

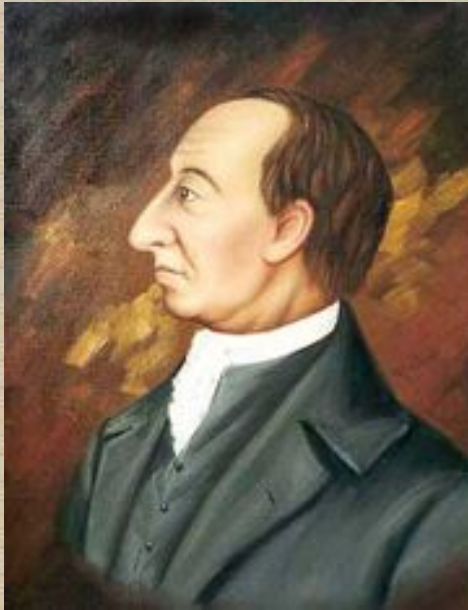
Relative Age Dating

Uniformitarianism

Principles of correlation

- ◆ Original horizontality
- ◆ Superposition
- ◆ Inclusion
- ◆ Cross-cutting relationships

Biostratigraphy



http://de.wikipedia.org/wiki/James_Hutton

James Hutton, Scottish Geologist

Royal Society of Edinburgh meetings - 1785

Formations of rocks and soils on the Earth's surface formed over long periods of time via processes observable on the modern Earth

This worldview became known as the **Principle of Uniformitarianism**, and specifically rejected supernatural causation to explain natural processes and formations.

Coal gas first used for illumination; Louis XVI of France signs to a law that a handkerchief must be square; British government establishes a permanent land force in the Eastern Caribbean, based in Barbados; The North Carolina General Assembly incorporates Lincolnton, North Carolina (named for American General Benjamin Lincoln) as the new county seat for Lincoln County. (<http://en.wikipedia.org/wiki/1785>)

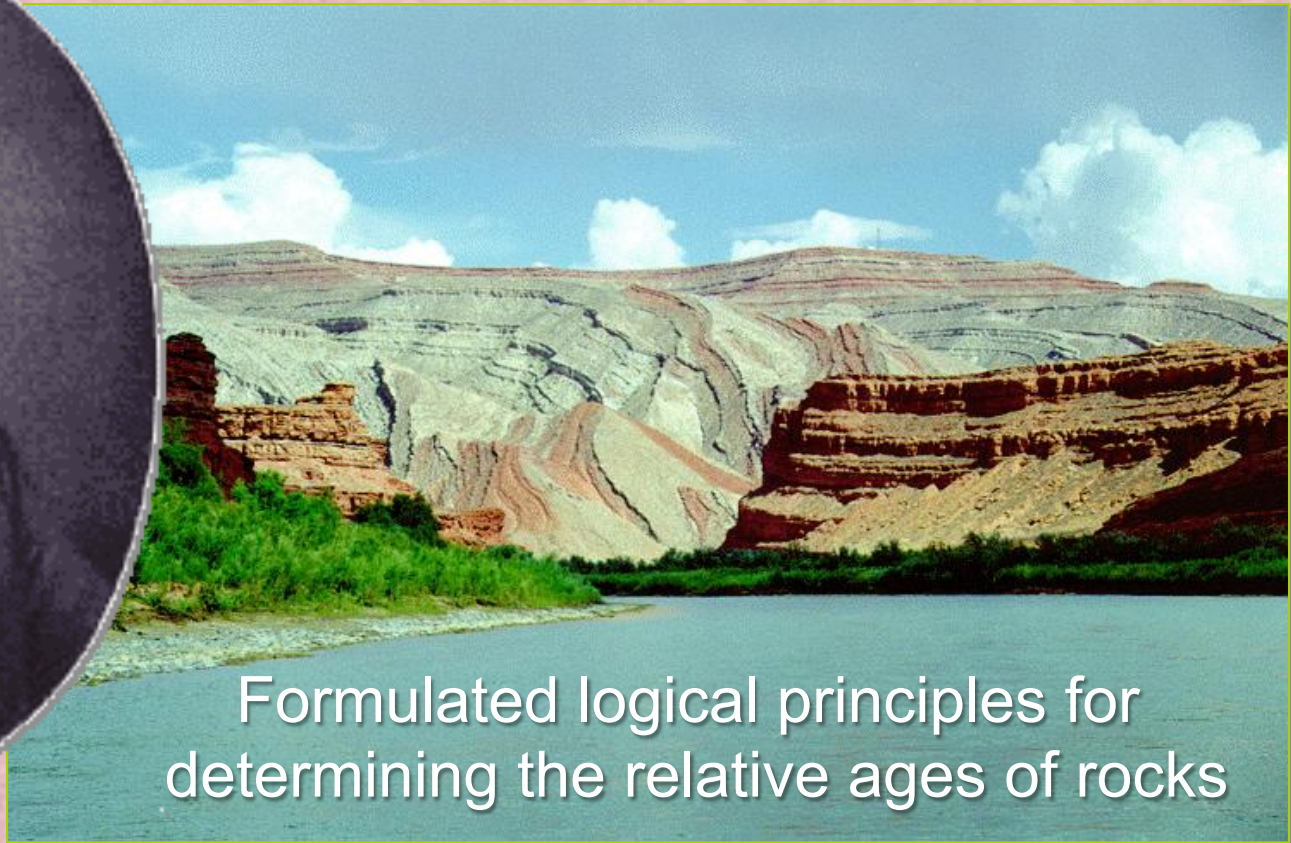
Principle of Uniformitarianism

Hutton's work did not gain much acceptance for a long time – probably because the writing was dry. Later, Charles Lyell published a three volume set of books about interpreting geologic history.

Unlike Hutton's indigestible prose, Lyell's books became required reading for the "natural philosophers" of the day.

Charles Darwin brought the first volume with him to South America on the Beagle, and arranged to have the second and third volumes sent when they were published

Nicholas Steno (1638-1686)

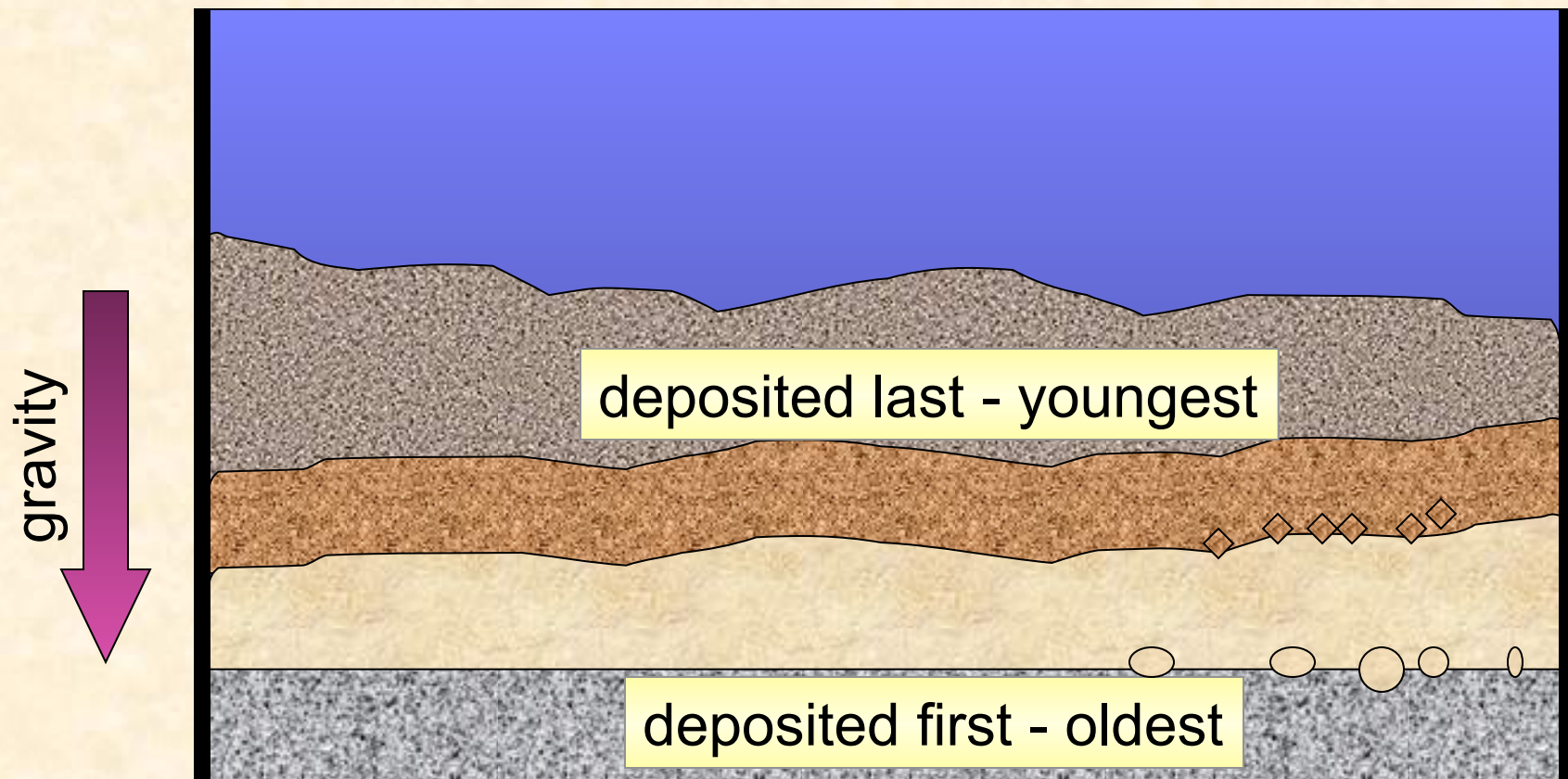


Formulated logical principles for determining the relative ages of rocks

http://www.rjsmith.com/san_juan_river.html
<http://www.ucmp.berkeley.edu/history/steno.html>

Principle of Original Horizontality

Sedimentary rocks were deposited in primarily horizontal beds

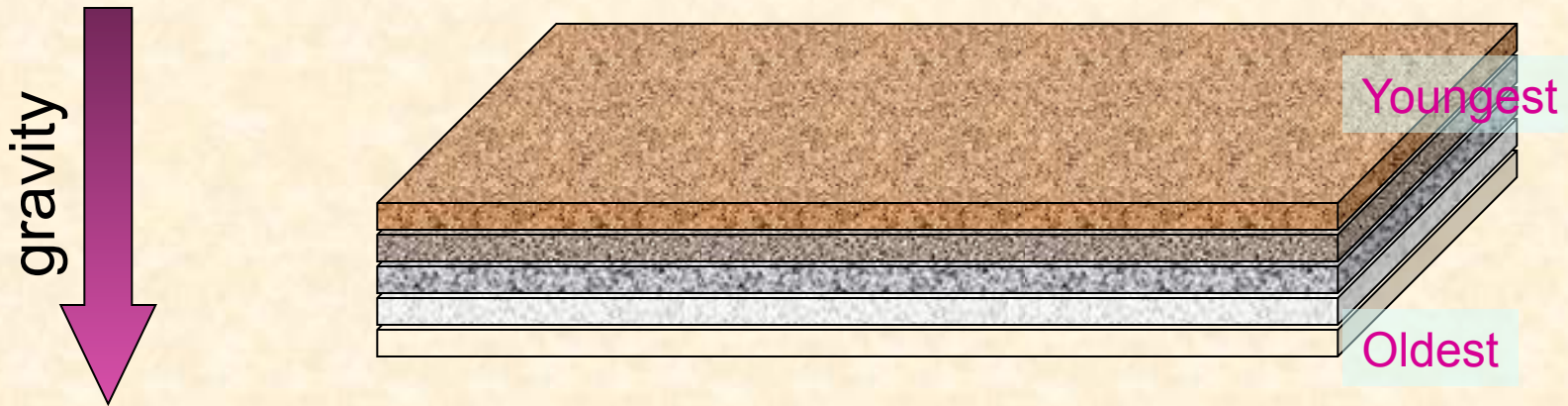


Principle of Superposition

In an undisturbed sedimentary sequence, the oldest rocks are on the bottom of the stack

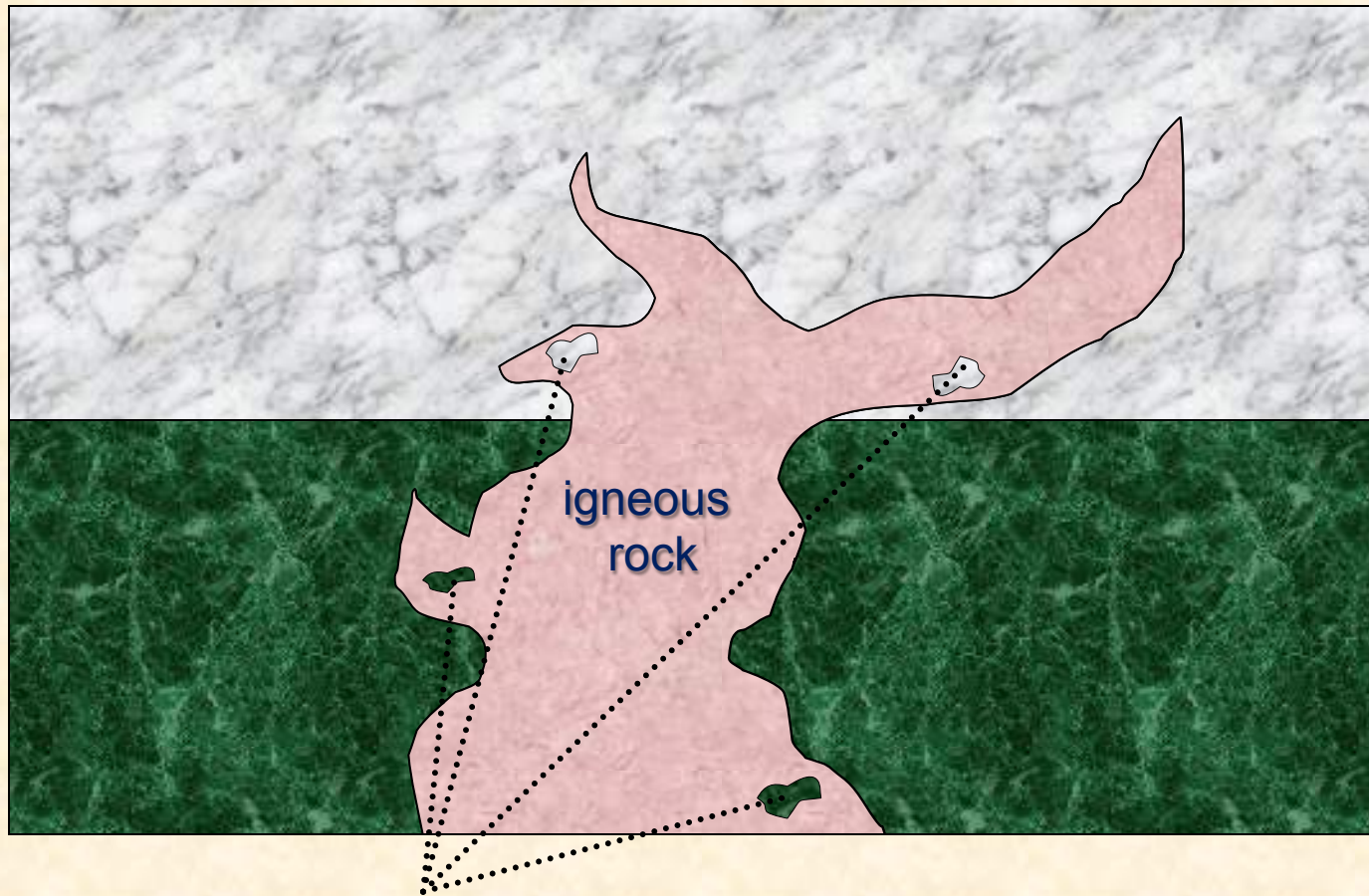
Principle of Superposition

In an undisturbed sedimentary sequence, the oldest rocks are on the bottom of the stack



Principle of Inclusion

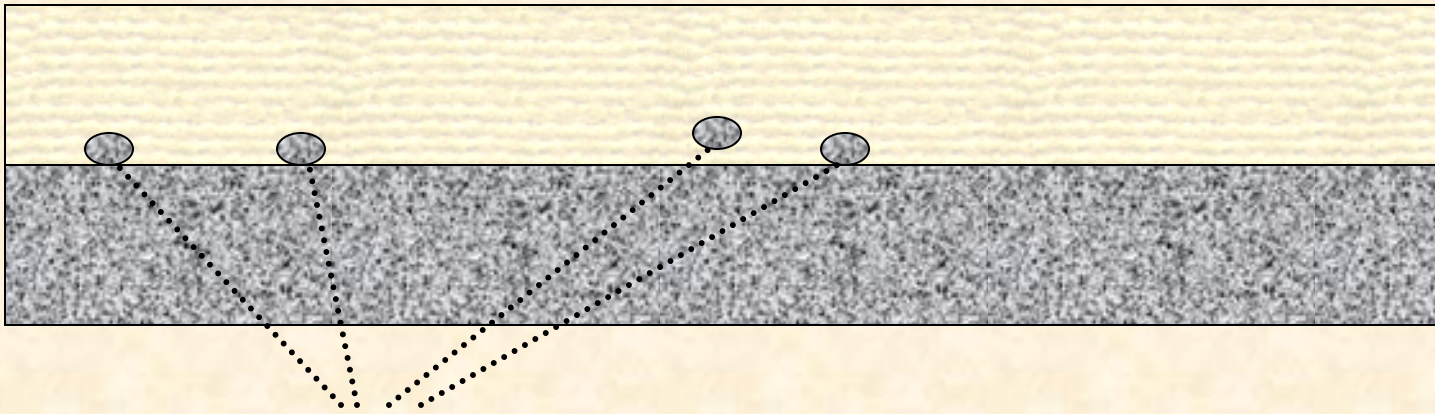
When clasts of one rock are found in another, the rock from which the clasts were derived is the older rock, since it must have already existed in order to be included in the new rock



Inclusions - pieces of older rock incorporated into younger rock

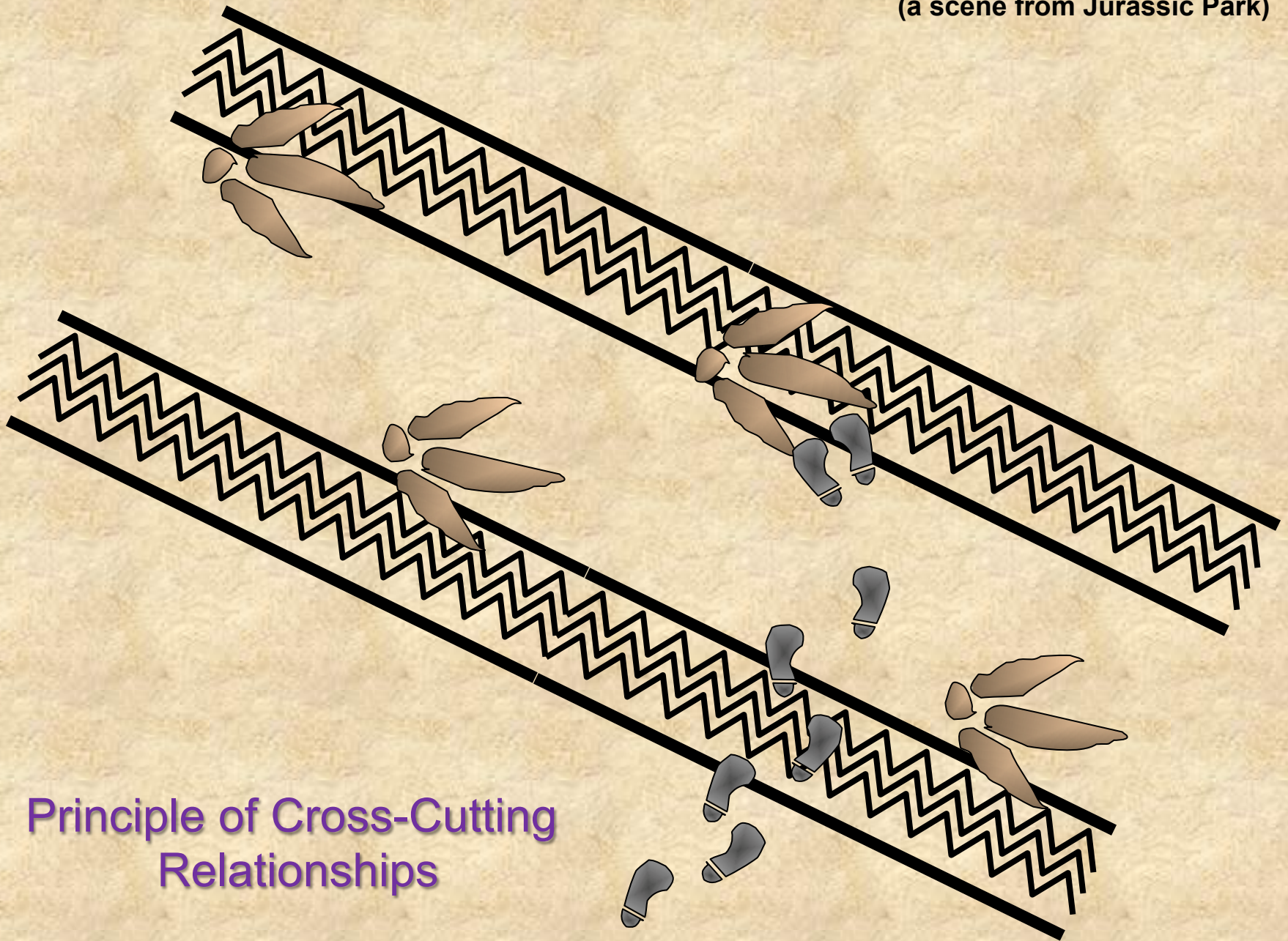
Principle of Inclusion

When clasts of one rock are found in another, the rock from which the clasts were derived is the older rock, since it must have already existed in order to be included in the new rock



Inclusions - pieces of older rock
(clasts) incorporated into younger rock

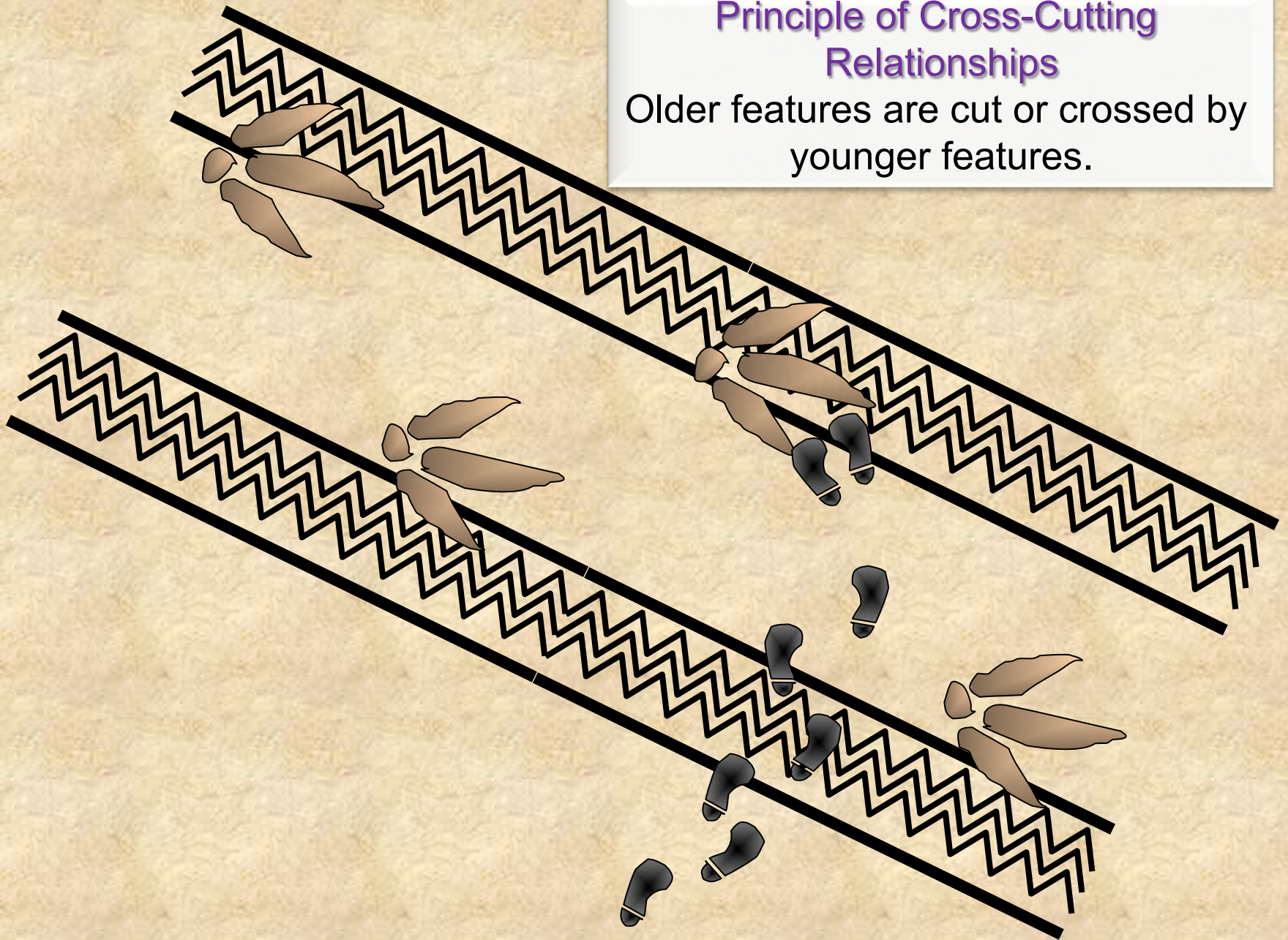
(a scene from Jurassic Park)



Principle of Cross-Cutting Relationships

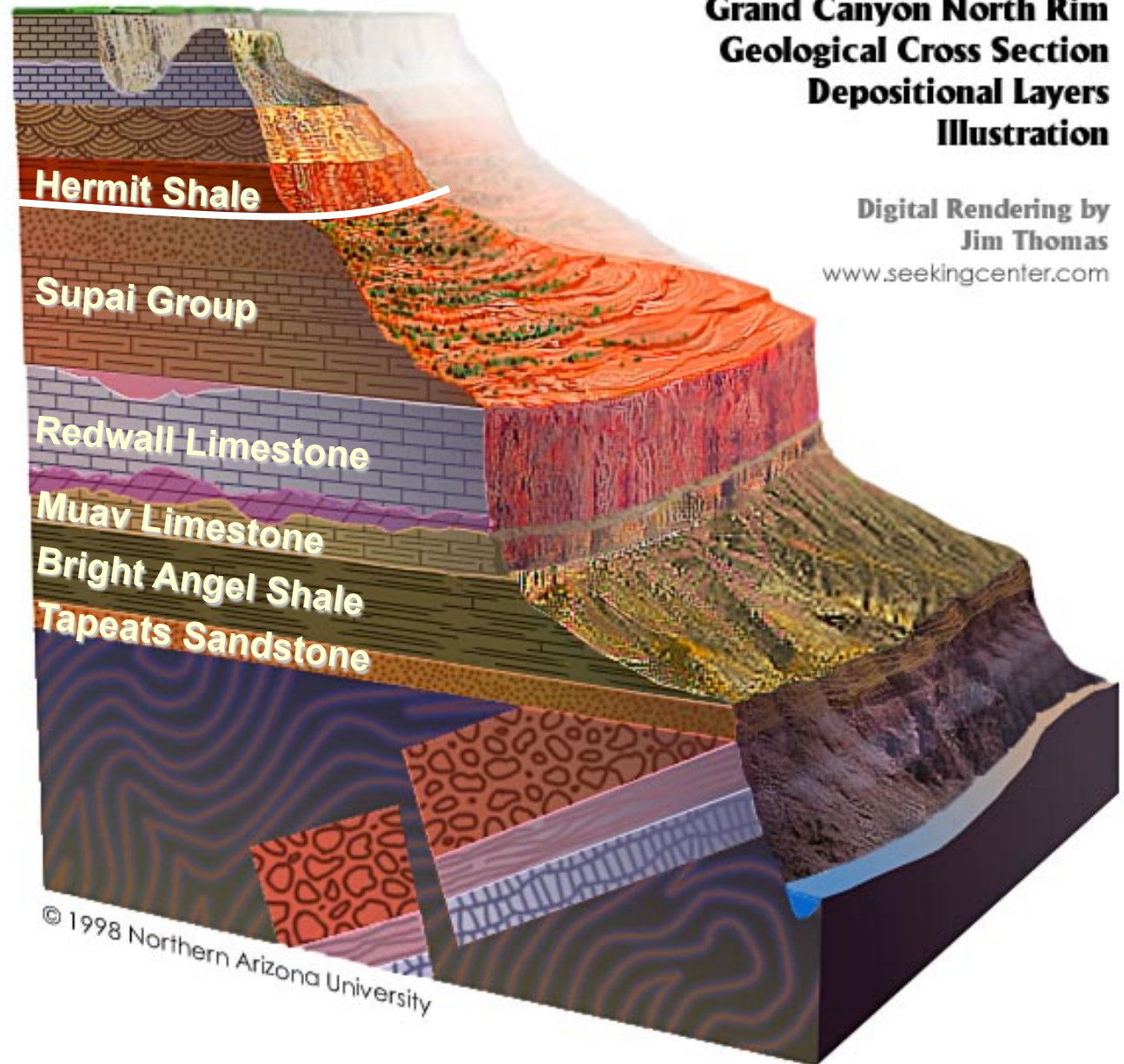
Principle of Cross-Cutting Relationships

Older features are cut or crossed by younger features.



Contact – surface separating two formations

Formation – bodies of rock with recognizable characteristic that are thick enough to map



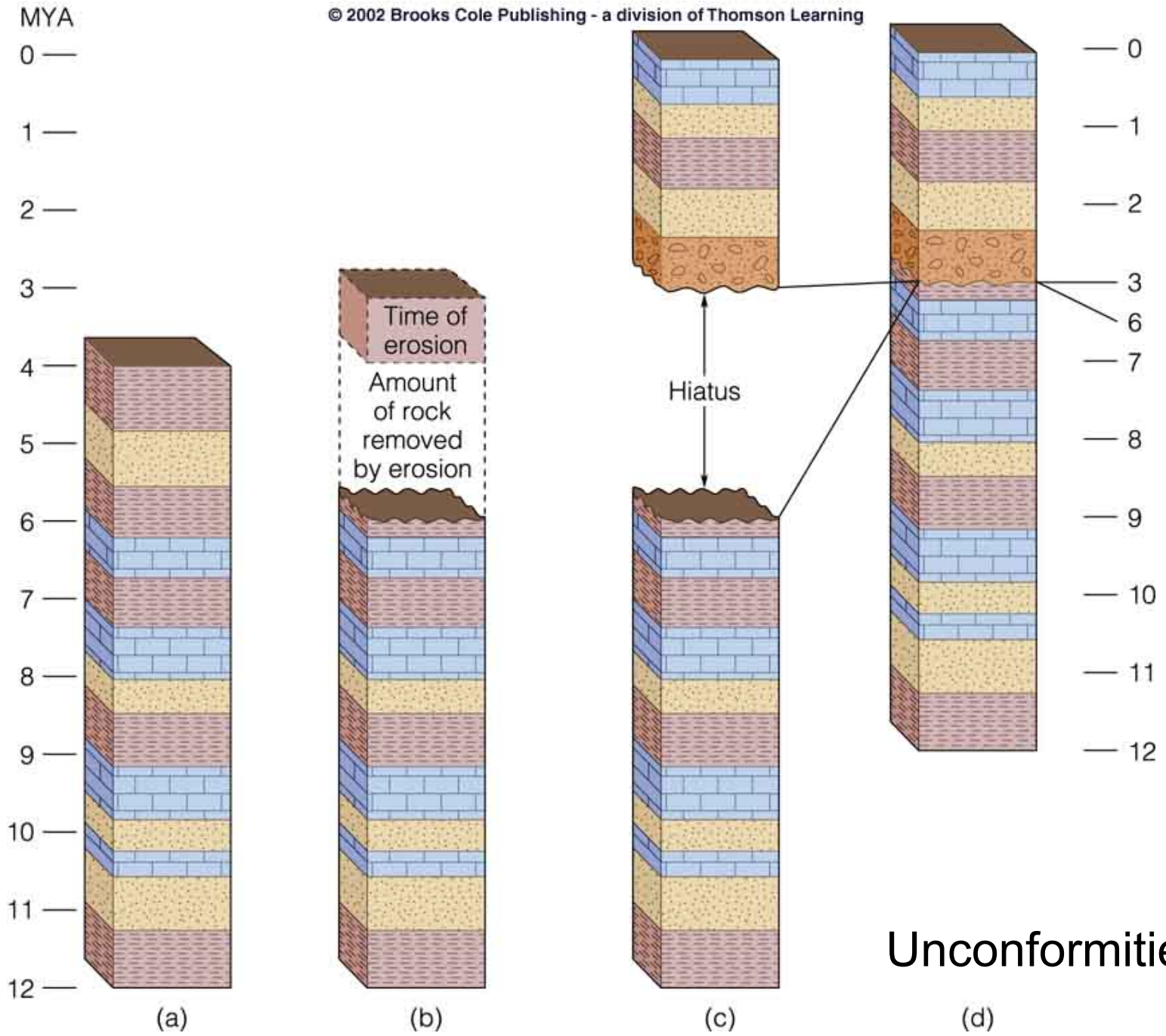
Reconstructing Geologic History

The geologic history of an area can be divided into times during which:

- ✦ Rock is being formed or altered
- ✦ Rock is being eroded

Periods of rock formation leave positive evidence of what geologic processes were in effect at the time of formation.

Periods of rock erosion leave **unconformities**.



Reconstructing Geologic History

Unconformities represent missing time in the geological sequence, either due to no rock being formed or rock being removed.

There are three kinds of unconformities:

- ✦ **disconformity** – unconformity between parallel strata. Represents a time of non-deposition or erosion without deformation of strata.
- ✦ **angular unconformity** – unconformity between non-parallel strata. Strata were deformed as well as eroded (not necessarily at the same time)
- ✦ **nonconformity** – unconformity representing erosion of a non-sedimentary rock

Reconstructing Geologic History

Grand Canyon North Rim Geological Cross Section Depositional Layers Illustration

Digital Rendering by
Jim Thomas
www.seekingcenter.com

disconformity

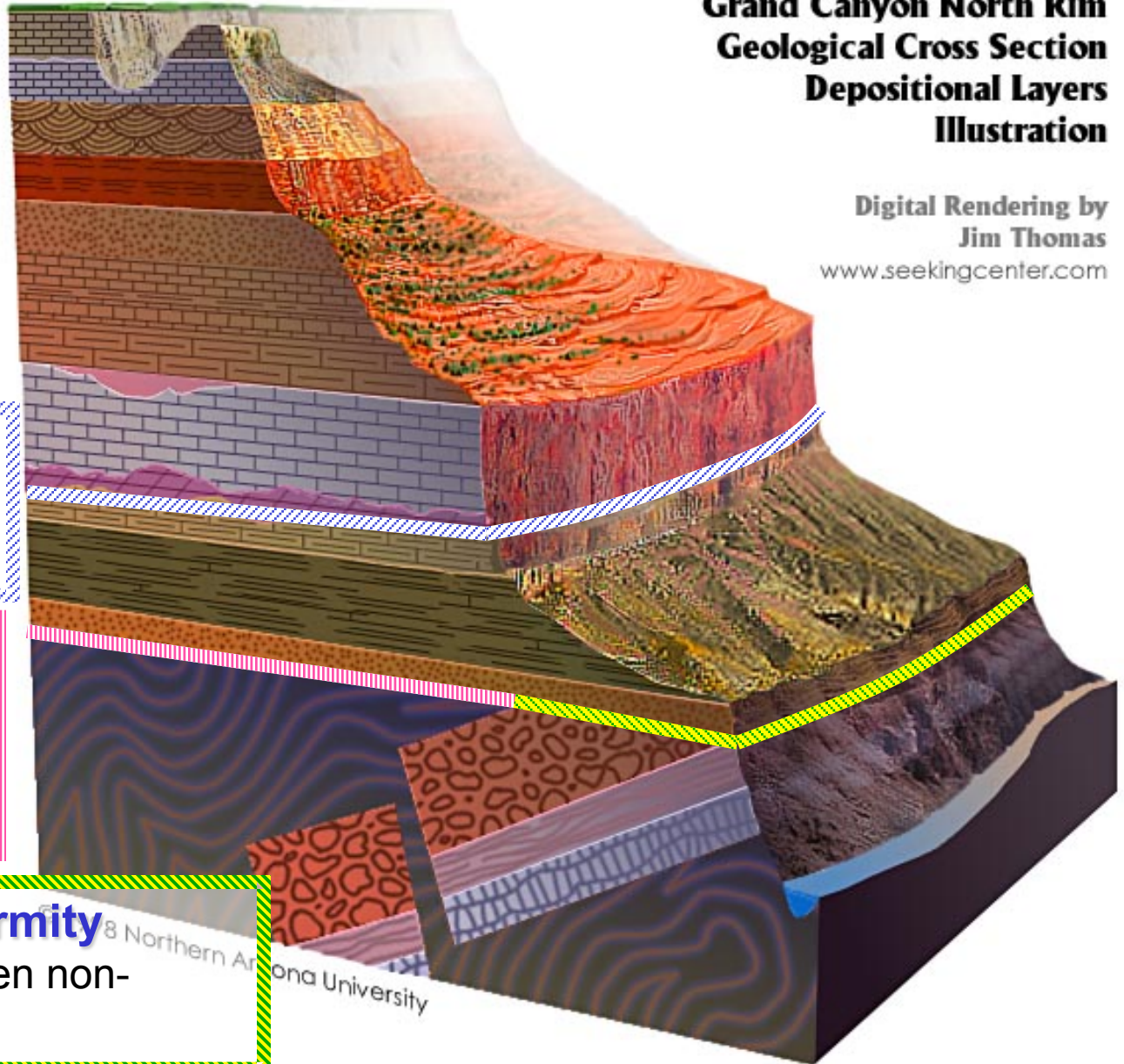
unconformity between parallel strata.

nonconformity

unconformity between non-sedimentary and sedimentary rocks

angular unconformity

unconformity between non-parallel strata





William "Strata" Smith 1769-1839

A trained surveyor with an avid interest in fossils, Smith suffered from rare condition for naturalist of his time - lowly birth. He worked in both the coal industry and supervised the digging of the Somerset Canal in England, but still spent time in debtors' prison.

Smith formulated the *Principle of Faunal Succession*, which he then used to draft the first modern geologic map, which serves as a model to the present day.

London Clay

Craig

GEOLOGICAL TABLE OF BRITISH ORGANIZED FOSSILS. WHICH IDENTIFY THE COURSES AND CONTINUITY OF THE STRATA IN THEIR ORDER OF SUPERPOSITION; AS ORIGINALLY DISCOVERED BY W. SMITH, Civil Engineer; WITH REFERENCE TO HIS GEOLOGICAL MAP OF ENGLAND AND WALES.

ORGANIZED FOSSILS which identify the respective STRATA.	NAMES of STRATA on the Sheets of the GEOLOGICAL COLLECTION.	COLORS on the MAP OF STRATA.	NAMES in the MEMOIR and the PECULIARITIES of the STRATA.	PRODUCTS of the STRATA.
Trochus, Turris, Turbo, Helix, Gasteropoda, Nautilus, Pecten, Cardium, etc.	London Clay	1	London Clay covering Highgate, Harrow, Shaker and other detached Hills	Syringium. A shell which Robert Brown found in chalk
Murex, Turbo, Cardium, Turbo, Helix, Turbo, etc.	Craig	2	Clay or Breckworth with Interposition of Sand and Gravel	{ St. Pauling Stone in all this extensive District but often has { Materials which make the best Bricks used in the Island
Fossils, Hippurites, Pecten, etc.	Upper Chalk	3	Chalk	Flints de la Craie, Marne de la Craie, etc.
Ammonites, Belemnites, etc.	Oak Tree Clay	4	Blue Marl	Flints de la Craie, Marne de la Craie, etc.
Ammonites, Belemnites, etc.	Marble	5	Blue Marl under the best Strata of the middle of the Island	Flints de la Craie, Marne de la Craie, etc.
Ammonites, Belemnites, etc.	Lias	6	Blue Lias under the best Strata of the middle of the Island	Flints de la Craie, Marne de la Craie, etc.
Ammonites, Belemnites, etc.	Murchisonian Limestone	7	Blue Lias under the best Strata of the middle of the Island	Flints de la Craie, Marne de la Craie, etc.
Ammonites, Belemnites, etc.	Coal Measures	8	Coal Districts and the Rocks & Clay which accompany the Coal	Flints de la Craie, Marne de la Craie, etc.
Ammonites, Belemnites, etc.	Mountain Limestone	9	Durham Limestone or Mountain Limestone	Flints de la Craie, Marne de la Craie, etc.
Ammonites, Belemnites, etc.	Red Rock & Sandstone	10	Red & Sandstone of the Southern and Northern Districts with Interposition of Limestone marked blue	Flints de la Craie, Marne de la Craie, etc.
Ammonites, Belemnites, etc.	Slate	11	Slate	Flints de la Craie, Marne de la Craie, etc.
Ammonites, Belemnites, etc.	Granite, Quartz & Gneiss	12	Granite, Quartz & Gneiss	Flints de la Craie, Marne de la Craie, etc.

The Figures of Reference to the Colours and Names show what Strata are found in each County—thus to find the Strata & Products of Norfolk look to the corresponding figures above, 1, 2, 3, 4, 5, 7, 8, 10 & 11.

Bedfordshire 1, 2, 3, 4, 5, 7, 8, 10, 11	Derby 10, 11, 12, 13, 14, 15	Derham 10, 11, 12, 13, 14, 15	Derbyshire 10, 11, 12, 13, 14, 15	Devon 1, 2, 3, 4, 5, 7, 8, 10, 11	Dorset 1, 2, 3, 4, 5, 7, 8, 10, 11	Durham 10, 11, 12, 13, 14, 15	Dorset 1, 2, 3, 4, 5, 7, 8, 10, 11	Durham 10, 11, 12, 13, 14, 15	Dorset 1, 2, 3, 4, 5, 7, 8, 10, 11	Dorset 1, 2, 3, 4, 5, 7, 8, 10, 11
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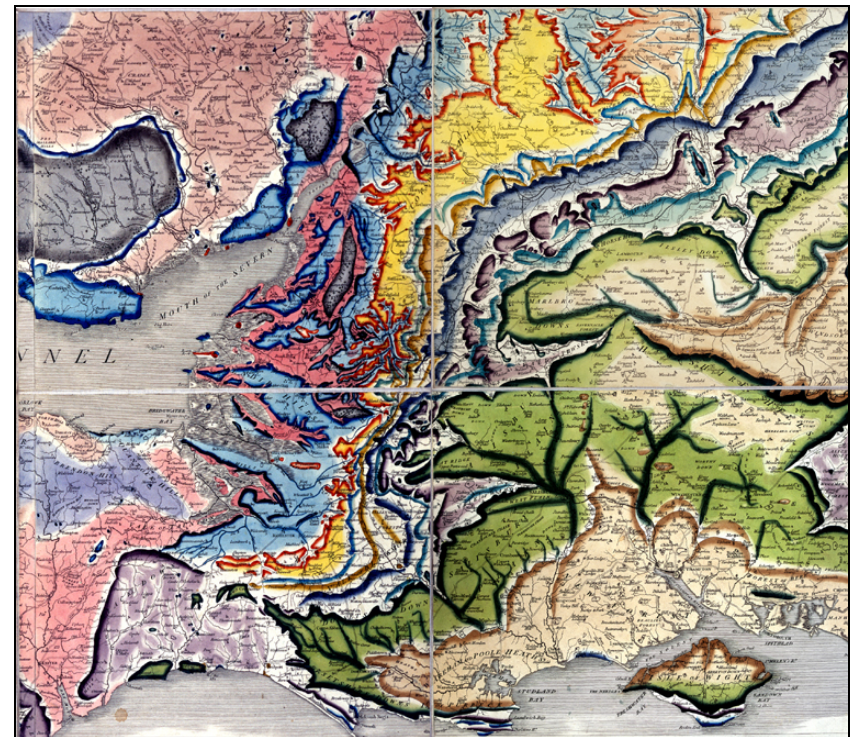
Oak Tree Clay

Upper Chalk



6x9 ft

William Smith's geologic map of England, Wales, and Scotland.



<http://www.unh.edu/esci/wmsmith.html>

Biostratigraphy

More Recent

Time

X

Extinction - last appearance of species in fossil record



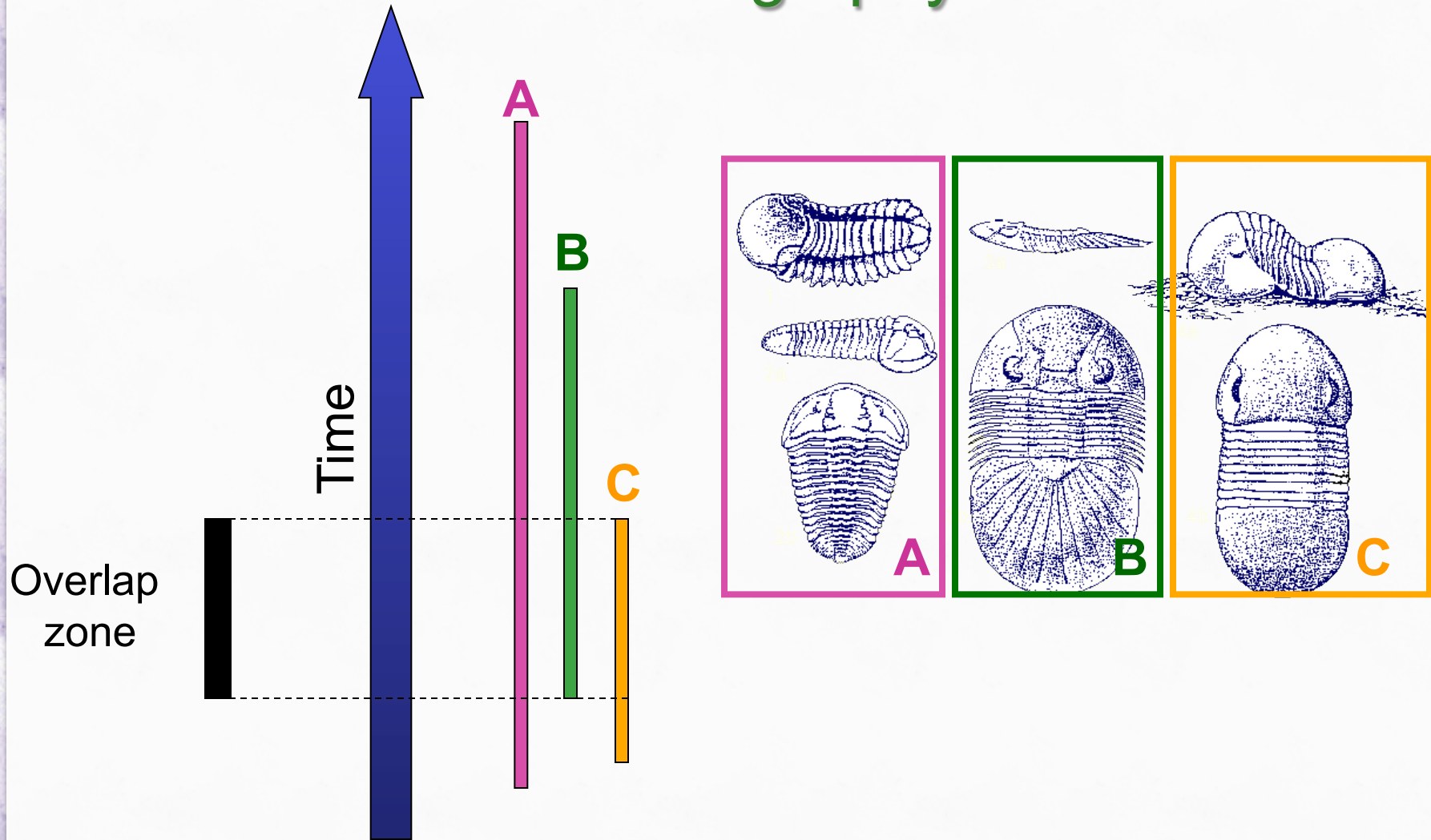
Fossil A




O

Origination - evolution of species

More Ancient

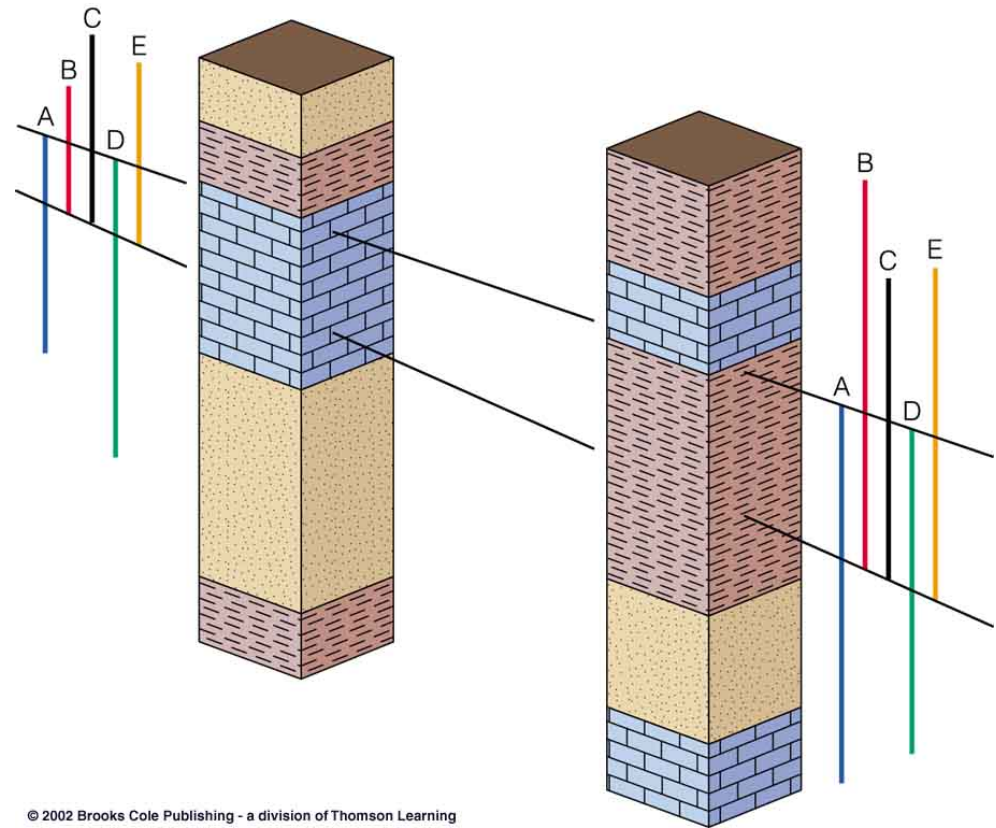
Biostratigraphy



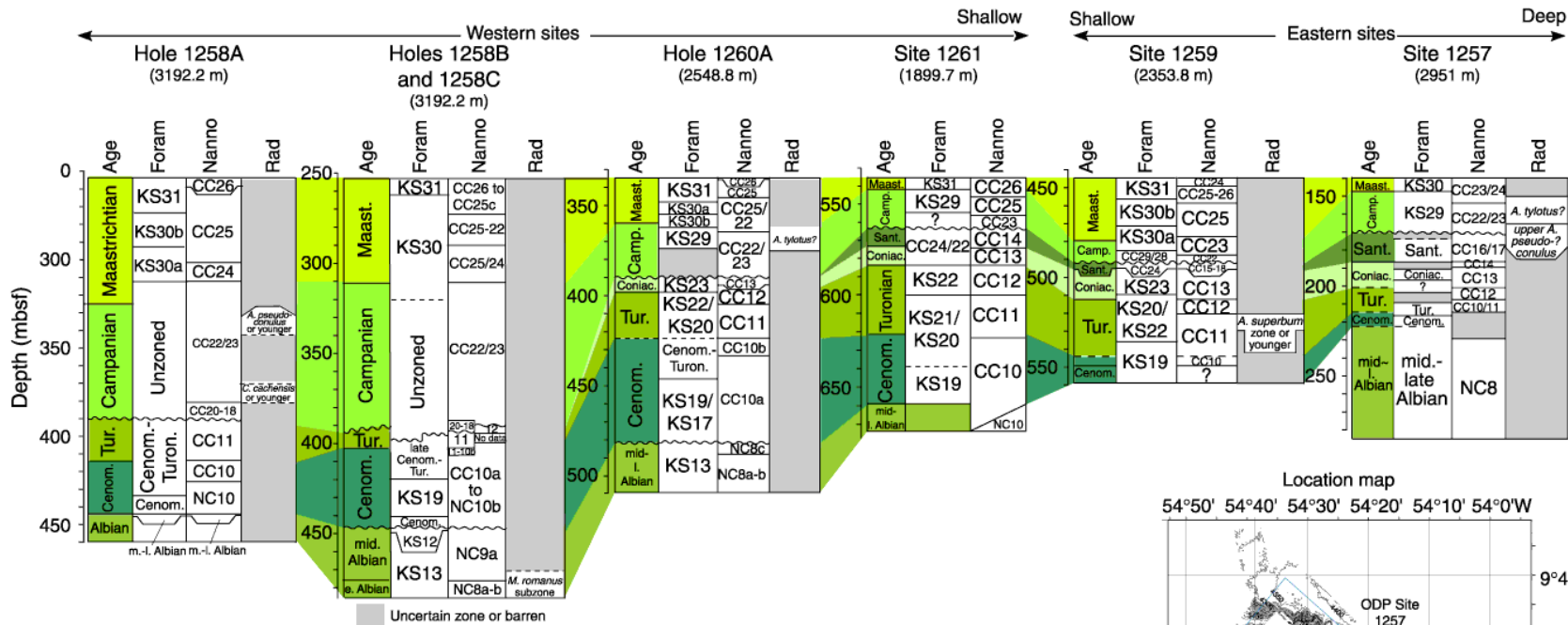
Cenozoic	Tertiary			
	Mesozoic	Cretaceous		
		Jurassic	 <i>Lingula</i>	 <i>Inoceramus</i>
		Triassic		
Paleozoic	Permian			
	Pennsylvanian			
	Mississippian			
	Devonian			
	Silurian			
	Ordovician		 <i>Isotelus</i>	
	Cambrian			

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Biostratigraphy



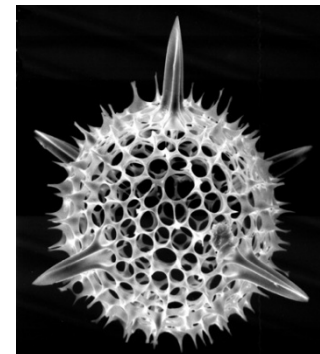
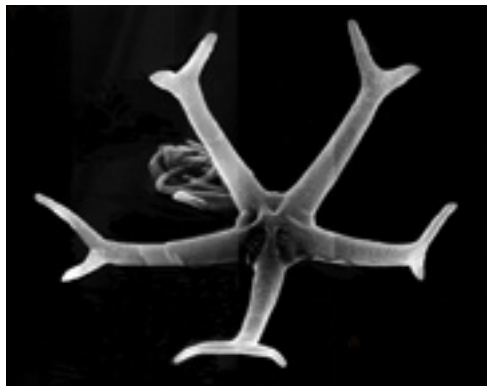
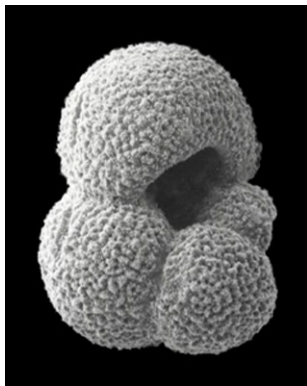
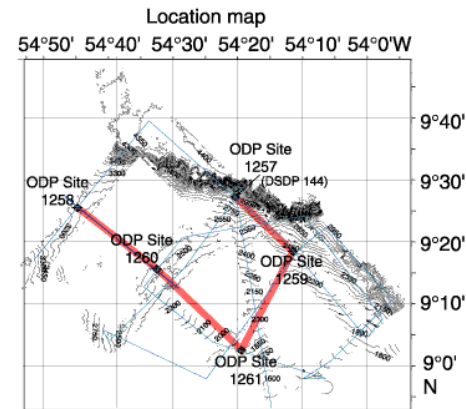
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<http://www-odp.tamu.edu/nps>

Biostratigraphy for several wells off the coast of Suriname, South America.

Correlation based on foraminifera, calcareous nannofossils and radiolarians.



Geologic Time Scale

EON	ERA	PERIOD	EPOCH	Ma		
Phanerozoic	Cenozoic	Quaternary	Holocene		0.01 -	
			Pleistocene	Late	0.8 -	
		Early		1.8 -		
		Tertiary	Neogene	Pliocene	Late	3.6 -
					Early	5.3 -
				Miocene	Late	11.2 -
					Middle	16.4 -
				Oligocene	Early	33.7 -
					Late	28.5 -
			Paleogene	Eocene	Late	33.7 -
					Middle	41.3 -
				Paleocene	Early	49.0 -
					Late	54.8 -
		Mesozoic	Cretaceous	Late	61.0 -	
	Early			65.0 -		
	Jurassic		Late	99.0 -		
			Middle	144 -		
			Early	159 -		
	Triassic		Late	180 -		
			Middle	206 -		
			Early	227 -		
			Late	242 -		
	Paleozoic		Permian	Late	248 -	
				Early	256 -	
			Pennsylvanian	290 -		
			Mississippian	323 -		
			Devonian		354 -	
			370 -			
	Cambrian		Silurian	Early	391 -	
		Late		417 -		
Ordovician		Late	423 -			
		Middle	443 -			
		Early	458 -			
Cambrian		D	470 -			
		C	490 -			
		B	500 -			
		A	512 -			
		520 -				
Precambrian	Proterozoic	Late	543 -			
		Middle	900 -			
		Early	1600 -			
	Archean	Late	2500 -			
		Middle	3000 -			
		Early	3400 -			
				3800?		



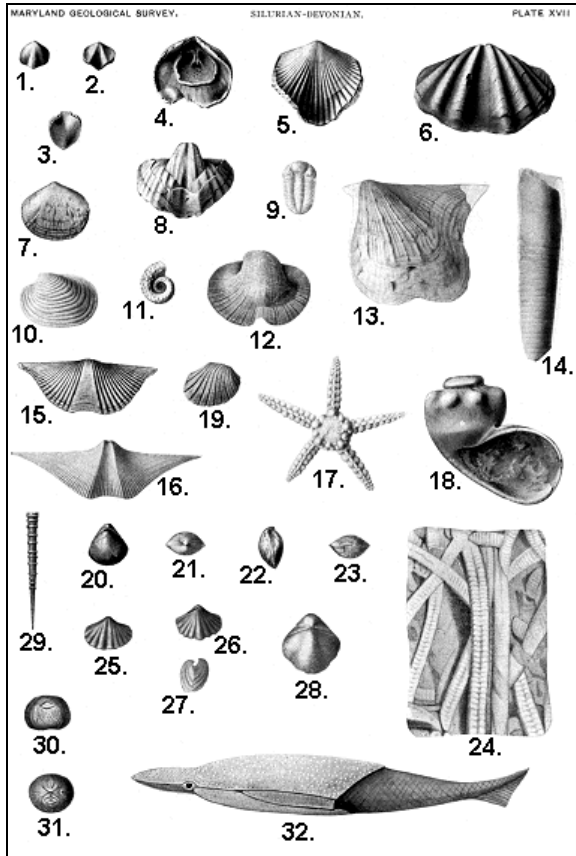
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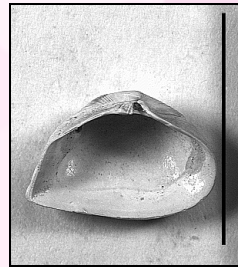
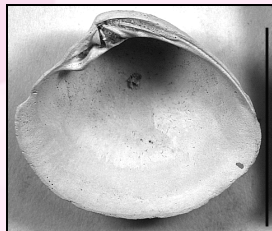
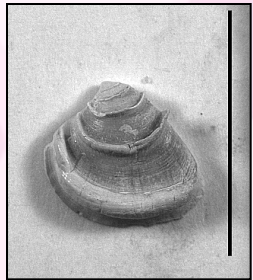
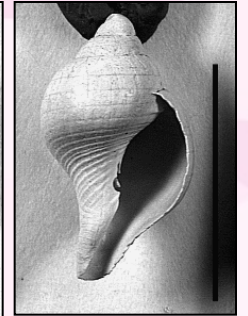
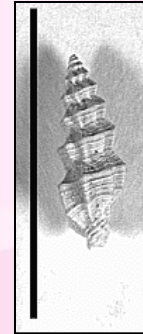
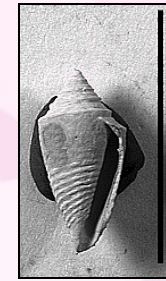
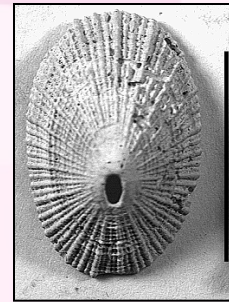
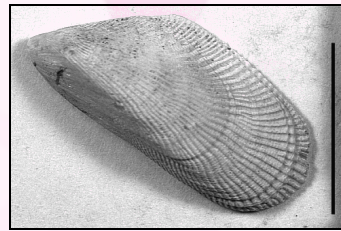
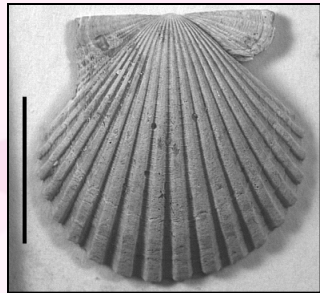
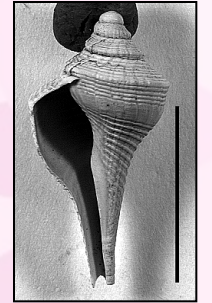
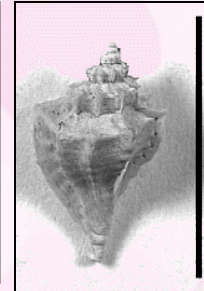
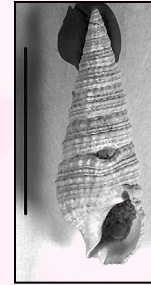
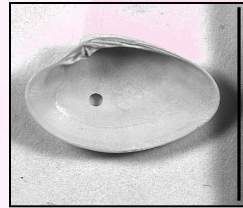
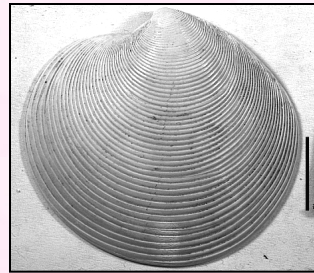
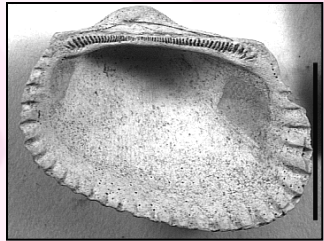
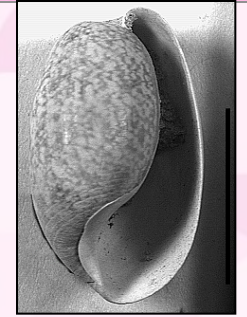
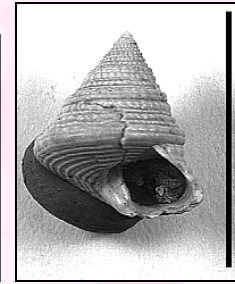
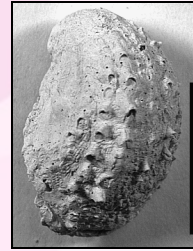
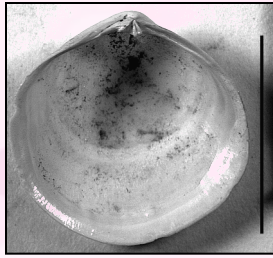
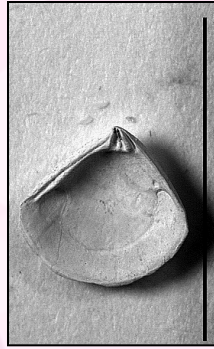
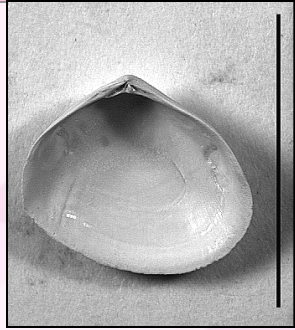
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Devonian Life



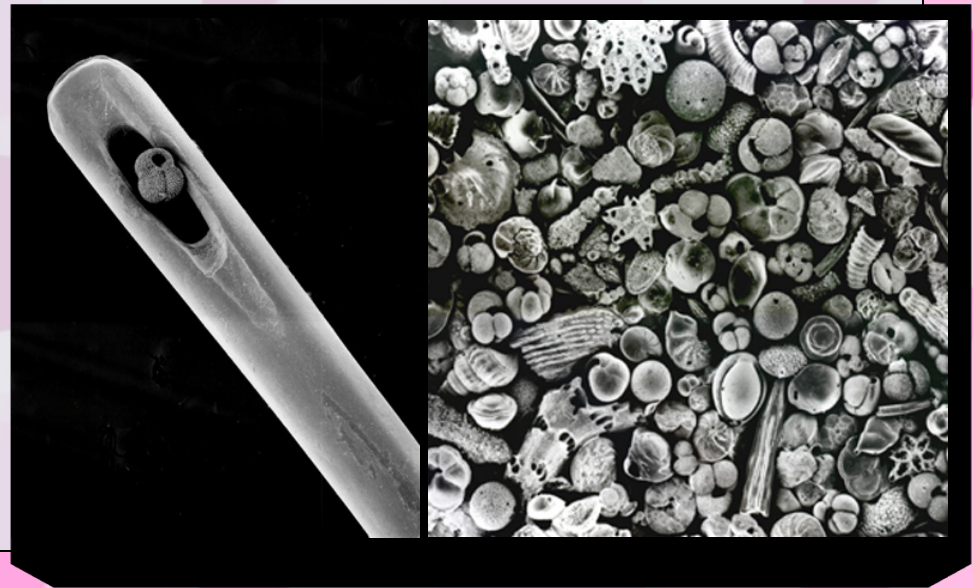
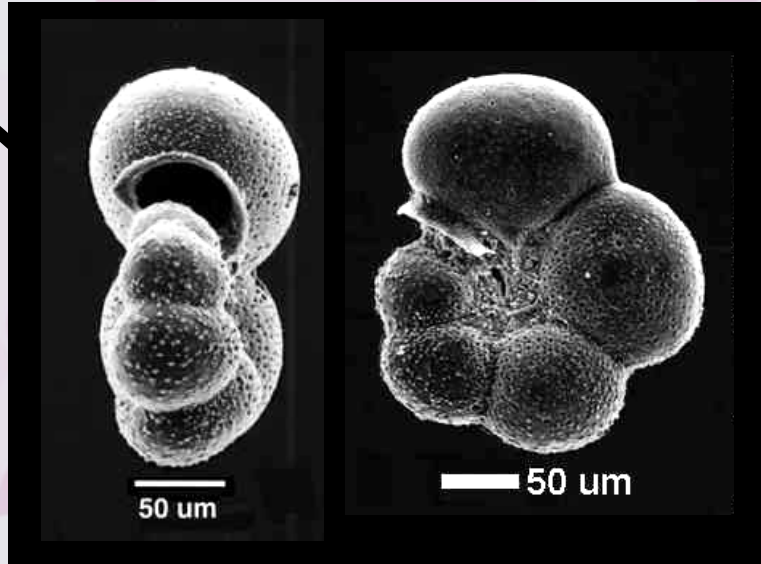
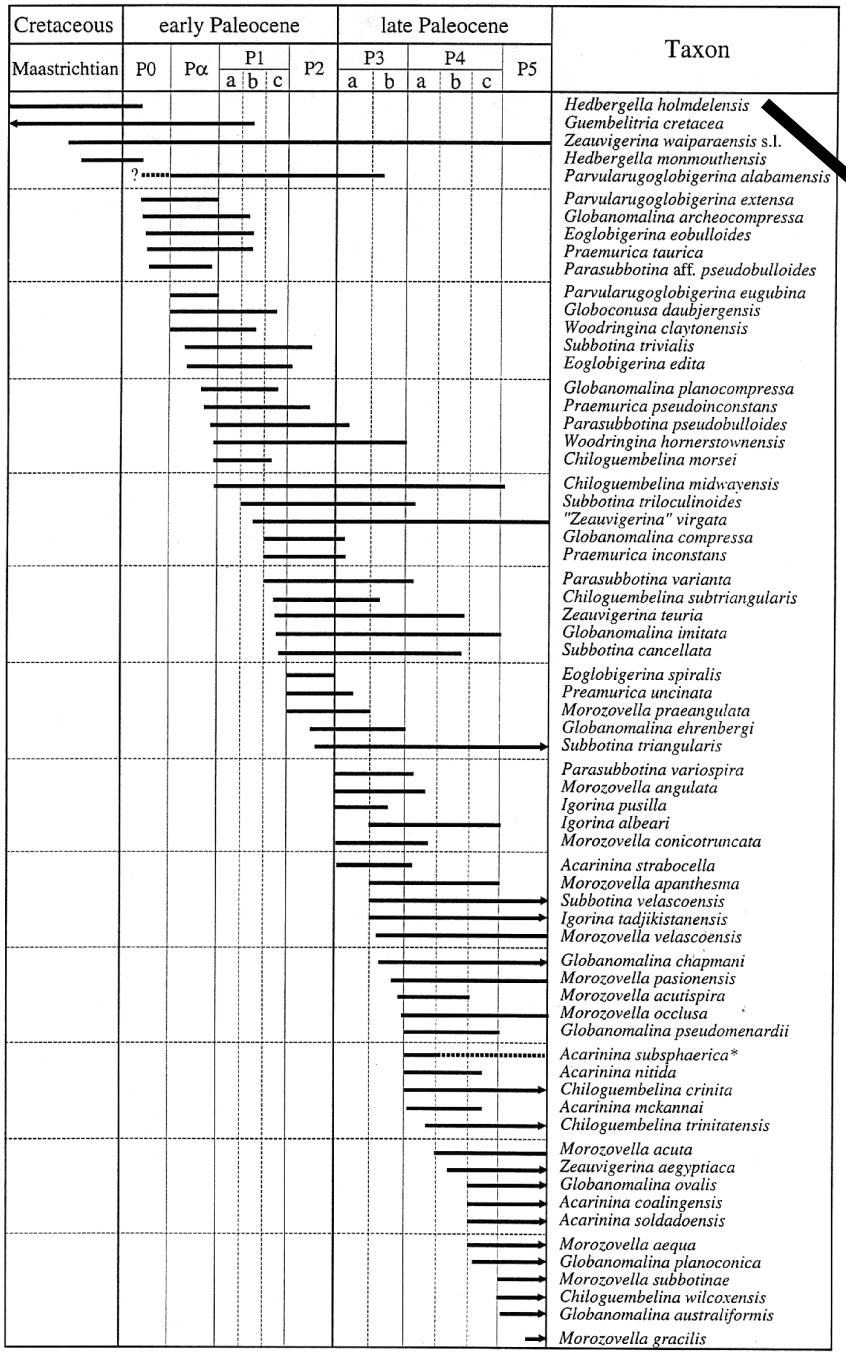
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Pleistocene
Molluscan Assemblage

Foraminifera



Geologic Time Scale

EON	ERA	PERIOD	EPOCH	Ma		
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		Early		1.8		
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					Early	5.3
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	Early			65.0		
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			Early	159		
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			Pennsylvanian	Late	248	
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	D	490				
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		Middle	900			
		Early	1600			
	Archean	Late	2500			
		Middle	3000			
		Early	3400			
			3800?			

The Geologic Time Scale subdivides the history of the Earth based on biostratigraphy and other dating techniques into:

4 Eons (Hadean, Archean, Proterozoic, Phanerozoic), each of which contains

Eras (e.g., Paleozoic, Mesozoic, Cenozoic) which are further subdivided into

Periods (e.g., Triassic, Jurassic and Cretaceous), **Epochs** and smaller time divisions