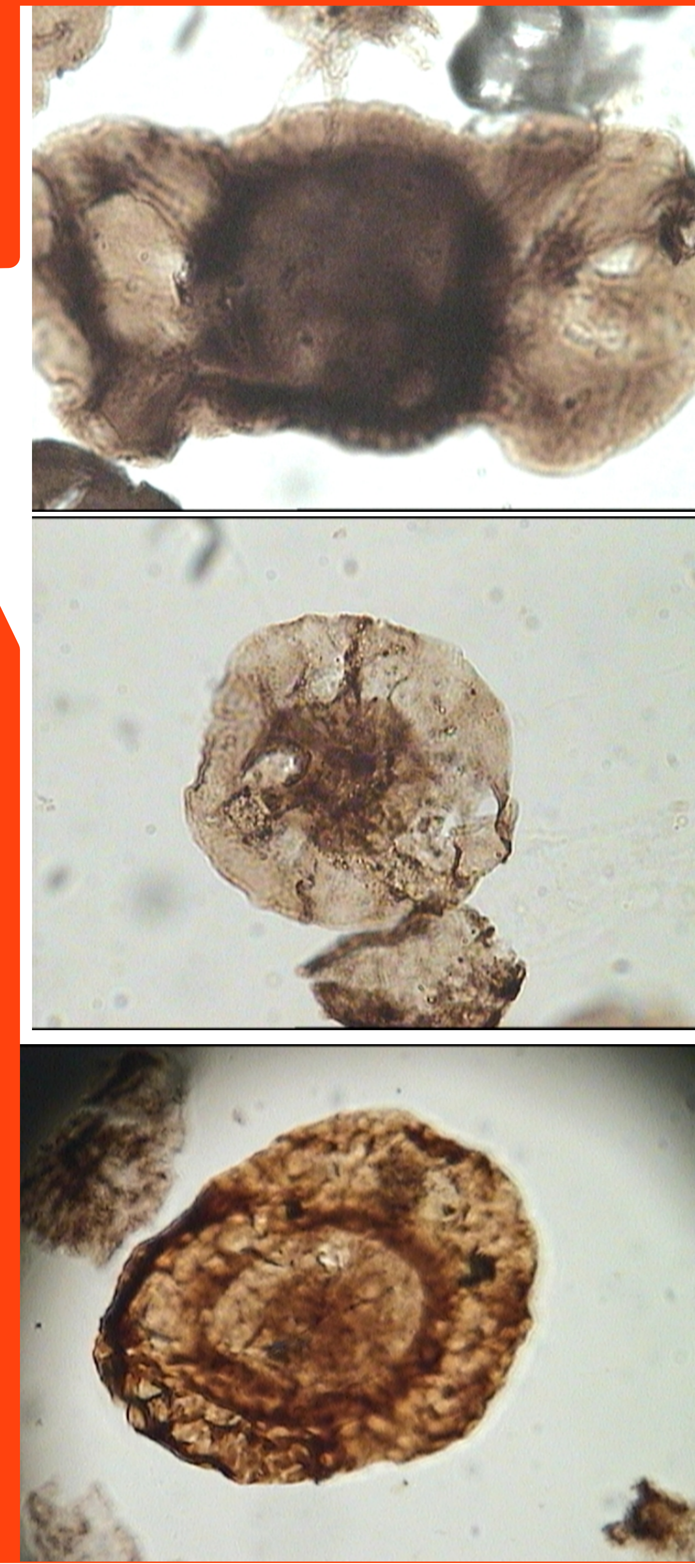
Also caving may prove a problem when trying to accurately identify geological boundaries although the pitfalls will be fewer if the biostratigrapher is aware of lithological changes in the well as determined from logs.

For example, an abundant well preserved assemblage of pollen and spores in a red-brown arkose is almost certainly the result of caving from overlying beds.

Also mixing of fossils of completely different ages is a probable sign of caving or some other contamination.



In situ Silurian acritarchs



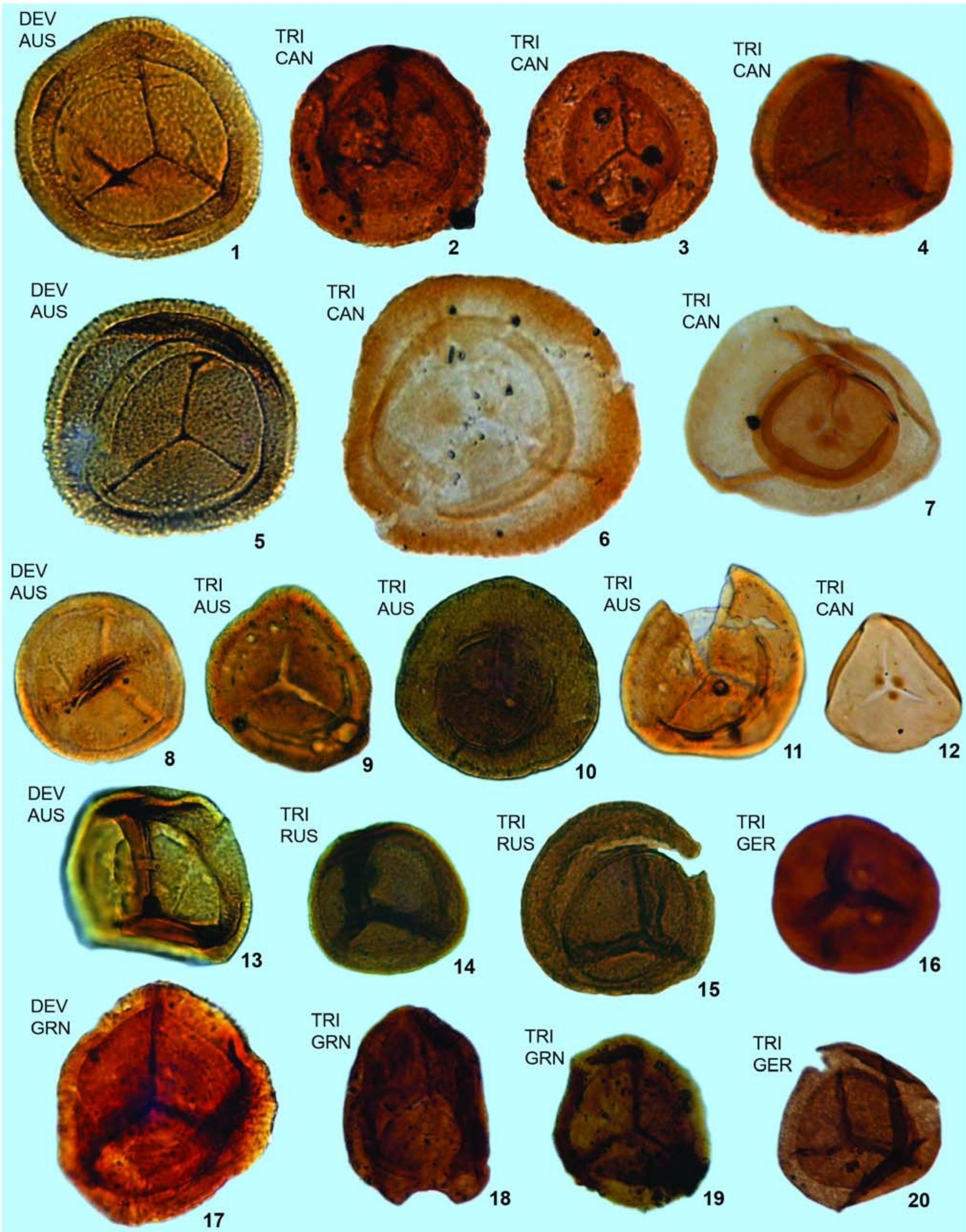
Caving: Middle Permian pollens

Palynostratigraphy

b) Reworking.

This is a relatively common phenomenon whereby erosion of rocks containing fossils may result in the fossil being redeposited in younger beds. With microfossils such reworking is often, although not always relatively obvious as the fossils are abraded or damaged in some other way. Such damage may be less or even nil in reworked microfossils. This may be especially true of reworked palynomorphs which may be equivalent size to clay particles. Reworking is obvious however, if:

- older fossils occur in situ with the in situ assemblages, e.g. chitinozoans with dinoflagellates;
- there are two different levels of carbonization;
- there are two types of preservation; sometimes the better preserved material is the reworked material.



J. Utting, A. Spina, J. Jansonius, D.C. McGregor, J.E.A. Marshall (2004). Reworked Paleozoic and Lower Triassic miospores

Palynostratigraphy

On occasion a conflict between the ages indicated by micropalaeontology and palynology may indicate reworking of one group of fossils and not the other.

c) Contamination in addition to caving and reworking.

Possible sources include:

- drilling mud and various additives
- contamined drilling equipment, e.g. coal fragments on drilling rods
- mixing up of samples at drilling site or subsequently
- laboratory contamination

Palynostratigraphy

A good example of such problem is Gudrid H-55 borehole (Labrador Sea) where Mississippian and Pennsylvanian palynomorphs and Maastrichtian to Early Paleocene palynomorphs all occur in core samples consisting of coarsely crystalline dolomite. The fossils mentioned above all appear to come from drilling mud in fissures in the dolomite or from coal fragments found either on the surface of the core or trapped in cavities.

Palynostratigraphy

d) Poor preservation or absence of fossils.

Poor preservation often makes reliable identification of fossils difficult and may explain tentative age determinations given in a report.
The degree of confidence in the identification may be expressed by a question mark before the generic name.
Absence of fossils occures frequently in any geological section.

Modern processing techniques are such that if any fossils are present in a sample they are probably found. This has not always been the case, but in the last few years significant improvements have been made especially in palynological processing techniques.

Palynostratigraphy

e) Facies dependance, etc.

All fossils are facies dominant to a greater or lesser extent. A problem with a number of assemblages is to distinguish “facies” from “zone”.
For example, the *Rzehakina epigona* assemblage of deep-water foraminifera occurs almost worldwide, usually in sediments of Palaeocene age. On the Labrador Shelf, however, this fauna appears to be no younger that Latest Cretaceous (Maastrichtian).

For benthic species especially, it is important to establish local ranges (teilzones): many mistakes have resulted from uncritically applying ranges established in distant basins.

Palynostratigraphy

A problem exists in deep-water sediments of removal of calcareous species below the Carbonate Compensation Depth: even above this level, certain thin-walled species may be selectively dissolved. This process especially affects planktic foraminifera.

Palynostratigraphy

f) The human factor.

All aspects of biostratigraphy depend on the correct identification of taxa. Because of poor preservation, homeomorphy, etc., misidentifications do happen. Usually, when a large assemblage is involved the misidentification of any single form is not critical. When the assemblage is sparse, hovewer, and dating is based on only one ot two forms, misideintification can lead to major errors.

Not all taxonomists agree as to what the limits of certain taxa should be, and consequently use a species name in more than one sense.

Palynostratigraphy

On the other hand, the same species may appear in different reports under different names, either because of taxonomic diseagreement, or through a change of the name being made through one of the articles of the Botanical or Zoological Codes of Nomenclature.