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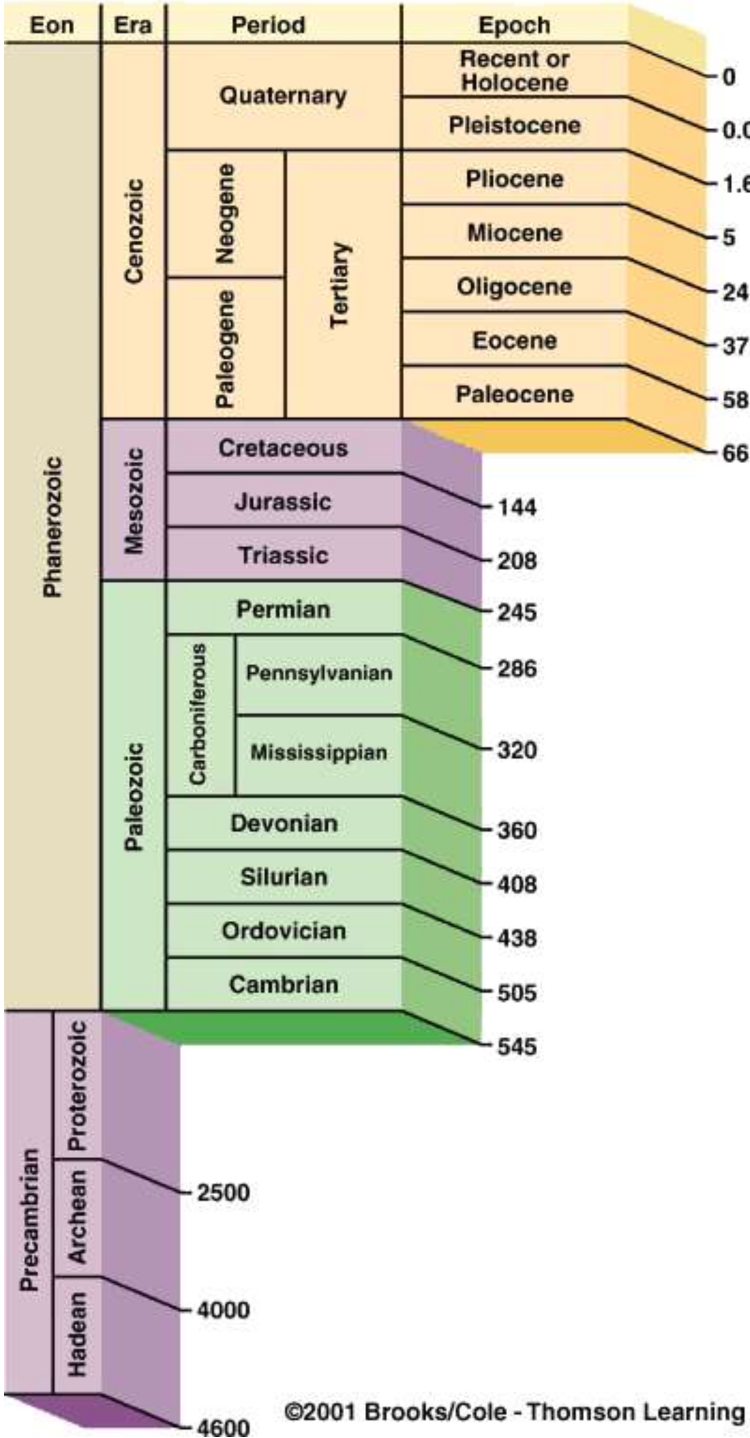
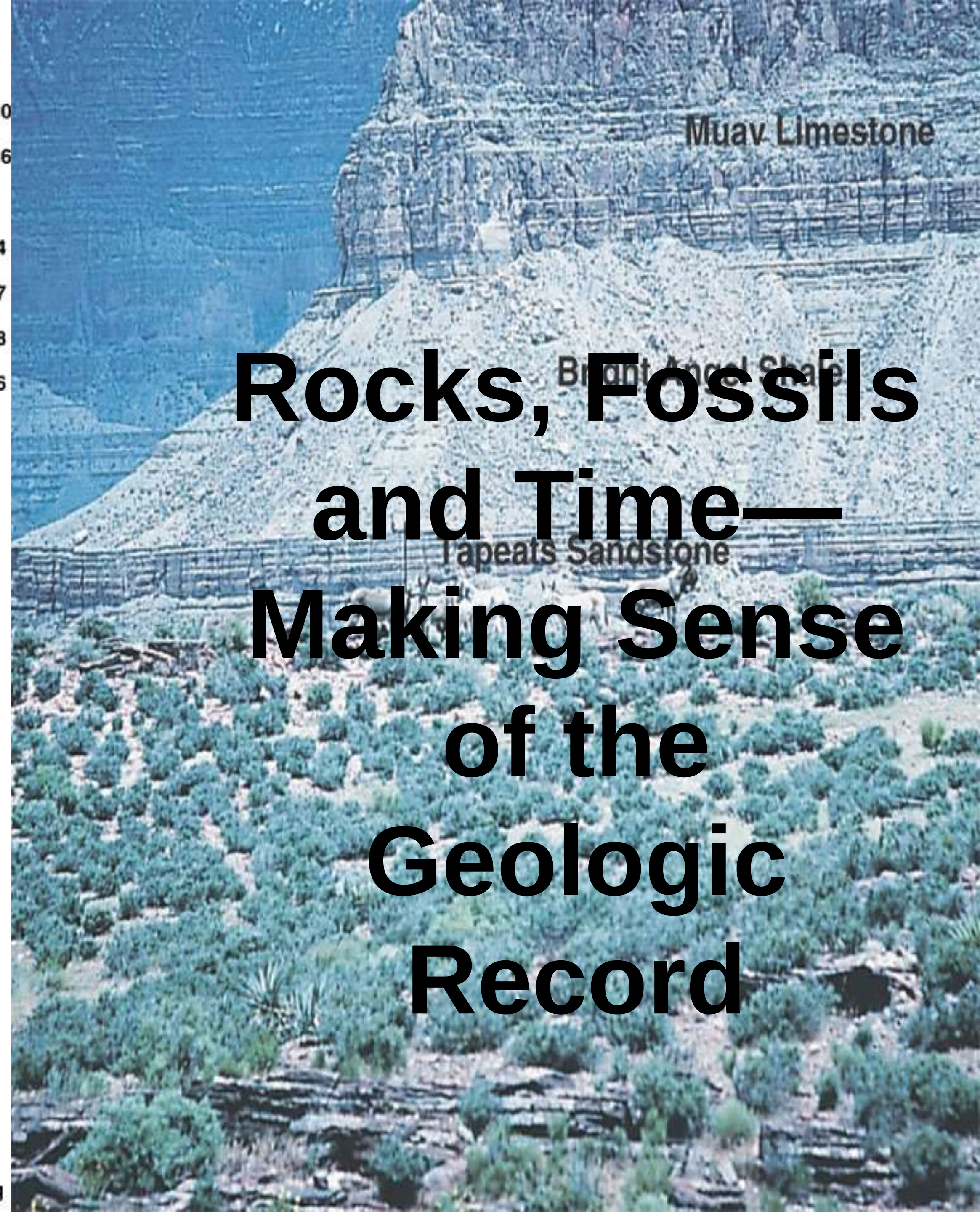




Rocks, Fossils and Time—Making Sense of the Geologic Record

Stratigraphy

- **Stratigraphy** deals with the study of any layered (stratified) rock, but primarily with sedimentary rocks and their
    - composition
    - origin
    - age relationships
    - geographic extent
- Many igneous rocks
    - – such as a succession of lava flows or ash beds are stratified and obey the principles of stratigraphy
- Many metamorphic rocks are stratified

Stratified Igneous Rocks

Lava flows

Stratified Sedimentary Rocks

Sandstone and Shale layers

Stratified Metamorphic Rocks

Slates

Vertical Stratigraphic Relationships

- Surfaces known as ***bedding planes*** separate individual strata from one another
  - or the strata grade vertically from one rock type to another
- Rocks above and below a bedding plane differ in composition, texture, color or a combination of these features
- The bedding plane signifies
  - a rapid change in sedimentation
  - or perhaps a period of nondeposition

Unconformities

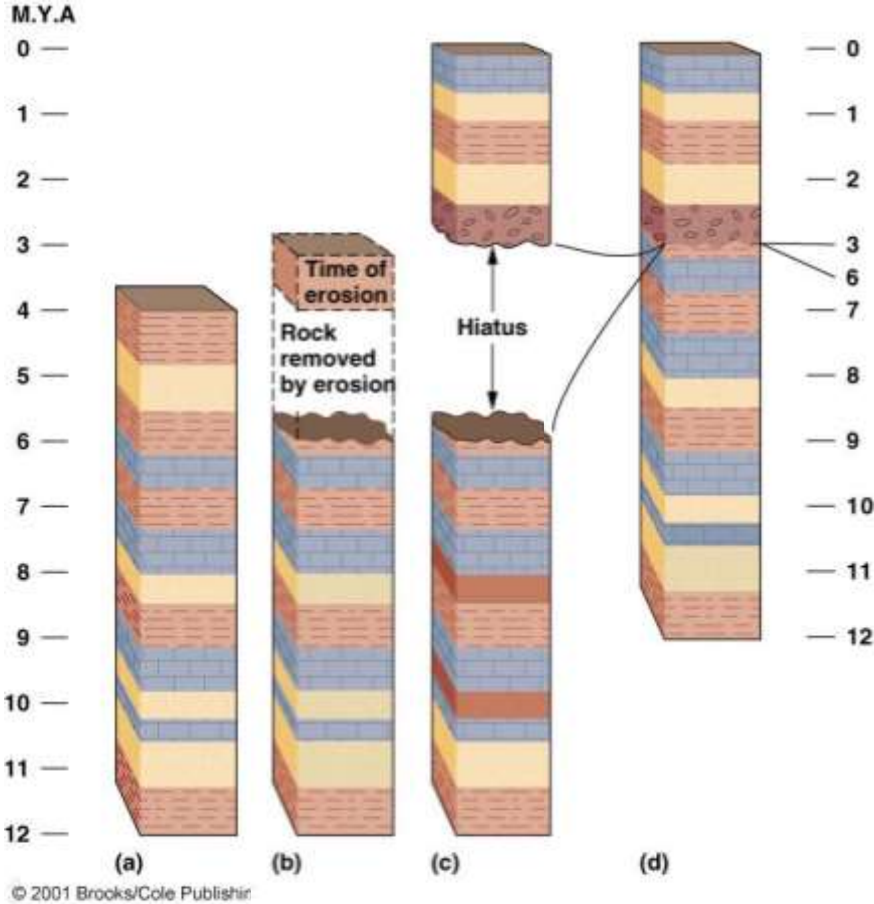
- **Unconformities** in sequences of strata represent times of nondeposition and/or erosion that encompass long periods of geologic time, perhaps millions or tens of millions of years

- The rock record is incomplete.
  - The interval of time not represented by strata is a ***hiatus***.

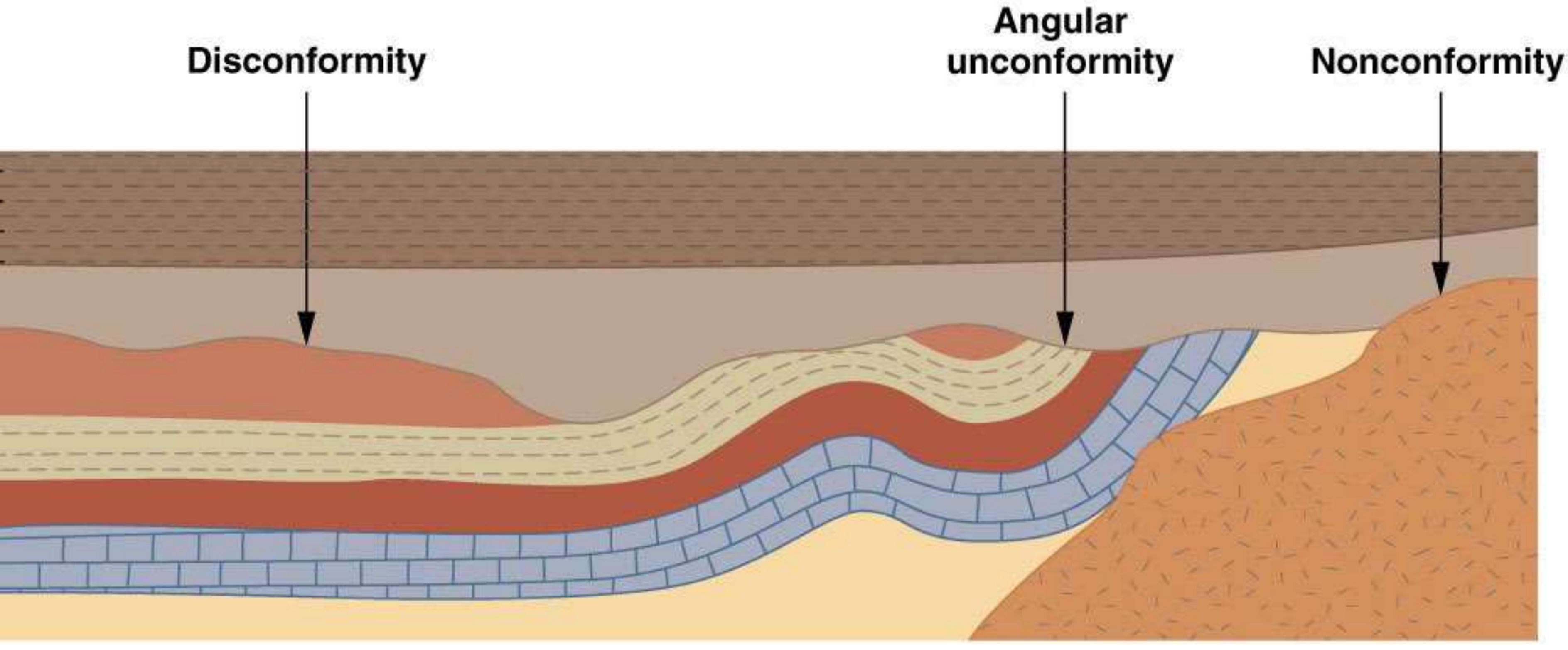
The origin of an unconformity

- The process of forming an unconformity
  - deposition began 12 million years ago (MYA),
  - continues until 4 MYA
    - For 1 million years erosion occurred and removed 2 MY of rocks
    - and giving rise to a 3 million year hiatus

- The last column
  - is the actual stratigraphic record
  - with an unconformity



Types of Unconformities



- Unconformities of regional extent may change from one type to another
- They may not represent the same amount of geologic time everywhere

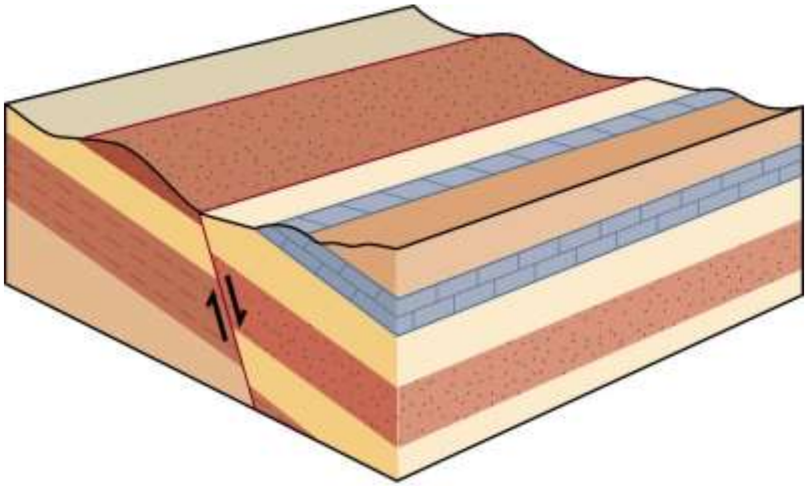
Disconformity

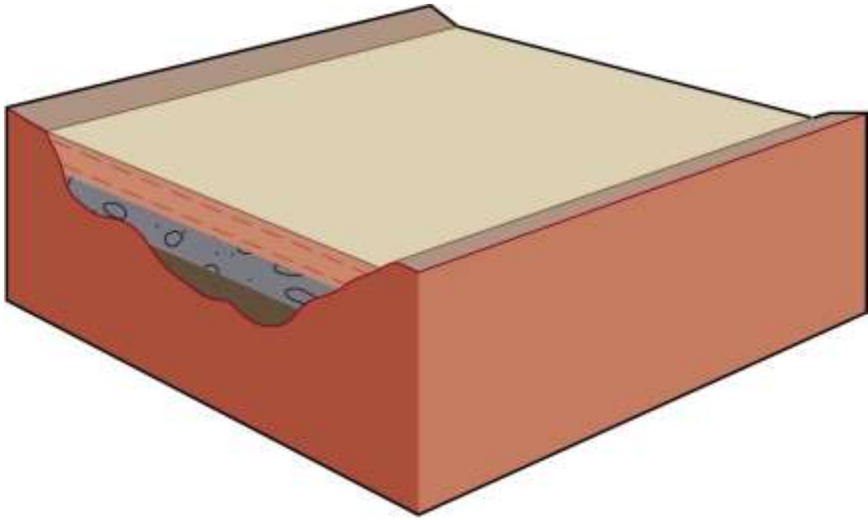
Angular Unconformity

Nonconformity

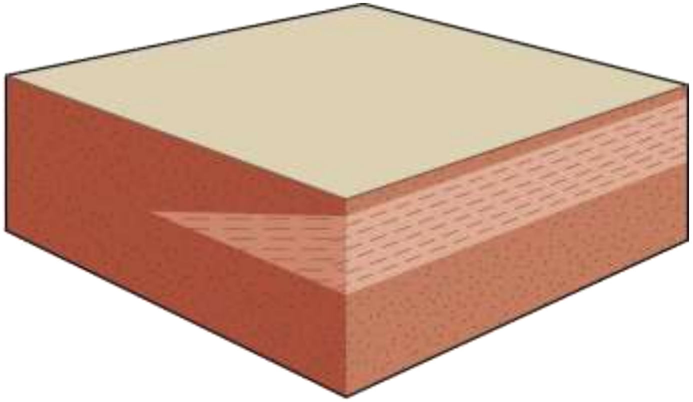
Lateral Relationships

- In 1669, Nicolas Steno proposed his **principle of lateral continuity**, meaning that layers of sediment extend outward in all directions until they terminate
  - Terminations may be
    - Abrupt at the edge of a depositional basin where eroded
    - where truncated by faults

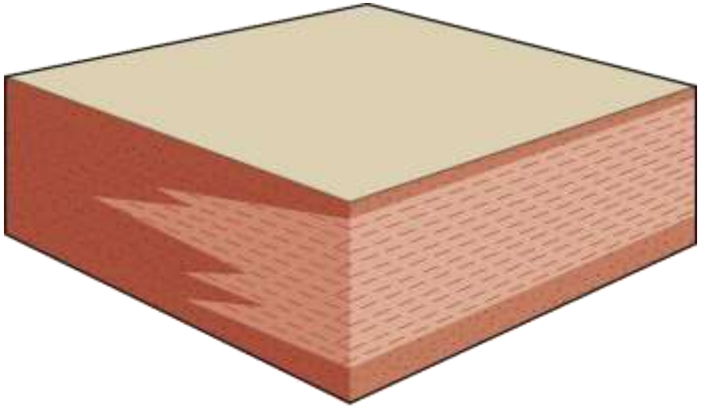


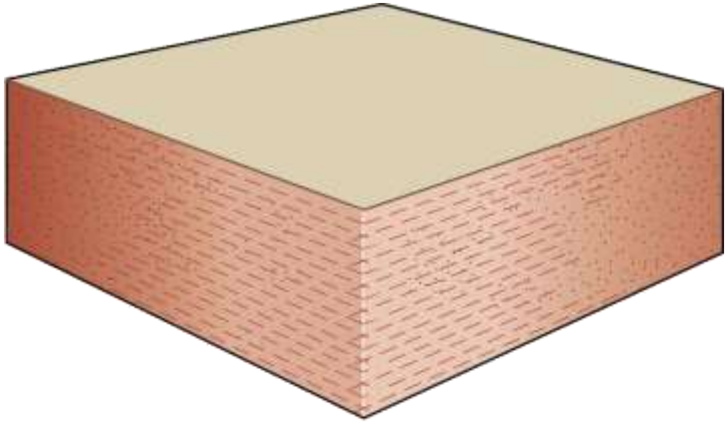


– or they may be gradual
  - where a rock unit becomes progressively thinner until it pinches out



- or where it splits into thinner units each of which pinches out,
  – called ***intertonging***





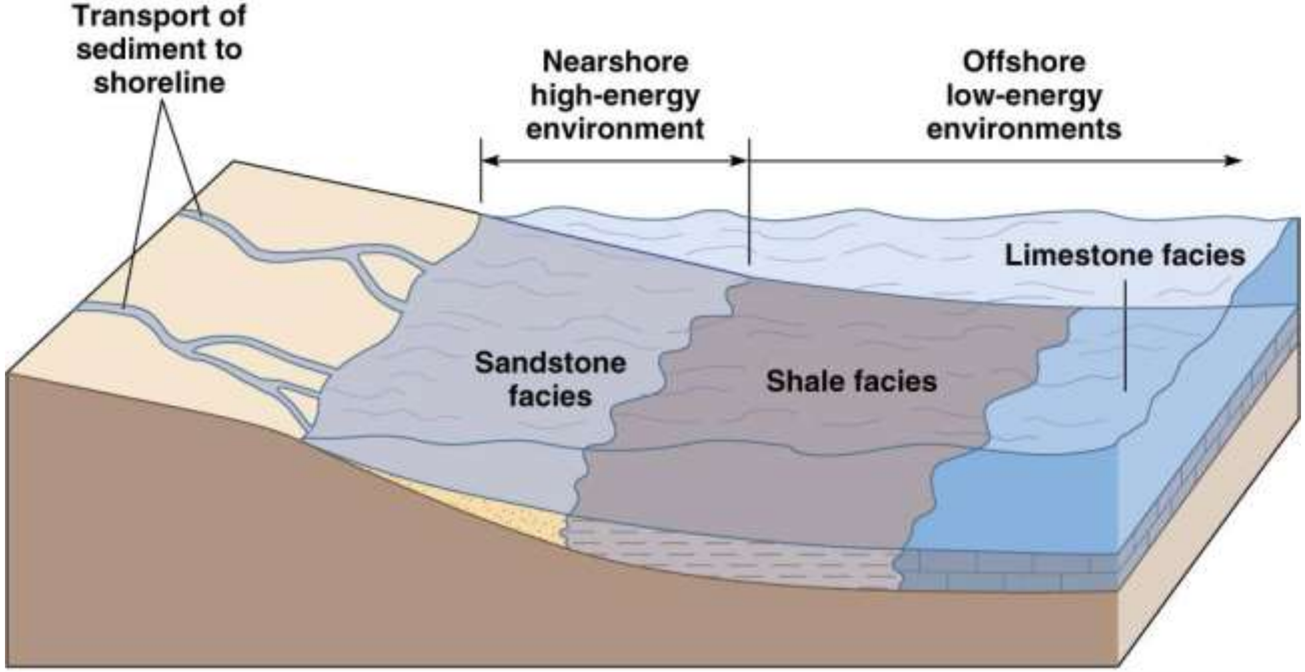
- where a rock unit changes by ***lateral gradation*** as its composition and/or texture becomes increasingly different

Sedimentary Facies

- Both intertonging and lateral gradation indicate simultaneous deposition in adjacent environments
- A **sedimentary facies** is a body of sediment with distinctive physical, chemical and biological attributes deposited side-by-side with other sediments in different environments

Sedimentary Facies

- On a continental shelf, sand may accumulate in the high-energy nearshore environment



  - while mud and carbonate deposition takes place at the same time in offshore low-energy environments

Marine Transgressions

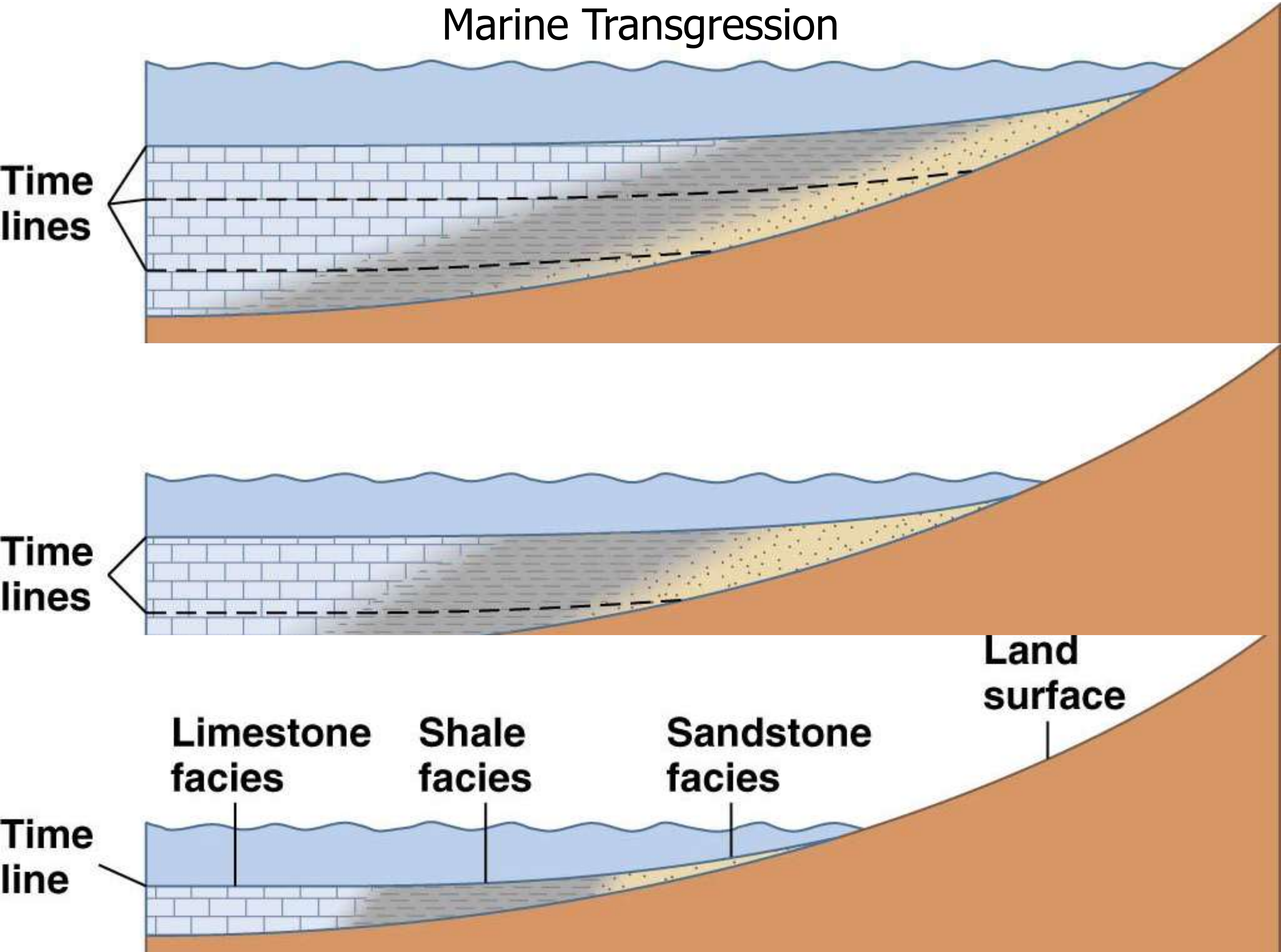
- A **marine transgression** occurs when sea level rises with respect to the land
- During a marine transgression,
  - the shoreline migrates landward
  - the environments paralleling the shoreline migrate landward as the sea progressively covers more and more of a continent

Marine Transgressions

- Each laterally adjacent depositional environment produces a sedimentary facies

- During a transgression, the facies forming offshore become superposed upon facies deposited in nearshore environments

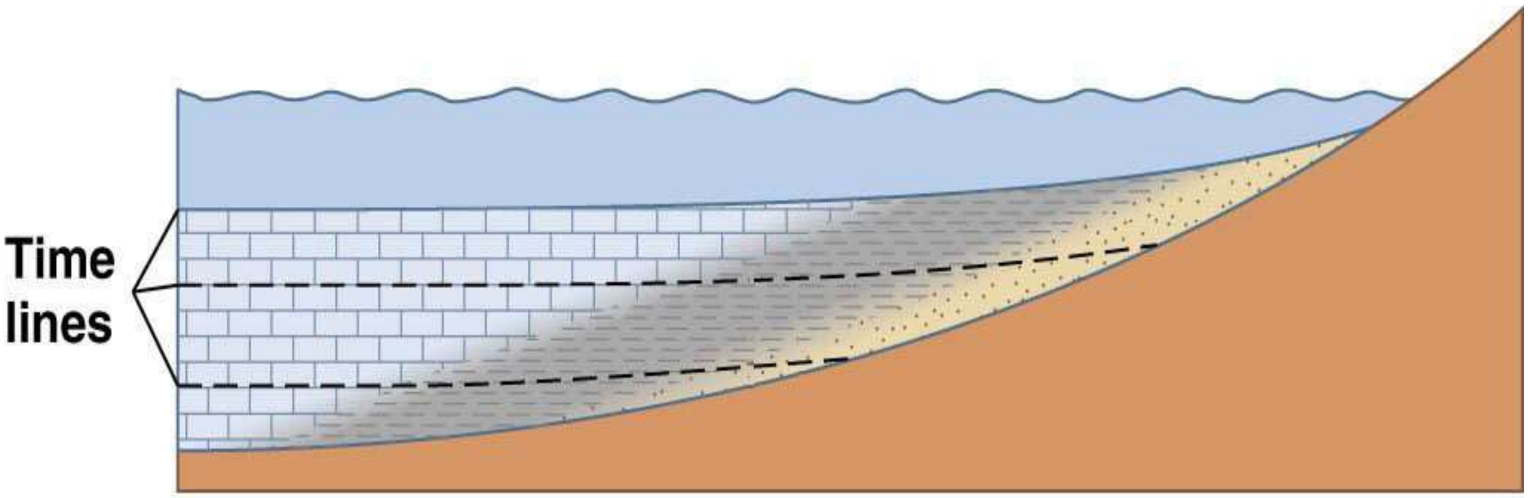
Marine Transgression



Marine Transgression

- The rocks of each facies become younger in a landward direction during a marine transgression

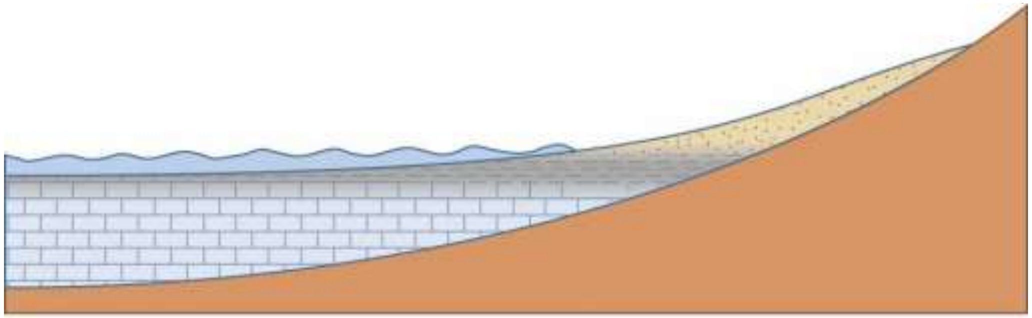
- One body of rock with the same attributes (a facies) was deposited gradually at different times in different places so it is ***time transgressive***
  - meaning the ages vary from place to place



A Marine Transgression Facies

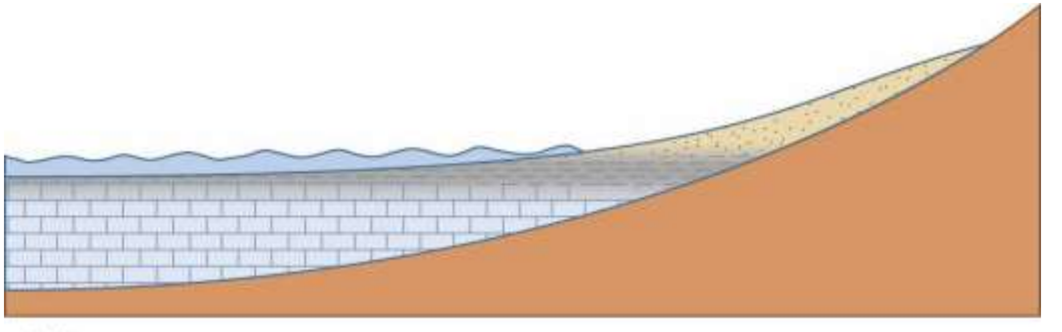
Marine Regression

- During a **marine regression**, sea level falls with respect to the continent
  - the environments paralleling the shoreline migrate seaward



Marine Regression

- A marine regression
  - – is the opposite of a marine transgression
- It yields a vertical sequence with nearshore facies overlying offshore facie sand rock units become younger in the seaward direction



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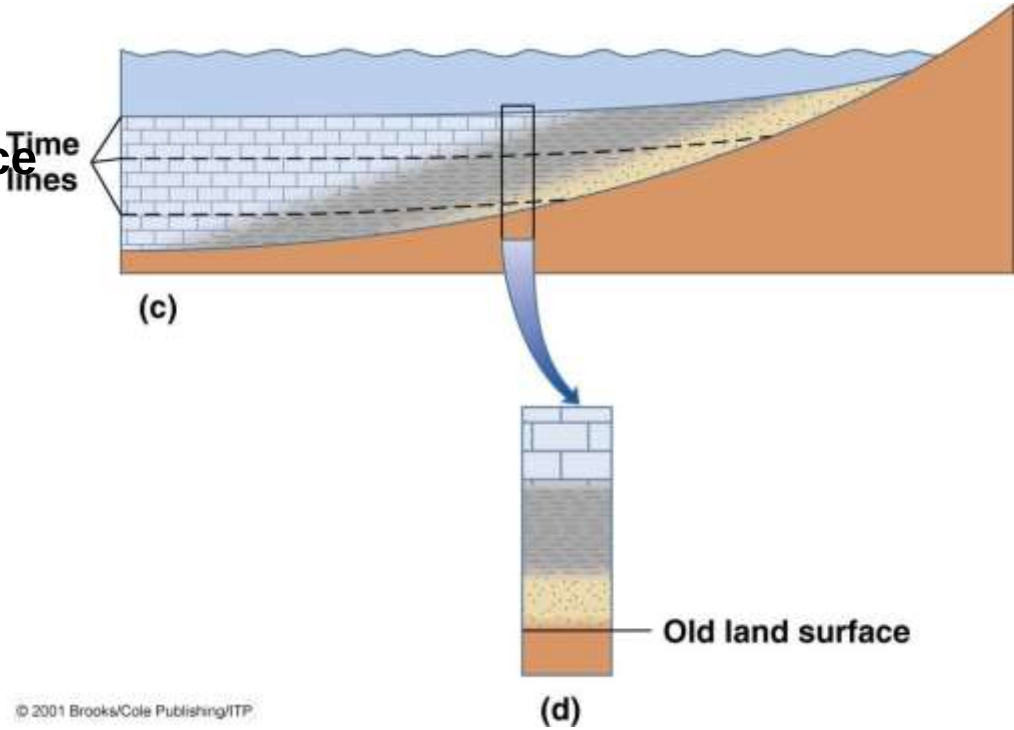
Walther's Law

- Johannes Walther (1860-1937) noticed that the same facies he found laterally were also present in a vertical sequence, now called **Walther's Law**

- **holds that**
  - **the facies seen in a conformable vertical sequence will also replace one another laterally**
  - **Walther's law applies to marine transgressions and regressions**

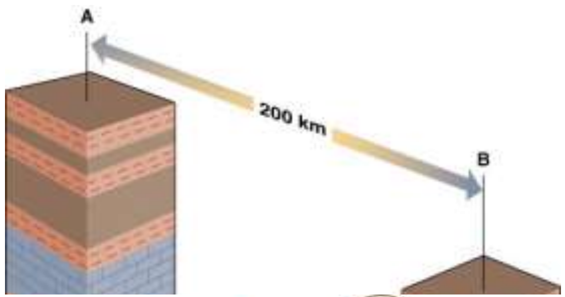


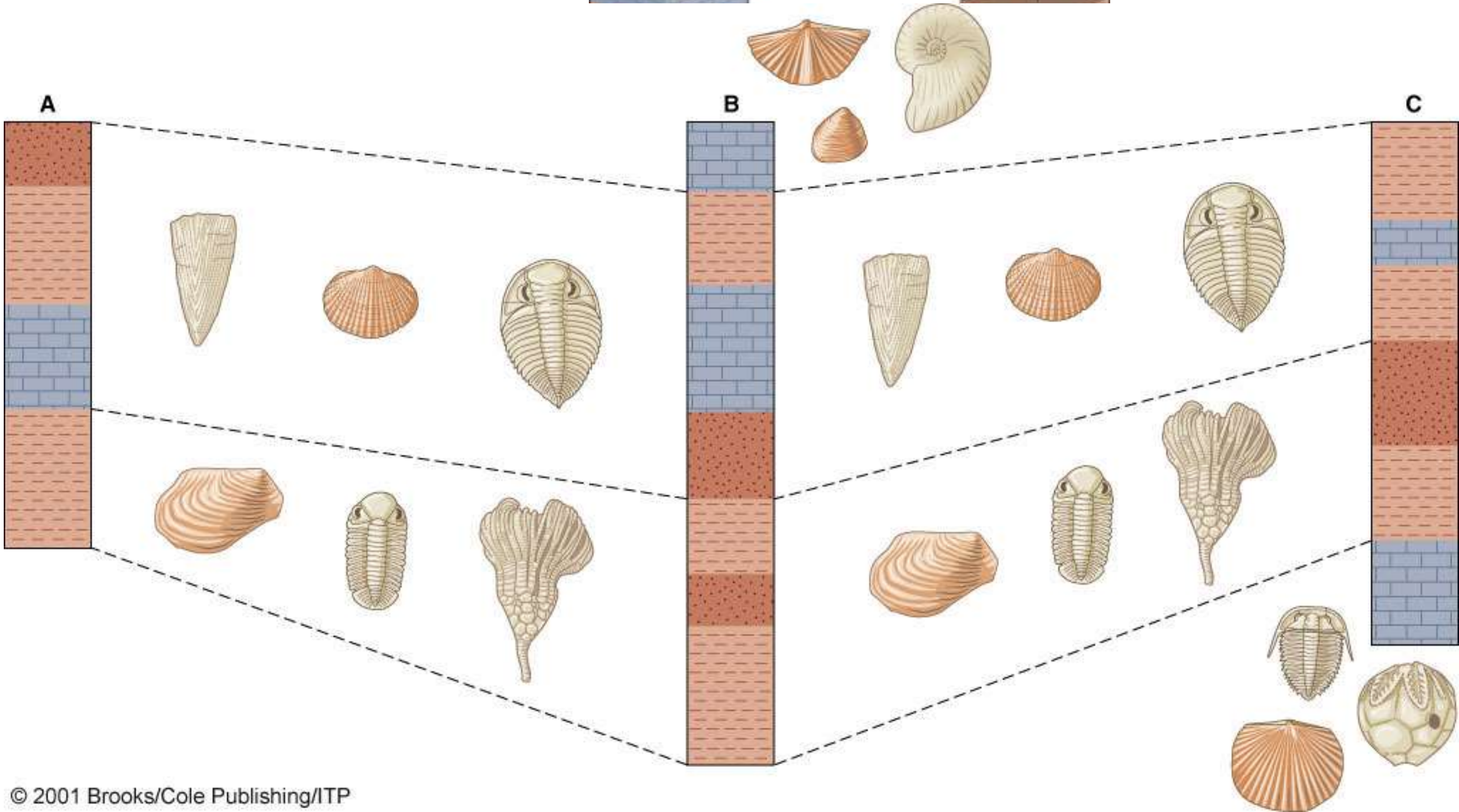
Fossils and Telling Time

- William Smith
  - 1769-1839, an English civil engineer independently discovered Steno's principle of superposition
- Realized that fossils in rocks followed the same principle
- He discovered that sequences of fossils, especially groups of fossils, are consistent from area to area
- Thereby discovering a method of relatively dating sedimentary rocks at different locations

Fossils from Different Areas

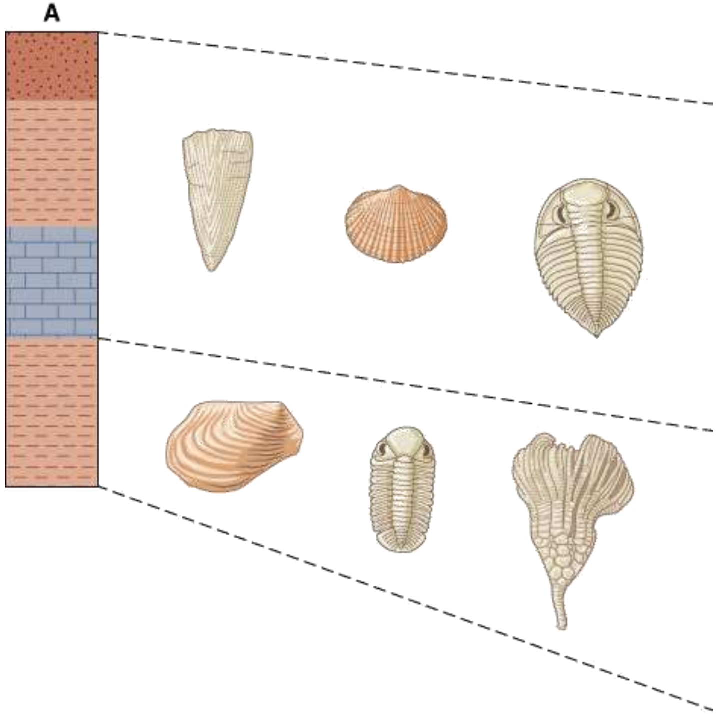
- To compare the ages of rocks from two different localities
- Smith used fossils





Principle of Fossil Succession

- Using superposition, Smith was able to predict the order in which fossils would appear in rocks not previously visited
  - Alexander Brongniart in France also recognized this relationship
- Their observations lead to the **principle of fossil succession**



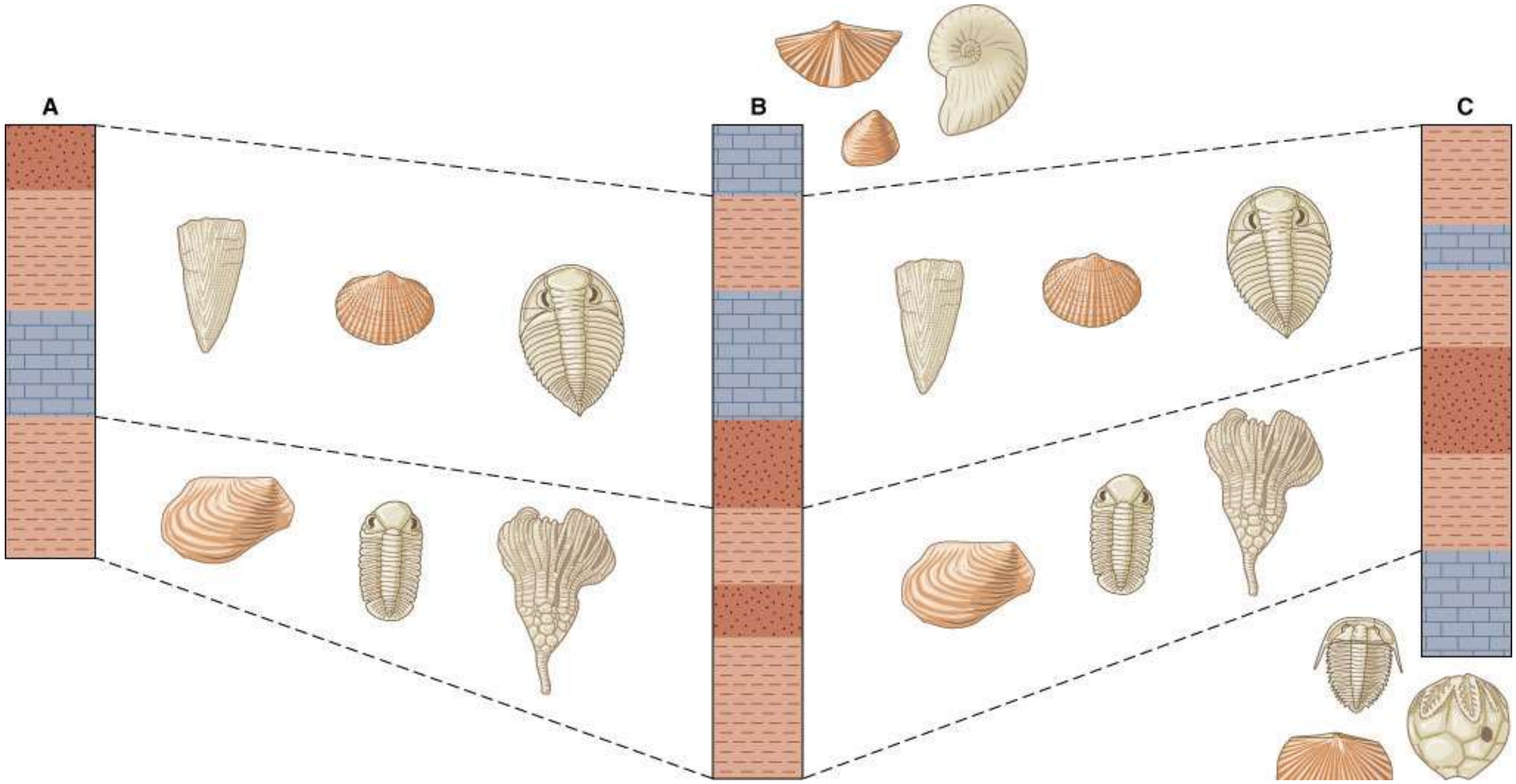
Principle of Fossil Succession

- **Principle of fossil succession** holds that fossil assemblages (groups of fossils) succeed one another through time in a regular and determinable order

- Why not simply match up similar rocks types?
  - Because the same kind of rock has formed repeatedly through time

- Fossils also formed through time,
  - but because different organisms existed at different times,
  - fossil assemblages are unique

Matching Rocks Using Fossils



- Geologists use the principle of fossil succession to match ages of distant rock sequences
  - Dashed lines indicate rocks with similar fossils thus having the same age

Stratigraphic Terminology

- Because sedimentary rock units are time transgressive, they may belong to one system in one area and to another system elsewhere

- At some localities a rock unit
  - straddles the boundary between systems

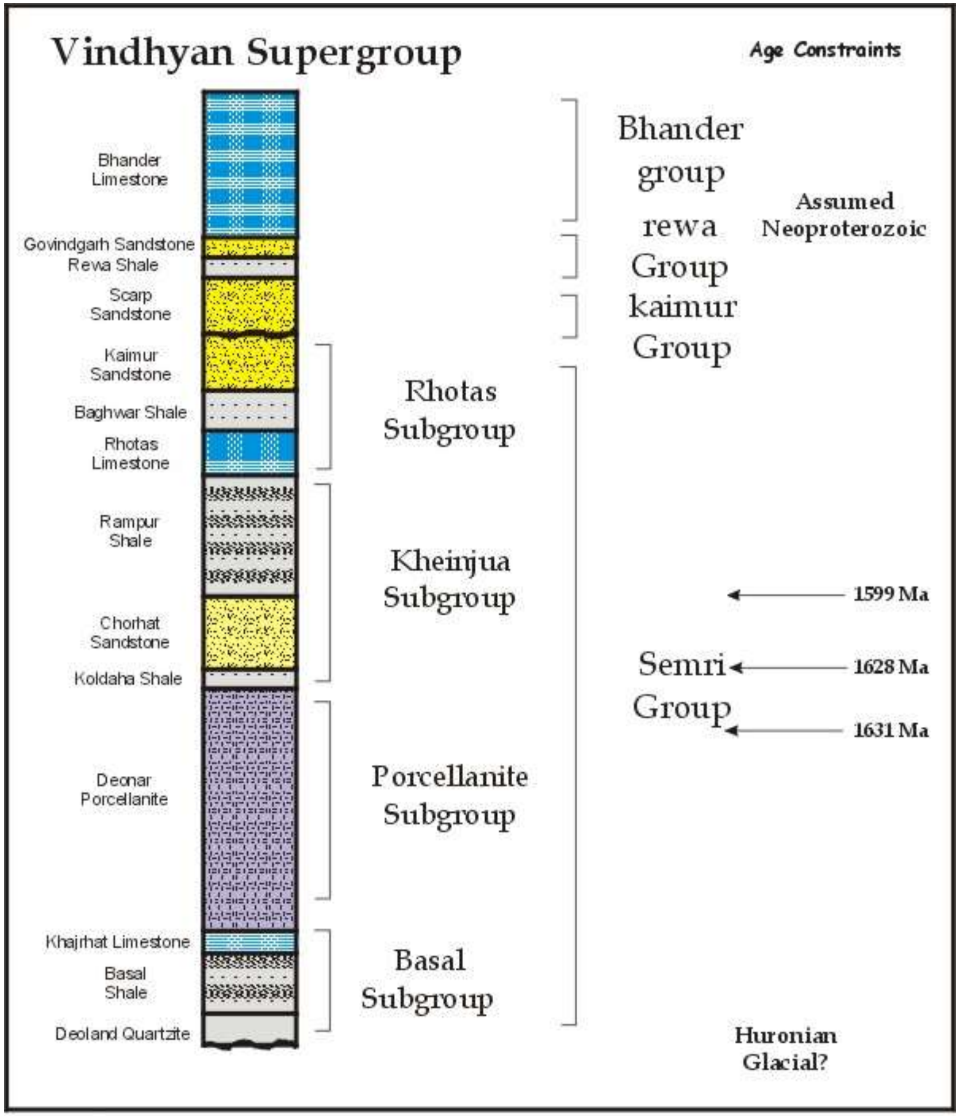
- We need terminology that deals with both:
  - rocks—defined by their content
    - **lithostratigraphic unit** – rock content
    - **biostratigraphic unit** – fossil content
  - and time—expressing or related to geologic time
    - **time-stratigraphic unit** – rocks of a certain age
    - **time units** – referring to time not rocks

Lithostratigraphic Units

- **Lithostratigraphic units** are based on rock type
  - with no consideration of time of origin
- The basic lithostratigraphic element is a **formation**
  - a mappable rock unit with distinctive upper and lower boundaries
  - It may consist of a single rock type
    - such as the **Redwall limestone**
  - or a variety of rock types
    - such as the **Morrison Formation**
- Formations may be subdivided
  - into ***members*** and ***beds***
  - or collected into ***groups*** and ***supergroups***

Lithostratigraphic Units

- Lithostratigraphic units in Vindhyan Supergroup



Ages from Ray et al., 2002 and Rasmussen et al., 2002

Biostratigraphic Units

- A body of strata recognized only on the basis of its fossil content is a **biostratigraphic unit**
    - the boundaries of which do not necessarily correspond to those of lithostratigraphic units
- The fundamental biostratigraphic unit
    - is the **biozone**

Time-Stratigraphic Units

- **Time-stratigraphic units**
    - also called ***chronostratigraphic units***
  - consist of rocks deposited during a particular interval of geologic time
- The basic time-stratigraphic unit is the **system**

Time Units

- Time units simply designate certain parts of geologic time

- **Period** is the most commonly used time designation
- Two or more periods may be designated as an ***era***
- Two or more eras constitute and ***eon***
- Periods can be made up of shorter time units
  - ***epochs*, **which can be subdivided into ***ages***

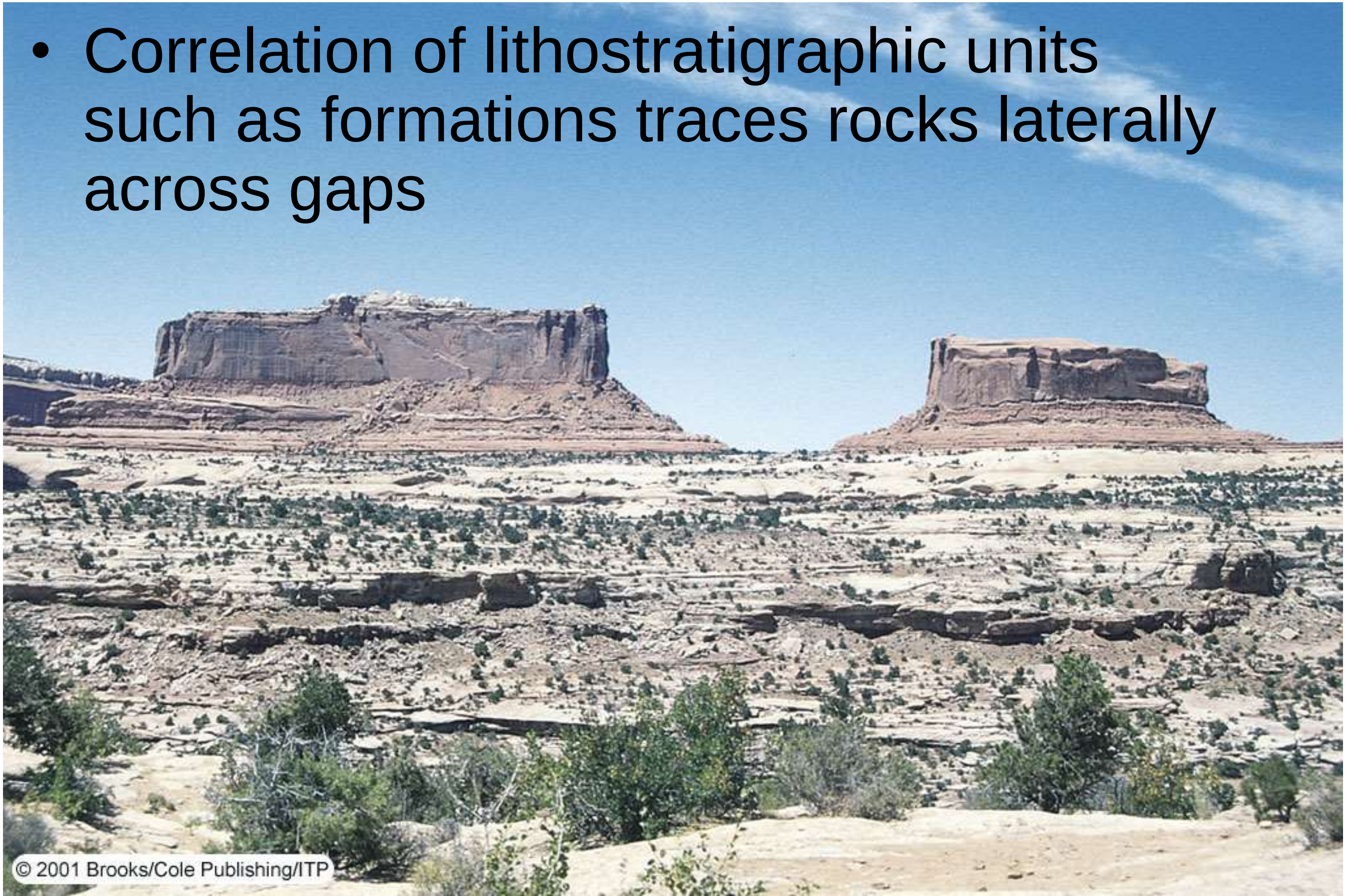
- **The time-stratigraphic unit, system, corresponds to the time unit, period**

Correlation

- **Correlation** is the process of matching up rocks in different areas
- There are two types of correlation:
  - Lithostratigraphic correlation
    - simply matching up the same rock units over a larger area with no regard for time
  - Time-stratigraphic correlation
    - demonstrates time-equivalence of events

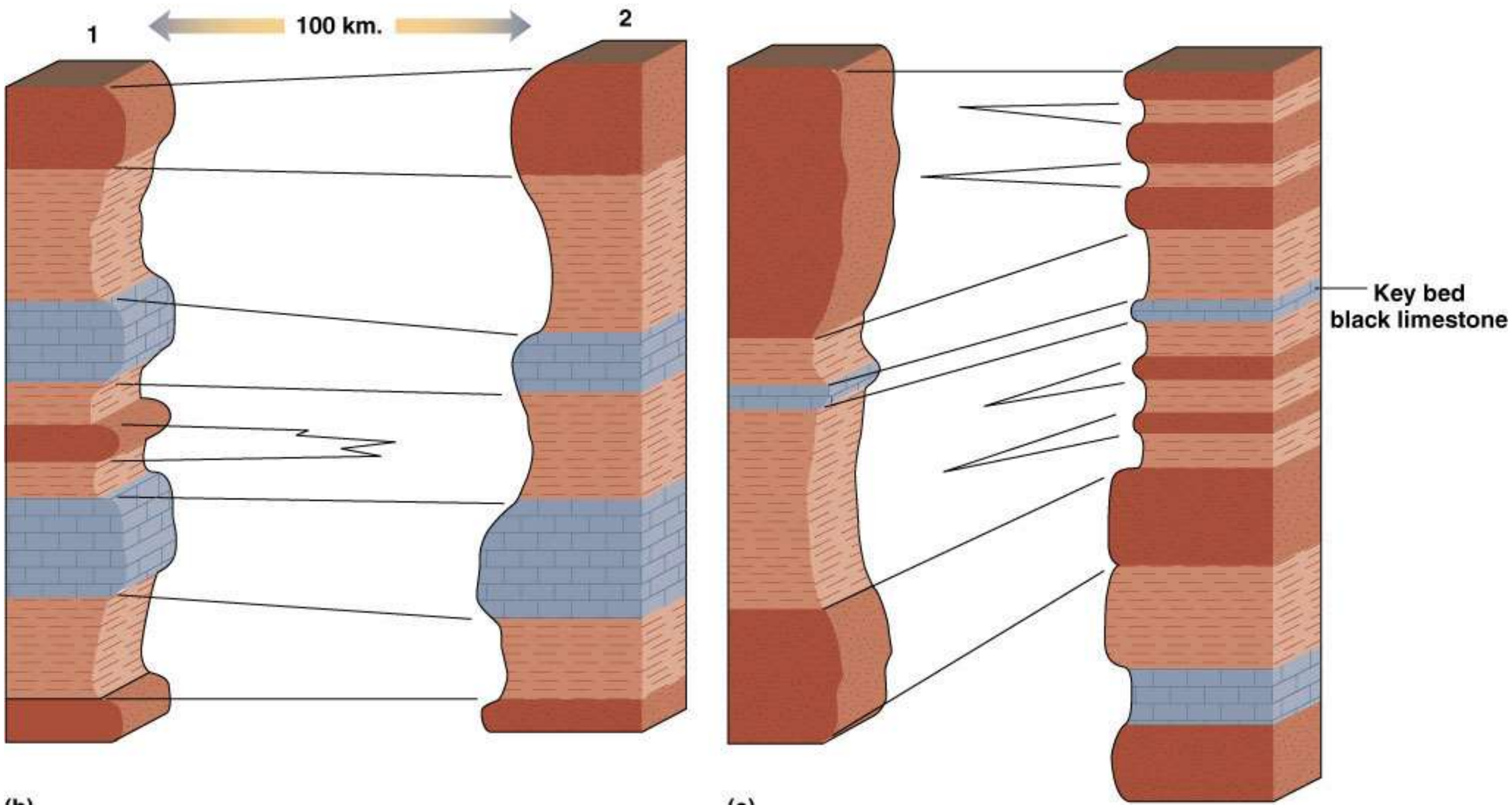
Lithostratigraphic Correlation

- Correlation of lithostratigraphic units such as formations traces rocks laterally across gaps



Lithostratigraphic Correlation

- We can correlate rock units based on
  - composition
  - position in a sequence
  - and the presence of distinctive key beds



Time Equivalence

- Because most rock units of regional extent are time transgressive we cannot rely on lithostratigraphic correlation to demonstrate time equivalence

- Example:
  - sandstone in Arizona is correctly correlated with similar rocks in Colorado and South Dakota
  - but the age of these rocks varies from Early Cambrian in the west to middle Cambrian farther east

Time Equivalence

- The most effective way to demonstrate time equivalence is time-stratigraphic correlation using biozones

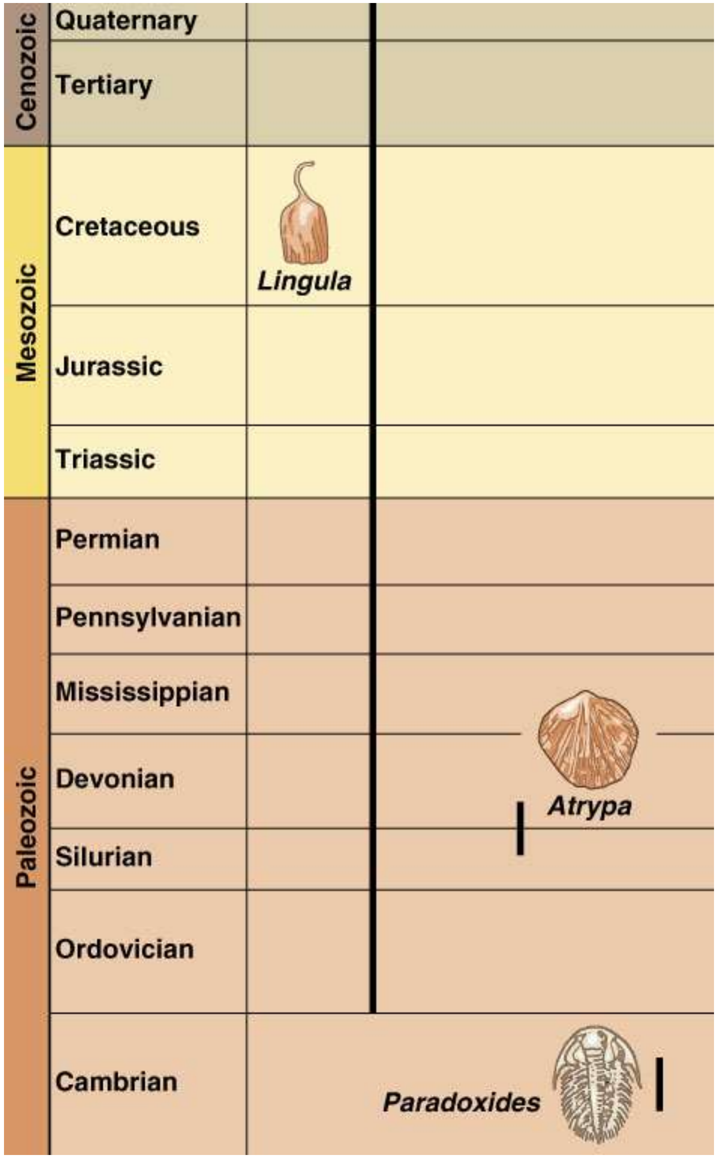
Biozones

- For all organisms now extinct, their existence marks two points in time
    - their time of origin
    - their time of extinction

- One type of biozone, the **range zone**, is defined by the ***geologic range*** (total time of existence) of a particular fossil group, species, or a group of related species called a genus

- Most useful are fossils that are
    - easily identified
    - geographically widespread
    - and had a rather short geologic range

Guide Fossils

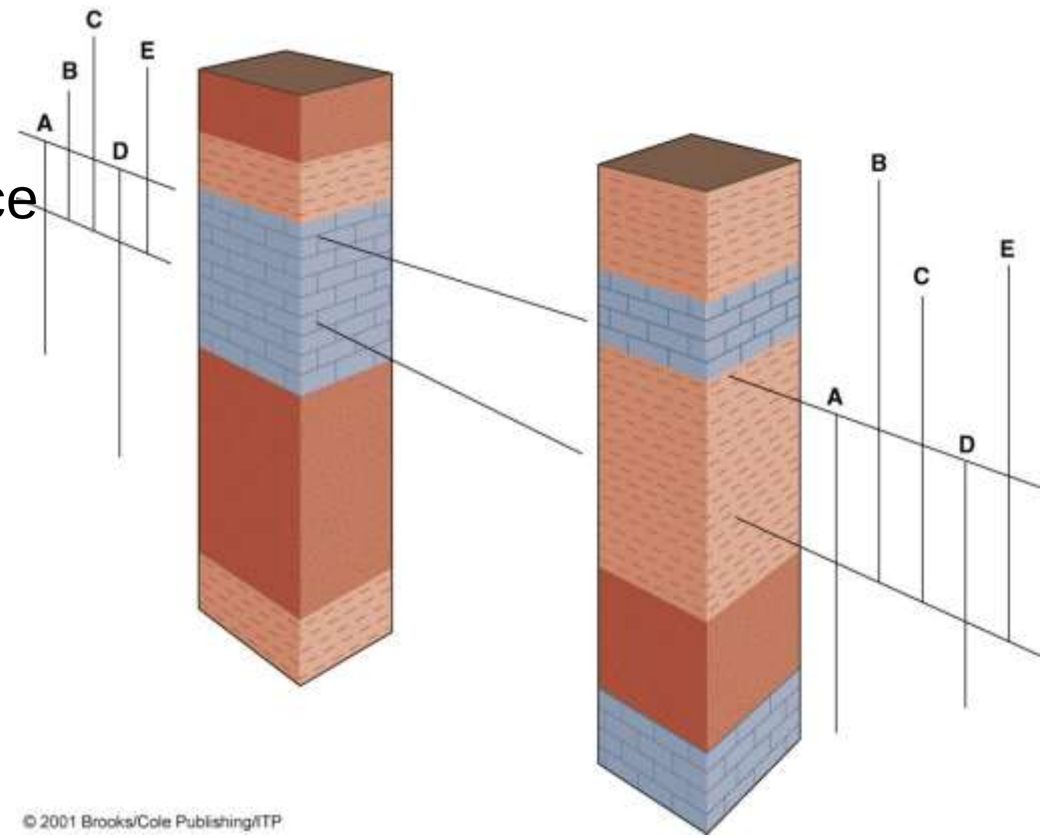


- The brachiopod *Lingula* is not useful because, although it is easily identified and has a wide geographic extent, it has too large a geologic range
- The brachiopod Atrypa and trilobite *Paradoxides* are well suited for time-stratigraphic correlation, because of their short ranges
- They are **guide fossils**

Concurrent Range Zones

- A **concurrent range zone** is established by plotting the overlapping ranges of two or more fossils with different geologic ranges

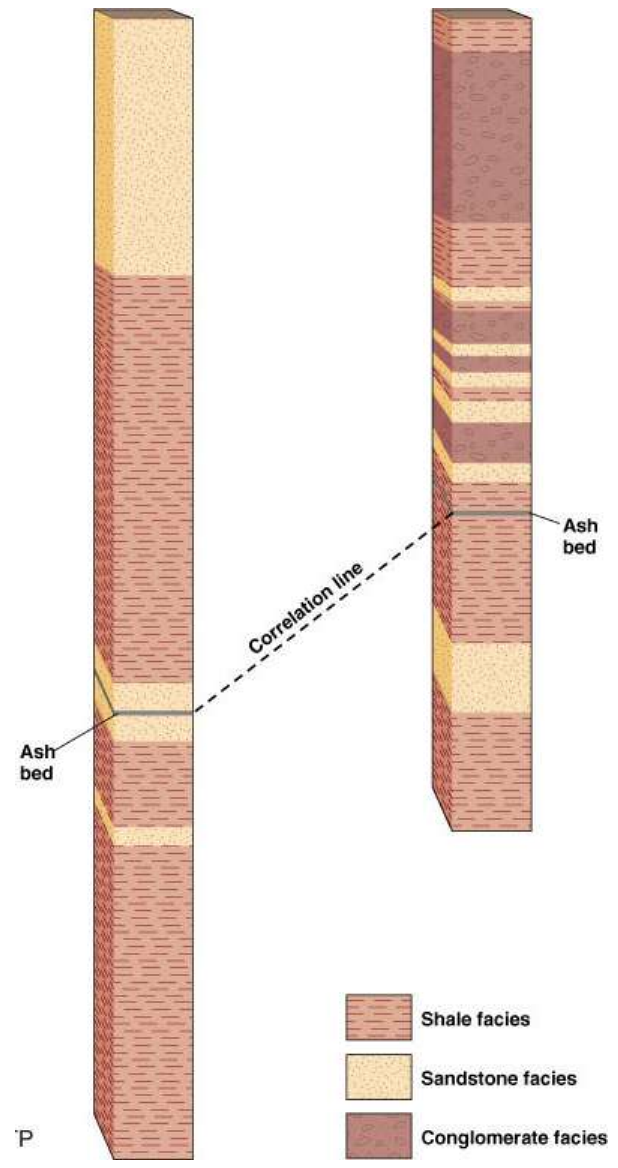
- This is probably the most accurate method of determining time equivalence



Short Duration Physical Events

- Some physical events of short duration are also used to demonstrate time equivalence:
  - distinctive lava flow
    - would have formed over a short period of time
  - ash falls
    - take place in a matter of hours or days
    - may cover large areas
    - are not restricted to a specific environment

- Absolute ages may be obtained for igneous events using radiometric dating



Absolute Dates and the Relative Geologic Time Scale

- Ordovician rocks
  - are younger than those of the Cambrian
  - and older than Silurian rocks
- But how old are they? When did the Ordovician begin and end?
- Since radiometric dating techniques work on igneous and some metamorphic rocks, but not generally on sedimentary rocks, this is not so easy to determine

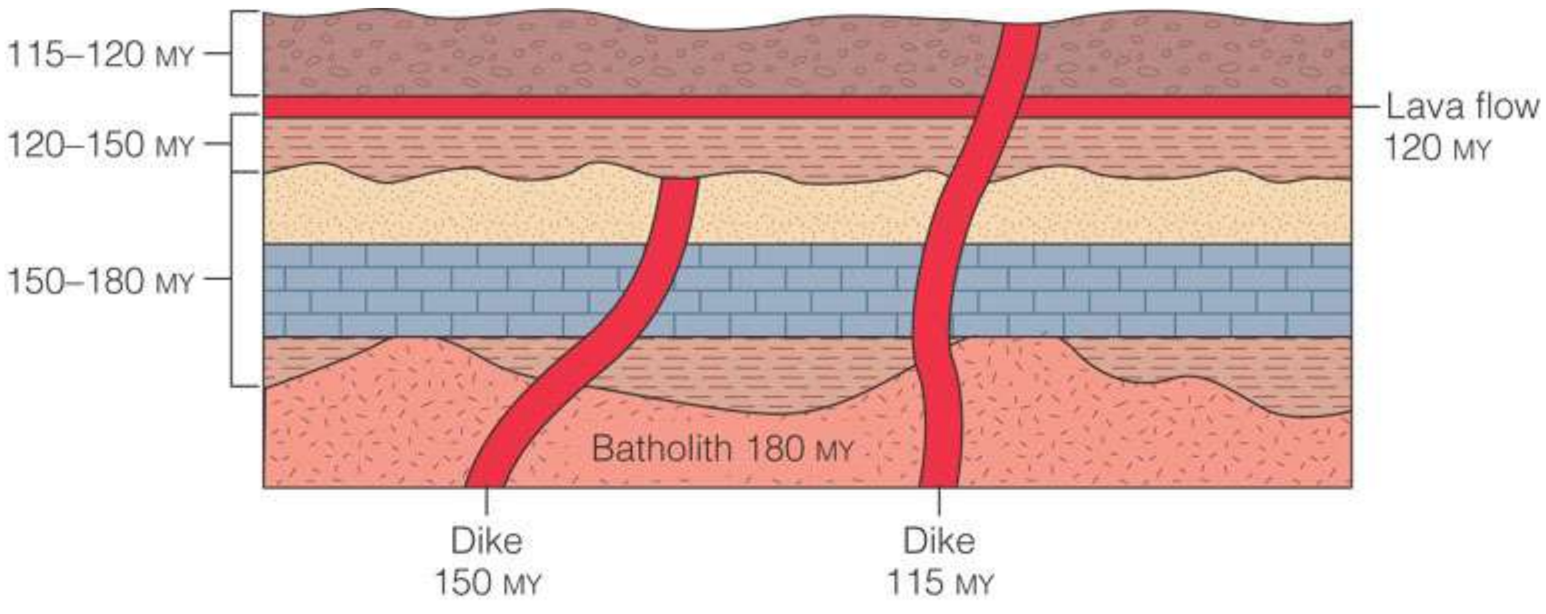
Absolute Dates for Sedimentary Rocks Are Indirect

- Mostly, absolute ages for sedimentary rocks must be determined indirectly by dating associated igneous and metamorphic rocks

- According to the principle of cross-cutting relationships,
  - a dike must be younger than the rock it cuts, so an absolute age for a dike gives a minimum age for the host rock and a maximum age for any rocks deposited across the dike after it was eroded

Indirect Dating

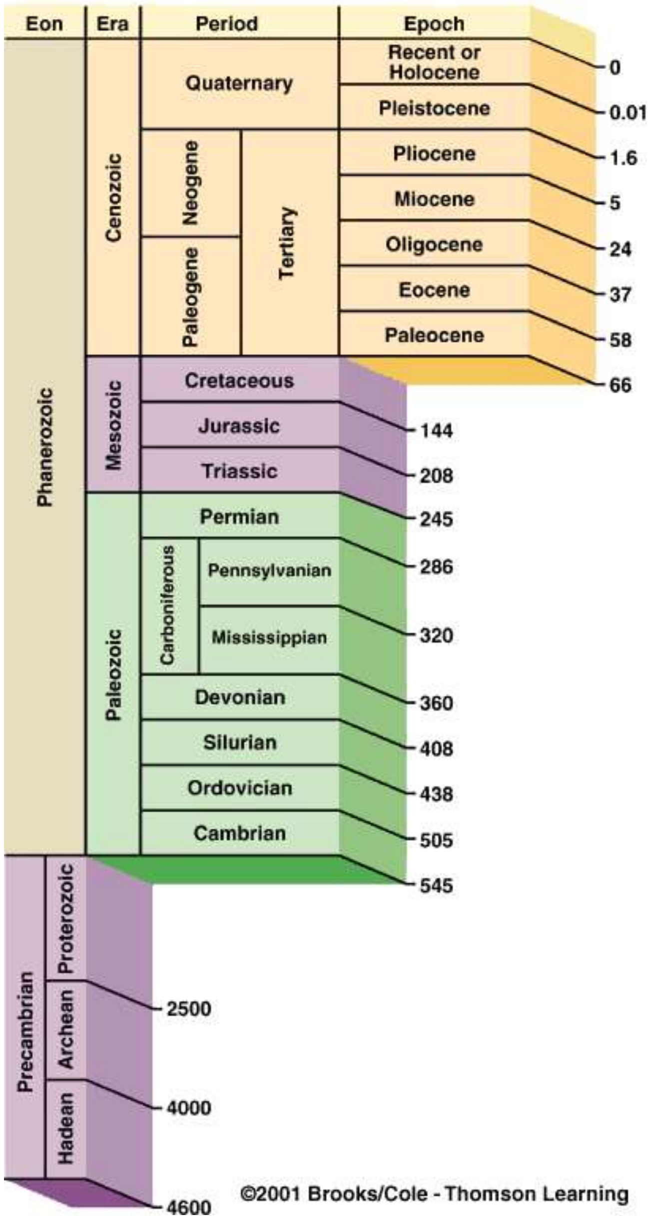
- Absolute ages of sedimentary rocks are most often found by determining radiometric ages of associated igneous or metamorphic rocks



Indirect Dating

- The absolute dates obtained from regionally metamorphosed rocks give a maximum age for overlying sedimentary rocks
- Lava flows and ash falls interbedded with sedimentary rocks are the most useful for determining absolute ages
- Both provide time-equivalent surfaces
  - giving a maximum age for any rocks above
  - and a minimum age for any rocks below

Indirect Dating



- Combining thousands of absolute ages associated with sedimentary rocks of known relative age gives the numbers on the geologic time scale