

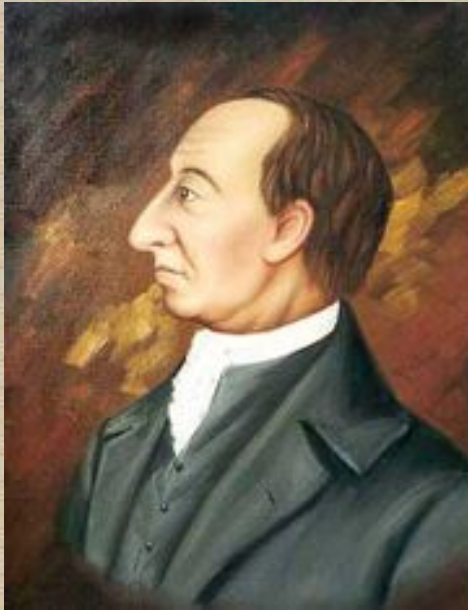
Relative Age Dating

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>)

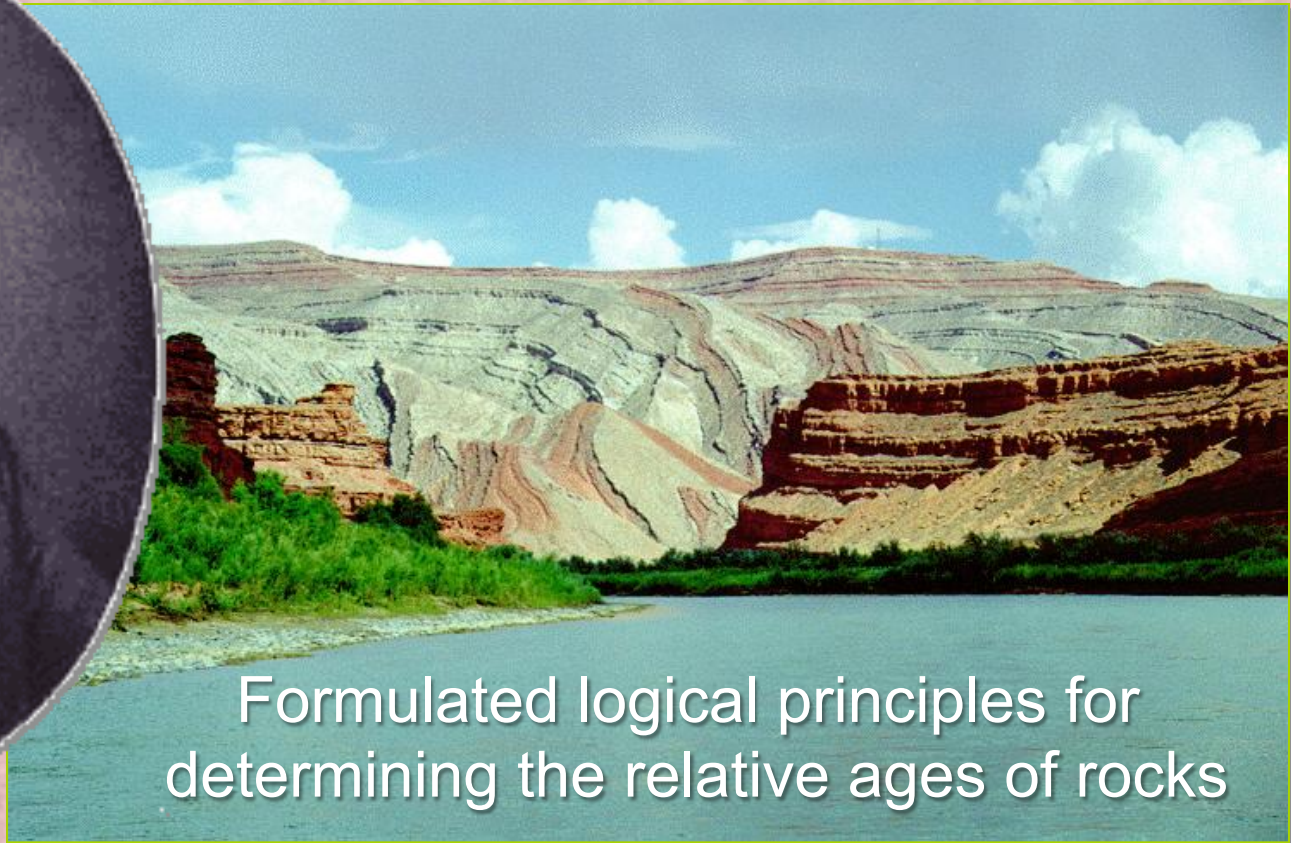
Principle of Uniformitarianism

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)

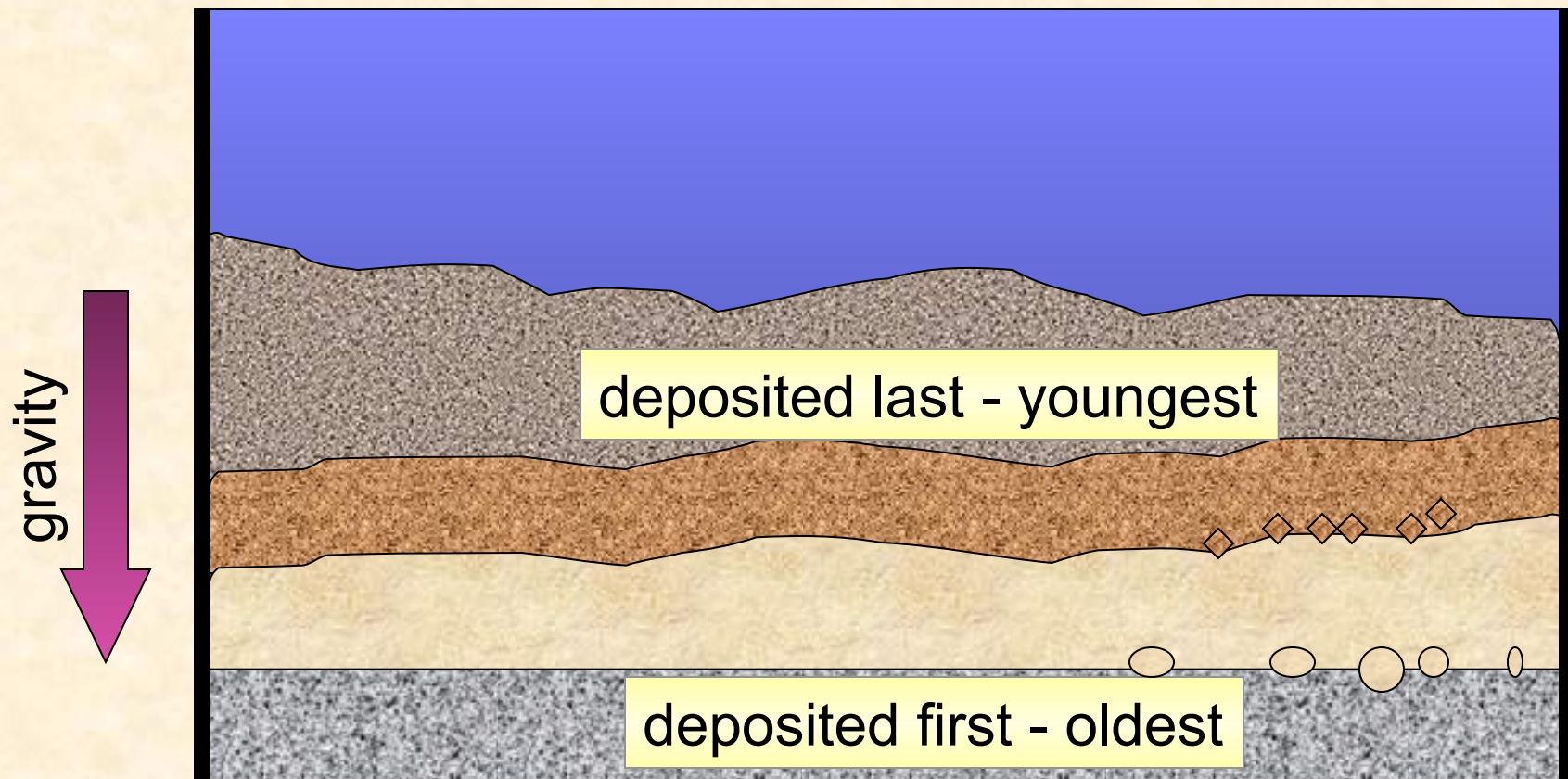


Formulated logical principles for determining the relative ages of rocks

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

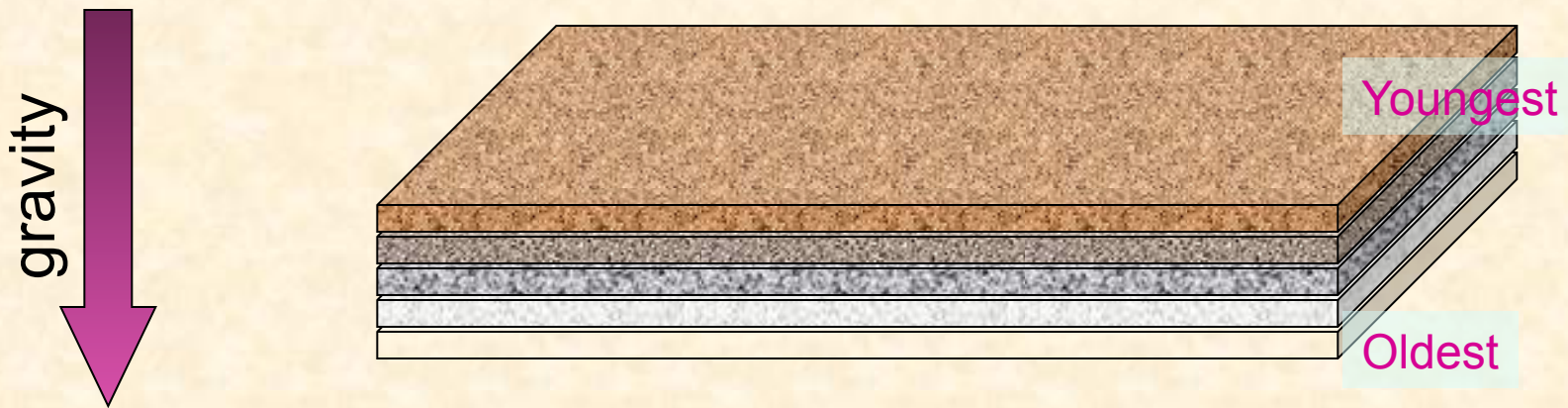


Principle of Superposition

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

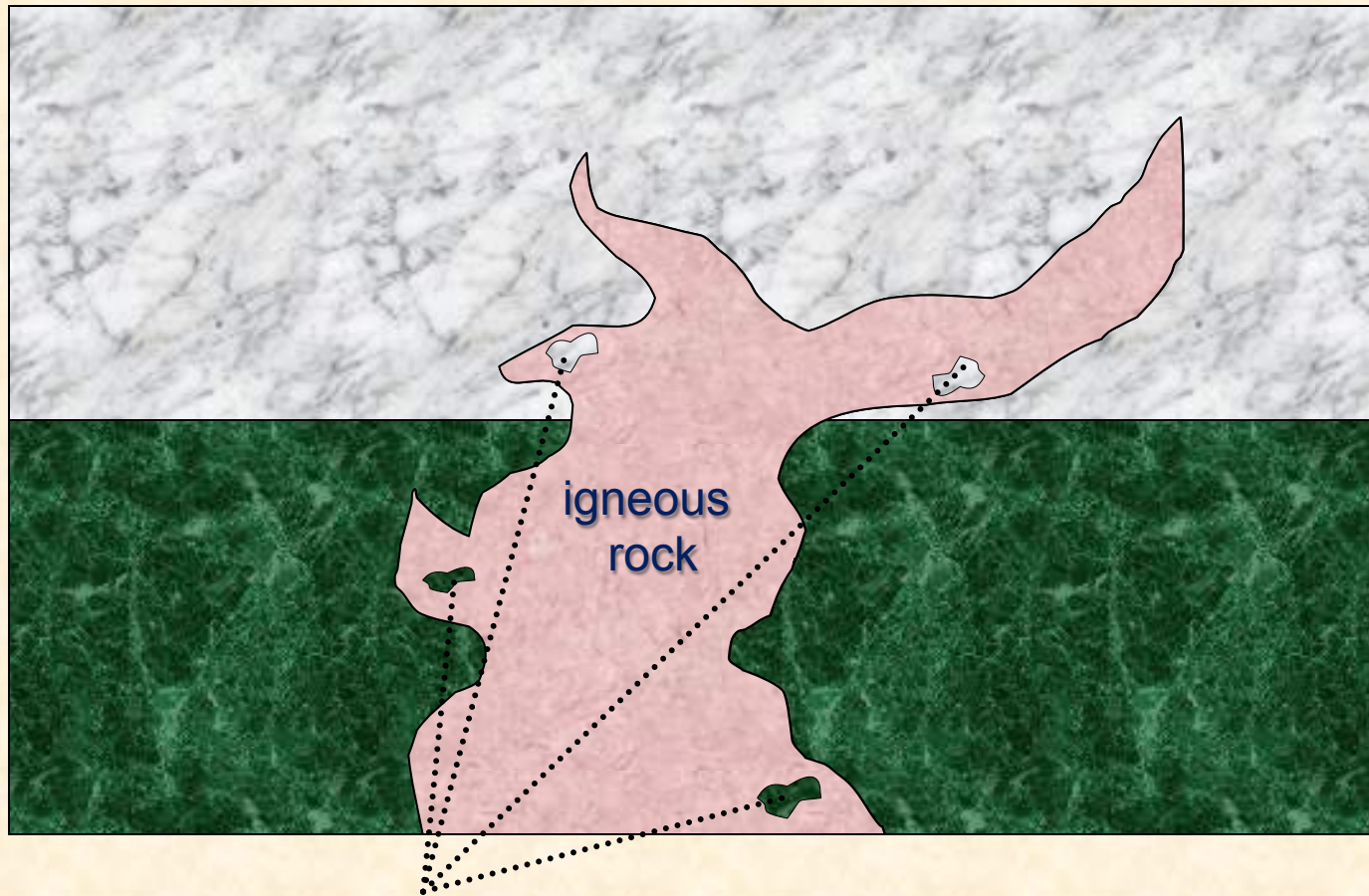
Principle of Superposition

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



Principle of Inclusion

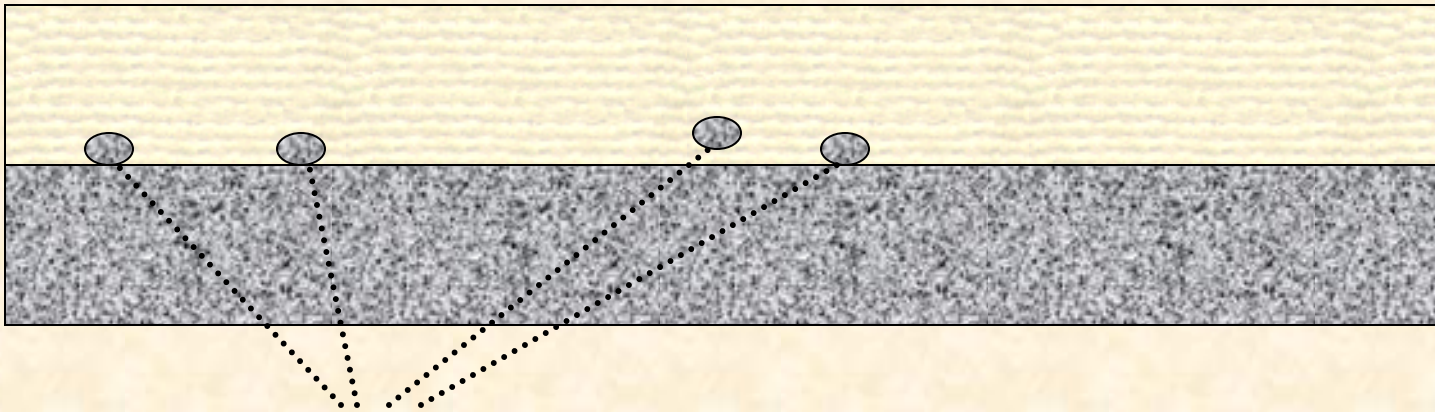
When clasts of one rock are found in another, the rock from which the clasts were derived is the older rock, since it must have already existed in order to be included in the new rock



Inclusions - pieces of older rock incorporated into younger rock

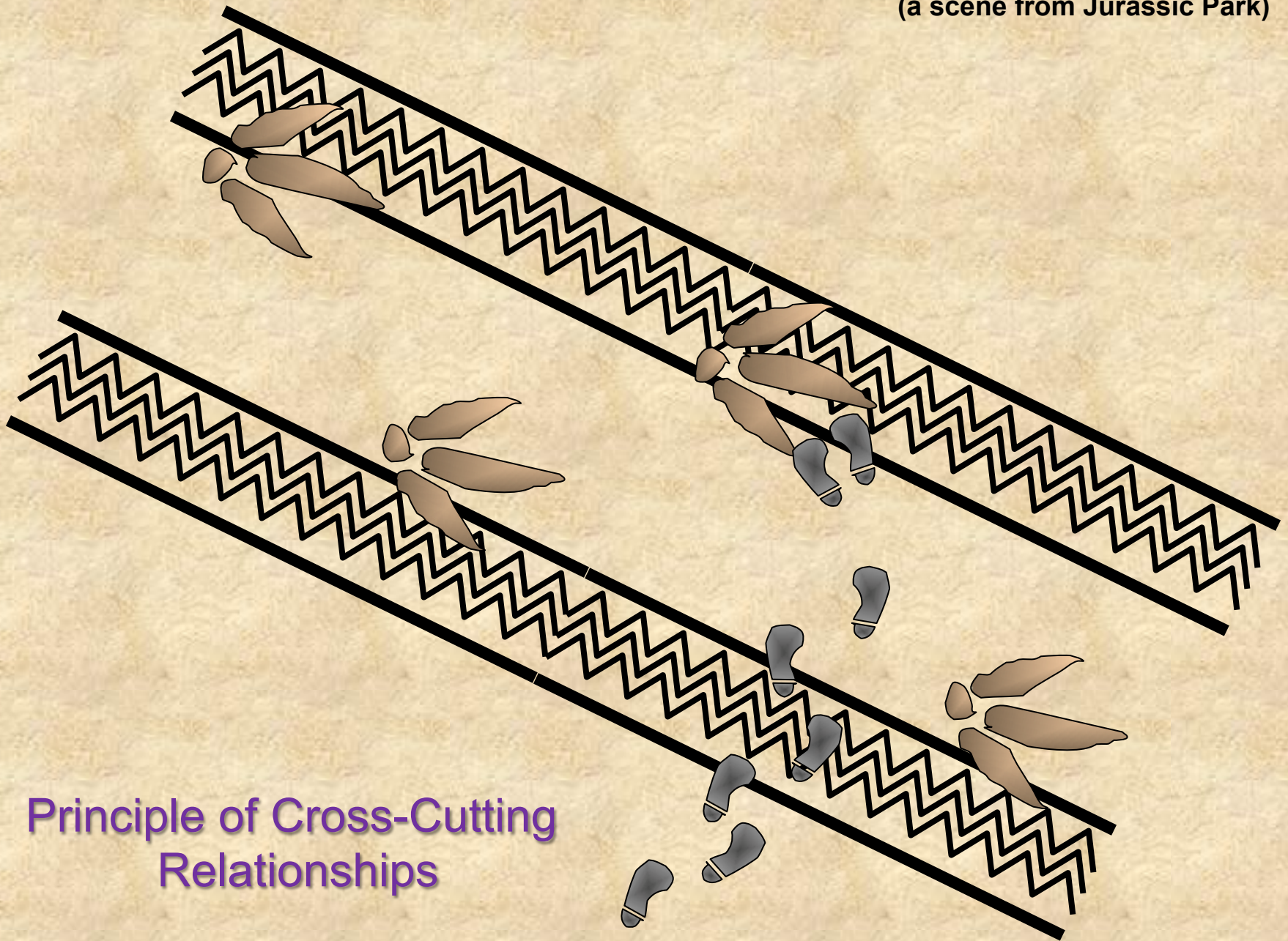
Principle of Inclusion

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

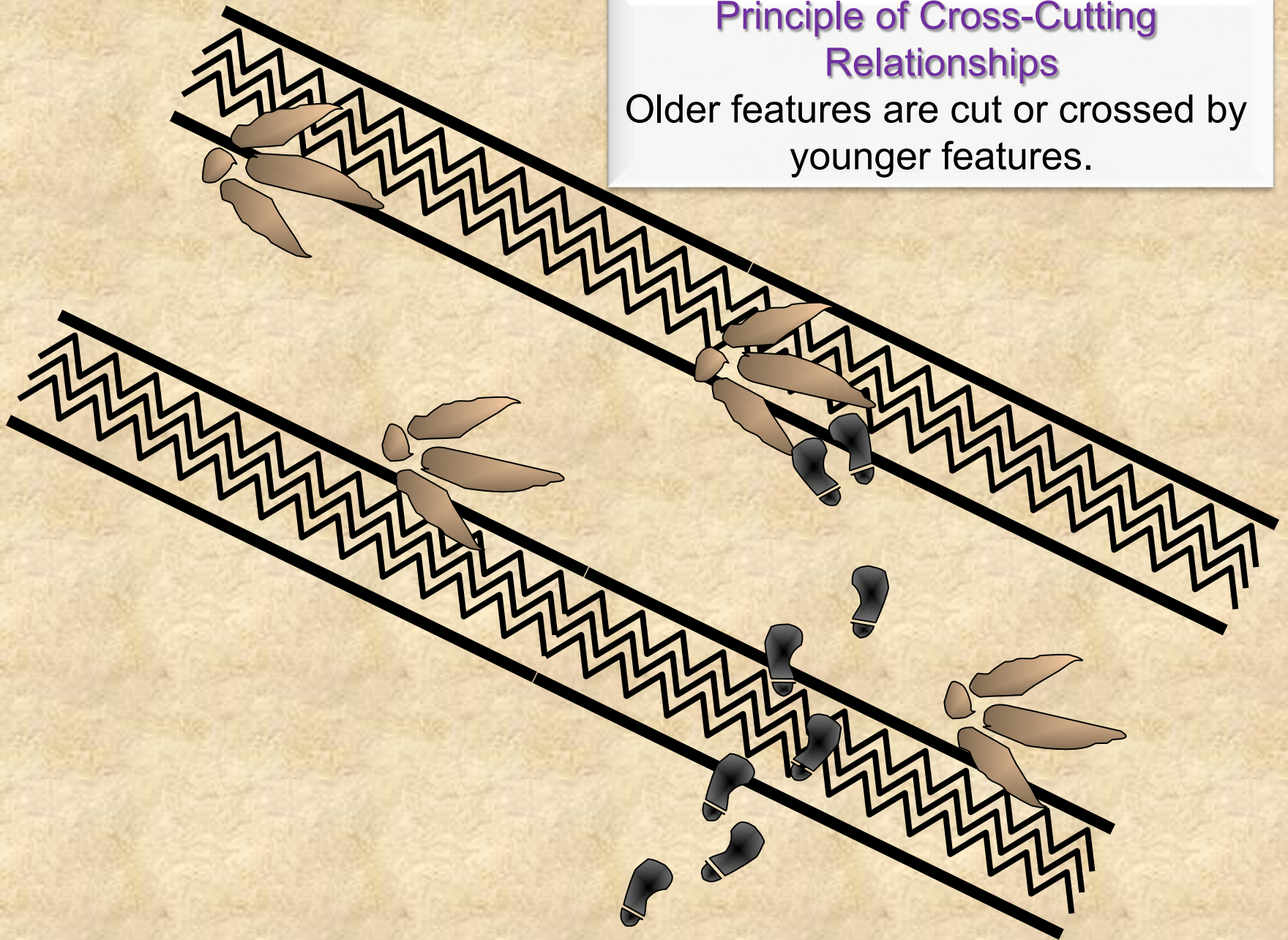
(a scene from Jurassic Park)



Principle of Cross-Cutting Relationships

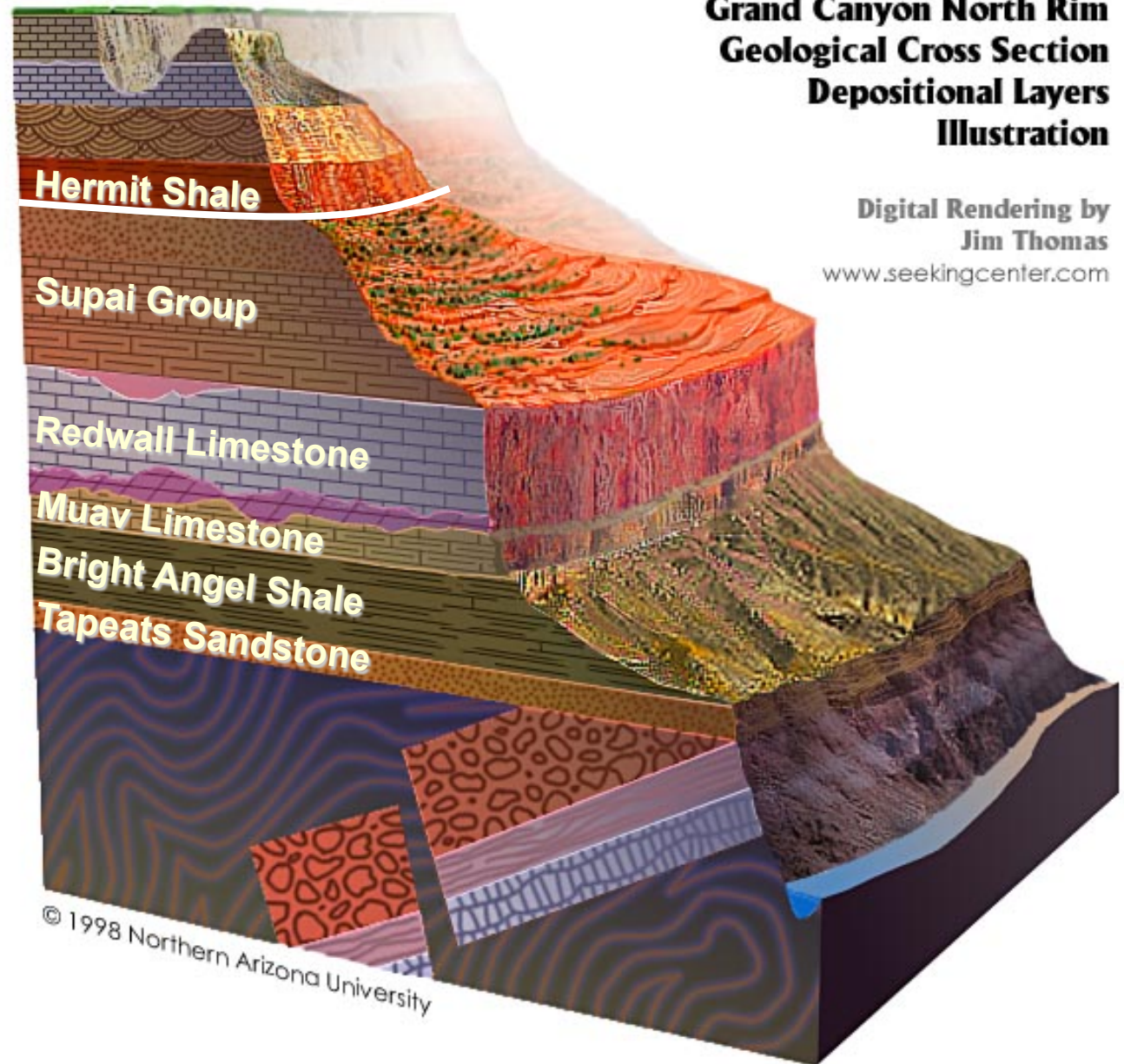
Principle of Cross-Cutting Relationships

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



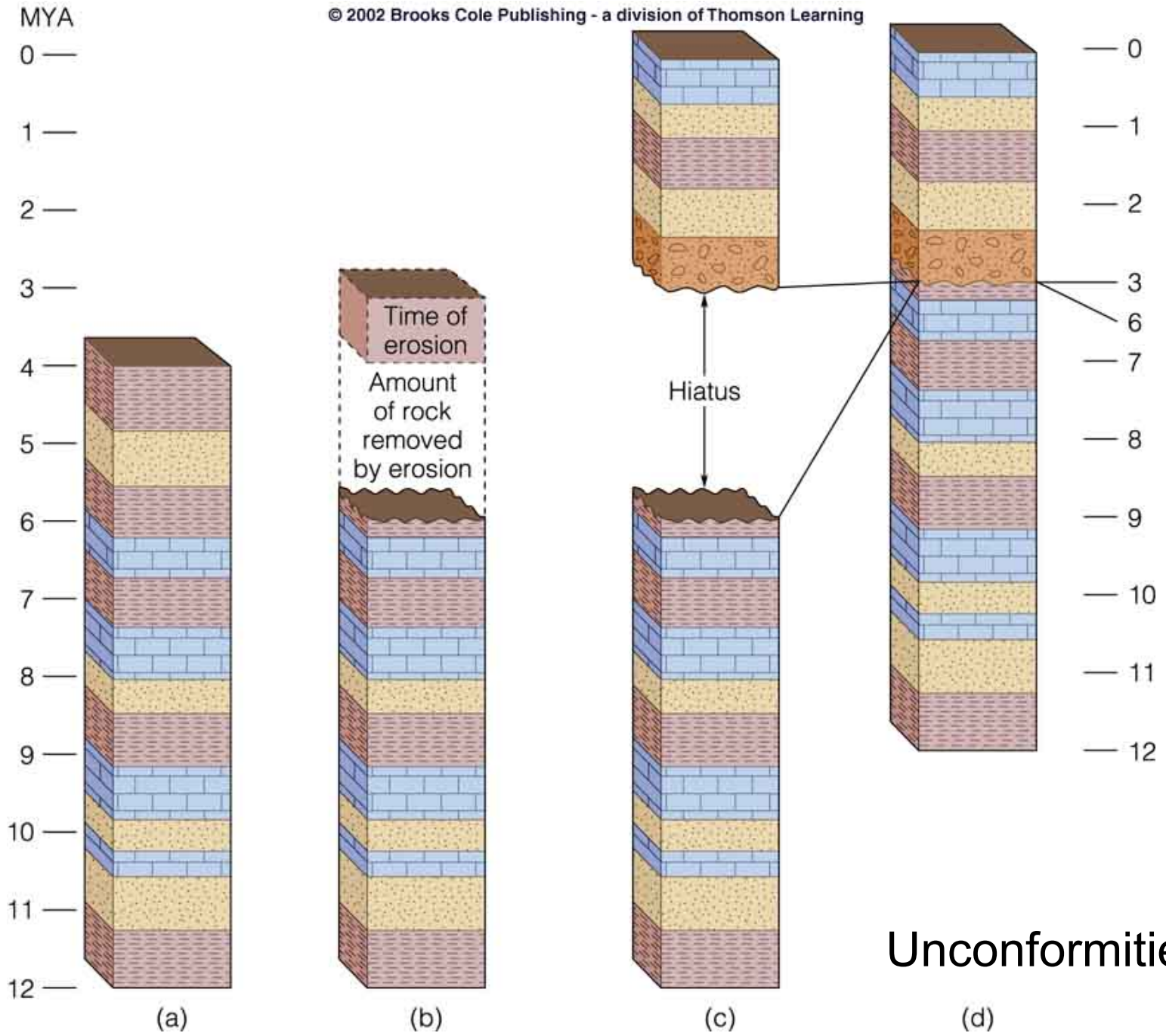
Reconstructing Geologic History

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

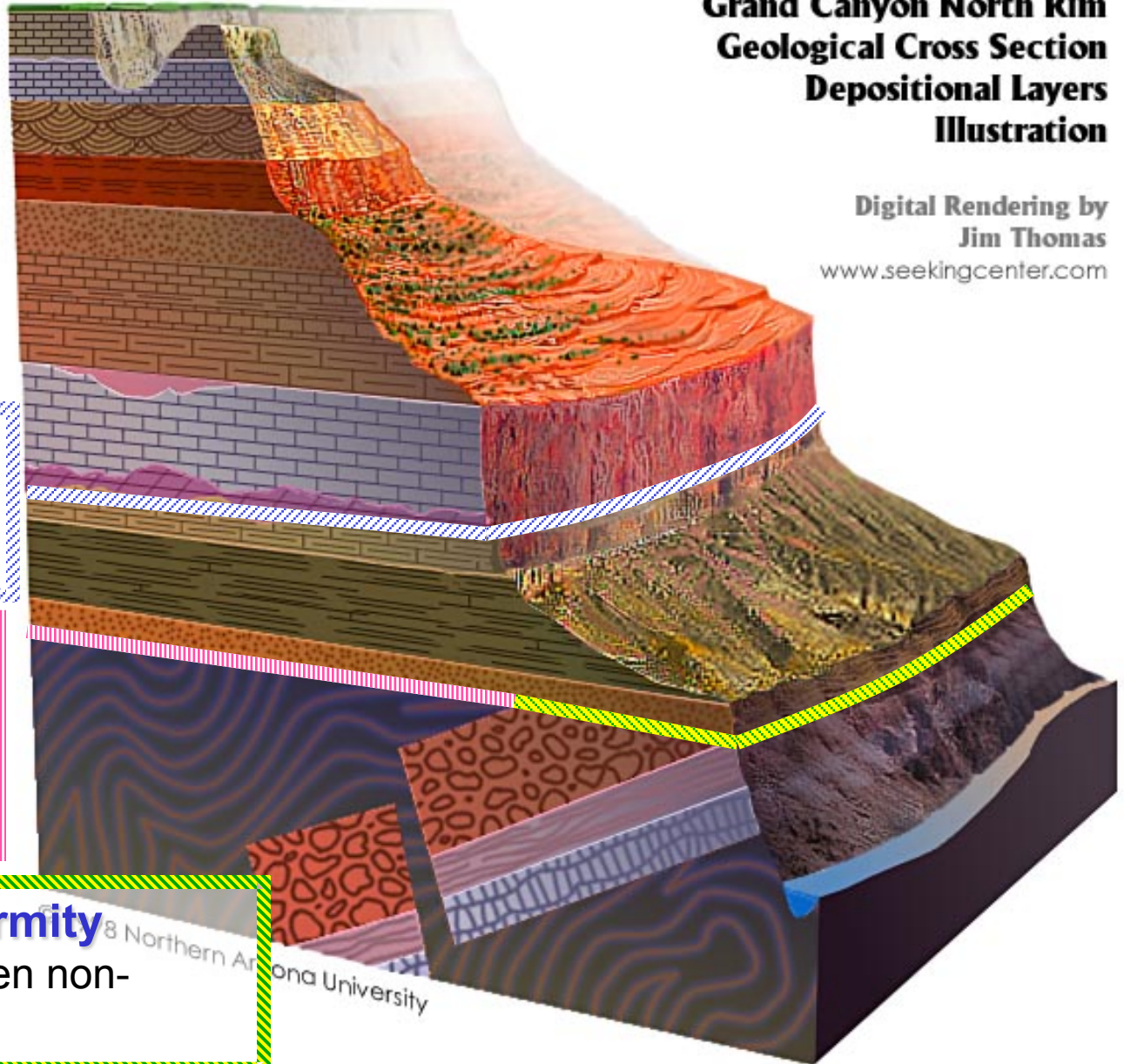
unconformity between parallel strata.

nonconformity

unconformity between non-sedimentary and sedimentary rocks

angular unconformity

unconformity between non-parallel strata



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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



- 371. *Vitiperna fluviorum* M. & S. 27
- 2. *Tellina* Sw.
- 3. *Ectenocardus* M. & S. 27
- 4. *Chama*
- 5. *Telata spinosa* M. & S. 27

Craig



London Clay

Craig

Upper Chalk

Oak Tree Clay

Craig



Base of a Fish.
Sharks tooth worn.
others, each are found in the Loam
Clay and more perfect state but they
are characteristic here from being very smooth
except base.
Fossil striae.

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.
Trilobites, <i>Beudanticeras, Cyathophylloids, Fenestrellas, &c.</i>	London Clay	1	London Clay covering Highgate, Harrow, Shaker and other detached Hills	Serpentine - from which Robert Brown's Cement is made
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Craig	2	Clay or Breckworth with <i>Begoniæ</i> of Sand and Gravel	{ No Building Stone in all this extensive District but often have Materials which make the best Bricks and Tiles in the Island {
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Upper Chalk	3	Sand & Light Loam upon a Sandy or shaly Substratum	{ Fines Clay, Blue Brick's Sand, and Loam and Bricks used for various Purposes
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Oak Tree Clay	4	Chalk	Flints de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	5	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	6	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	7	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	8	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	9	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	10	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	11	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	12	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	13	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	14	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	15	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	16	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	17	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	18	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	19	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	20	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	21	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	22	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	23	Chalk	Flint de la Vallée de la Somme
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<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	27	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	28	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	29	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	30	Chalk	Flint de la Vallée de la Somme
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<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	32	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	33	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	34	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	35	Chalk	Flint de la Vallée de la Somme
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<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	43	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	44	Chalk	Flint de la Vallée de la Somme
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<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	51	Chalk	Flint de la Vallée de la Somme
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<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	62	Chalk	Flint de la Vallée de la Somme
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<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	69	Chalk	Flint de la Vallée de la Somme
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<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	72	Chalk	Flint de la Vallée de la Somme
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<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	74	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	75	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	76	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	77	Chalk	Flint de la Vallée de la Somme
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<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	80	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	81	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	82	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	83	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	84	Chalk	Flint de la Vallée de la Somme
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<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	92	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	93	Chalk	Flint de la Vallée de la Somme
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<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	95	Chalk	Flint de la Vallée de la Somme
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<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	97	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	98	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	99	Chalk	Flint de la Vallée de la Somme
<i>Merina Turca, Leptæna, Cyathophylloids, Fenestrellas, &c.</i>	Blue Marl	100	Chalk	Flint de la Vallée de la Somme

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.

Batholite 2, 4, 5, 7, 8, 10, 11, 21, 22.	Devon 2, 4, 5, 7, 8, 10, 11, 21, 22, 23, 24, 25.	Devon 2, 4, 5, 7, 8, 10, 11, 21, 22, 23, 24, 25.	Devon 2, 4, 5, 7, 8, 10, 11, 21, 22, 23, 24, 25.	Devon 2, 4, 5, 7, 8, 10, 11, 21, 22, 23, 24, 25.	Devon 2, 4, 5, 7, 8, 10, 11, 21, 22, 23, 24, 25.	Devon 2, 4, 5, 7, 8, 10, 11, 21, 22, 23, 24, 25.	Devon 2, 4, 5, 7, 8, 10, 11, 21, 22, 23, 24, 25.
Blue Marl 2, 4, 5, 7, 8, 10, 11, 21, 22.	Blue Marl 2, 4, 5, 7, 8, 10, 11, 21, 22.	Blue Marl 2, 4, 5, 7, 8, 10, 11, 21, 22.	Blue Marl 2, 4, 5, 7, 8, 10, 11, 21, 22.	Blue Marl 2, 4, 5, 7, 8, 10, 11, 21, 22.	Blue Marl 2, 4, 5, 7, 8, 10, 11, 21, 22.	Blue Marl 2, 4, 5, 7, 8, 10, 11, 21, 22.	Blue Marl 2, 4, 5, 7, 8, 10, 11, 21, 22.

Oak Tree Clay

- Fig. 1. *Melania Heddingtonensis*
- 2. *Turbo*?
- 3. *Trochus*
- 4. *Ampullaria*

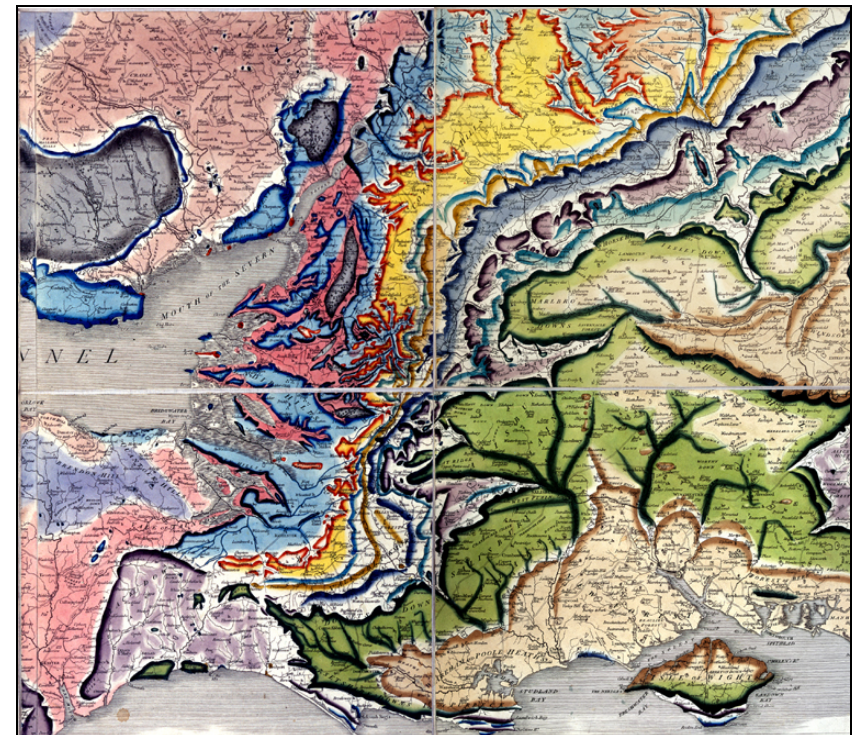
Upper Chalk



Maricated Echinus spine.
Sharks tooth with two sharp ridges.
Sharks tooth serrated.



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



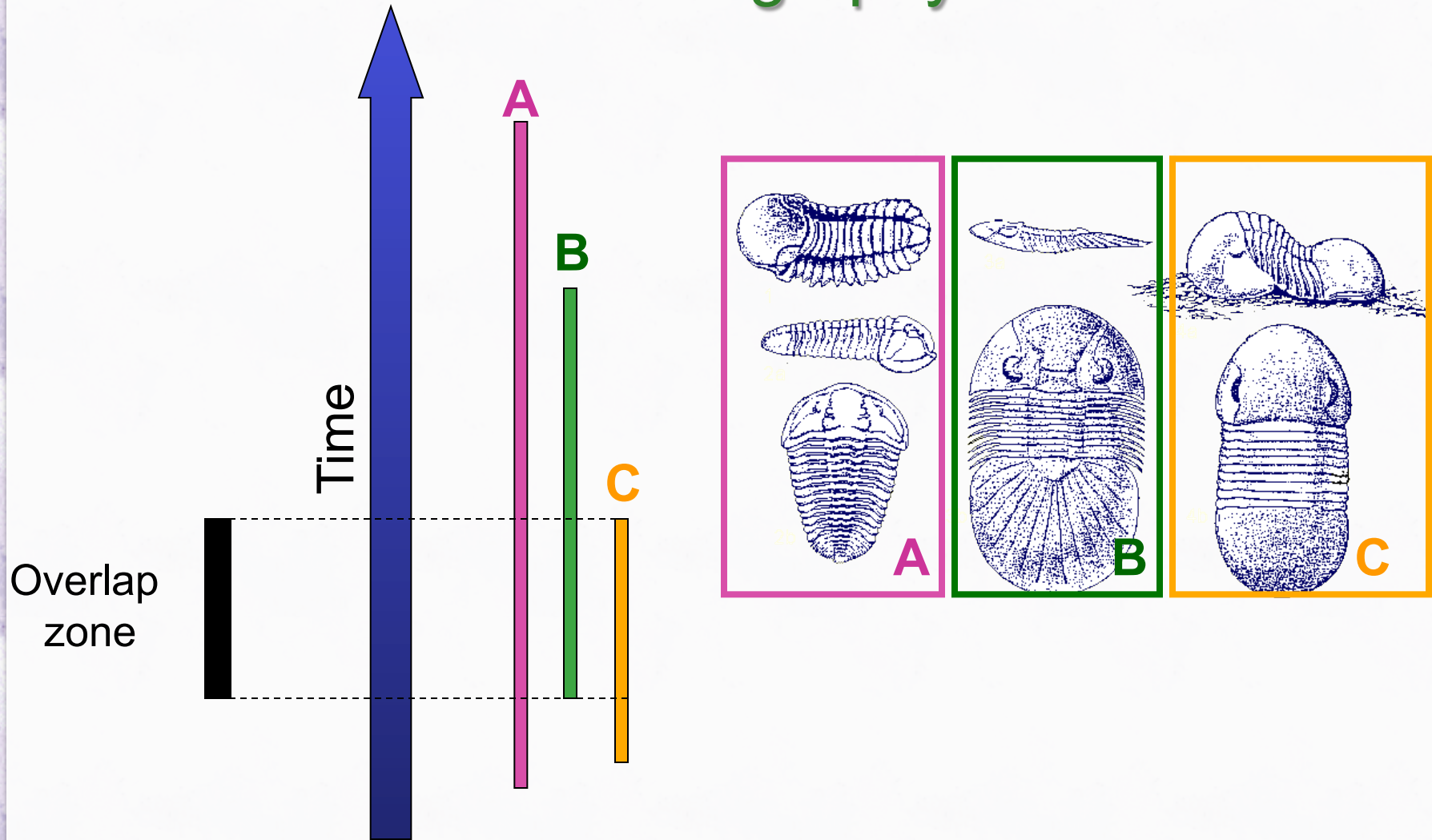
Fossil A




O

Origination - evolution of species

More Ancient

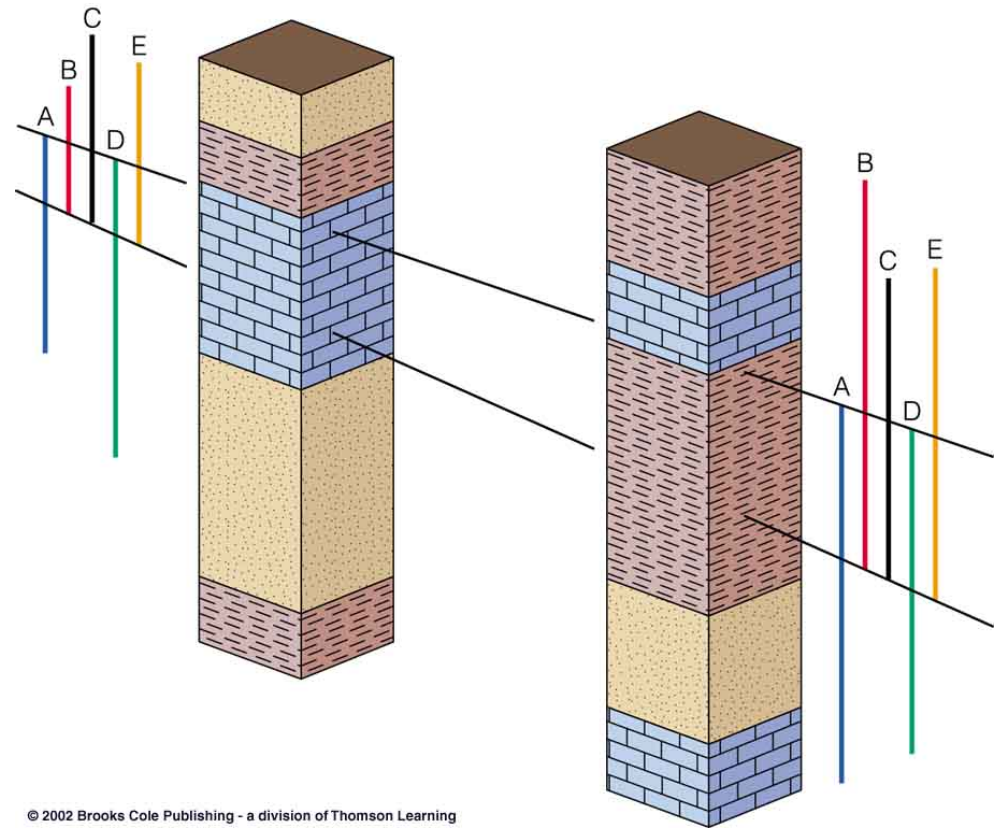
Biostratigraphy



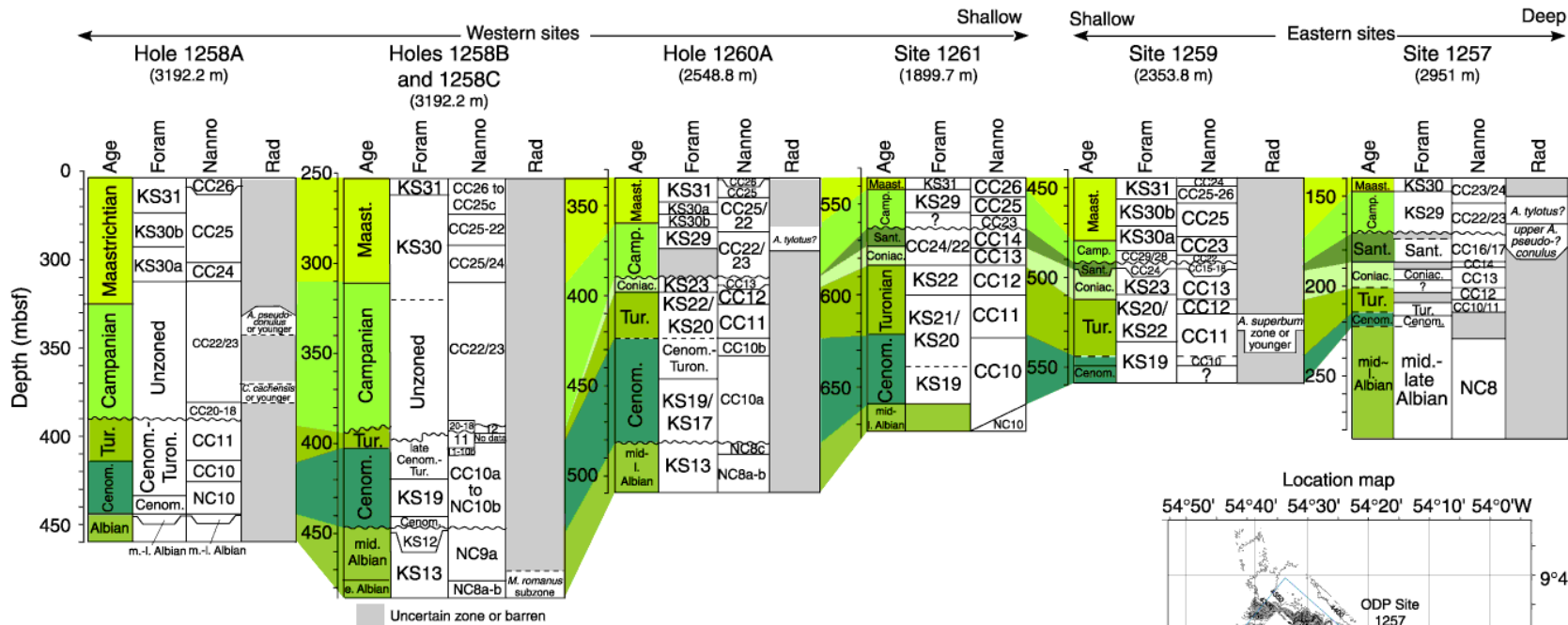
Cenozoic	Tertiary			
	Mesozoic	Cretaceous		
		Jurassic	 <i>Lingula</i>	 <i>Inoceramus</i>
		Triassic		
Paleozoic	Permian			
	Pennsylvanian			
	Mississippian			
	Devonian			
	Silurian			
	Ordovician		 <i>Isotelus</i>	
	Cambrian			

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Biostratigraphy



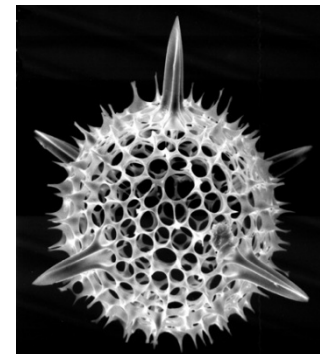
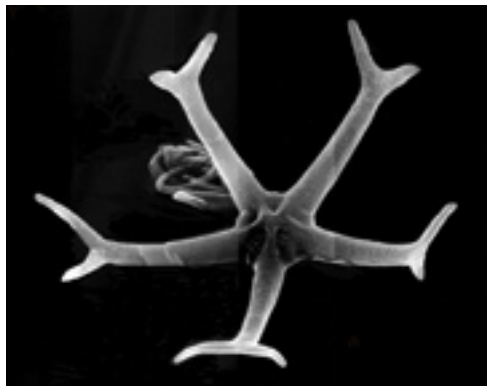
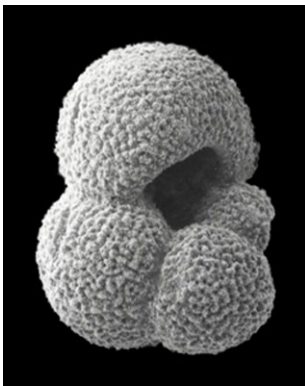
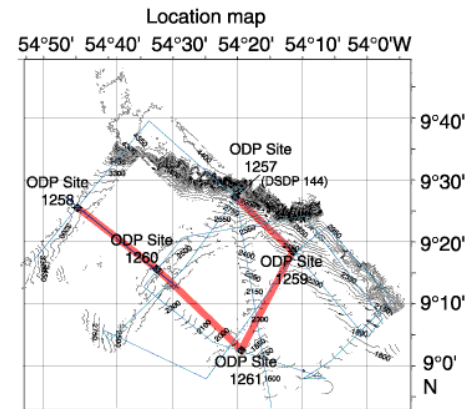
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<http://www-odp.tamu.edu/nps>

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

Correlation based on foraminifera, calcareous nannofossils and radiolarians.



Geologic Time Scale

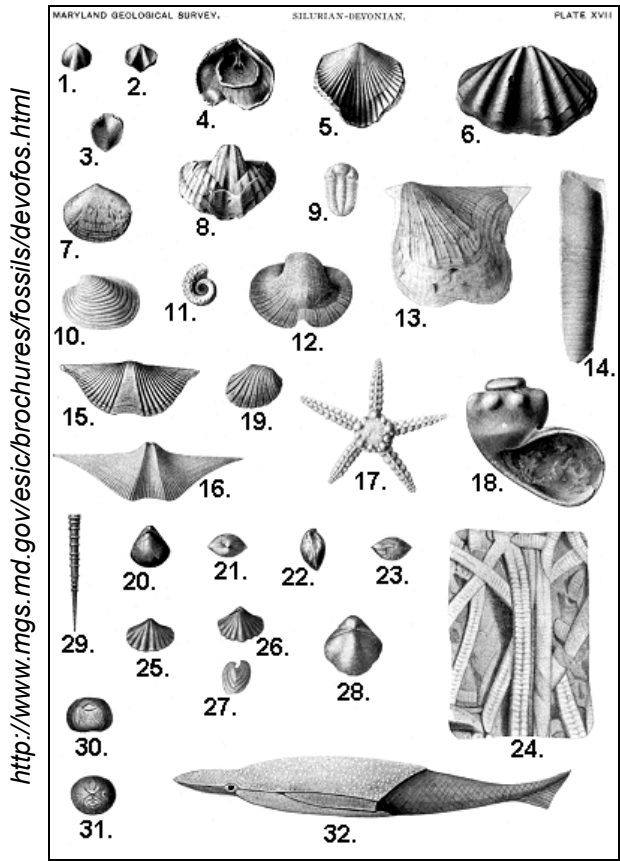
EON	ERA	PERIOD	EPOCH	Ma		
Phanerozoic	Cenozoic	Quaternary	Holocene		0.01	
			Pleistocene		0.8	
		Tertiary	Neogene	Pliocene		1.8
				Miocene		3.6
				Oligocene		5.3
				Eocene		11.2
				Paleocene		16.4
			Paleogene	Eocene		33.7
				Oligocene		28.5
				Miocene		33.7
				Pliocene		41.3
				Pleistocene	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

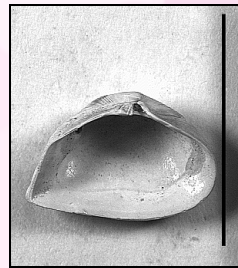
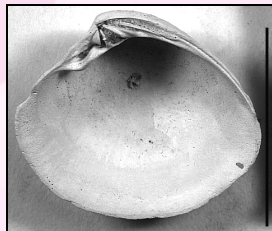
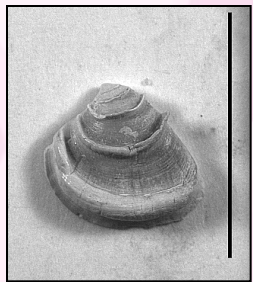
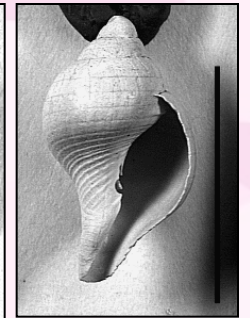
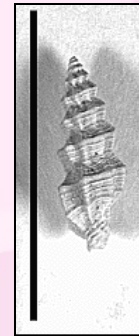
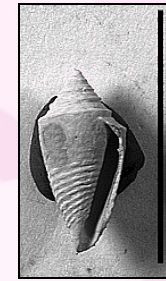
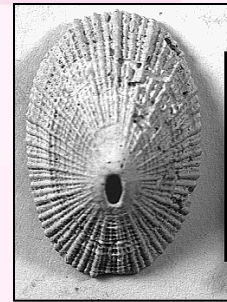
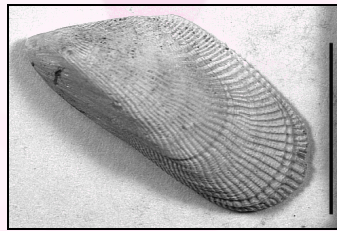
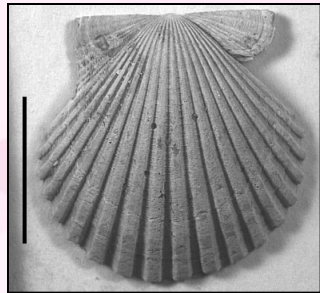
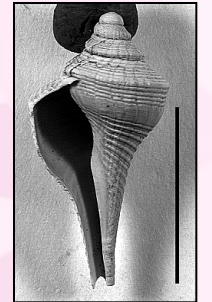
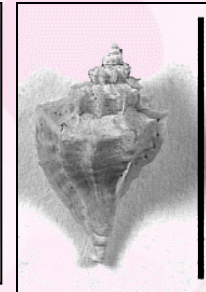
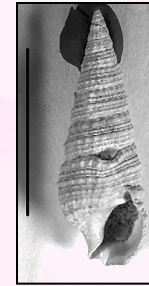
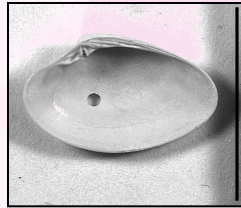
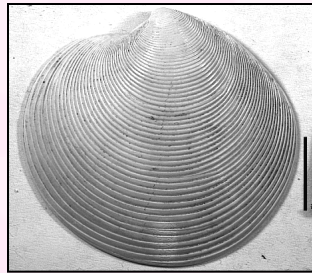
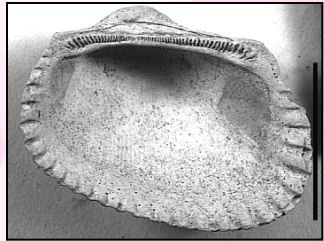
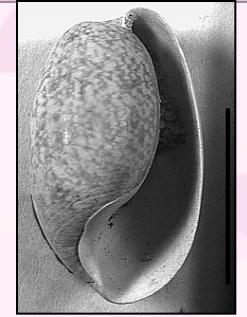
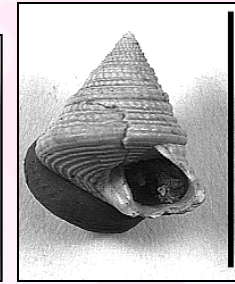
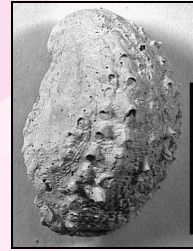
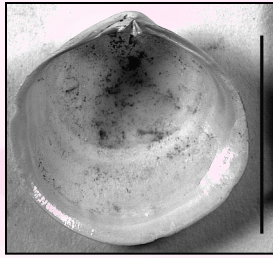
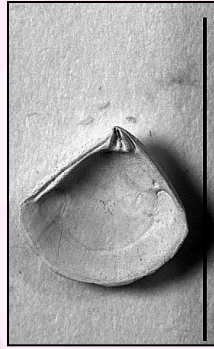
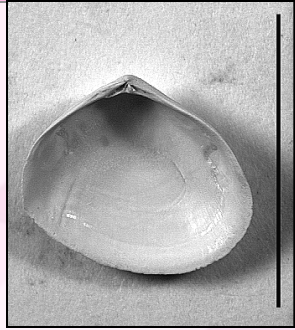


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<http://pubs.usgs.gov/gip/geotime/>

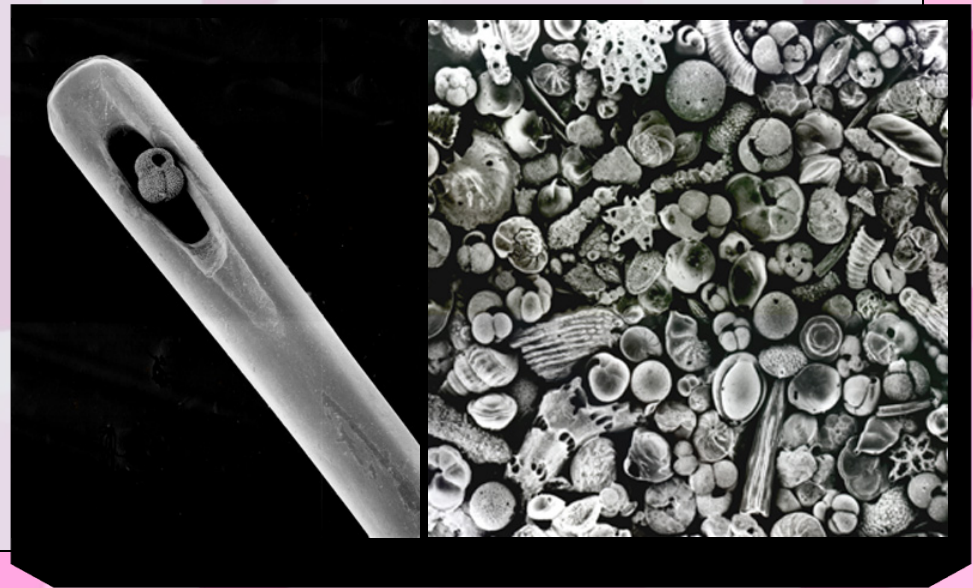
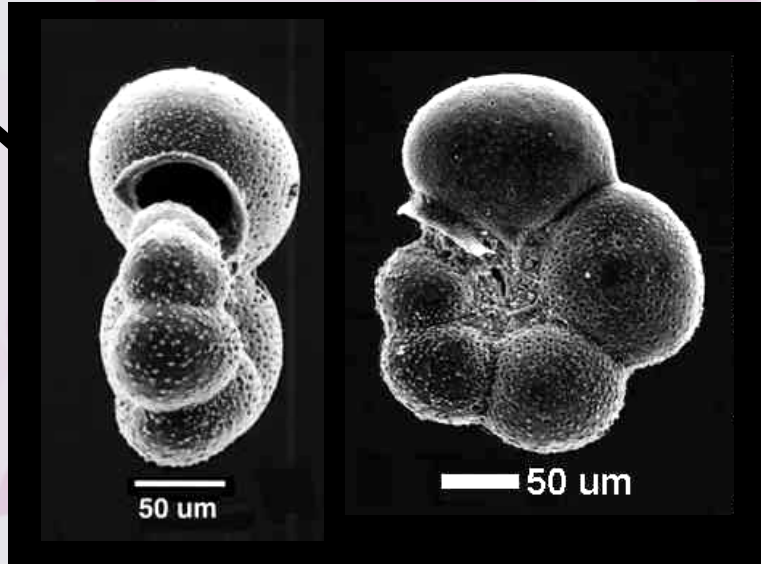
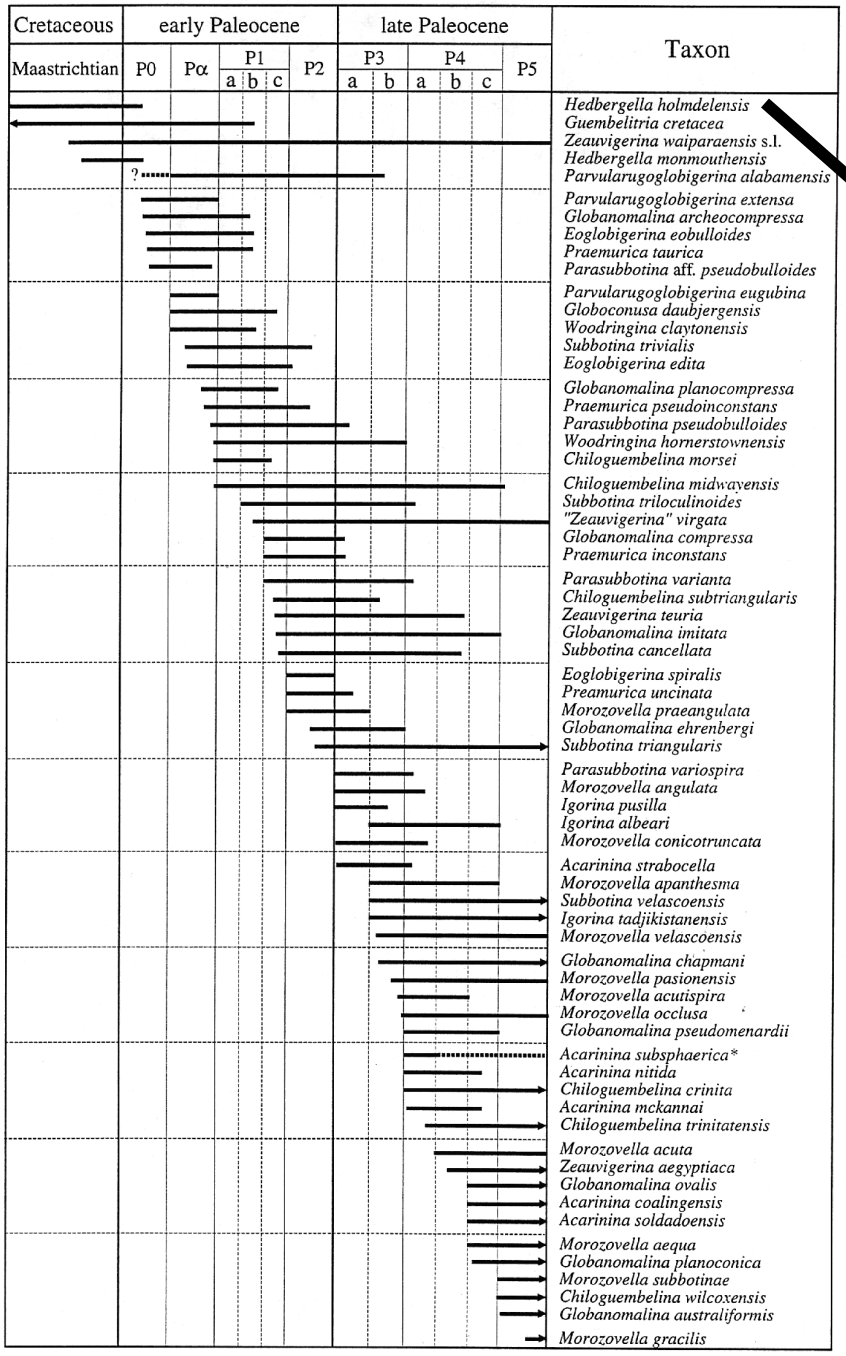
Devonian Life





Pleistocene
Molluscan Assemblage

Foraminifera



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	Late	33.7	
				Early	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		
	Late			99.0		
	Middle			144		
	Early			159		
	Early			180		
	Jurassic		Late	206		
			Middle	227		
			Early	242		
	Triassic		Late	248		
			Early	256		
	Paleozoic		Permian	Late	290	
			Pennsylvanian	Early	323	
			Mississippian	Early	354	
			Devonian	Late	370	
				Middle	391	
				Early	417	
			Silurian	Late	423	
		Early		443		
Ordovician		Late	458			
		Middle	470			
	Early	490				
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	C	500				
	B	512				
	A	520				
	A	543				
Precambrian	Proterozoic	Late	900			
		Middle	1600			
		Early	2500			
	Archean	Late	3000			
		Middle	3400			
		Early	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