Historical Geology:

Study of the evolution of Earth, its environments, and its life through time

Combines many subdisciplines of geology

- Sedimentology
- Stratigraphy
- Structural Geology
- Plate Tectonics & Paleogeography
- Paleobiogeography
- Paleontology

Examines geologic history as a **pattern** (the particular changes in sequence throughout time) and as **process** (rules or principles that govern these changes).

Some of the topics covered:

- **Paleoenviroment analysis**: interpreting ancient environmental conditions from the rock record (e.g.: river & lake systems, deltas, lagoons, deep marine, etc.)
- **Geologic Time**: how to determine numerical and relative dates in time
- The **Geologic Column**: its construction and its operation
- **Orogenesis**: the rise (and fall) of mountain ranges
- The principles of **organic evolution**
- The formation and distribution of continental rocks through time
- Origin, diversification, and extinction of the major groups of organisms in Earth's history

History of Geologic Thought

•1669 Nicolaus Steno
Stratigraphy
- principle of superposition
- principle of original horizontality
- principle of lateral continuity

•Abraham Werner (1750-1817)
neptunism
- primitive rocks
- transition rocks
- alluvium

•James Hutton (1726-1797)
"Father of geology"

•plutonism
uniformitarianism
"Theory of the Earth" 1785
- Cyclical view of earth's history
Profound changes can be the result of small changes over long periods of time.

•

•William "Strata" Smith
principle of biologic succession,

Founders of Historical Geology

Abraham Gottlieb Werner 1749-1817

Most influential geologist of the late 18th century
Studied at the Freiburg Mining Academy
Taught mineralogy at Freiburg.
Developed the "Neptunian" classification of rocks
All rocks of the crust were deposited or precipitated from sea water
A universal ocean once covered the Earth
Followers called "Neptunists"

Founders of Historical Geology

Abraham Gottlieb Werner 1749-1817

Primitive Rocks	**Deposited first**
	Came from hot, steamy fluid with many dissolved minerals
	Coarse grained igneous and metamorphic
Transition Rocks	**Ocean basins formed, waters cooled**
	Fossiliferous, stratified rocks
	Deformed rocks
	Ocean resembled modern oceans

Founders of Historical Geology

Flötzgebirge	**Flat lying sedimentary rocks** **Contained lava flows**
Alluvium	**All unconsolidated material**

Founders of Historical Geology

James Hutton 1726-1797

Father of Modern Geology

Edinburgh physician & geologist?
Opponent to Neptunism

Believed *fire* was the answer.

Recognized change on the Earth's surface
(Surficial processes were active)

Developed cyclic view of Earth

"No vestige of a beginning, no prospect of an end".

Founders of Historical Geology

Laid foundation for *uniformitarianism*

"The past history of our globe must be explained by what can be seen to be happening now".

By observing geologic processes in operation around him, Hutton could infer the origin of features observed in rocks.

"Present is the key to the past".

Archibald Geike 1835-1924

Uniformitarianism

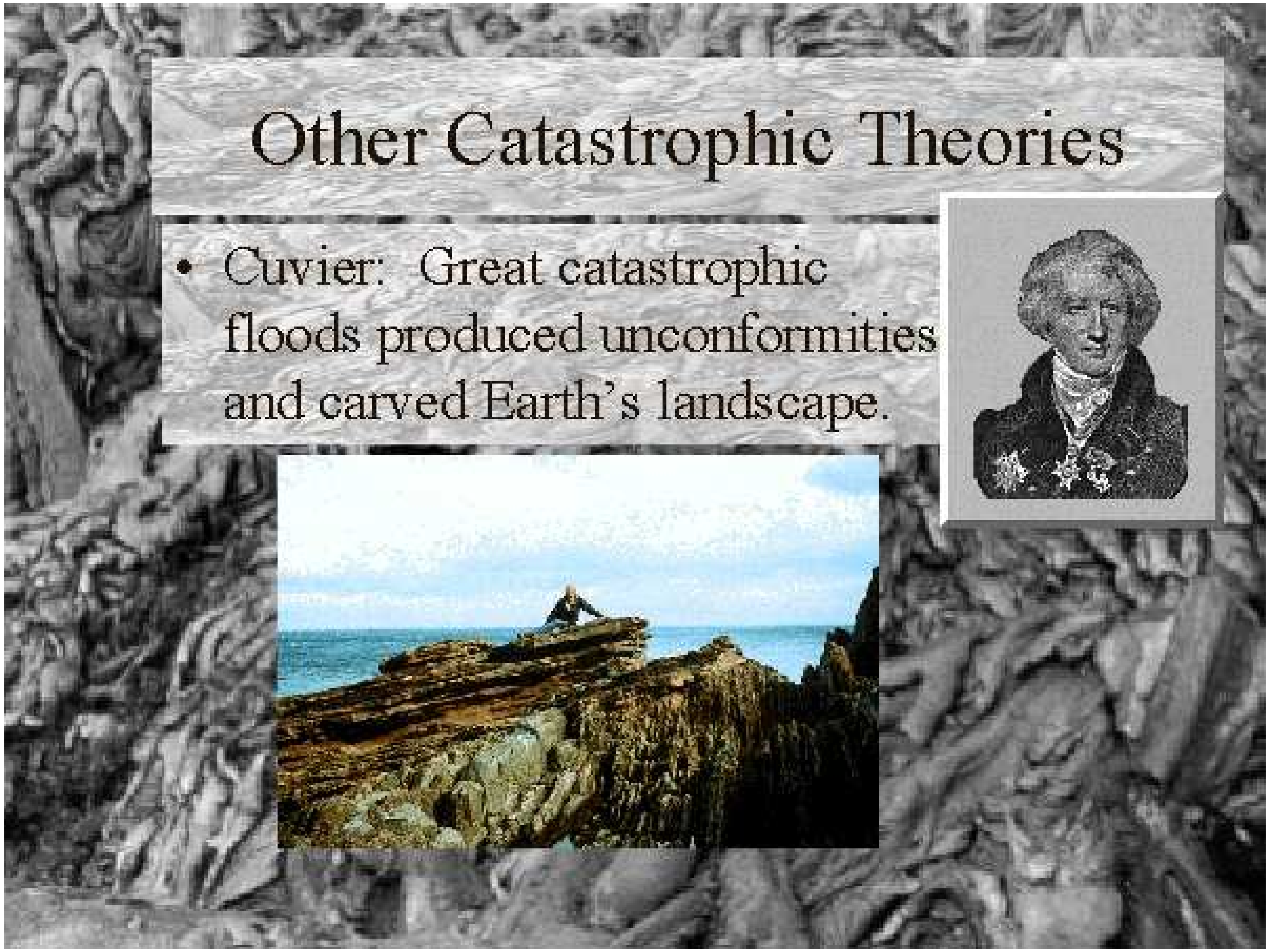
Not just another nine-syllable word.

- *The present is the key to the past.*

- *Not just another nine-syllable definition.*

Doctrine of Uniformitarianism: The physical and chemical laws that govern nature are uniform

Cuvier (1769-1832)
catastrophism
Showed that fossil animals found in different stratigraphic intervals in Paris Basin had undergone extinction (did not believe that new species arose)
Recurrent catastrophic events causing widespread extinction and resulting in sharp boundaries between fossil layers.



Founders of Historical Geology

William Smith 1769-1839

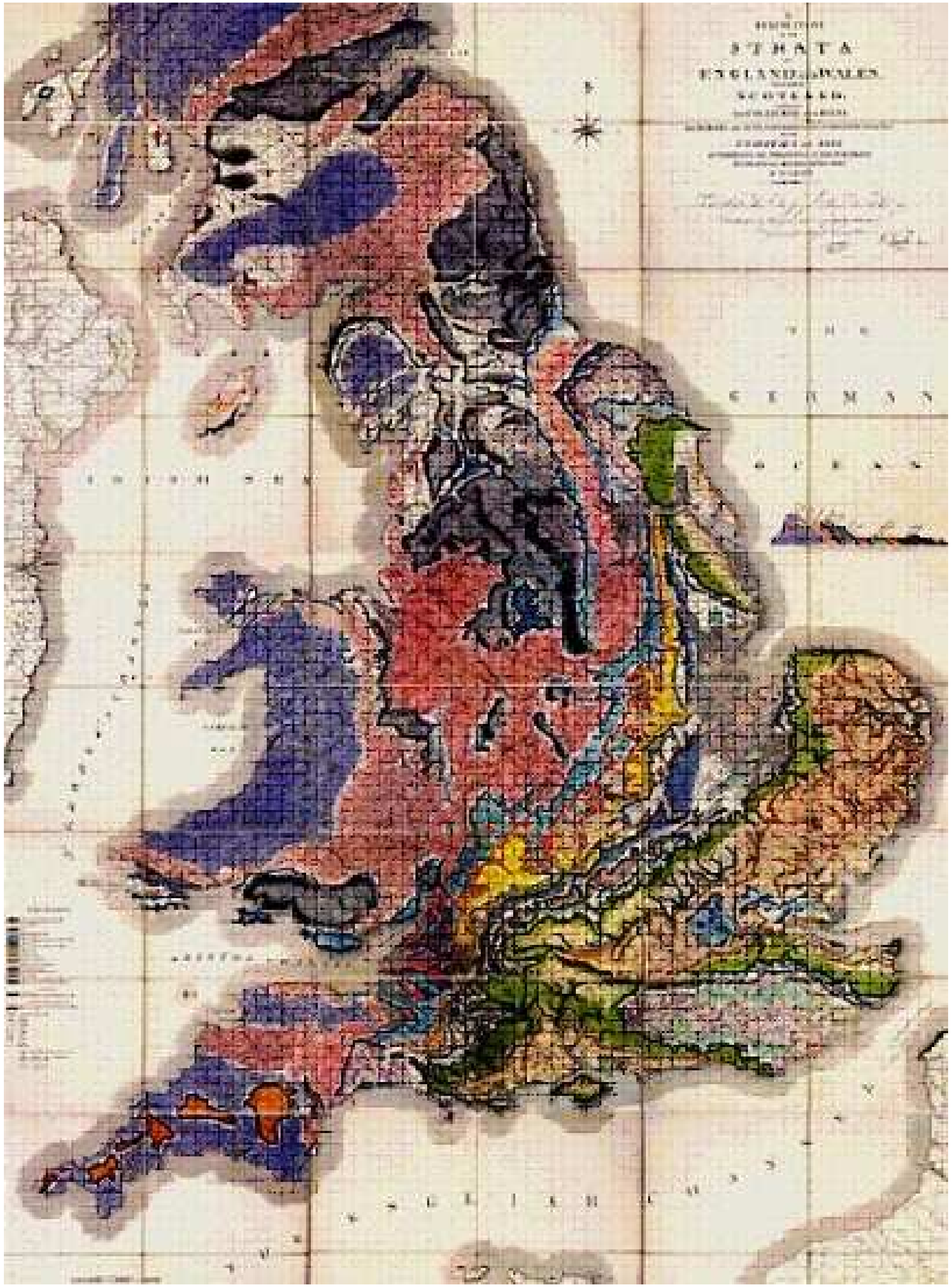
English surveyor and mining engineer

Created the first geologic map

Understood sequences of rock, applied soils, lithology, and fossils

First to recognize that rocks could be identified by their fossil assemblages

First to "correlate" rocks of the same age but different lithology


STRATA
ENGLAND WALES
SCOTLAND
IRISH SEA
GERMAN

Founders of Historical Geology

William Smith 1769-1839

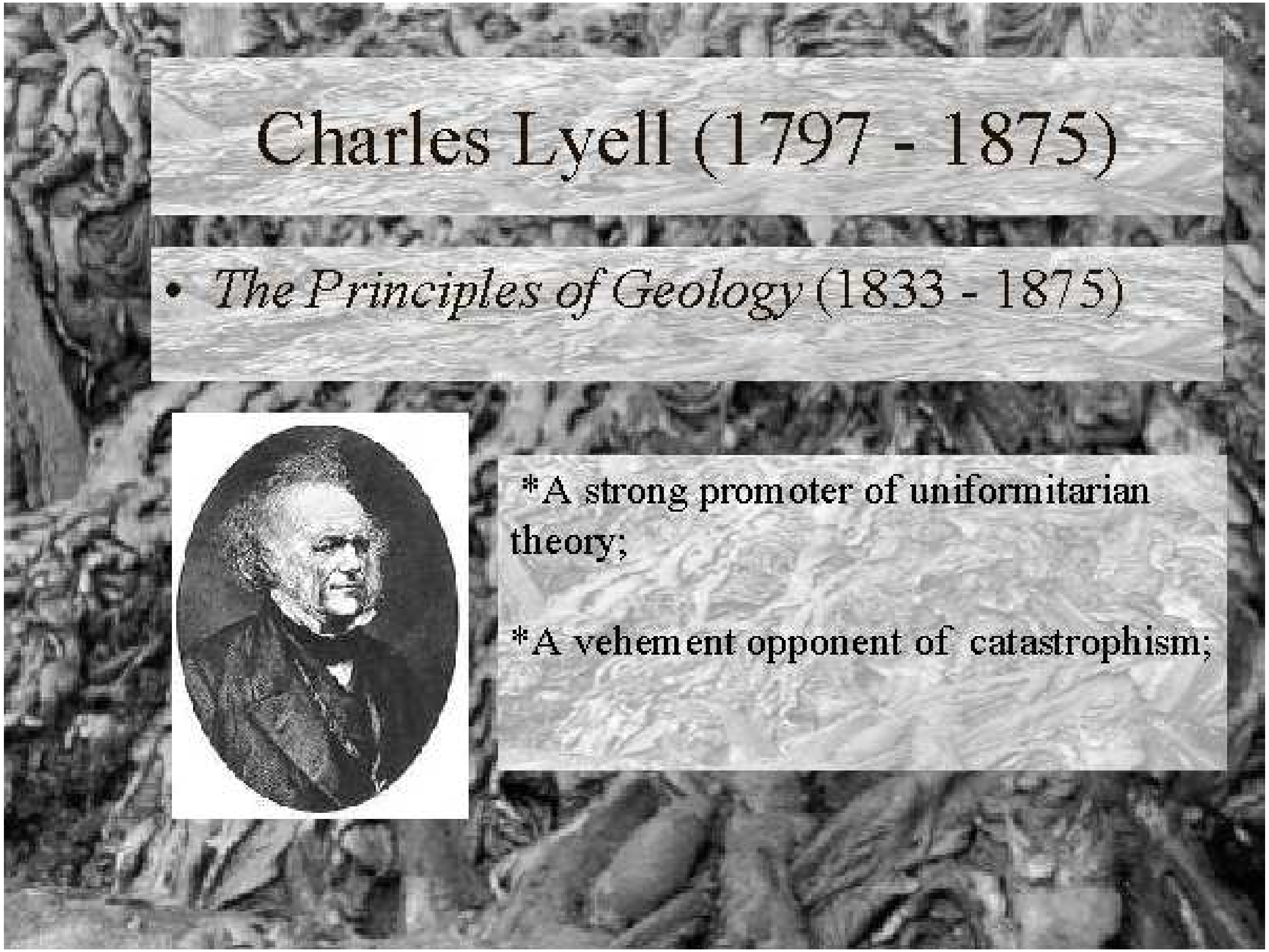
Correlation led to Principle of Faunal Succession

If we know the position of each rock layer in a sequence, we know their relative age.
Then, if we look a the fossils in the layers, we can determine the relative ages of them.
This sequence will occur again and again in the geologic record on a widespread geographic scale.
Can then be used to provide relative age of the rocks.

Smith determined that the life forms of each age in Earth history were unique for given intervals

Fossils could then be used to determine the chronology of the rocks

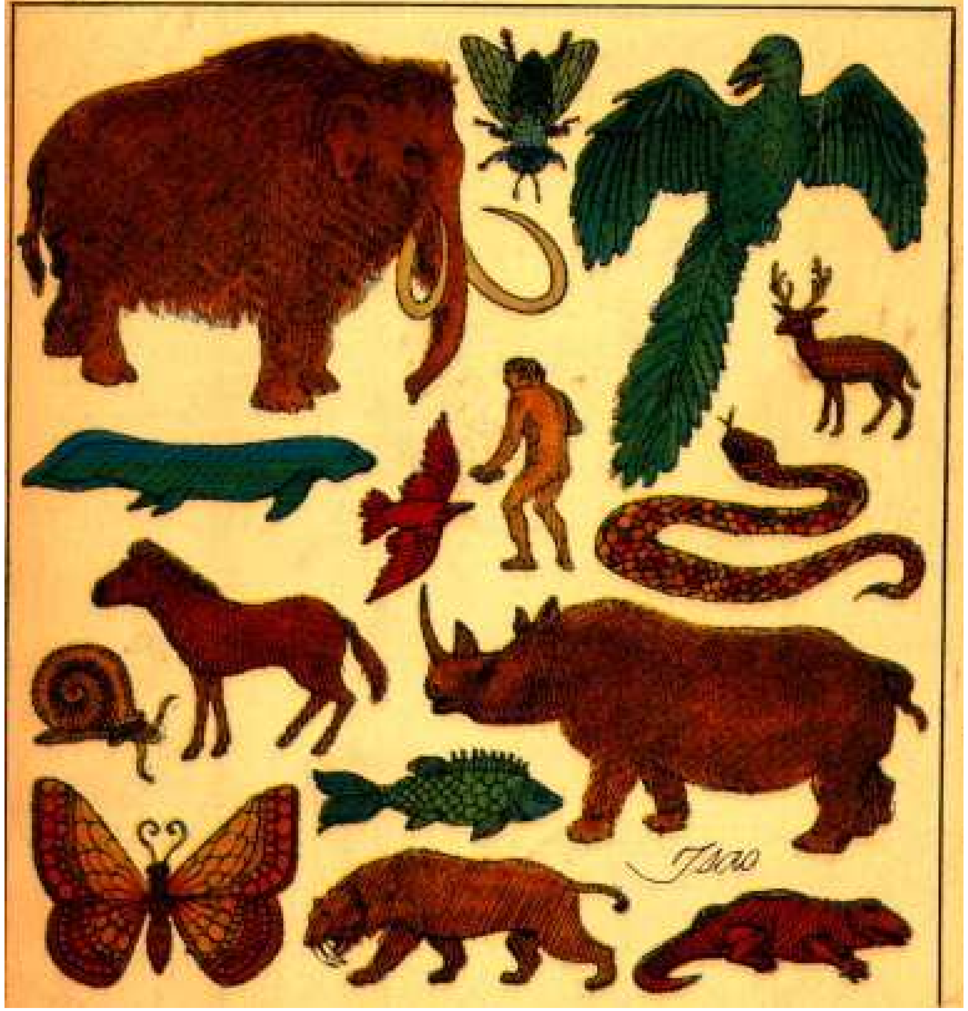
Smith saw it, knew it was right, but didn't know WHY



Charles Lyell (1830) "Principles of Geology"
The same processes we see today also acted in the past.
principle of cross-cutting relationships
Primary, Secondary, Tertiary, Recent.

Charles Darwin
The Origin of Species

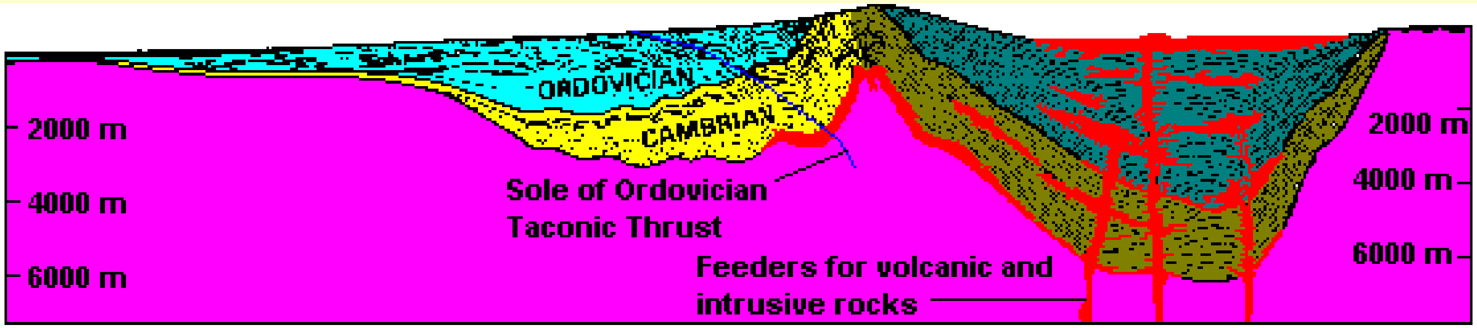
With a special Introduction by JULIAN HUXLEY



Geosynclinal Model - Dana, Hall, end of 19th century

James Hall , James Dwight Dana

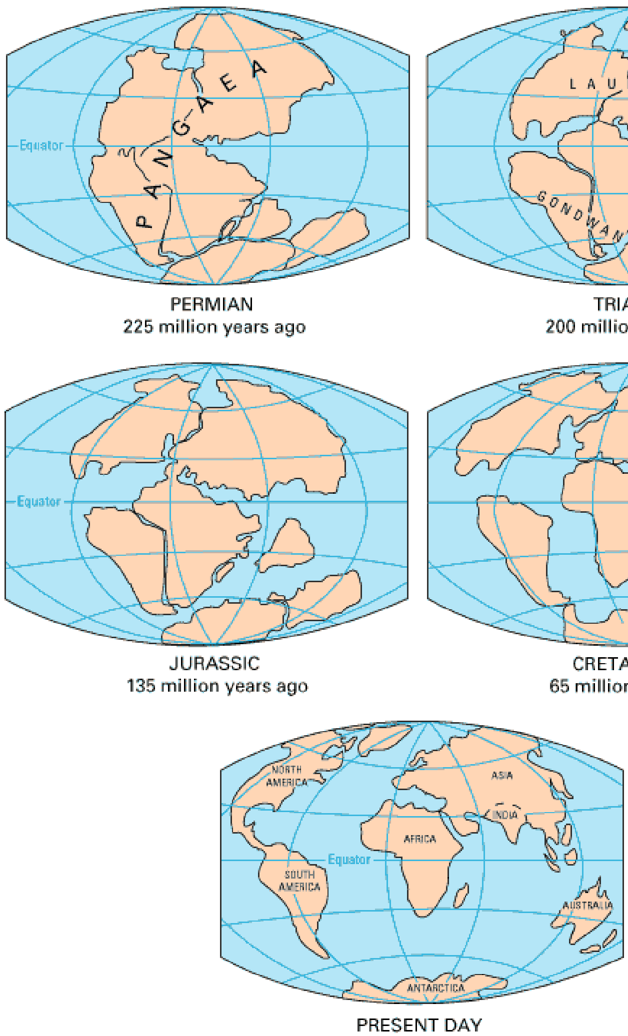
In the late 19th century, geologists interpreted the structure of mountain ranges this way. They reasoned that the sedimentary rocks had to accumulate in basins, and since the two belts of rock were so different, there was likely a barrier between them. The uplifted deep crustal rocks found in the cores of many mountain ranges seemed to support the idea of a ridge. The two belts of sedimentary rock were envisioned as accumulating in great troughs, formed by folding of the entire crust. These crustal warps were called *geosynclines*. The intervening ridge was termed a *geanticline*. The deep-water, volcanic belt, with its great accumulations of rocks, was called the *eugeosyncline* (*eu* = Greek "real", i.e. the "real" geosyncline, and the shallow-water belt was called the *miogeosyncline* (*mio* = Greek "somewhat", i.e. the "sort of" geosyncline.



Marcel Bertrand described nappes in 1884, Hans Schardt proved their existence in 1893, Maurice Lugeon expanded and popularized the notion in 1902.

Marcel Bertrand

Wegeners's findings were published in 1915 in his book *Die Entstehung der Kontinente und Ozeane* (The origin of the continents and oceans). His ideas were not widely accepted as critics thought that the evidence were not strong enough, that the underlying cause of the drift was not explained and that the drift was impossible.



In 1962, **Harry Hess** proposed the hypothesis that midocean ridges represent narrow zones where ocean crust forms.

Seafloor spreading is a part of the **theory of plate tectonics**.

At the Mid-Atlantic Ridge (and other places), material from the mantle rises through the faults between oceanic plates to form new crust as the plates move away from each other as a result of continental drift. It is still a matter of some debate whether continental drift is driven primarily by the force of rising magma at Harry Hess--theory of sea-floor spreading (early 1960's)

•Could explain bands of similar-aged rocks on the ocean floor

•Also explains bands of normal and reversed magnetism

Plate Tectonics theory--late 1960's.

•Based on new understanding of lithosphere and asthenosphere.

•Tied sea-floor spreading together with Wegener's idea of continental drift.

•Lithosphere made of rigid *tectonic plates* that move over the asthenosphere.

Spreading centers

Mantle material moves upward, carrying heat.

Heat causes expansion and rising of sea floor.

Volcanism occurs (also earthquakes)

Convection in the mantle drives the system

Large scale thermal convection in the mantle.

Convection cells. Roughly circular.

Mantle heat probably due to radioactive decay

If the rising part of a convection cell is beneath a continent, it will cause it to RIFT apart.

Also causes seafloor to rift apart at mid-ocean ridge.

Continents move alont with ocean crust, and do not plow through it.

Wilson Cycle: Hypothesis by J. Tuzo Wilson in the 1970s that includes a cycle of continental fragmentation, opening and subsequent closing of ocean basins and plate convergence (reassembly of the continent).

Wilson cycle

1. A continent rifts when it breaks up

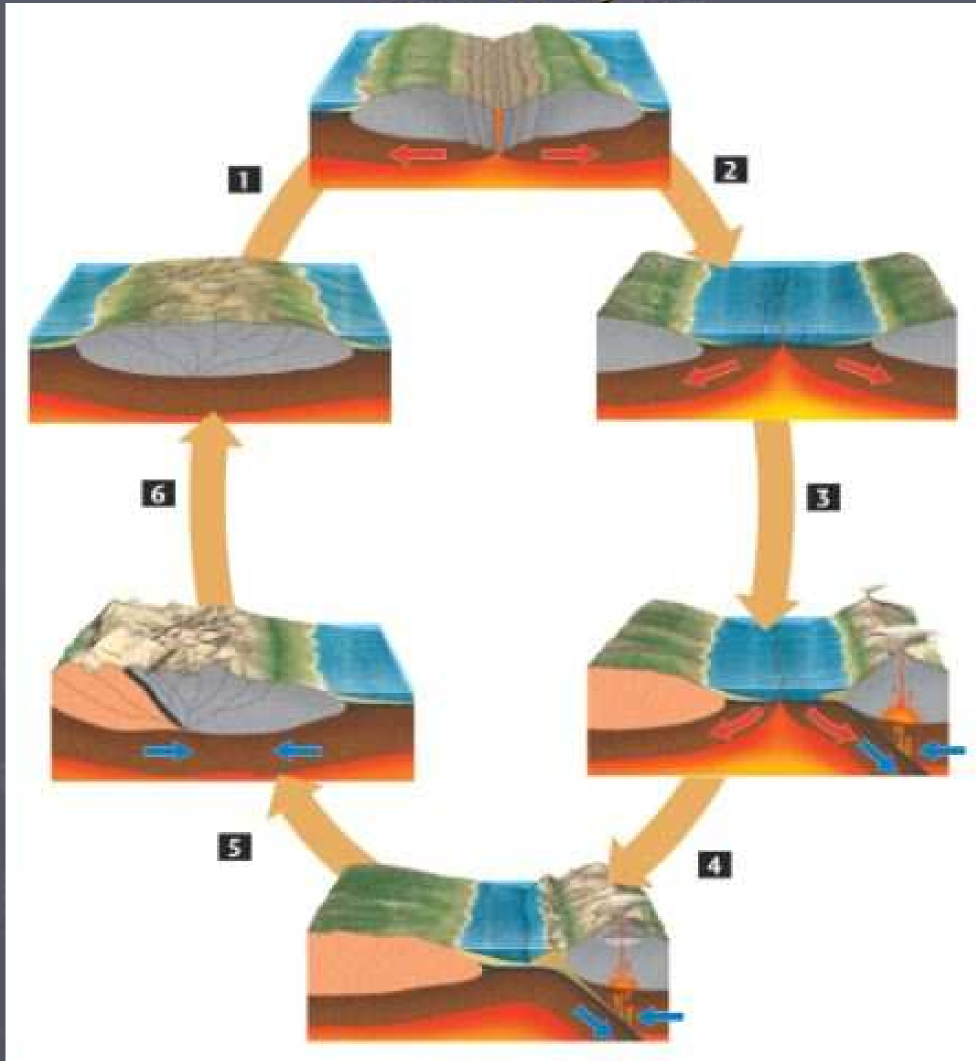
2. As spreading continues an ocean opens, passive margin cools and sediments accumulate

3. Convergence begins; an oceanic plate subducts, creating a volcanic chain at an active margin

4. Terraine accretion-from the sedimentary wedge welds material to the continent

5. As two continents collide orogeny thickens the crust and building mountains

6. The continent erodes, thinning the crust

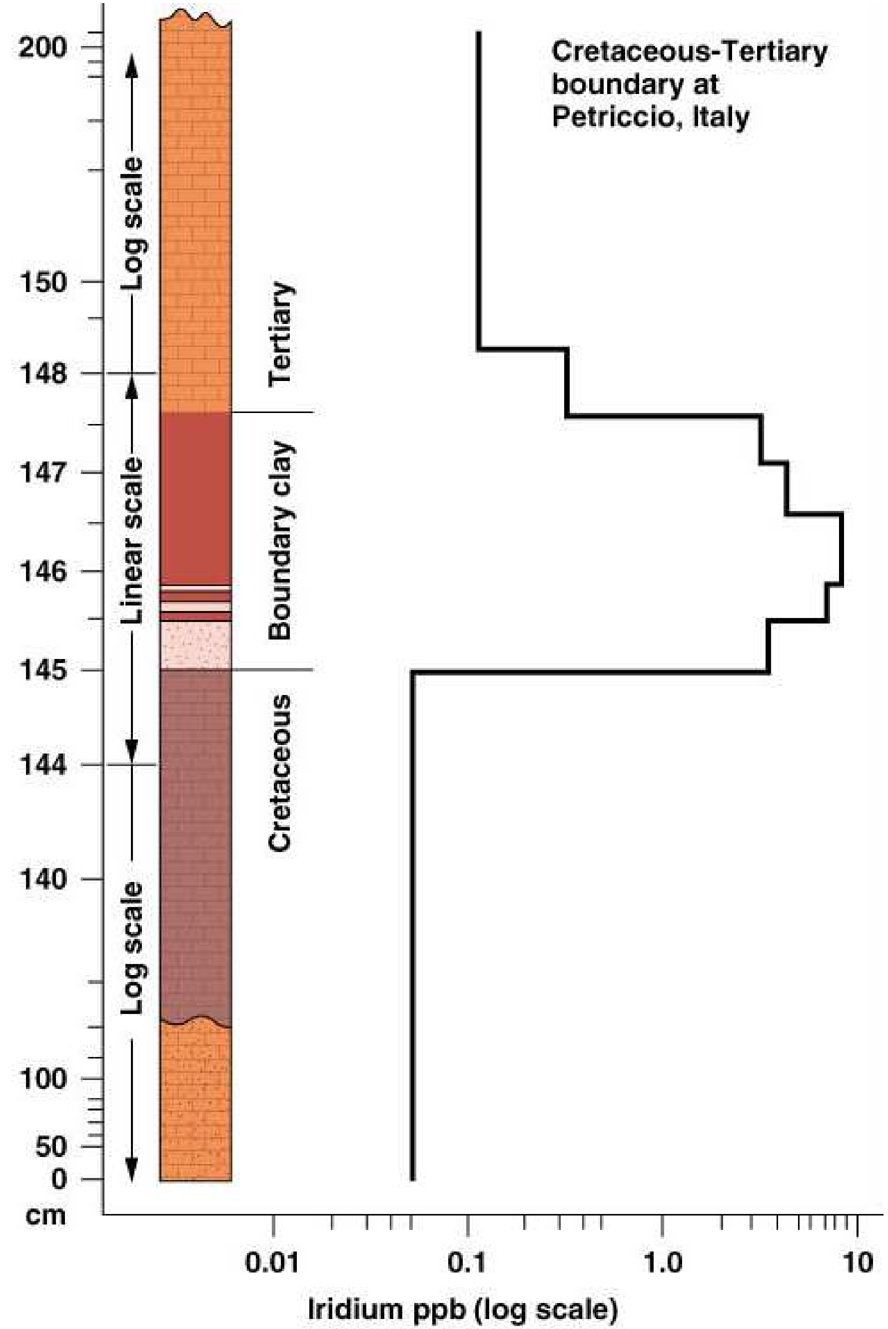


The asteroid impact theory was first proposed by Louis and Walter Alvarez in 1980.

They discovered high concentrations of **iridium** - an element rarely found on Earth but found in abundance in **extraterrestrial bodies** such as asteroids and meteorites - in a thin layer of clay from Italy. The iridium was found at the Cretaceous-Tertiary (K/T) boundary, the layer of geological deposits dated at 65 million years when the dinosaurs became extinct.

Cretaceous-Tertiary Boundary

- K/T boundary site in Italy
- 2.5-cm-thick clay layer shows high concentration of iridium



In 1980 Walter and Luis Alvarez and their colleagues Frank Asaro and Helen Michel published an historic paper suggesting that an asteroid about 10 kilometers (6 miles) in diameter struck the earth sixty-five million years ago at the end of the Cretaceous. The resulting impact should have left a crater at least 160 kilometers (100 miles) in diameter. If the impact site were in the ocean, huge tsunami ("tidal waves") would rise several kilometers in height, sweeping hundreds of kilometers across the continents, sweeping away everything in their path. As hot material ejected from the impact rained back down, huge fires would start up all over the world. Dust thrown up by the impact would have spread out covering the entire world in darkness. Temperatures would have dropped precipitously. Plants would have failed to receive enough sunlight to allow photosynthesis to continue. After the plants died, plant-eating animals dependent on them would die, as would meat-eating animals once their plant-eating prey were gone. Conditions in the oceans would not be much better as massive acid rain buildup poisoned the water and destroyed shell-bearing creatures, disrupting the entire food chain. About 70% of all species died out at the end of the Cretaceous. This included the dinosaurs which had dominated the landscape for over 160 million years.

This theory is that an asteroid 4-9miles in diameter hit the Earth.
Since the asteroid scattered awful amount of dust and debris in the atmosphere, the dust and debris blocked the most of the sunlight, and the temperature lowed down globally. The low temperature caused the mass extinction.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Chicxulub

Yucatan Penisula, Mexico

180 km diameter

More than 100 times the diameter of Berringer

65,000,000 million years ago

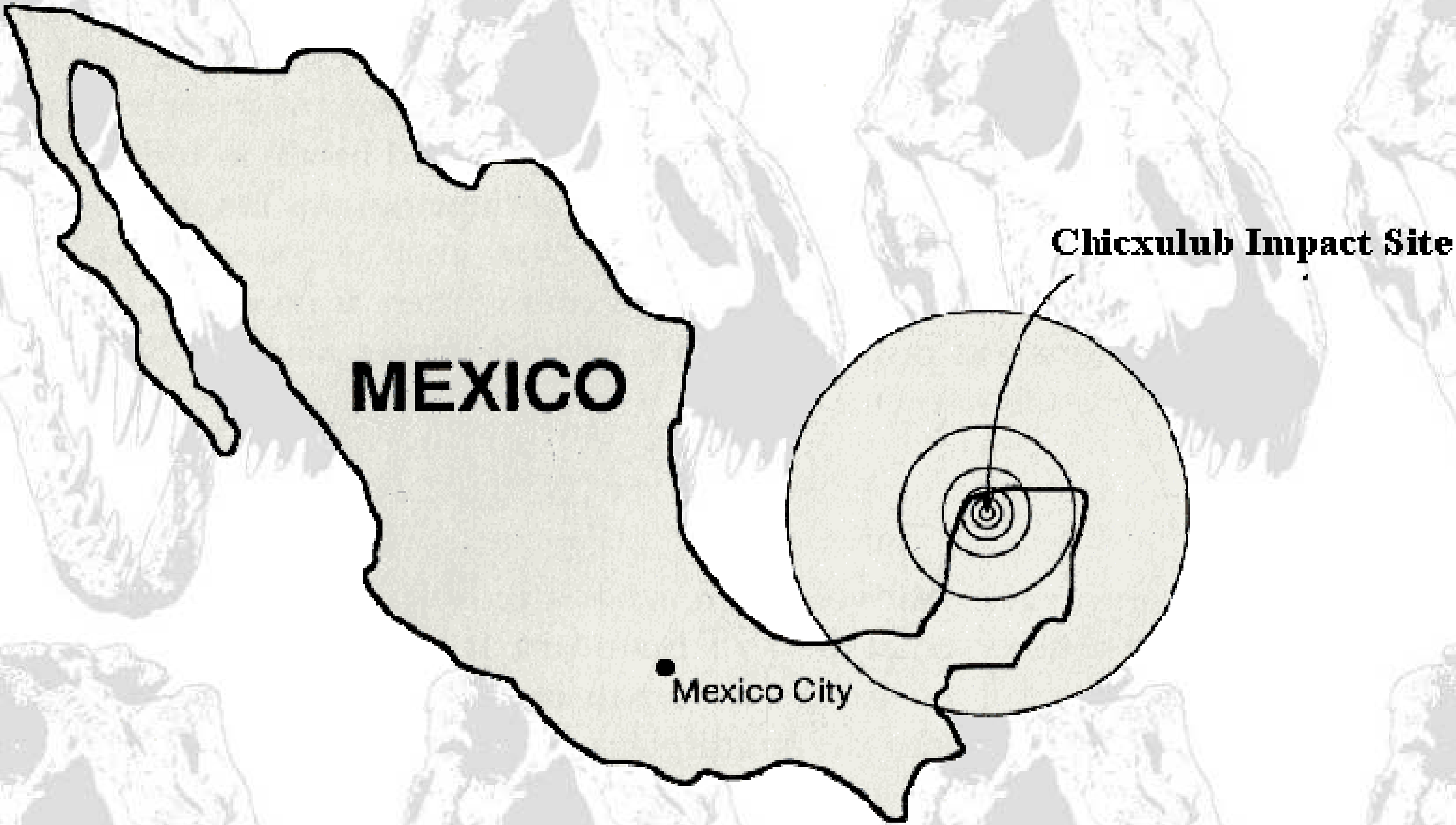
Cretaceous mass extinction

Disappearance of the dinosaurs

Worldwide debris

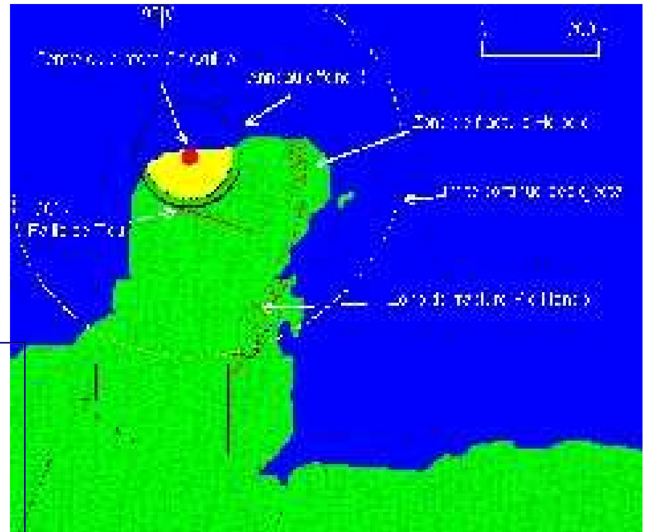
Iridium anomaly

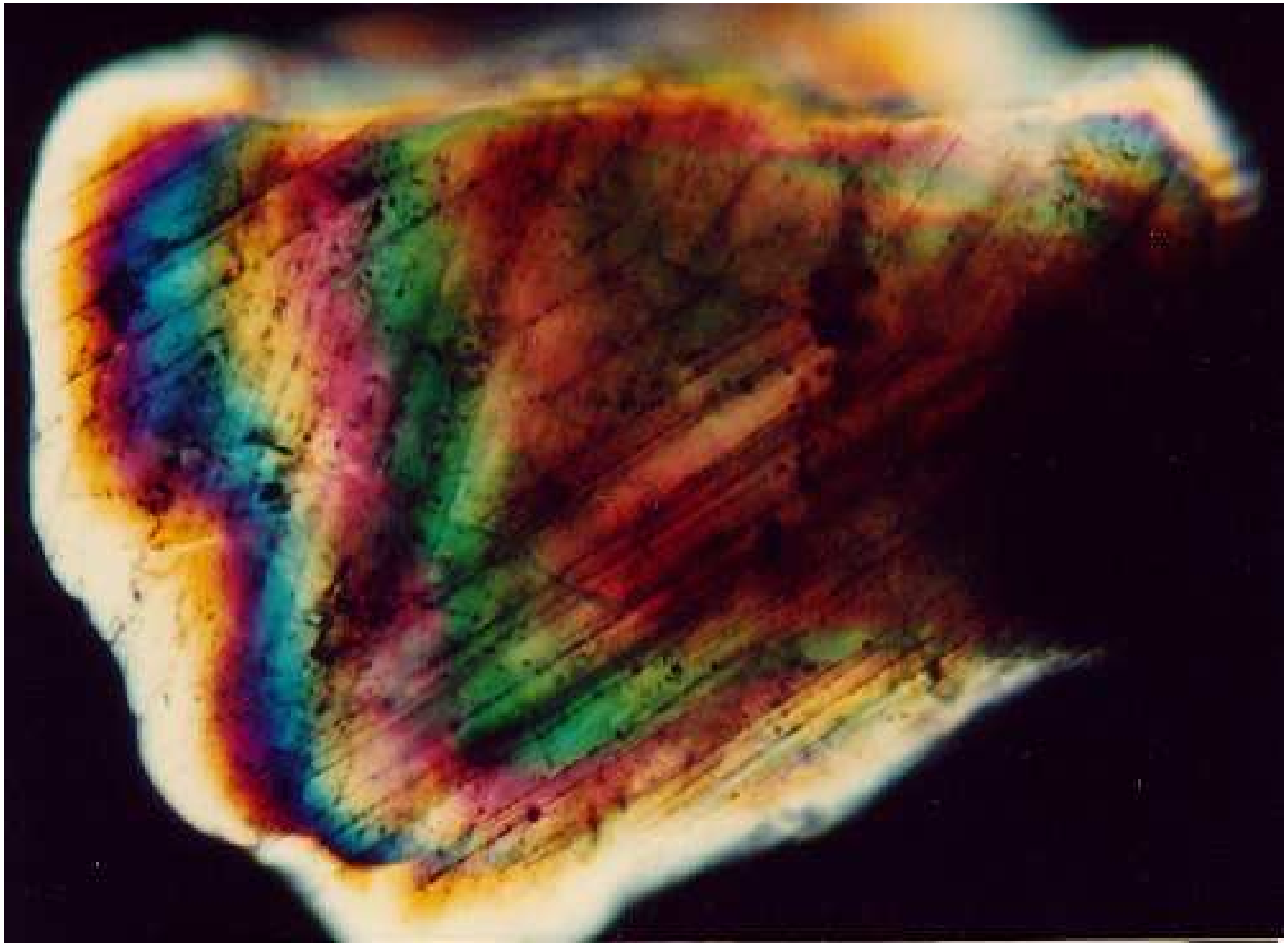
in clay at K/T boundary



Chicxulub Impact Site

tectites





A 0.32 mm **shocked quartz** grain from intracrater breccia sample Y6 N14 of the Chicxulub crater. The drill hole Yucatán-6 was located ~50 km from the crater's center and penetrated ~500 metres of impact melt and breccias at its base. The melt and breccia units contain clear evidence of production by impact, including mineral grains showing evidence of shock metamorphism. In the mineral quartz the passage of a strong shock wave can cause dislocation of the grain's crystal structure along preferred crystallographic orientations. This quartz grain shows at least 8 sets of planar deformation features when rotated; two strong sets (and part of a third set) of shock lamellae are visible in this orientation. The lamellae are decorated with inclusions. Impact is the only natural process known to produce shock waves of sufficient strength to cause deformation of this type.

Basic geological terms

1. **Boundaries - Contacts**

- Contacts separate different rock types

a) Conformable

-No rocks or interpreted time is missing

-***b) Unconformable - unconformity***

- Rocks and or interpreted time is missing at the contact

(1) Angular Unconformity fig. 8.5

- Angular discordance of bedding

(2) Disconformity Fig. 8.4

- Irregular erosional surface

- Nonirregular erosional surface

(3) Nonconformity

-Sed. rocks overlie older, massive igneous and/or metamorphic rocks

(4) Diasthem – minor depositional break without erosion

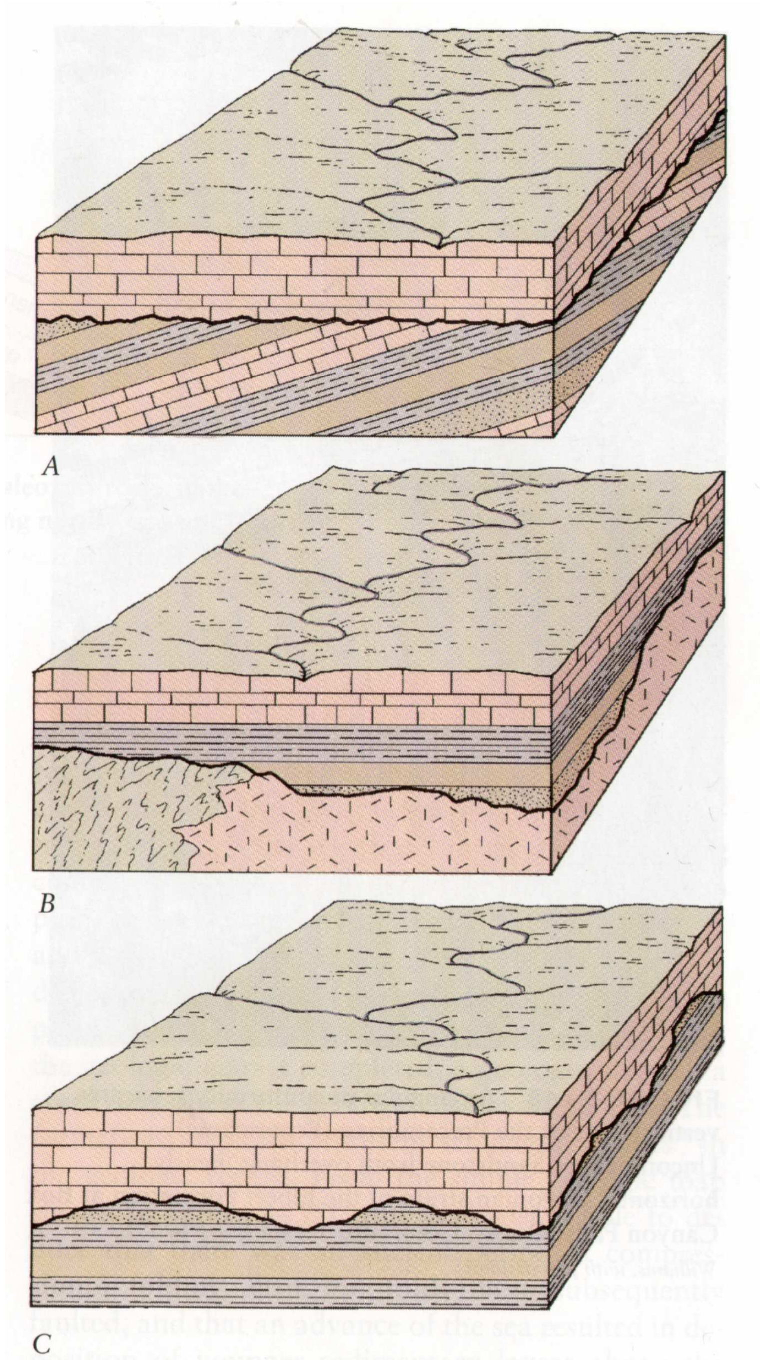
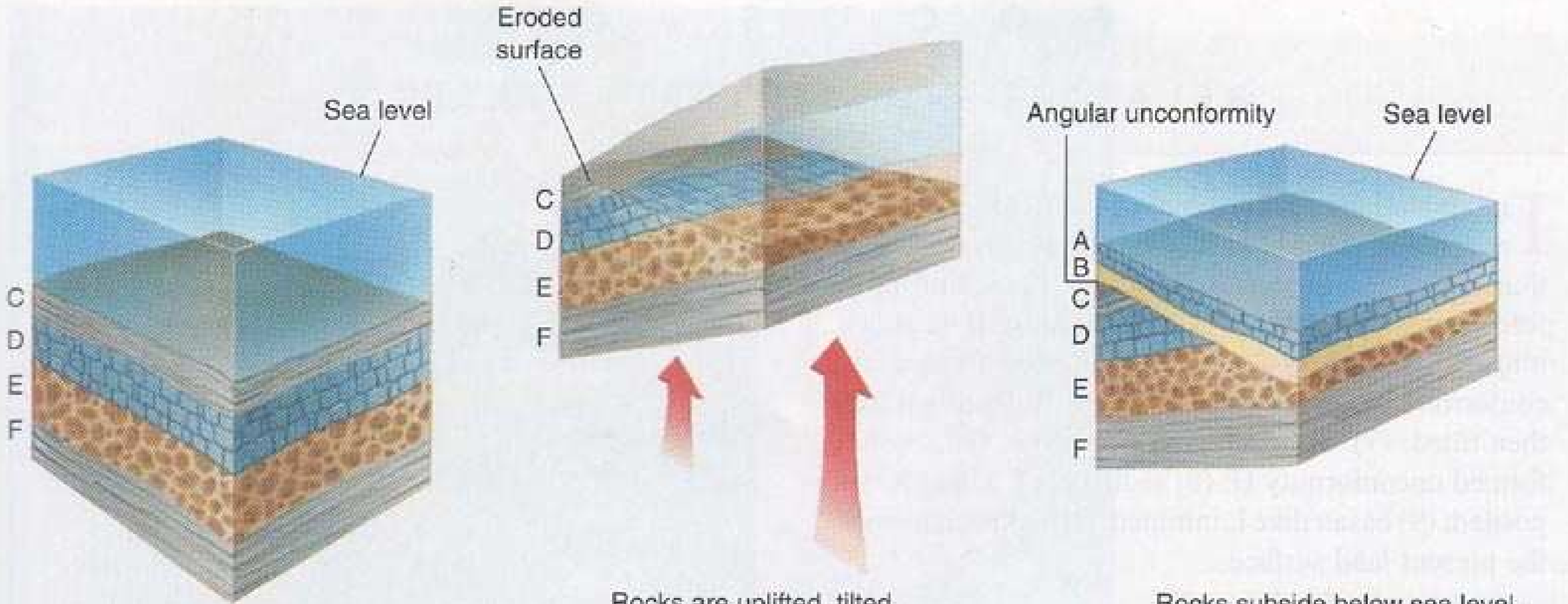


FIGURE 3–47 Three types of erosional unconformities. (A) Angular unconformity. (B) Nonconformity. (C) Disconformity.



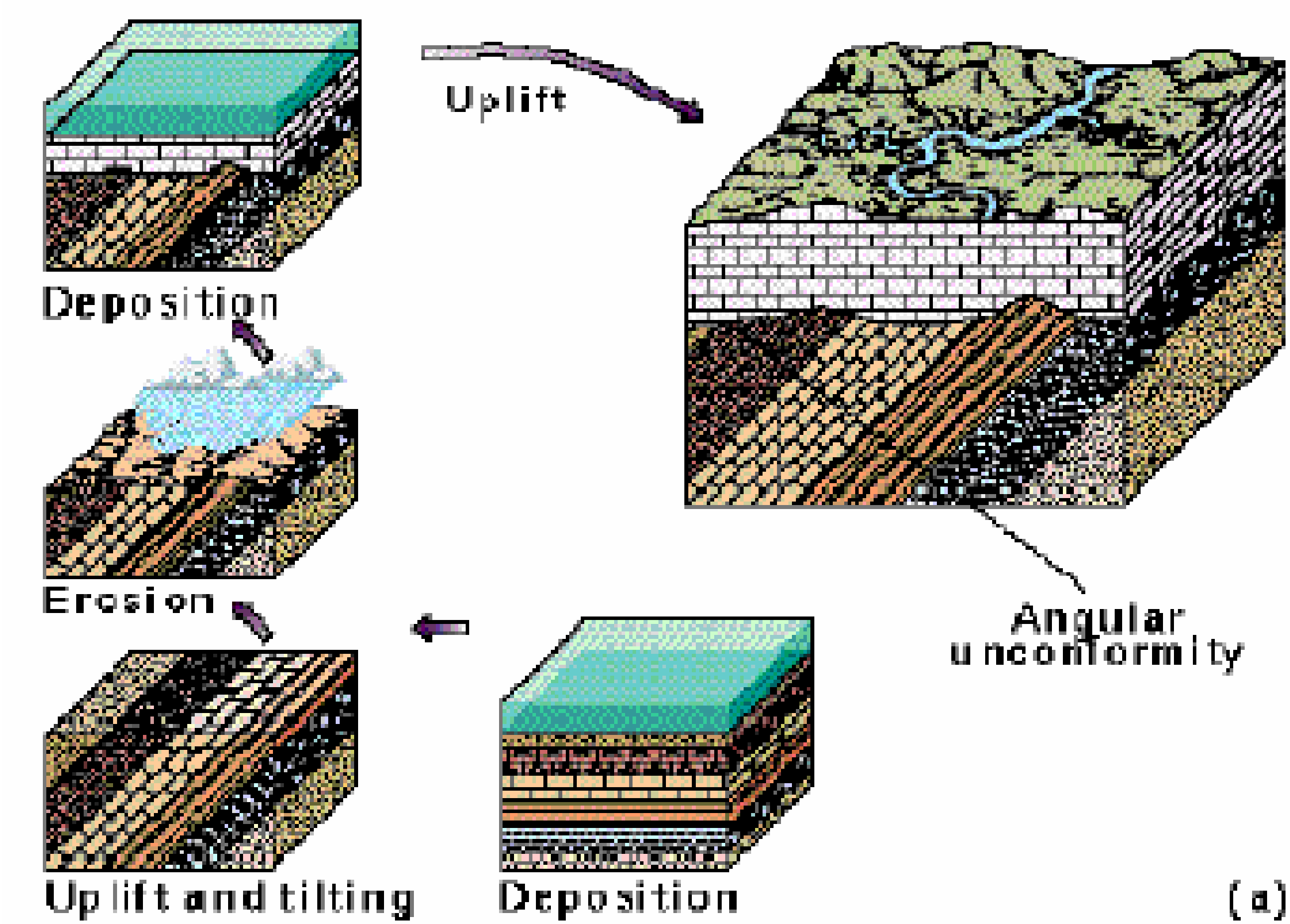
Sediment is deposited below sea level.

Rocks are uplifted, tilted, and eroded.

Rocks subside below sea level, and layers A and B are deposited on the eroded surface.

•Unconformities (Hiatus)

•Development of an Unconformity

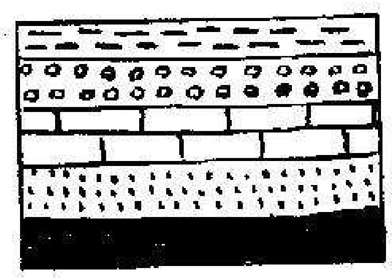


Hutton Reads the Unconformity at Siccar Point, Scotland

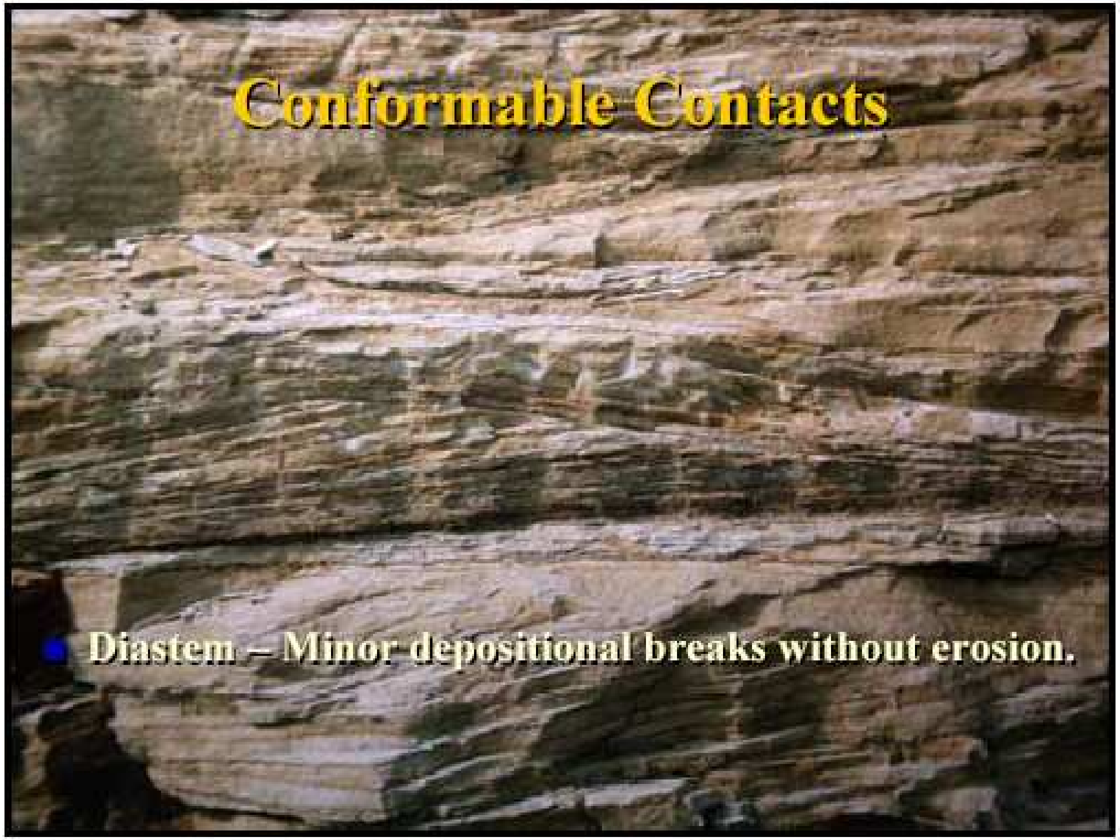
- Unconformity is ancient erosion surface buried by younger strata
- Gently dipping strata of the Old Red sandstone rest on truncated vertical beds of Caledonian strata
- What do you see?

PARACONFORMITIES

Paraconformities are characterized by a surface of nondeposition separating two parallel units of sedimentary rock, which is virtually indistinguishable from a sharp conformable contact; there is no obvious evidence of erosion. An examination of the fossils shows that there is a considerable *time gap* represented by the surface.



Paraconformity


Conformable Contacts
Diastem – Minor depositional breaks without erosion.

Subsidence

- The earth's surface sinks due to sediment or tectonic loading

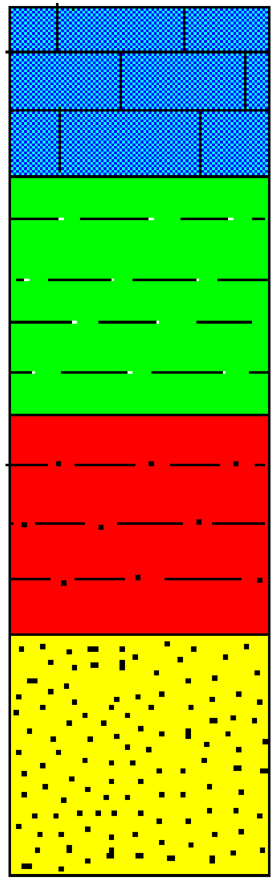
Transgression

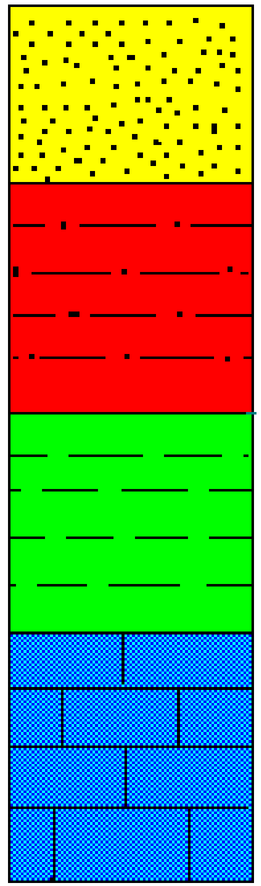
-Shift of depositional base level landward
-Movement of shoreline in a landward direction

-*Regression*

-Movement of shoreline in a seaward direction
-Shift of depositional base level seaward

•**Transgressive sequence**
•Deeper water facies overlie shallow water facies.
A "**deepening upward**" sequence.

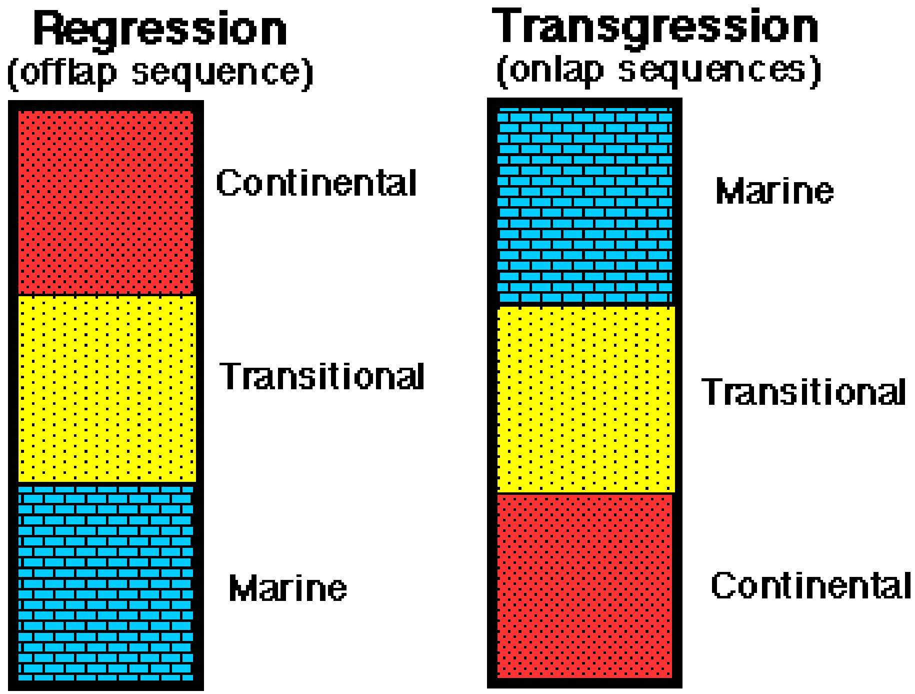




•**Regressive sequence**
•Shallow water facies overlie deeper water facies.
A **"shallowing upward"** sequence.

•Regression (offlap sequence)

•Transgression (onlap sequence

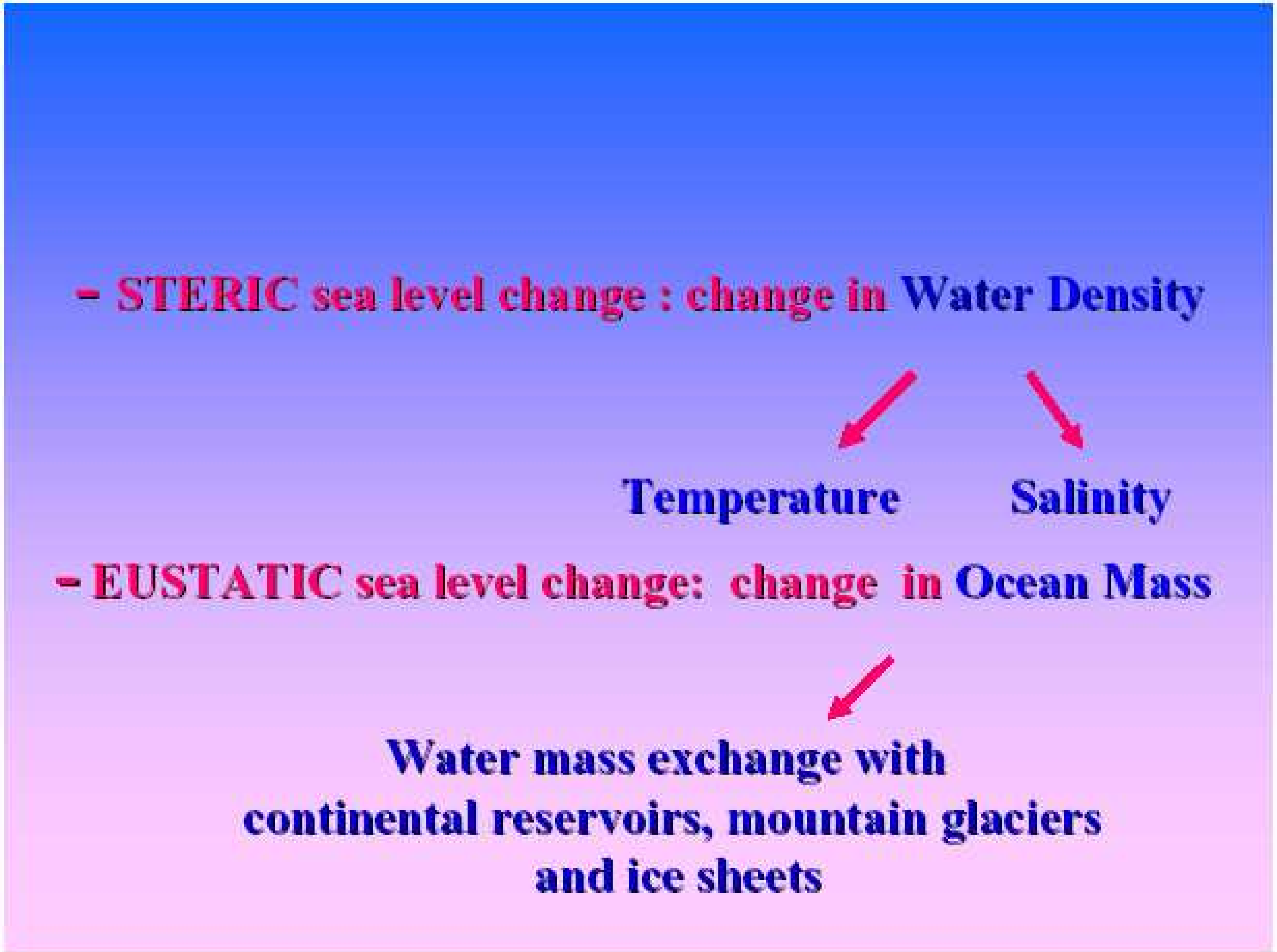


Sea-level change

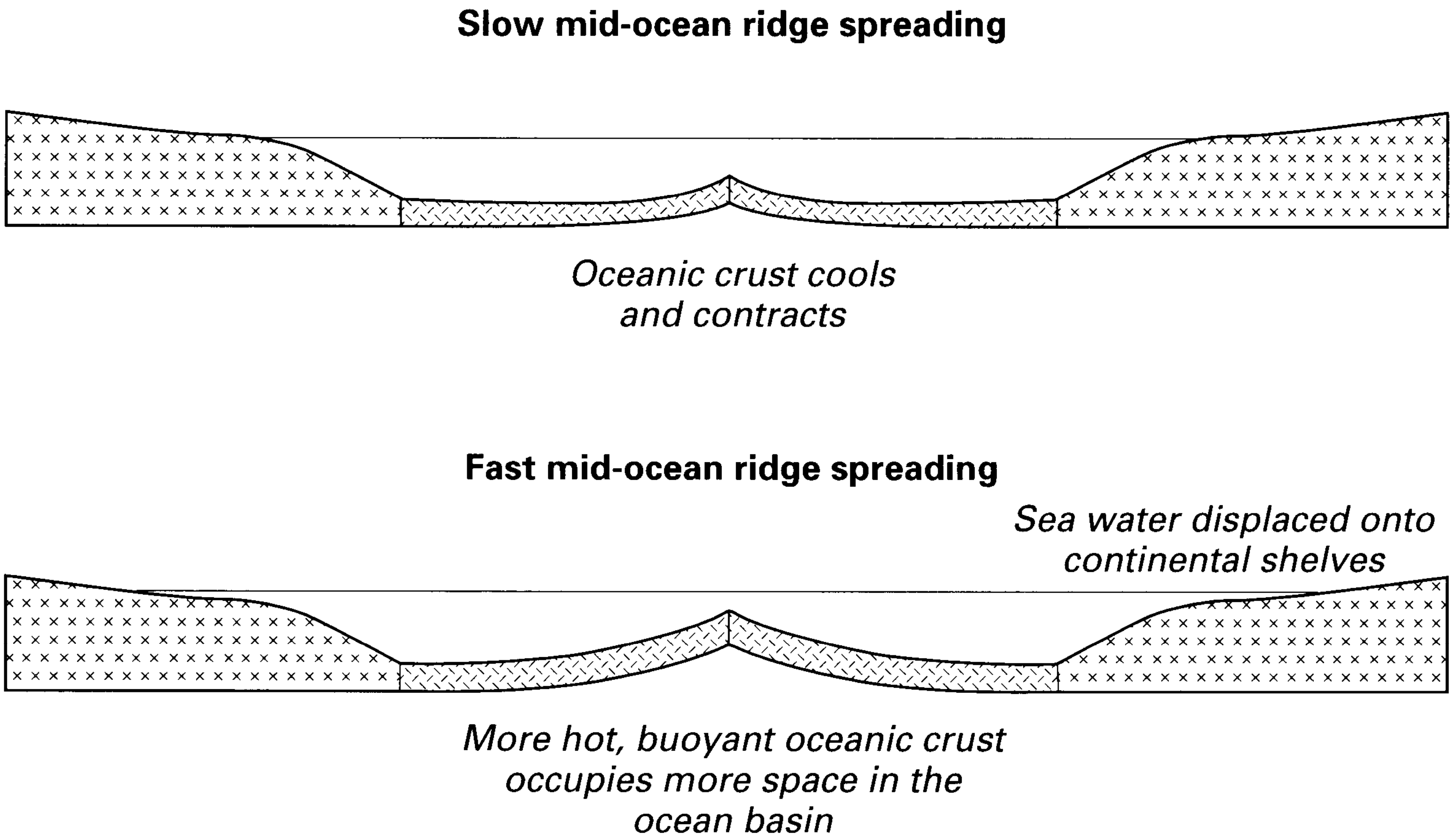
Relative sea-level change includes a **global component** (**eustasy**) that is uniform worldwide and can be measured relative to a fixed datum (e.g., the center of the Earth), and **regional to local** components (**isostasy**, **tectonism**) that are spatially variable

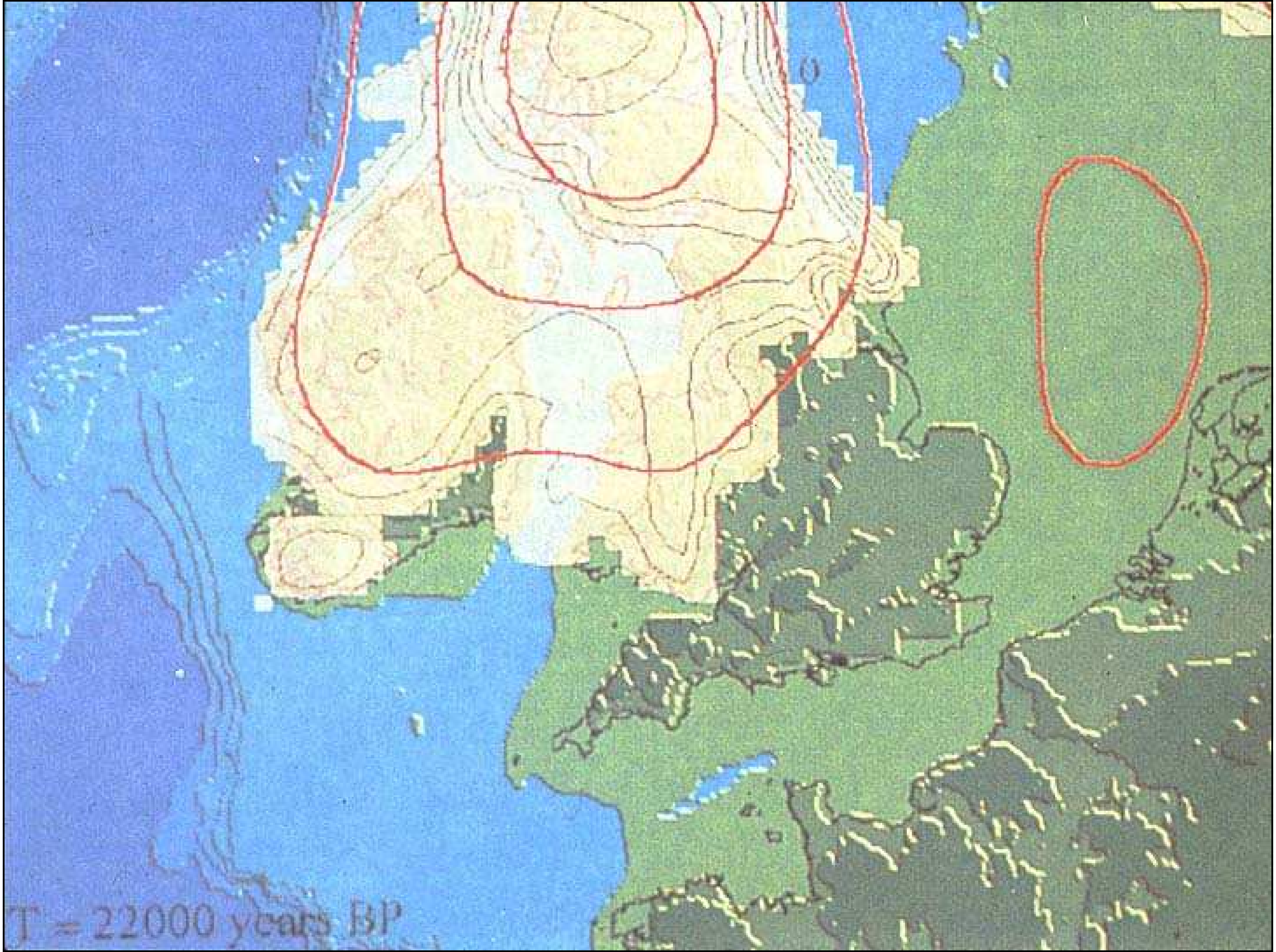
Eustasy involves changes in ocean-basin volume, as well as changes in ocean-water volume (amplitudes ~101–102 m)

- **Tectono-eustasy** (time scales of 10–100 Myr)
- **Glacio-eustasy** (time scales of 10–100 kyr)



•**Steric** sea-level changes include density changes (temperature, salinity) and dynamic changes (atmospheric pressure, ocean currents, wind set-up), but these changes are typically on the order of a few meters at the most

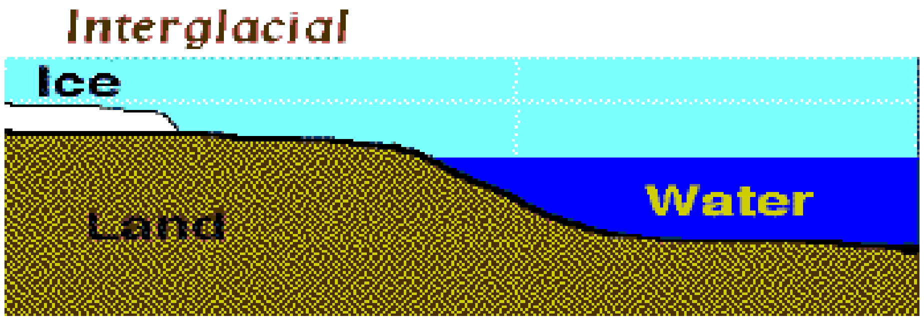

Slow mid-ocean ridge spreading
Oceanic crust cools
and contracts
Fast mid-ocean ridge spreading
Sea water displaced onto
continental shelves
More hot, buoyant oceanic crust
occupies more space in the
ocean basin

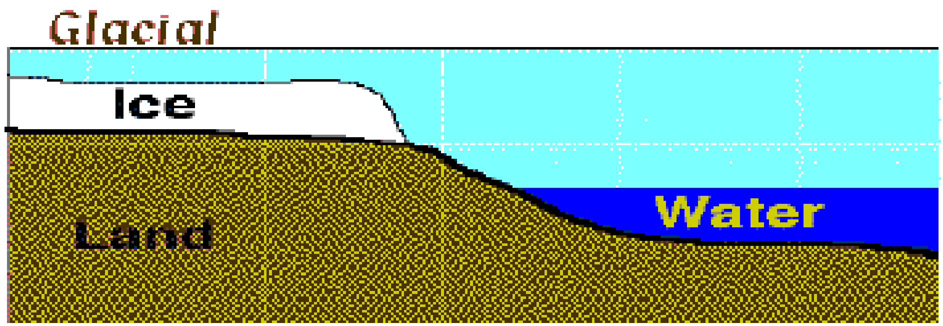

T = 22000 years BP

•Changes in Sea Level

•Eustatic Sea Level Changes

•- Climate (ice ages)

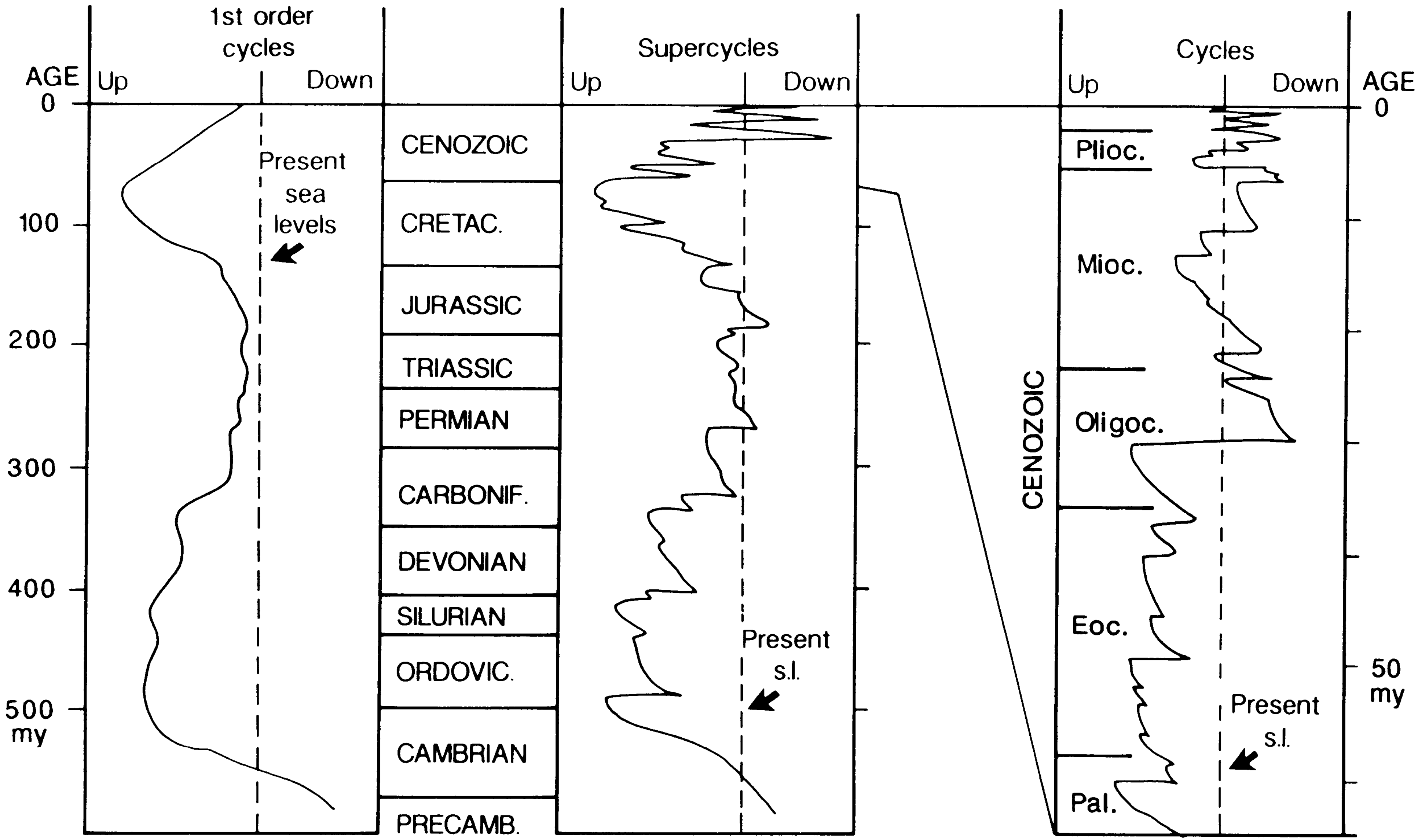




•Tectonic (development of mid-ocean ridges)

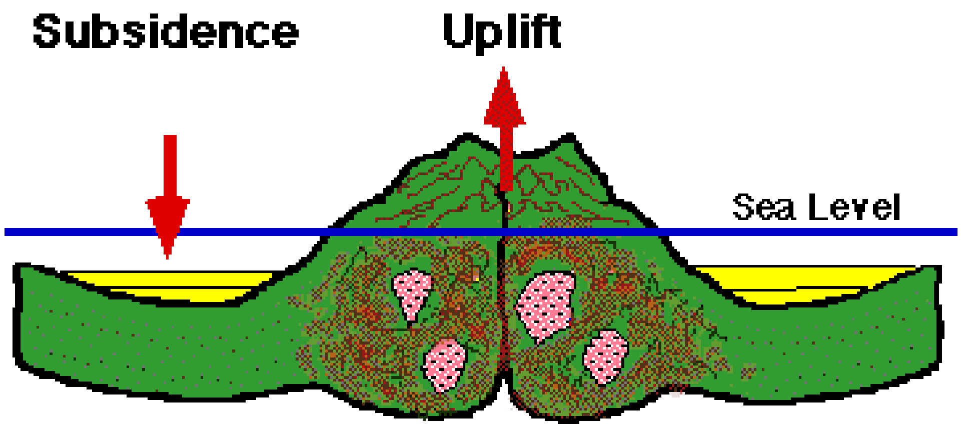
•Figure 3.14, p. 50

VAIL SEA LEVEL CHANGE CURVE



•Local Sea Level Changes

•- Uplift
- Subsidence



Basic stratigraphic principles

1. **The principle of superposition** - in a vertical sequence of sedimentary or volcanic rocks, a higher rock unit is younger than a lower one. "Down" is older, "up" is younger.
2. **The principle of original horizontality -** rock layers were originally deposited close to horizontal.
3. **The principle of original lateral extension -** A rock unit continues laterally unless there is a structure or change to prevent its extension.
4. **The principle of cross-cutting relationships -** a structure that cuts another is younger than the structure that is cut.
5. **The principle of inclusion -** a structure that is included in another is older than the including structure.
6. **The principle of "uniformitarianism" -** processes operating in the past were constrained by the same "laws of physics" as operate today.
7. **The principle of faunistic succession**
8. **The Walter law**

THE PRINCIPLE OF SUPERPOSITION

•In a sequence of strata, any stratum is younger than the sequence of strata on which it rests, and is older than the strata that rest upon it. "...at the time when any given stratum was being formed, all the matter resting upon it was fluid, and, therefore, at the time when the lower stratum was being formed, none of the upper strata existed." Steno, 1669.

PRINCIPLE OF INITIAL HORIZONTALITY

•Strata are deposited horizontally and then deformed to various attitudes later. "Strata either perpendicular to the horizon or inclined to the horizon were at one time parallel to the horizon." Steno, 1669.

PRINCIPLE OF STRATA CONTINUITY

•Strata can be assumed to have continued laterally far from where they presently end. "Material forming any stratum were continuous over the surface of the Earth unless some other solid bodies stood in the way." Steno, 1669

PRINCIPLE OF CROSS CUTTING RELATIONSHIPS

* Things that cross-cut layers probably postdate them. "If a body or discontinuity cuts across a stratum, it must have formed after that stratum." Steno, 1669

Reading the Record of Time in Sedimentary Rocks - Steno's Laws

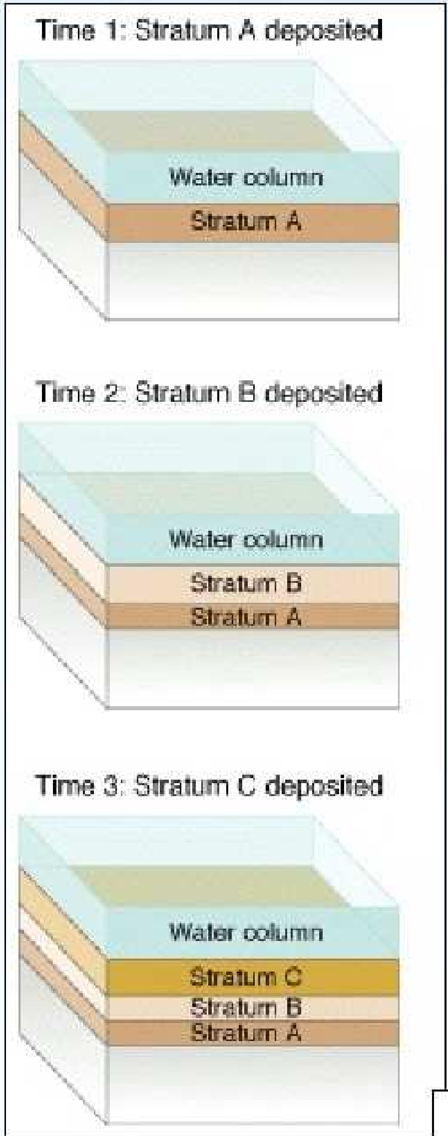
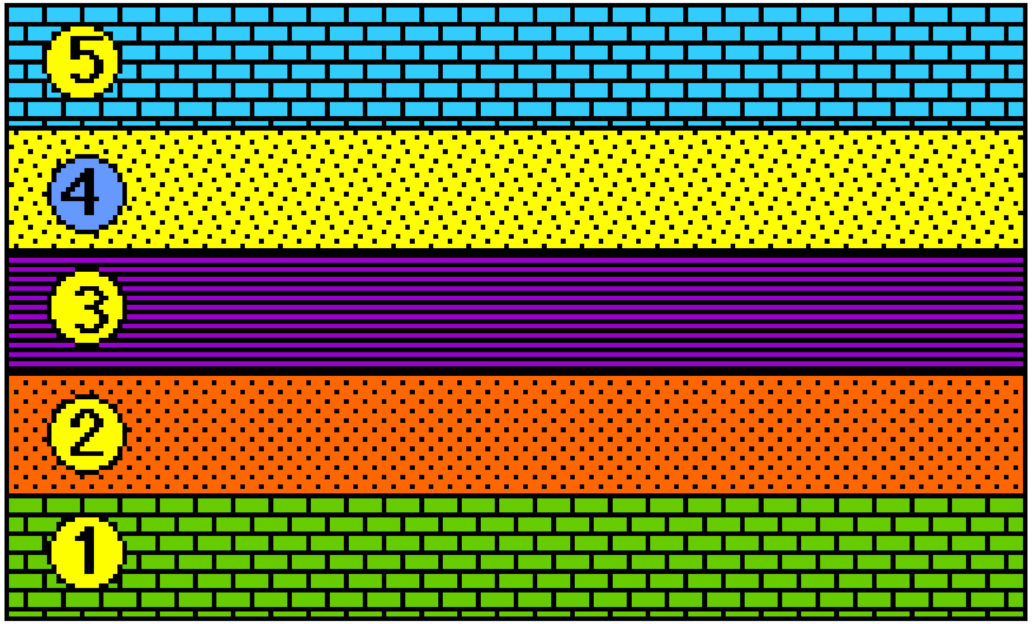


Fig 3-4

- Law of Superposition
  - sediment deposited in layers on seafloor or land surface
  - each succeeding layer buries strata underneath
  - oldest stratum at bottom
  - youngest stratum at top

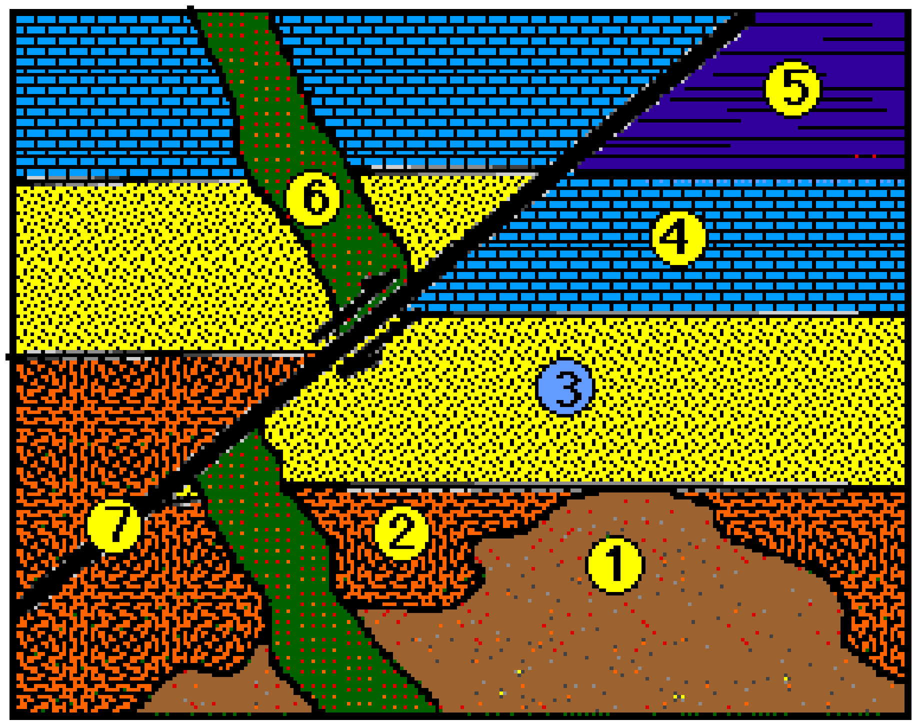
•**Principle of Superposition**

•**Principle of Original Horizontality**



•**Principle of Cross-cutting Relationships**

The crosscutting unit is younger



Steno's Stratigraphic Laws

- Law of Superposition
  - strata are progressively younger from bottom to top of section
- Law of Original Horizontality
  - strata deposited in horizontal layers
  - tilted rocks have been deformed

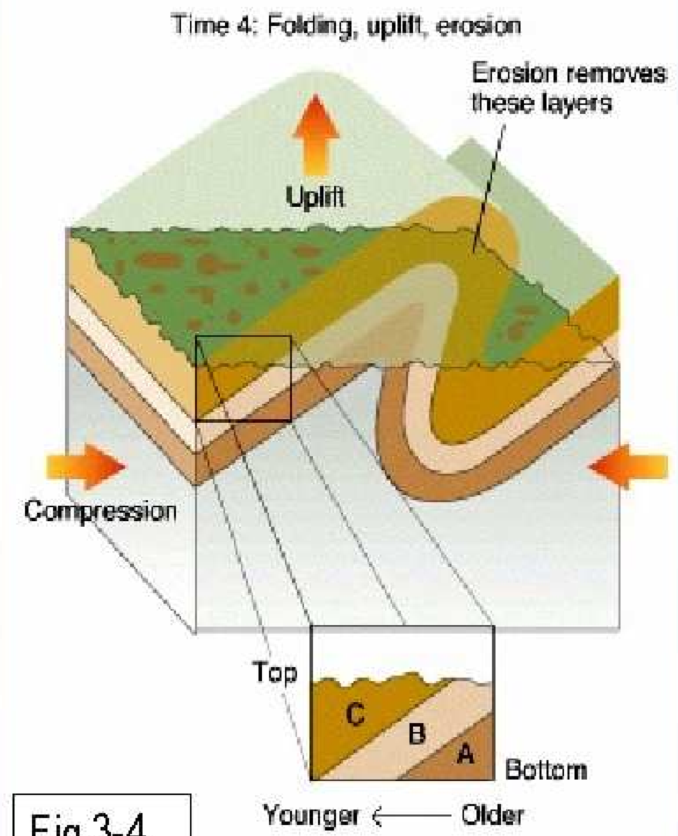
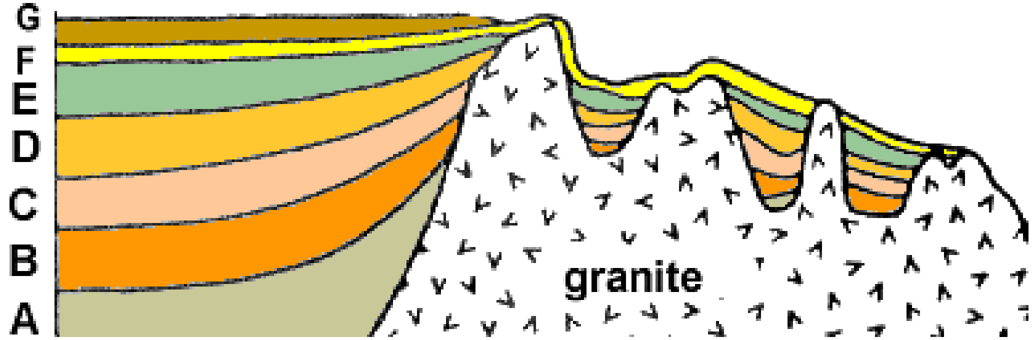


Fig 3-4

Nicholas Steno, a Danish physician living in Italy in 1669 proposed that the Earth's strata accumulated with three basic principles. Steno pointed out obvious, but overlooked principles of sediment accumulation. They included the **Principle of Original Horizontality**, **Principle of Superposition**, and **Principle of Original Continuity**. If sediments accumulate in a large basin, the laws of gravity will deposit the beds, horizontal to the surface of the Earth. Beds can "pinch out" along the sides of the basin as in the figure below.

The Principle of Superposition states that in a sequence of sedimentary rock layers, the bottom layers are older than the top layers. The bottom layers were deposited first. In the figure below A is the oldest bed and G is the youngest.

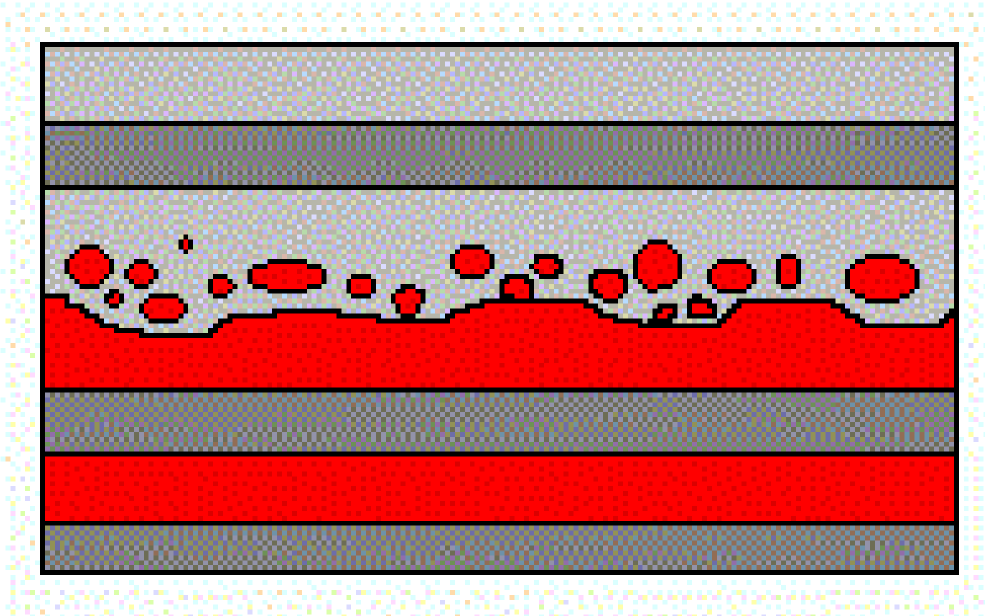
The Principal of Original Continuity states that the beds can be traced over a long interval if the basins were open. For instance, Bed F can be traced continuously to the smaller basin in the figure below. The other beds below F can then be correlated to Beds A-E.



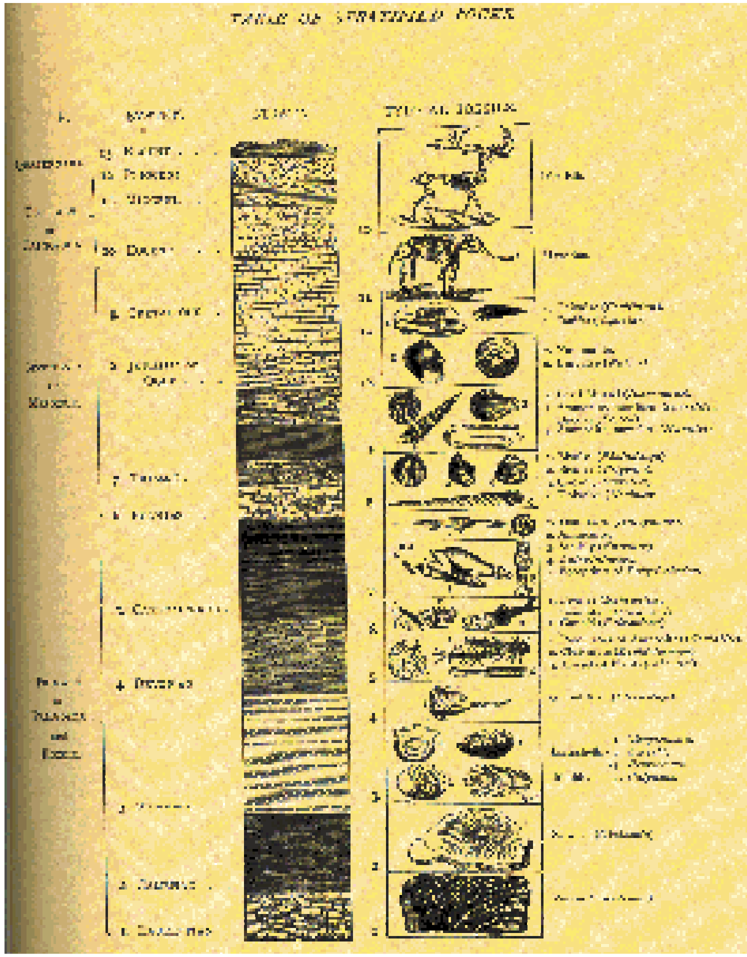
Principle of inclusions See Levin, 5th edition, p. 14-15

Note the irregular erosional surface. This is an **unconformity**. The clasts (in the bed above the unconformity) are derived from the underlying (older) bed.

The gravel clasts are **older** than the layer which contains them. The layer containing the gravel must be **younger** than the layer from which the clasts originate



The **Principle of Faunal Succession** was later added by **William Smith** in the late 1700's who observed and studied fossils embedded in rock layers. This principle states that **the oldest fossils in a series of sedimentary rock layers will be found in the lowest layer** (layer A). Progressively younger fossils occur in higher layers (layer B). This is the same concept as superposition, but it helped geologists realize that you can look at the age of these layers and assign relative dates. This parallels evolution. Younger organisms replace older organisms as the older ones become extinct.



The Geological Record

- In Darwin's day the basic concepts of the new science of geology were just beginning to be filled in.
- In the 1790's an enthusiastic amateur, Wm. "Strata" Smith, had realized that the types of fossils found in each rock layer were quite different from those in other strata.

Walther's Law - Facies Successions

Facies situated in conformable vertical successions of strata are also situated in laterally adjacent environments

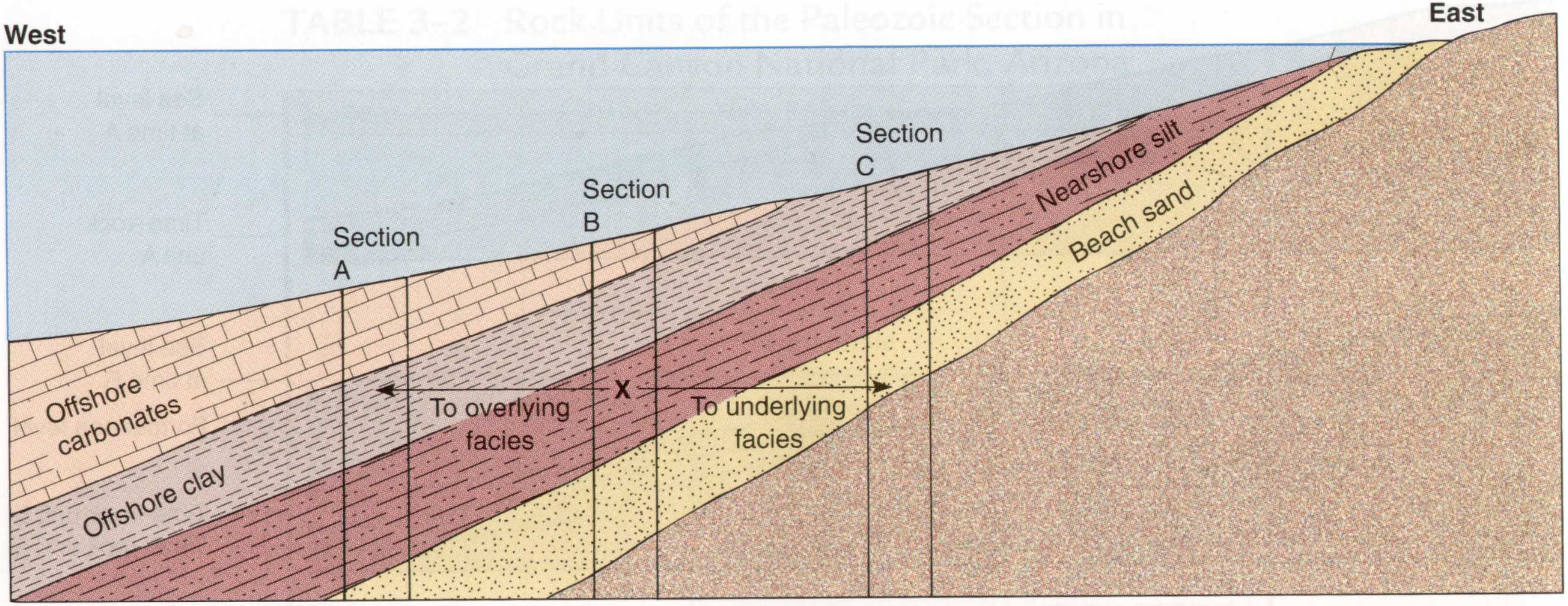
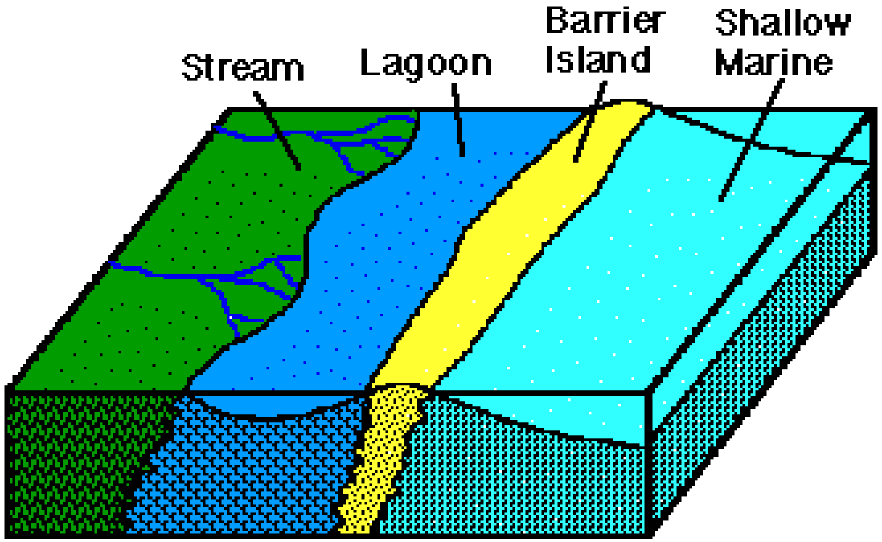
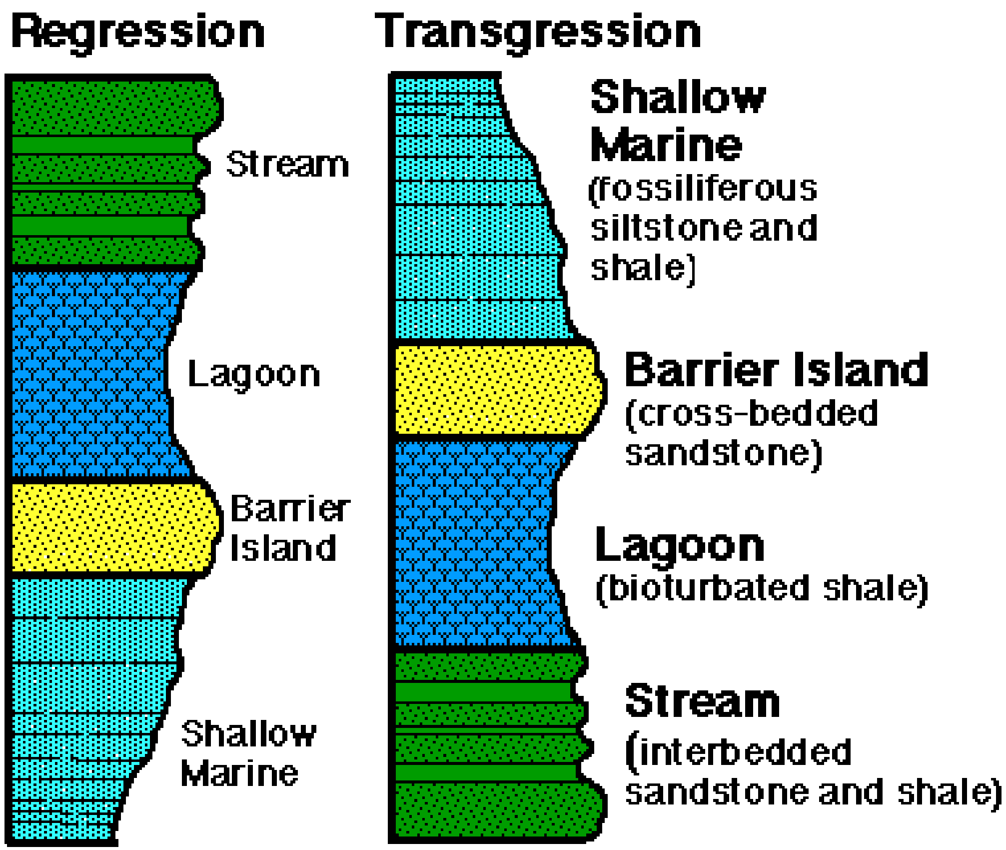


FIGURE 3–41 An illustration of Walther's Principle, which states that vertical facies changes correspond to lateral facies changes. *(After Brice, J. C., Levin, H. L., and Smith, M. S. 1993.* Laboratory Studies in Earth History, *5th ed. Dubuque, IA: William C. Brown.)*

•Walther's Law

•Facies that are adjacent laterally
•will be superimposed vertically





Principle of uniformitarism (actualism)

PRINCIPLE OF UNIFORMITARIANISM based onrealizing that "The Present is the key to the Past."a. To understand past, study processes at work today.b. Origin of rocks understood by how rocks form now.c. Geologic processes are uniform through Earth history, with only a few minor exceptions.d. Rates that processes work are NOT uniform.

PRINCIPLE OF ACTUALISM--a more general statement saying: "The laws of nature are constant thru time."1. Scientific experiments always give same results.2. Actualism is a fundamental concept of all science; itwas generalized from geological Uniformitarianism.

Differencies in the past

Chemical parameters

1) **Different salinity of the oceans – Precambriam**
2) **Composition of the atmosphere**
3) **Different sediments (some U deposits, banded iron formations)**

Evolution of bilogical systems

1) **Hadaikum – no life**
2) **Absence of floral cover**
3) **Changes in environmental requirements**
4) **Changes in erosion**

Different intensity of geological processes – orogenic cycles, climatic oscillations
Different astronomical parameters – slower the rotation of Earth

LENGTH OF THE DAY

Narrative:
The length of day and number of days per year is slowly changing.

Tidal friction on Earth of lunar and solar tides slows it down. Also, the moon is slowly retreating from the Earth.

Rate: rotation - slows by 1.7 milliseconds/year
moon retreat - 5 cm/year

Geophysical calculations of slowing are validated by evidence from fossils - which record daily bands and lunar cycles.
(primarily the frequency and magnitude of tides)

-Stromatolites
-Corals
-Bivalves

900 million years B.C. -- day: 18 hours; 440 days/year

150 million years B.C. -- day: 23.5 hours; 370 days/year
(late Jurassic)

Modern -- day: 24 hours; 365.25 days/year

Circadian rhythm in higher animals does not adjust to a period of less than 17-19 hours per day.
Therefore, records the time of emergence of metazoans.

Basic geological terms

1. Boundaries - Contacts

- Contacts separate different rock types

a) Conformable

-No rocks or interpreted time is missing

-***b) Unconformable - unconformity***

- Rocks and or interpreted time is missing at the contact

(1) Angular Unconformity fig. 8.5

- Angular discordance of bedding

(2) Disconformity Fig. 8.4

- Irregular erosional surface

- Nonirregular erosional surface

(3) Nonconformity

-Sed. rocks overlie older, massive igneous and/or metamorphic rocks

4) **Paraconformity** - are characterized by a surface of nondeposition separating two parallel units of sedimentary rock

(4) Diasthem – minor depositional break without erosion

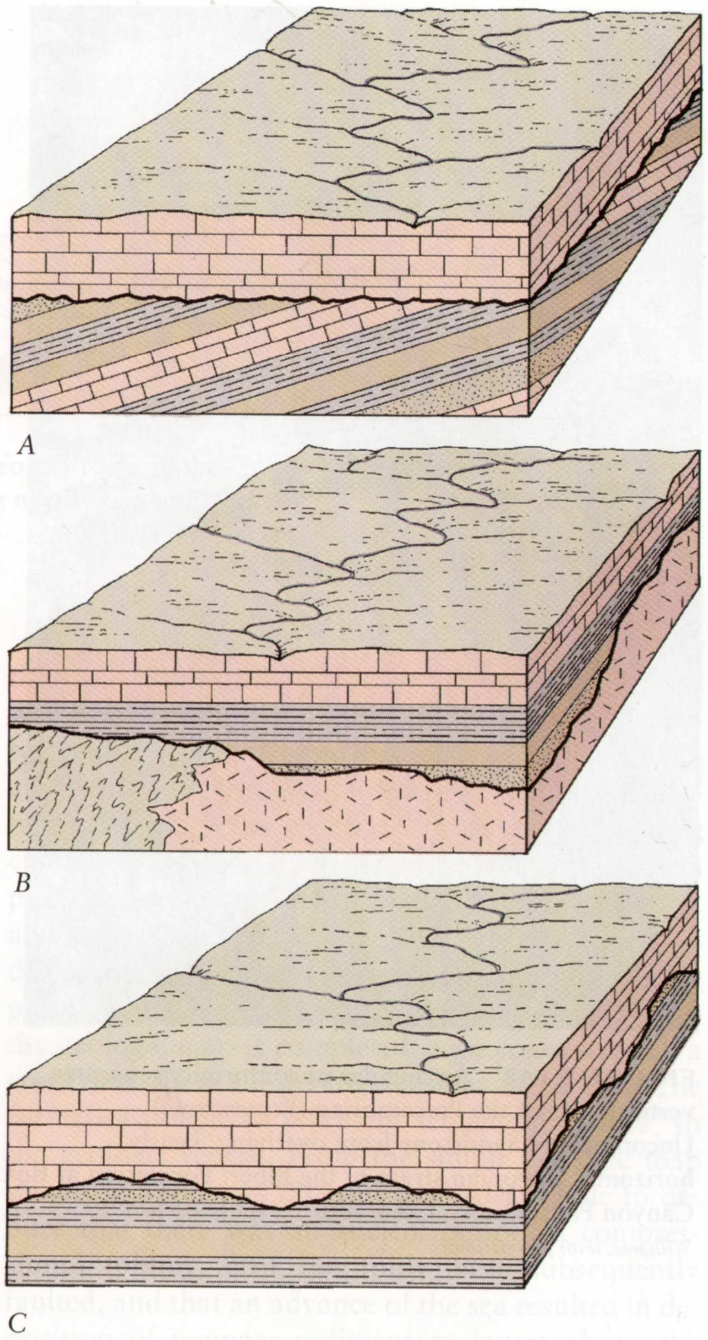
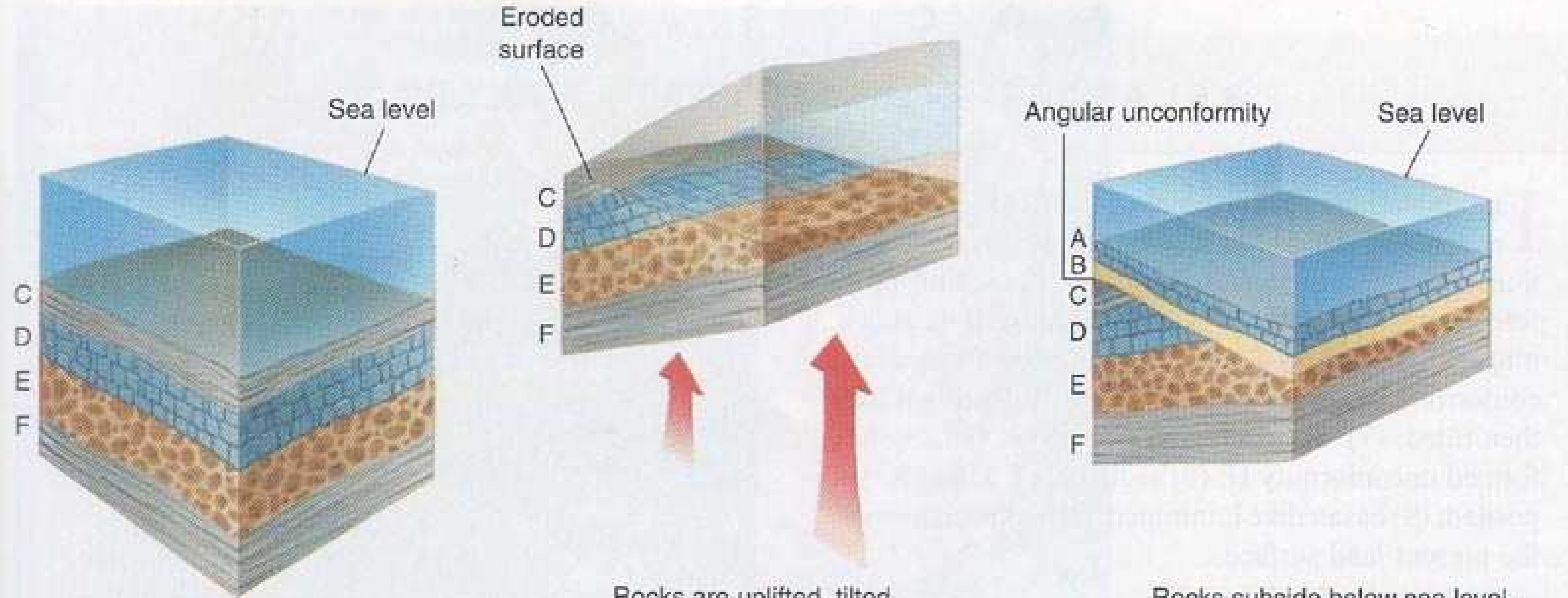


FIGURE 3–47 **Three types of erosional unconformities.** (A) Angular unconformity. (B) Nonconformity. (C) Disconformity.

Angular Unconformity

Nonconformity - sed. rocks overlie older, massive igneous and/or metamorphic rocks

Disconformity - unconformity in this case is directly recognizable as a surface resulting from erosion of underlying beds. The rocks above and below a disconformity are parallel in this case .



Sediment is deposited below sea level.

Rocks are uplifted, tilted, and eroded.

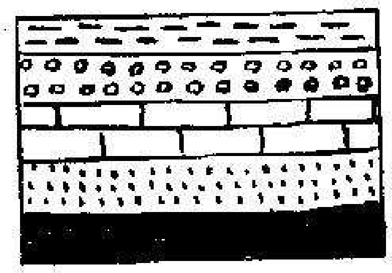
Rocks subside below sea level, and layers A and B are deposited on the eroded surface.

Hutton Reads the Unconformity at Siccar Point, Scotland

- Unconformity is ancient erosion surface buried by younger strata
- Gently dipping strata of the Old Red sandstone rest on truncated vertical beds of Caledonian strata
- What do you see?

PARACONFORMITIES

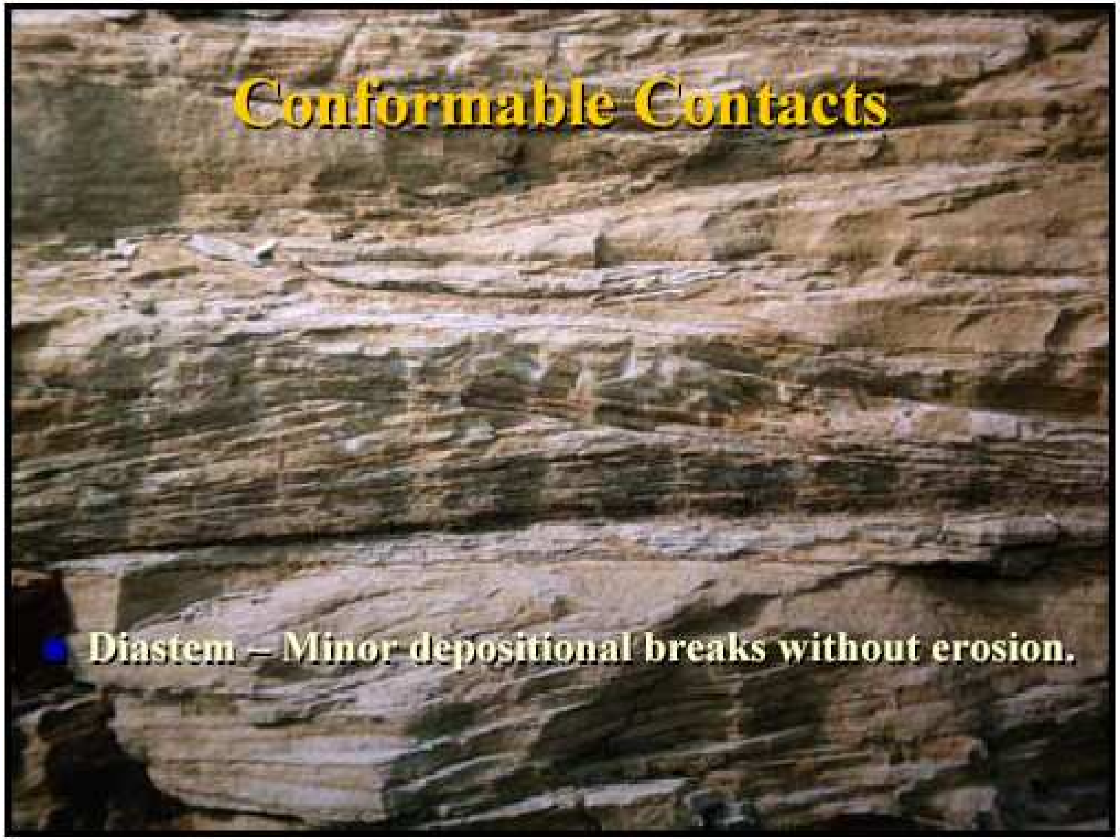
Paraconformities are characterized by a surface of nondeposition separating two parallel units of sedimentary rock, which is virtually indistinguishable from a sharp conformable contact; there is no obvious evidence of erosion. An examination of the fossils shows that there is a considerable *time gap* represented by the surface.



Paraconformity

Diastem

- A **diastem** is a relatively short interruption in sedimentation, with little or no erosion before deposition is resumed.
- The time involved in a diastem may be days or years (e.g. the time between floods on a flood plain).
- In a sedimentary succession a diastem may be a bedding plane or may not be visible at all.



Subsidence

- The earth's surface sinks due to sediment or tectonic loading

Transgression

-Shift of depositional base level landward
-Movement of shoreline in a landward direction

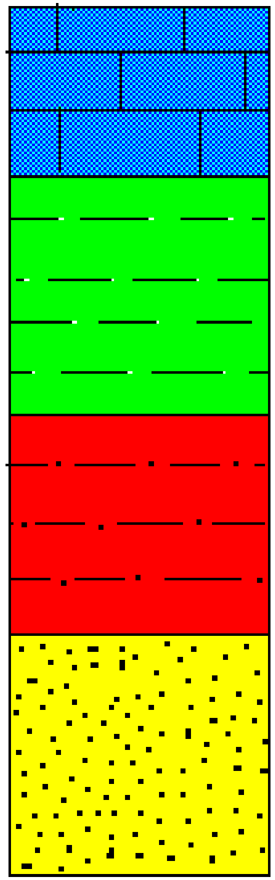
-*Regression*

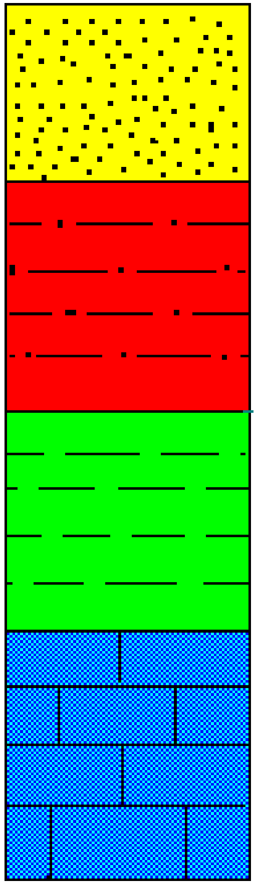
-Movement of shoreline in a seaward direction
-Shift of depositional base level seaward

•Transgressive sequence

•Deeper water facies overlie shallow water facies.

A "**deepening upward**" sequence.





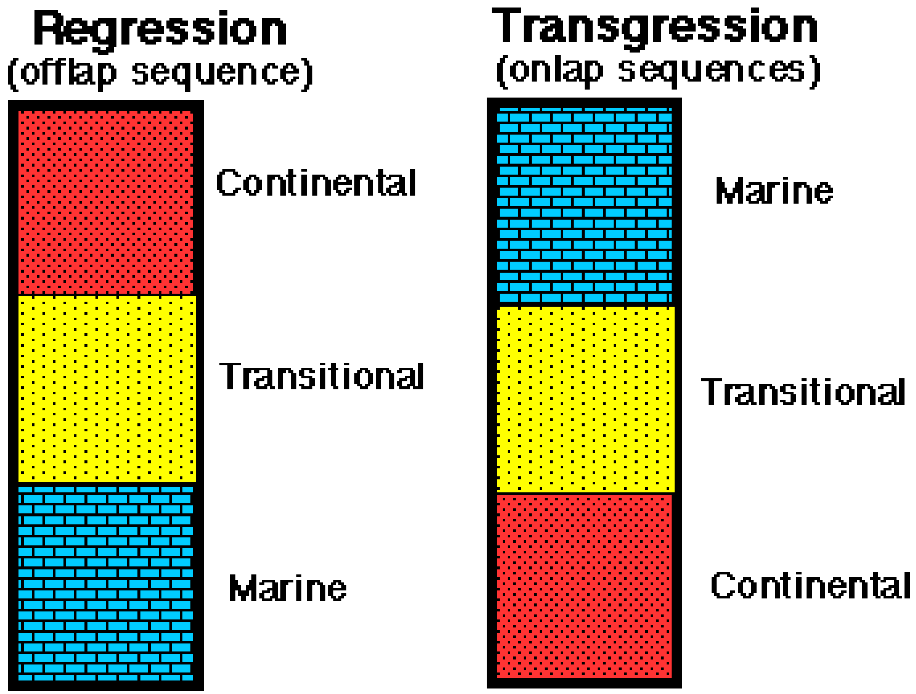
•Regressive sequence

•Shallow water facies overlie deeper water facies.

A **"shallowing upward"** sequence.

•Regression (offlap sequence)

•Transgression (onlap sequence



- STERIC sea level change : change in Water Density

  ↙ Temperature ↘ Salinity

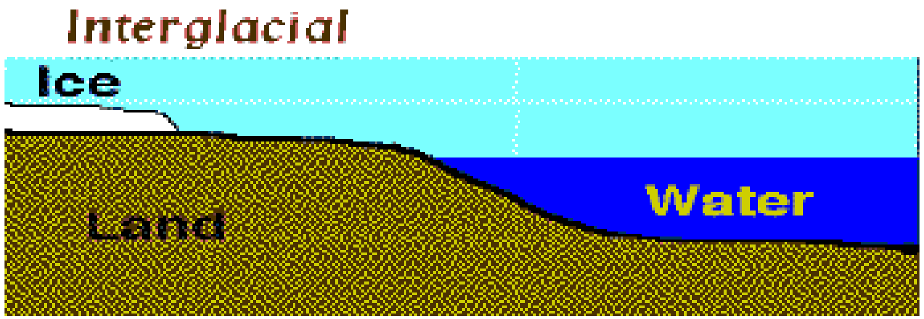
- EUSTATIC sea level change: change in Ocean Mass

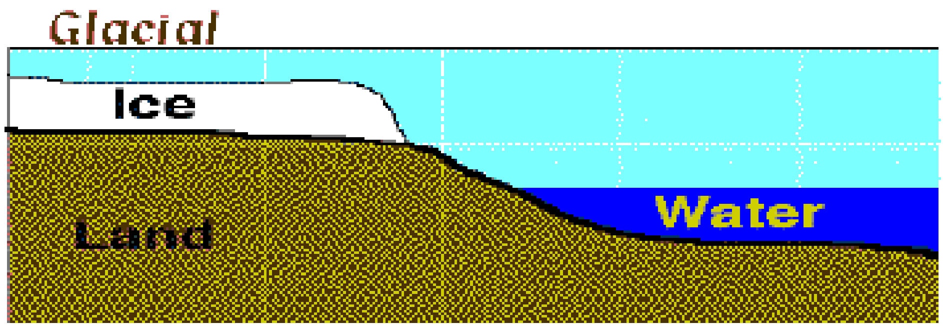
  ↙ Water mass exchange with continental reservoirs, mountain glaciers and ice sheets

•Changes in Sea Level

•Eustatic Sea Level Changes

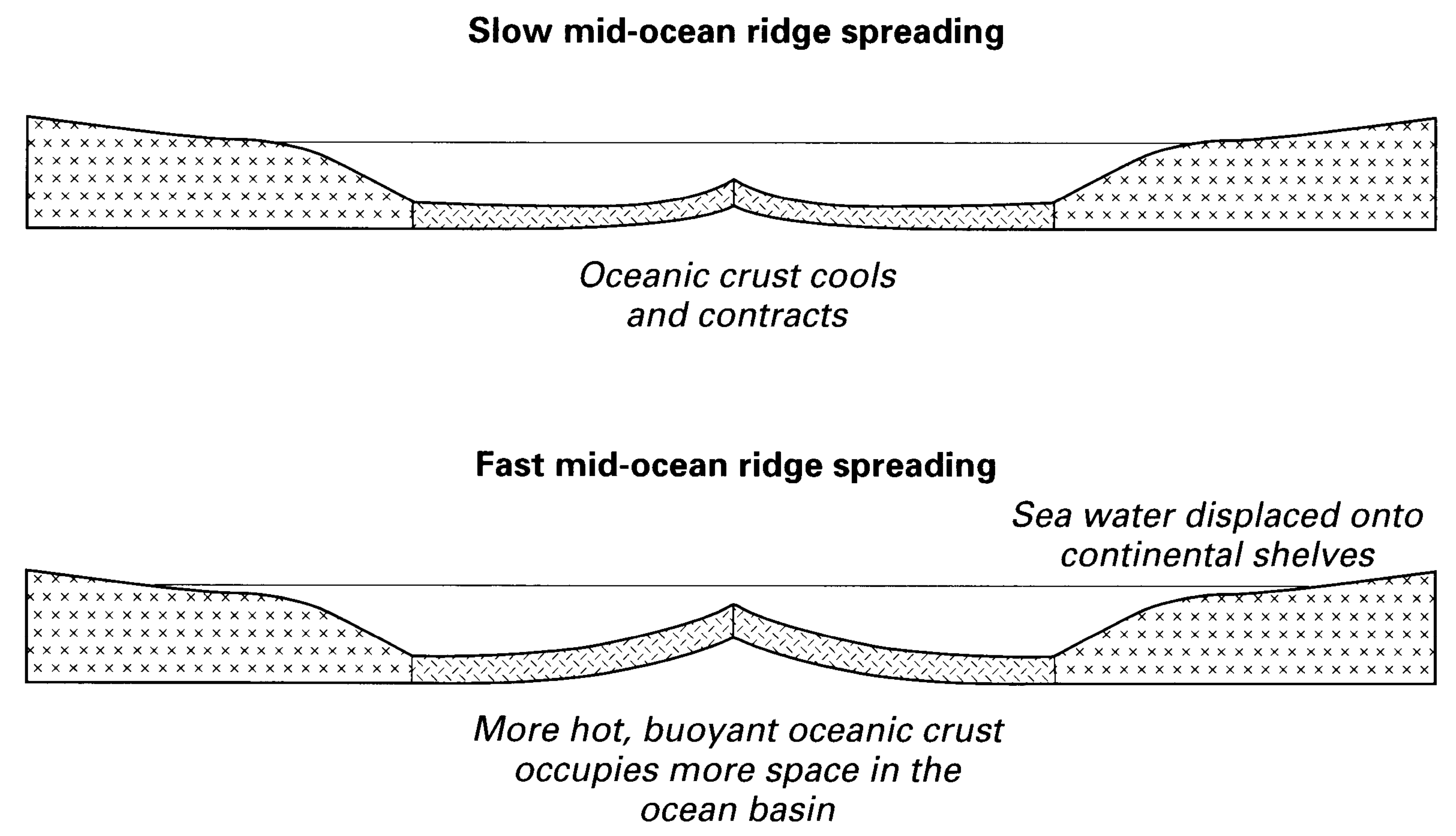
•- Climate (ice ages)





•Tectonic (development of mid-ocean ridges)

•Figure 3.14, p. 50


Slow mid-ocean ridge spreading
Oceanic crust cools and contracts
Fast mid-ocean ridge spreading
Sea water displaced onto continental shelves
More hot, buoyant oceanic crust occupies more space in the ocean basin

•Local Sea Level Changes

•- Uplift
- Subsidence