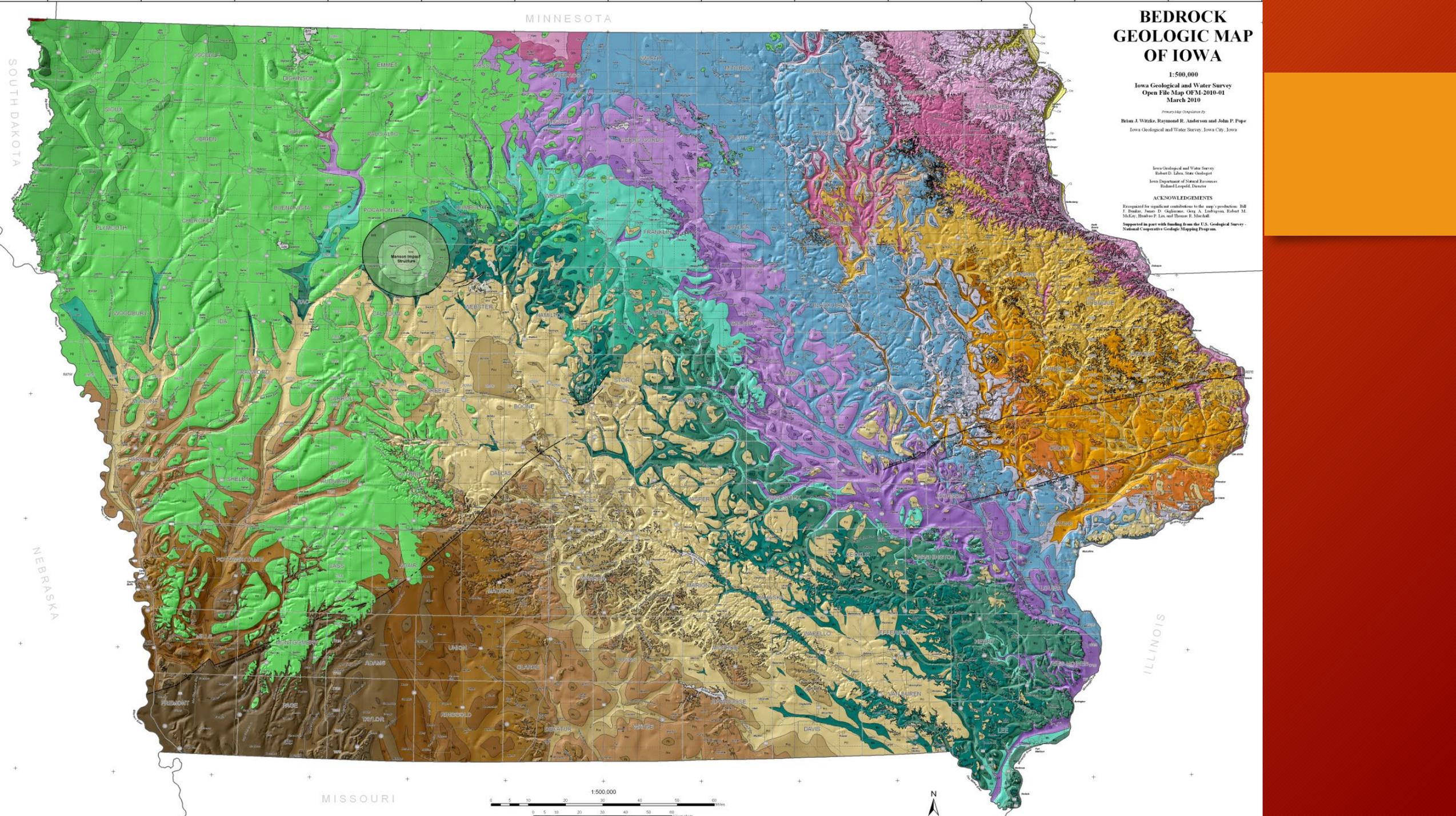


Iowa's Bedrock

Geological Resources of Iowa
University of Northern Iowa &
The Iowa Limestone Producers Association



MINNESOTA

BEDROCK GEOLOGIC MAP OF IOWA

1:500,000

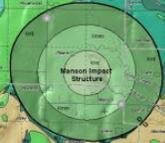
Iowa Geological and Water Survey
Open File Map OFM-2010-01
March 2010

Primary Map Compilation by
Brian A. Witke, Raymond R. Anderson and John P. Pope
Iowa Geological and Water Survey, Iowa City, Iowa

Iowa Geological and Water Survey
Robert D. Liles, State Geologist
Iowa Department of Natural Resources
Richard Leopold, Director

ACKNOWLEDGEMENTS

Recognized for significant contributions to the map's production: Bill J. Easter, James D. Gagliano, Greg A. Lindgren, Robert M. McKay, Douglas F. Lee, and Thomas E. Marshall.
Supported in part with funding from the U.S. Geological Survey - National Cooperative Geologic Mapping Program.



MISSOURI



N

SOUTH DAKOTA

NEBRASKA

ILLINOIS



INTERNATIONAL CHRONOSTRATIGRAPHIC CHART

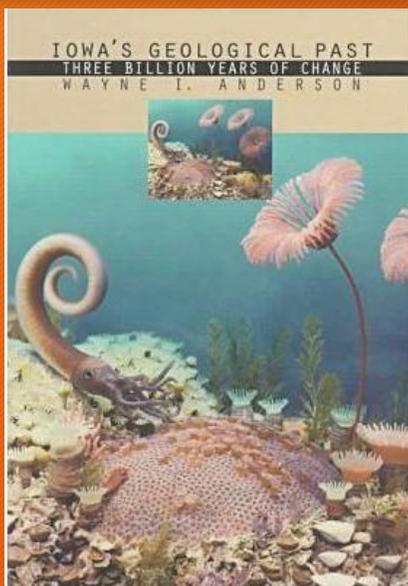
www.stratigraphy.org

International Commission on Stratigraphy

v 2019/05



Geologic Time

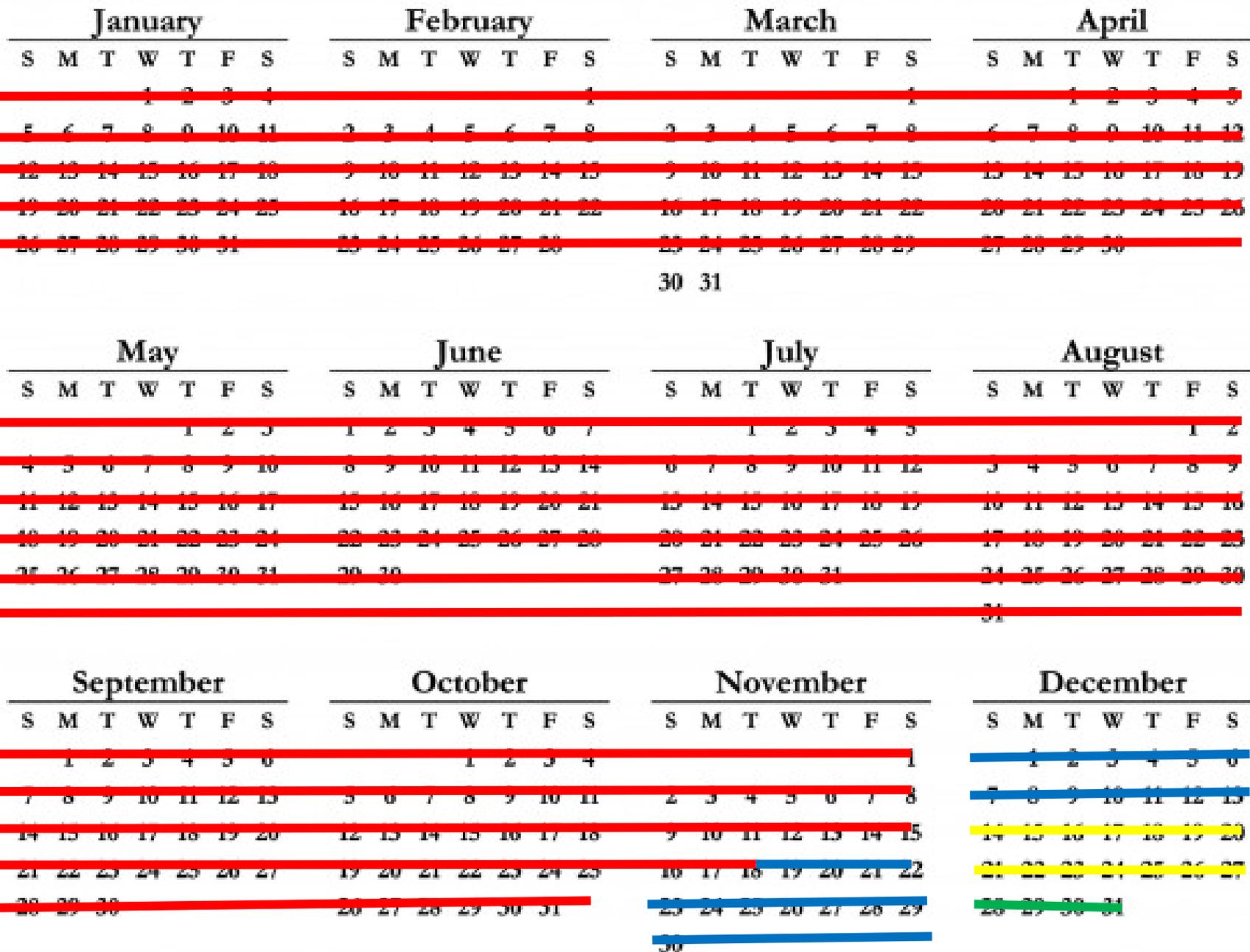


Wayne Anderson
Jim Walters
Ray Anderson
Brian Glenister

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)	
Phanerozoic	Cenozoic	Quaternary	Holocene	Meghalayan Northgrippian Greenlandian Upper	UL M M L/E	present 0.0042 0.0062 0.0117	
			Pleistocene	Middle		0.126	
				Calabrian		0.773	
			Neogene	Pliocene	Gelasian		1.80
					Piacenzian		2.58
		Miocene		Zanclean		3.600	
				Messinian		5.333	
				Tortonian		7.246	
		Paleogene	Oligocene	Serravallian		11.63	
				Langhian		13.82	
	Burdigalian				15.97		
	Aquitanian				20.44		
	Chattian				23.03		
	Eocene		Rupelian		27.82		
			Priabonian		33.9		
			Bartonian		37.8		
			Lutetian		41.2		
			Ypresian		47.8		
	Paleocene		Thanetian		56.0		
			Selandian		59.2		
			Danian		61.6		
			Maastrichtian		66.0		
			Campanian		72.1 ± 0.2		
	Mesozoic	Cretaceous	Upper	Santonian		83.6 ± 0.2	
				Coniacian		86.3 ± 0.5	
Turonian					89.8 ± 0.3		
Lower			Cenomanian		93.9		
			Albian		100.5		
Carboniferous		Upper	Aptian		~ 113.0		
			Barremian		~ 125.0		
		Lower	Hauterivian		~ 129.4		
			Valanginian		~ 132.9		
			Berriasian		~ 139.8		
Phanerozoic	Mesozoic	Jurassic	Tithonian		~ 145.0		
			Upper	Kimmeridgian		152.1 ± 0.9	
				Oxfordian		157.3 ± 1.0	
			Middle	Callovian		163.5 ± 1.0	
				Bathonian		166.1 ± 1.2	
		Bajocian			168.3 ± 1.3		
		Lower	Aalenian		170.3 ± 1.4		
			Toarcian		174.1 ± 1.0		
			Pliensbachian		182.7 ± 0.7		
			Sinemurian		190.8 ± 1.0		
	Hettangian			199.3 ± 0.3			
	Triassic	Upper	Rhaetian		201.3 ± 0.2		
			Norian		~ 208.5		
			Carnian		~ 227		
			Ladinian		~ 237		
			Anisian		~ 242		
		Middle	Olenekian		247.2		
			Induan		251.2		
			Changhsingian		251.902 ± 0.024		
			Wuchiapingian		254.14 ± 0.07		
			Lopingian		259.1 ± 0.5		
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			Wordian		265.1 ± 0.4		
			Roadian		268.8 ± 0.5		
			Kungurian		272.95 ± 0.11		
Artinskian				283.5 ± 0.6			
Paleozoic	Permian	Cisuralian	Sakmarian		290.1 ± 0.26		
			Asselian		293.52 ± 0.17		
			Gzhelian		298.9 ± 0.15		
		Upper	Kasimovian		303.7 ± 0.1		
			Moscovian		307.0 ± 0.1		
	Carboniferous	Upper	Bashkirian		315.2 ± 0.2		
			Serpukhovian		323.2 ± 0.4		
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Phanerozoic	Paleozoic	Devonian	Famennian		358.9 ± 0.4		
			Upper	Frasnian		372.2 ± 1.6	
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			Middle	Eifelian		387.7 ± 0.8	
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			Ludlow		423.0 ± 2.3		
			Wenlock		425.6 ± 0.9		
	Llandovery			427.4 ± 0.5			
	Mesozoic	Silurian	Upper	Sheinwoodian		430.5 ± 0.7	
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				Rhuddanian		440.8 ± 1.2	
				Hirnantian		443.8 ± 1.5	
		Lower	Katian		445.2 ± 1.4		
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		Ordovician	Upper	Darriwilian		458.4 ± 0.9	
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	Floian				485.4 ± 1.9		
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	Phanerozoic	Paleozoic	Upper	Jiangshanian		~ 489.5	
				Paibian		~ 494	
Middle			Guzhangian		~ 497		
			Drumian		~ 500.5		
			Wuliuan		~ 504.5		
Cambrian		Series 2	Stage 4		~ 509		
			Stage 3		~ 514		
		Lower	Stage 2		~ 521		
			Stage 1		~ 529		
			Fortunian		541.0 ± 1.0		
Precambrian	Proterozoic	Neo-proterozoic	Ediacaran		~ 635		
			Cryogenian		~ 720		
			Tonian		1000		
		Meso-proterozoic	Stenian		1200		
			Ectasian		1400		
	Paleo-proterozoic	Calymmian		1600			
		Statherian		1800			
		Orosirian		2050			
	Archean	Neo-archean	Rhyacian		2300		
			Siderian		2500		
Meso-archean				2800			
				3200			
				3600			
Hadean	Eo-archean			~ 4000			
				~ 4600			

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)
Phanerozoic	Mesozoic	Jurassic	Tithonian			~ 145.0
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			Changhsingian		251.902 ± 0.024	
			Wuchiapingian		254.14 ± 0.07	
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	Paleo-proterozoic	Calymmian		1600		
		Statherian		1800		
		Orosirian				



- Precambrian
 - 4 Billion years —————
- Paleozoic
 - 545-245 Ma —————
- Mesozoic
 - 245-65 Ma —————
- Cenozoic
 - 65-2Ma —————
- Pleistocene
 - 2Ma-11,200

3 hours

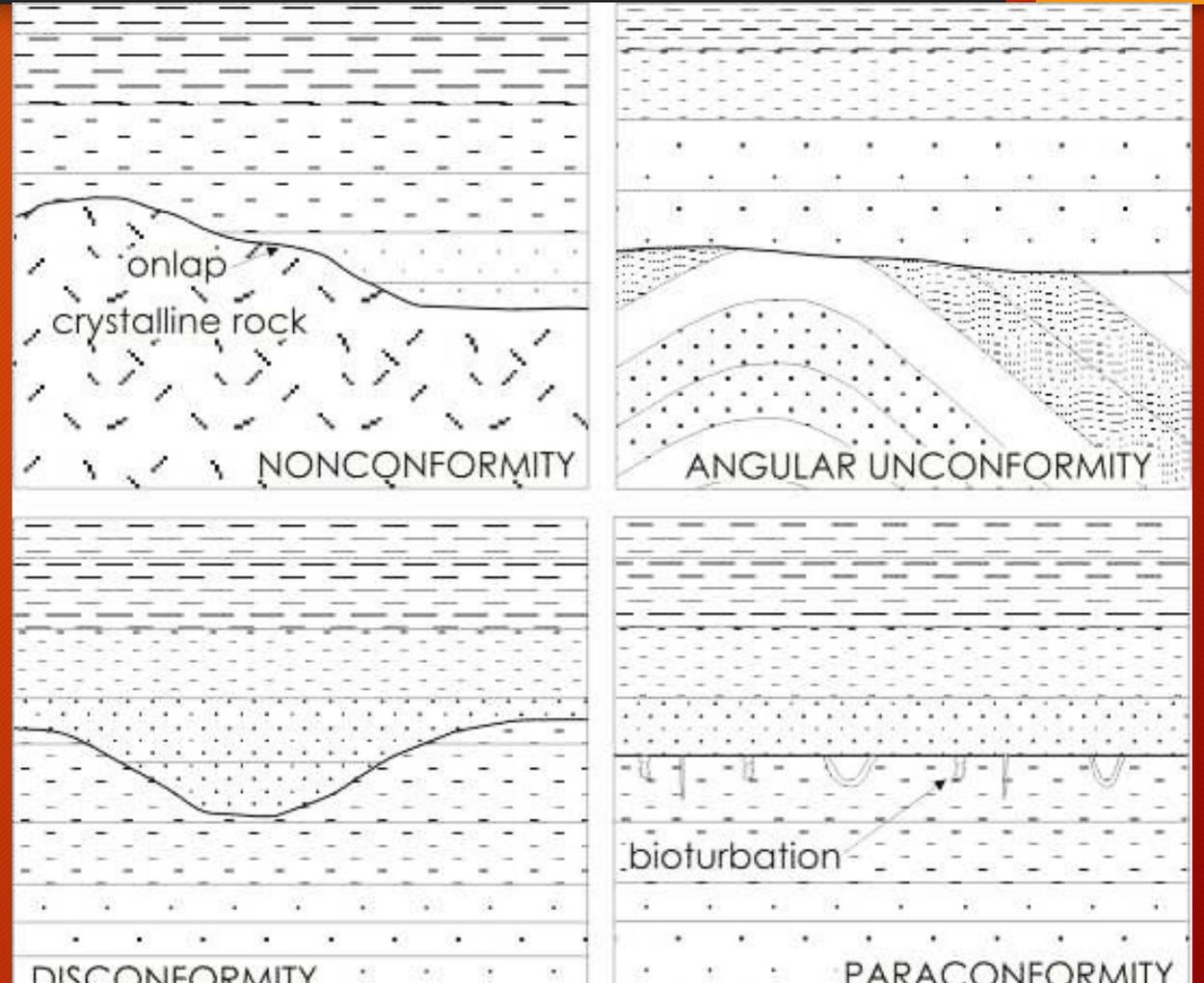
The Holocene

- About the past 11,200 years
 - North America was populated
 - Civilizations have come and gone
 - Volcanoes have erupted
 - Glaciers have melted
 - Atmospheric Carbon dioxide has skyrocketed
 - The Cubs won 2 World Series...

About 1.1
minutes

Unconformities (Gaps in time, 'missing pages')

- A. Geologic strata never formed OR deposited
- B. Geologic strata were formed and/or deposited, but were partially or completely eroded



Major Unconformities in Iowa

- Base of Cambrian
- Within Ordovician
- Base of Devonian
- Between the Mississippian and Pennsylvanian
- Between the Jurassic and Cretaceous
- Iowa does not have any exposed rocks dating to the Permian or Triassic

Origin of Geologic Time Names

- Use of tribal names
 - Ordovician - Ordovices (historic Welsh tribe that was the last to submit to the Romans.)
 - Silurian - Silures (ancient Wales tribe)
- Geographic localities
 - Cambrian - Cambria (Roman name for Wales)
 - Devonian - Region of Devonshire England

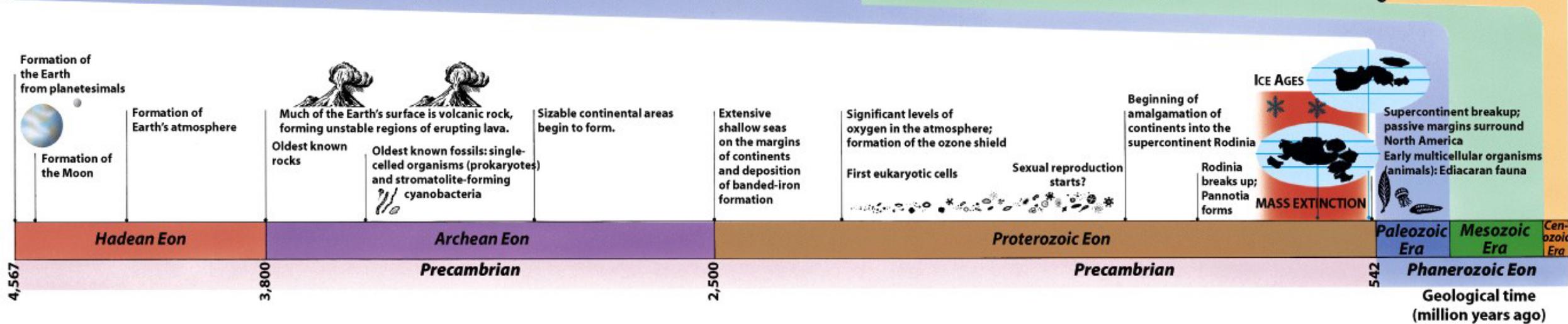
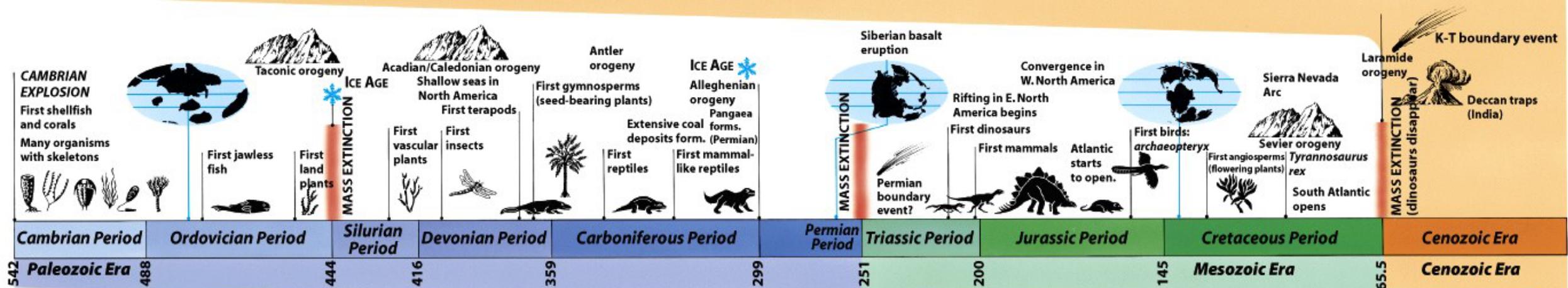
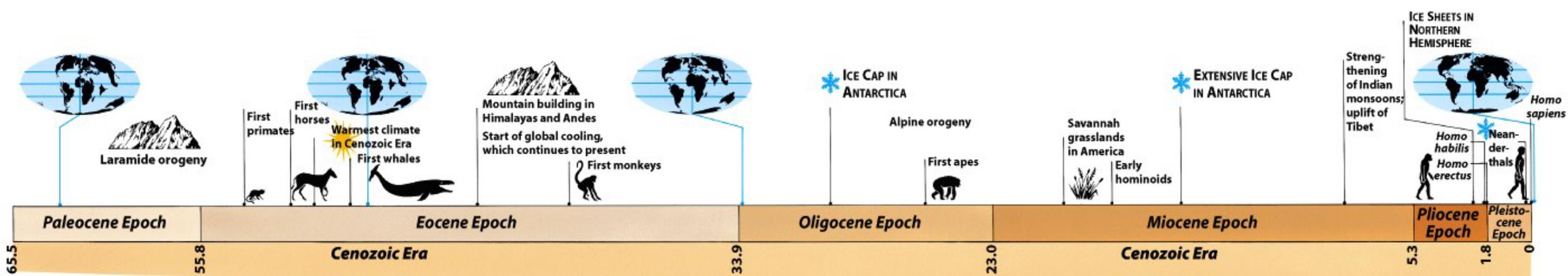
What do we use to interpret Iowa Geologic History?

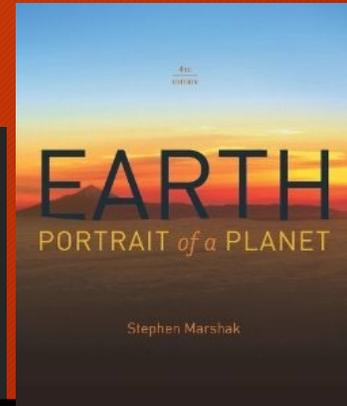


Precambrian - The Oldest Rocks

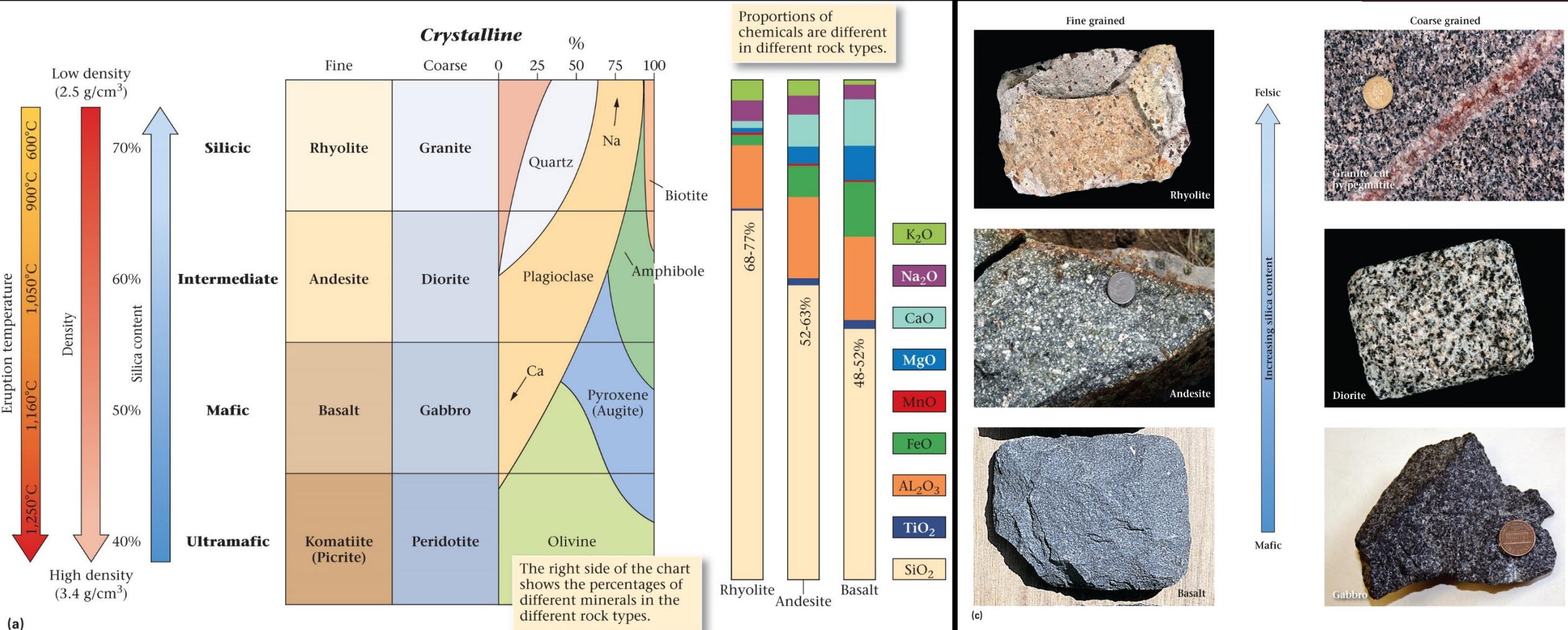
541 Ma
to
4.6 Ga

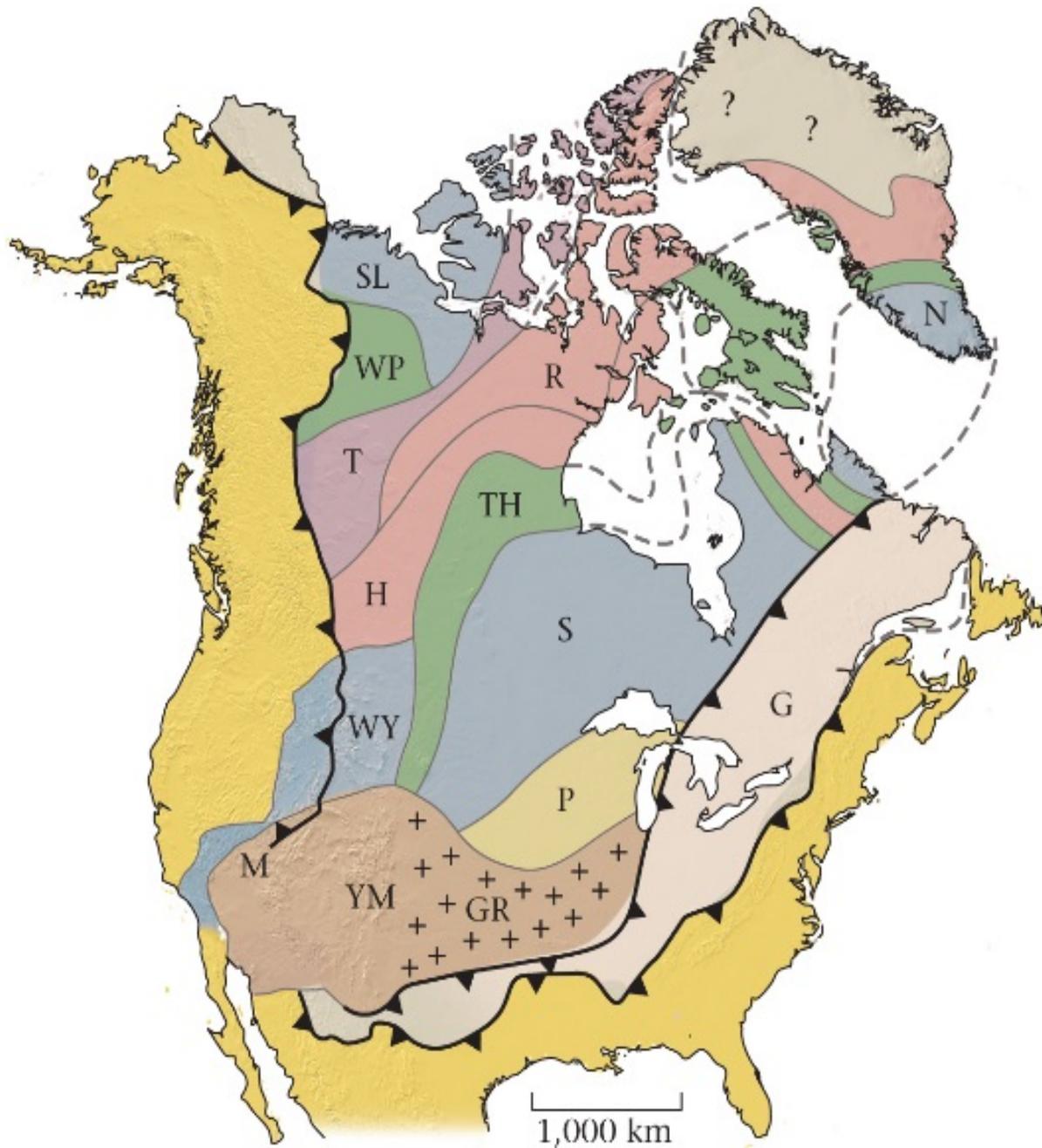
- Iowa's geologic history began approx. 3Ga ago with igneous and metamorphic rocks.
- Followed by mountain building events: Penokean, Central Plains, and Eastern Granite-Rhyolite Province 'orogenies' a product of plate tectonics.
- Iowa's oldest exposed rock is the Sioux Quartzite (approx. 1.6 Ga)
- 1.1Ga North America and Iowa were nearly torn apart by the Mid-continent Rift System



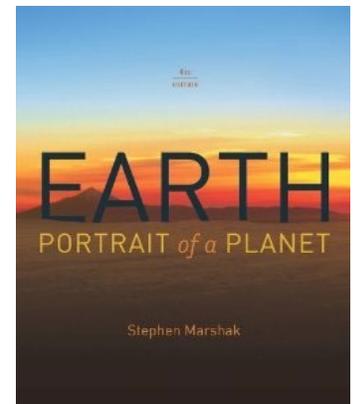


Extended concept (Igneous Intrusive vs Extrusive rocks)



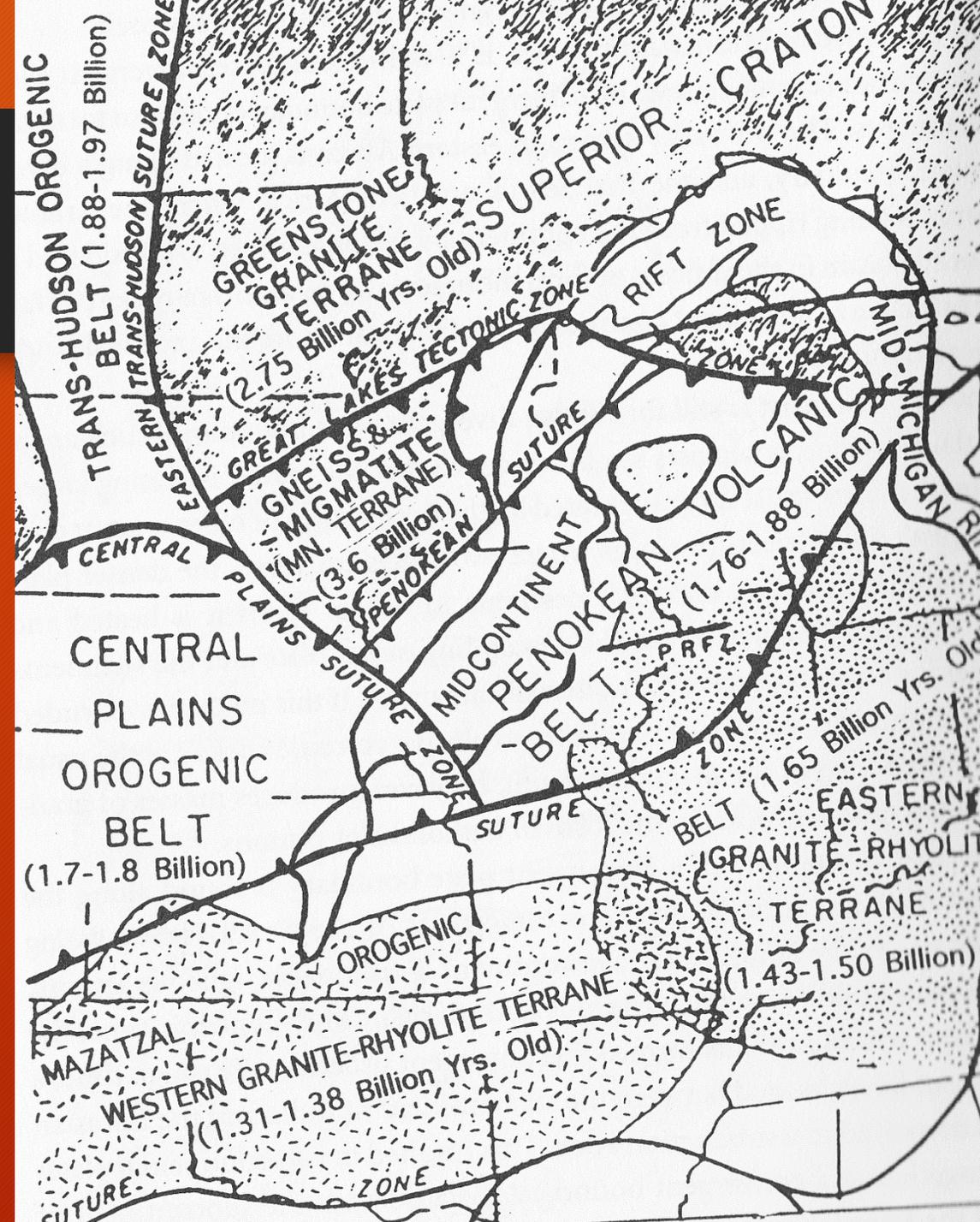


- Phanerozoic orogen
- 1.1- Ga collisional orogen (G = Grenville)
- ++ 1.6- to 1.7- Ga accreted crust covered by granite and rhyolite, where patterned (GR = granite-rhyolite province)
- 1.6- to 1.7- Ga accreted crust (YM = Yavapai and Mazatzal)
- 1.8- Ga accreted crust (P = Penokean)
- 1.8- Ga collisional orogen (TH = Trans-Hudson; WP = Wopmay)
- 1.9- Ga collisional orogen (T = Thelon)
- Archean rocks, later deformed and metamorphosed in the Proterozoic (H = Hearn; R = Rae)
- Relicts of Archean crust (WY = Wyoming; M = Mojave; S = Superior; N = Nain; SL = Slave)



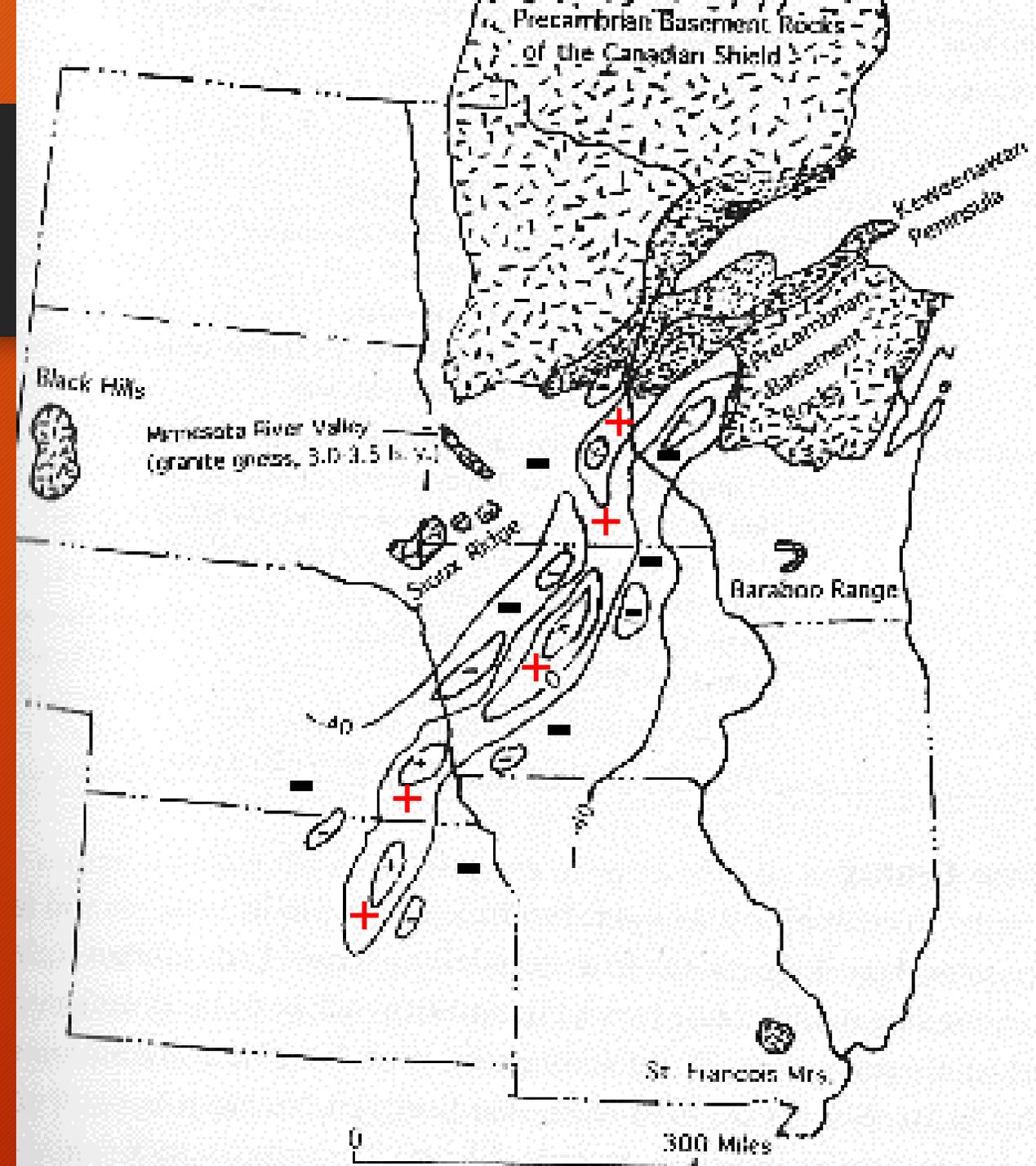
Regional Basement Structure

- Oldest rock = Minnesota tarrane 3.6Ga, Penokean Volcanic belt 1.8Ga, the Granite provenances in the south approx. 1.4Ga
- Black Hills Granite (famously represented by Mount Rushmore) via a Tertiary uplift/orogeny



Iowa's Igneous & Metamorphic 'Basement'

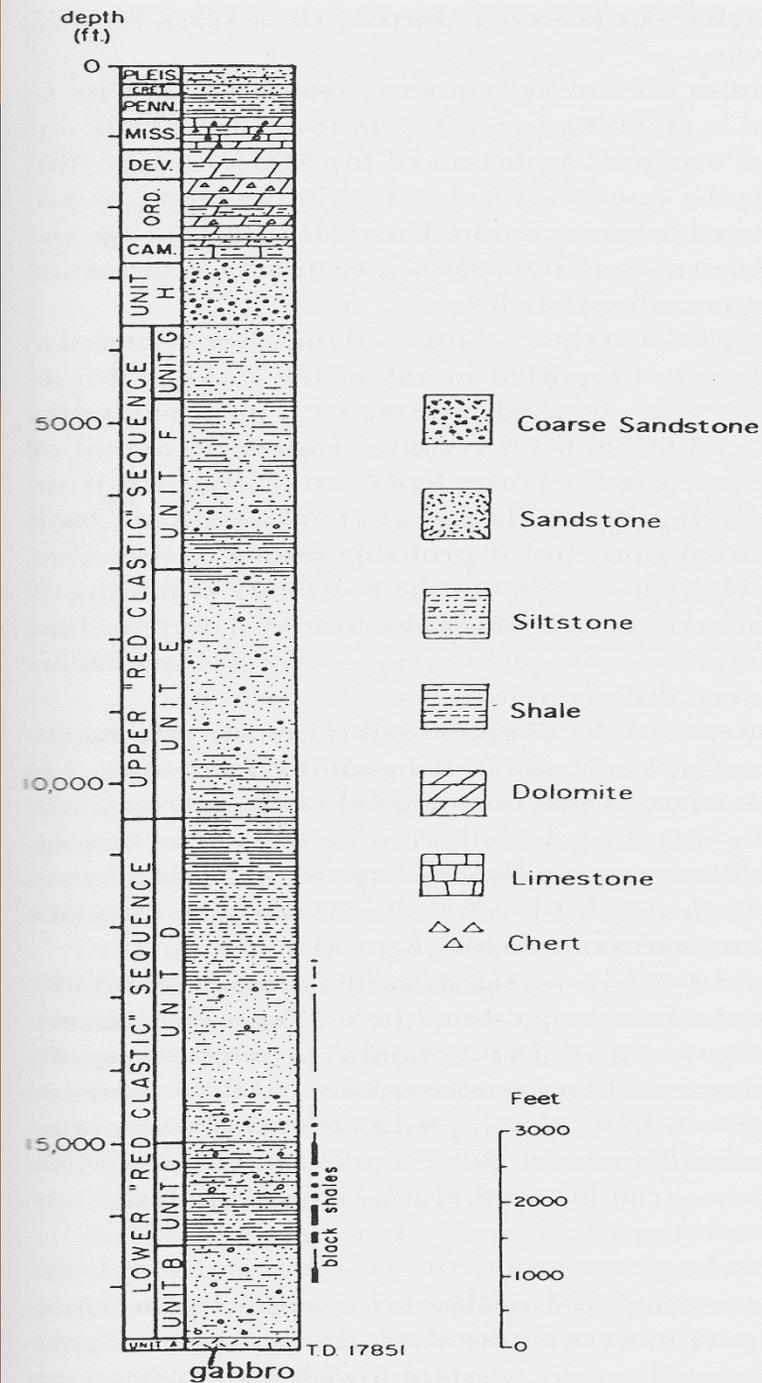
- Gravity surveys supplement direct observations (samples)
 - (+) anomalies indicate dense rock bodies i.e. basalt and gabbro
 - (-) anomalies indicate low density rocks i.e. sandstone and shale



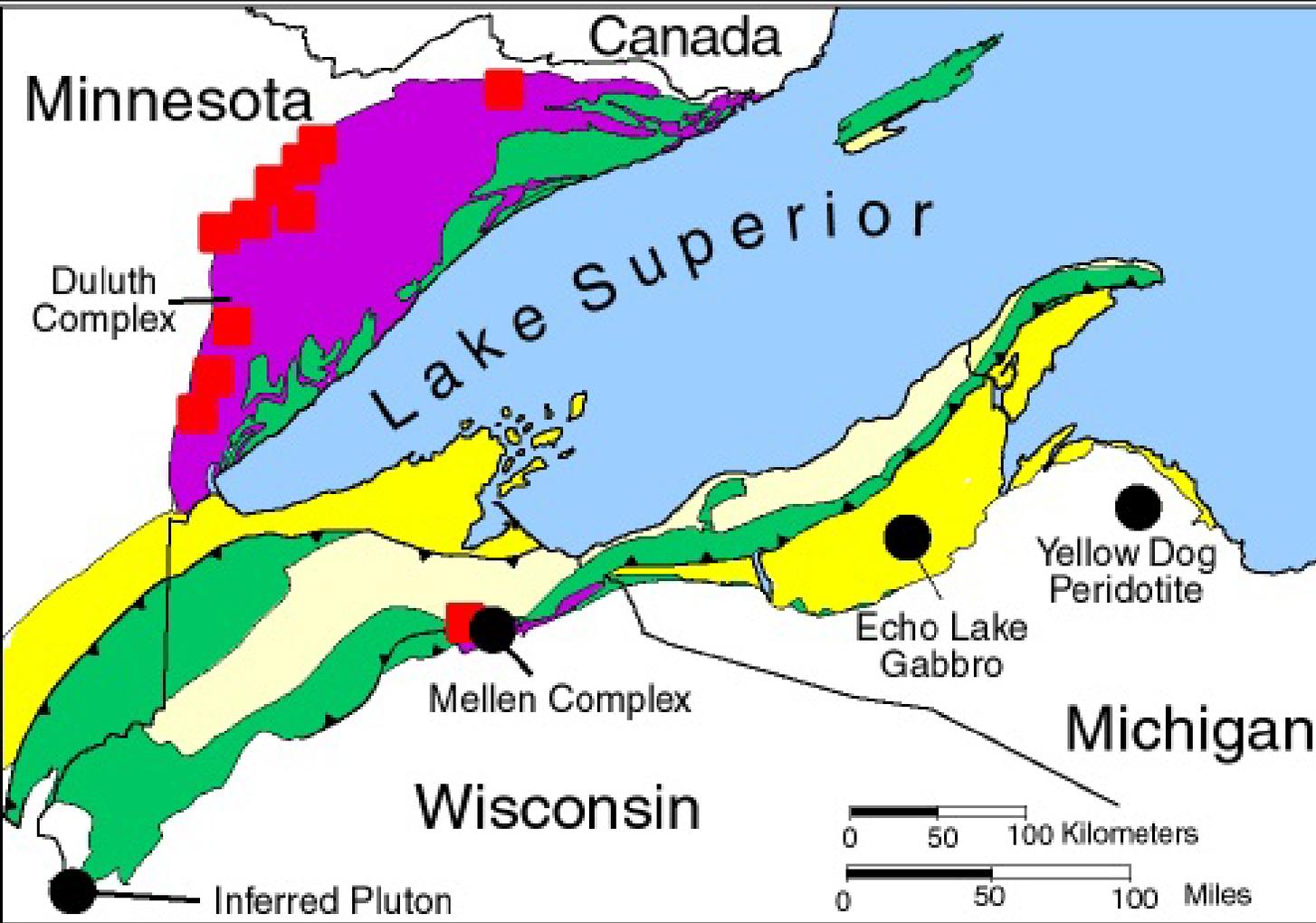
The Eischeid Well - Iowa's Deepest Drilled Well

- Carroll County
- Amaco Production Company
- 208 days of drilling to reach a depth of 17,851ft (one of the deepest in the Midwest!)
- \$20,000,000.00

Lower 'Red-clastic'
Upper 'Red-clastic'

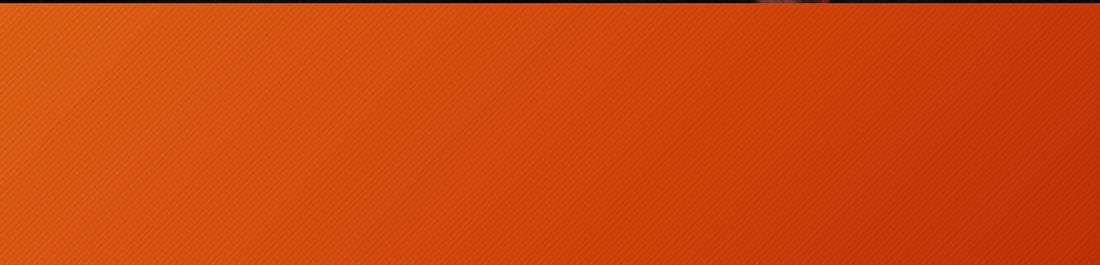


Duluth Complex & North shore Lake Superior



EXPLANATION

-  Sandstone
-  Gabbro
-  Basalt
-  Known nickel and copper sulfide mineralization
-  Favorable target
-  Faults, in part defining the edge of the rift



BIF

2.2 Ga

to

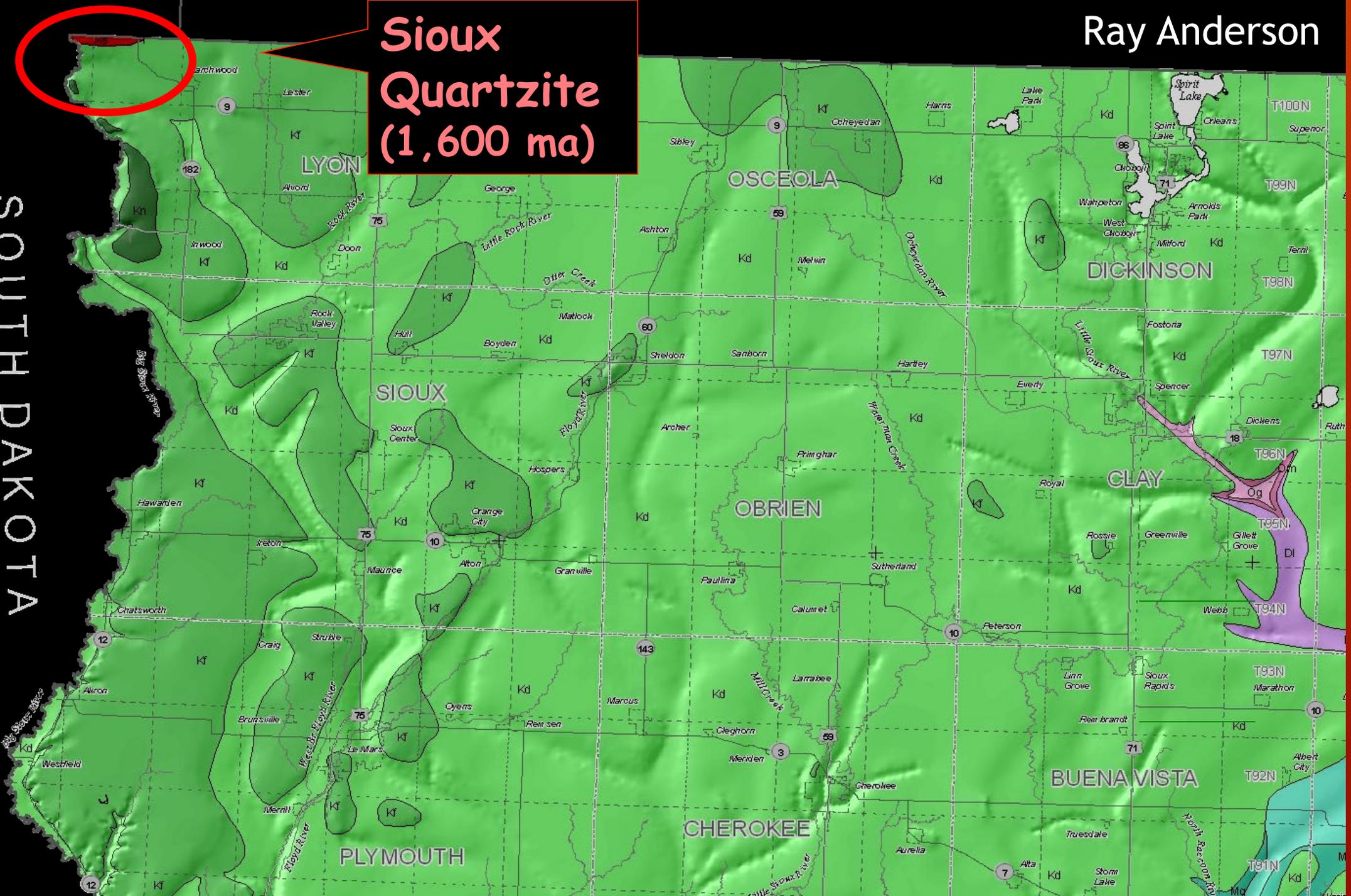
2.4 Ga



Ray Anderson

Sioux
Quartzite
(1,600 ma)

SOUTH DAKOTA



Sioux Quartzite

- Gitchi Manitou State Preserve
 - 1969
- The rock is still quarried near Sioux Falls, SD
- Was mistakenly called Sioux Granite
- NOT part of an uplift rather the Sioux Ridge is likely a product of differential weathering



Sioux Quartzite

- Environment of Deposition?
 - Upper portion = tidal/shallow marine
 - Lower portion = fluvial/river
- The formation is up to 7,800ft thick
- Correlated with the Baraboo Quartzite
 - Occurs in eastern at great depths



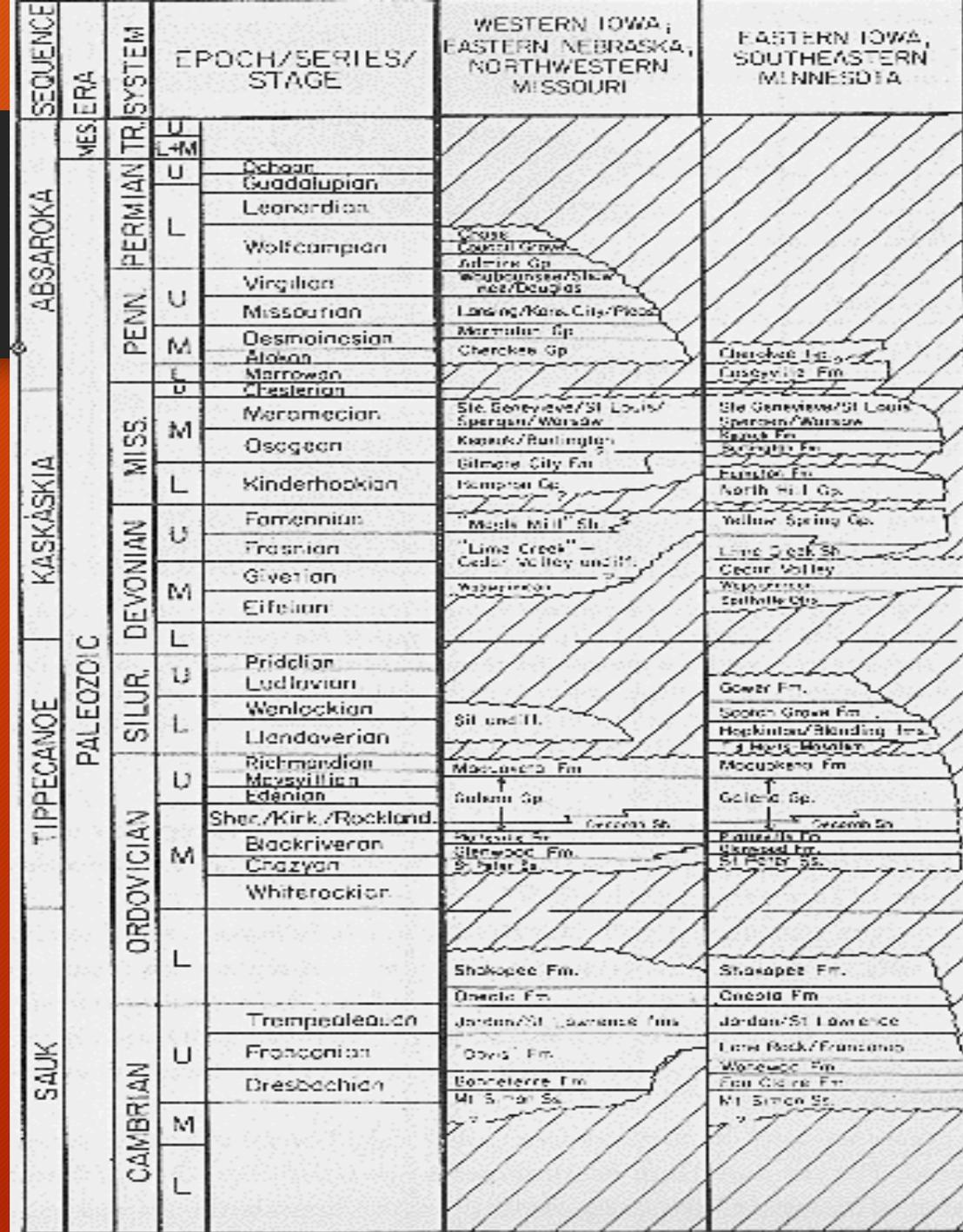
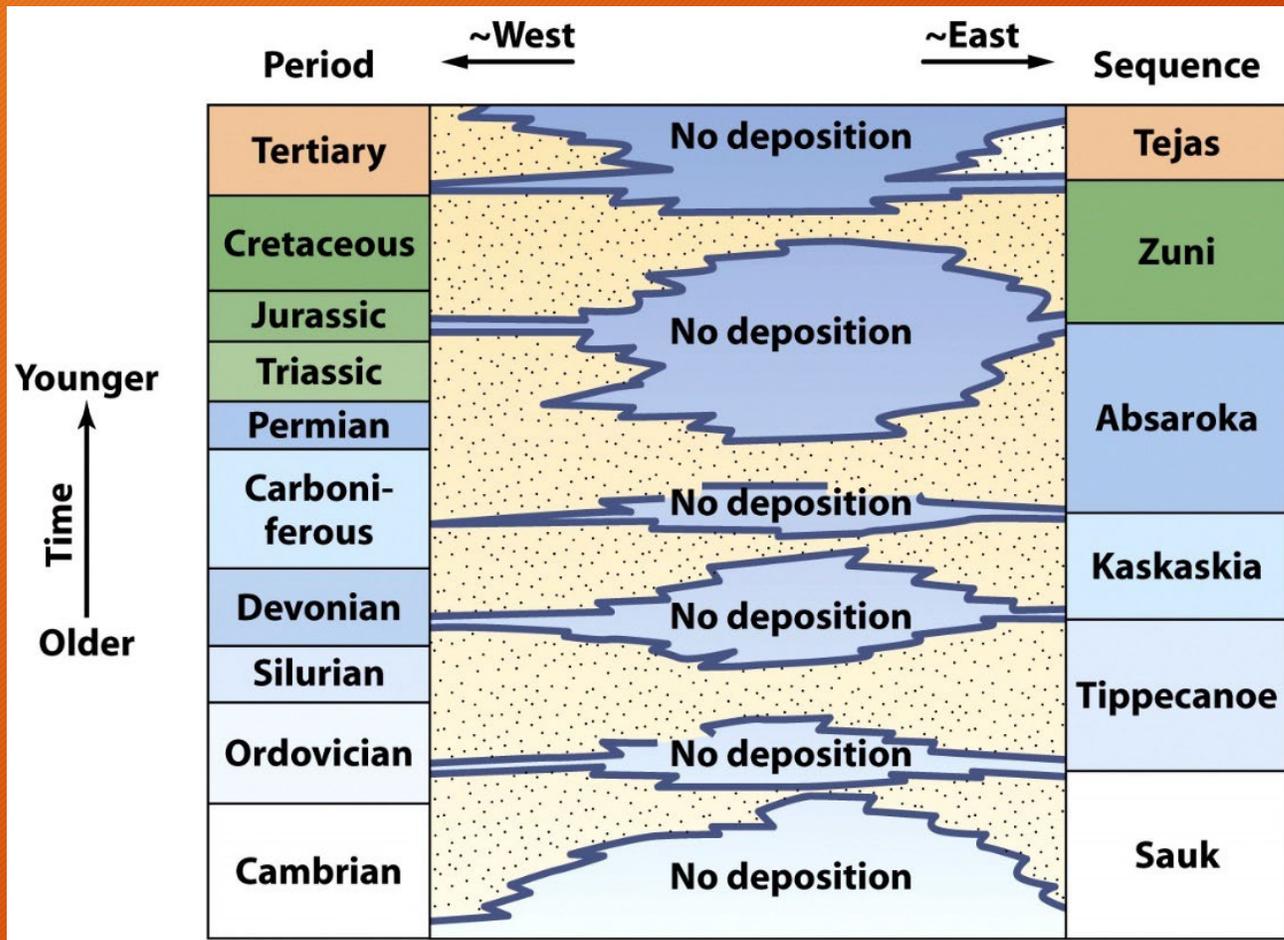
Federal building in Sioux Falls, SD

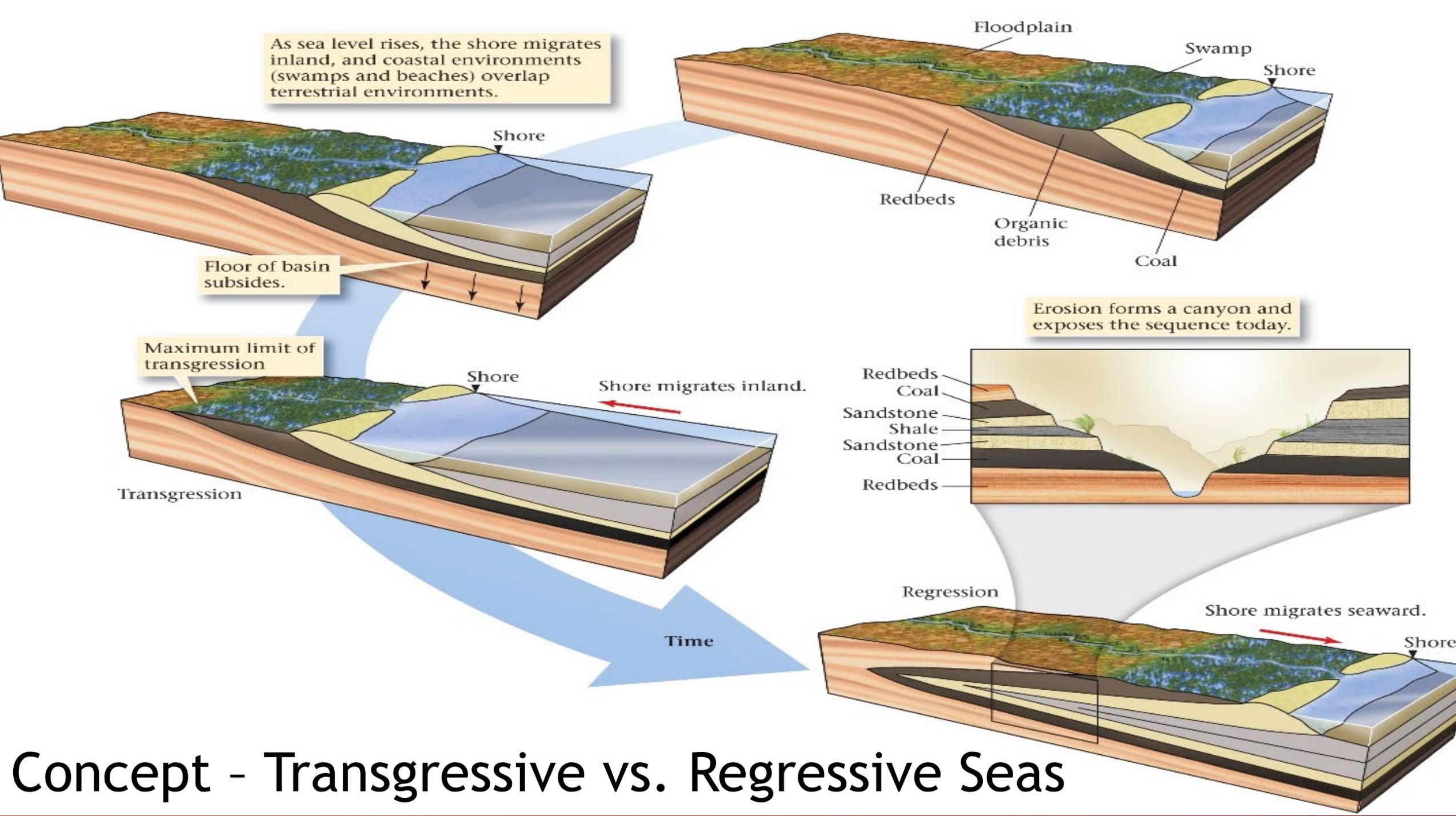
Pipestone

- Pipestone National Monument, MN
- Adjacent red to pink mudstones
 - Catlinite (after George Catlin, 1800s)
- Prized by Native Americans and traded throughout the Great Plains and Colombia River Basin



Iowa's Paleozoic



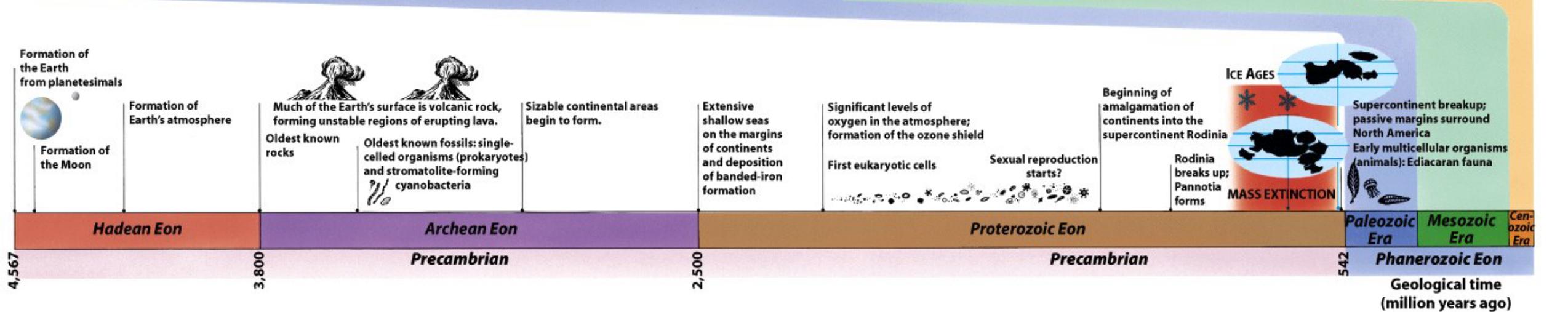
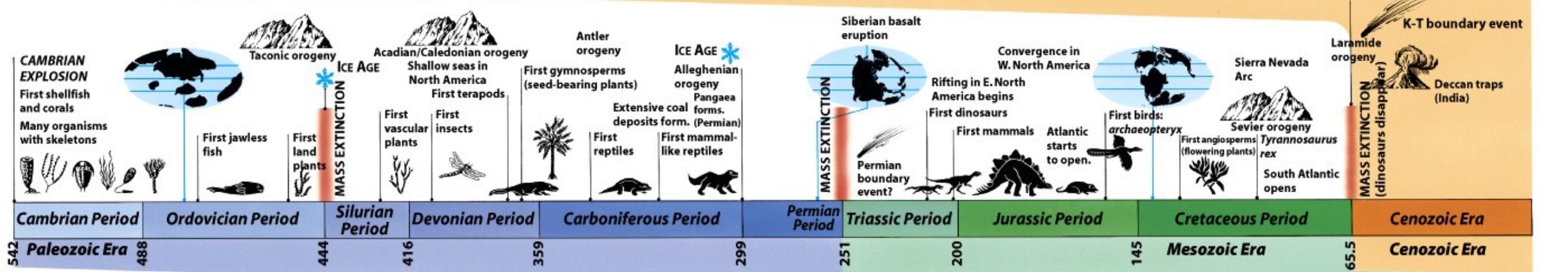
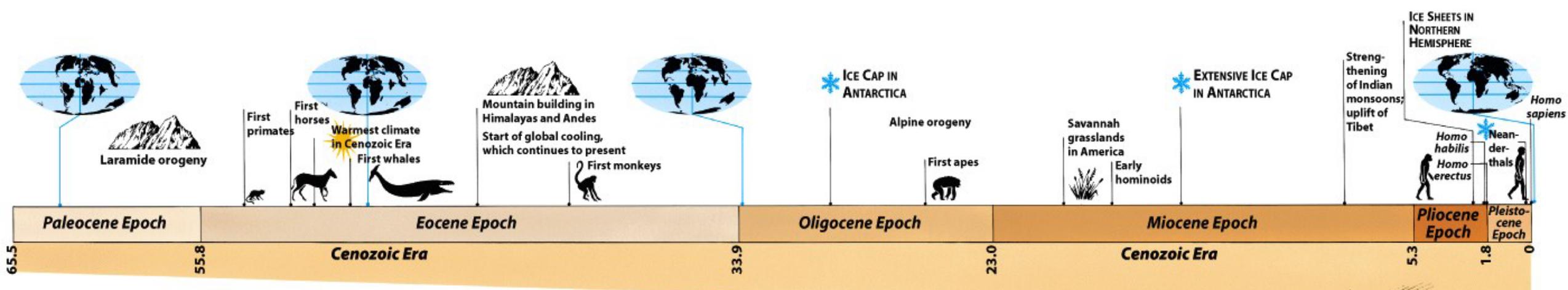


Concept - Transgressive vs. Regressive Seas

Cambrian - Sandy Marine Shelves & Shorelines

485 Ma
to
541 Ma

- The Cambrian is generally known as a period for the Explosion of Life and for a dramatic increase in available/atmospheric O₂
- The early to mid-Cambrian saw massive periods of weathering/erosion and as a product there is a large unconformity until the late Cambrian in Iowa
- During the Late Cambrian, shallow seas encroached upon Iowa and reworked the eroded (Precambrian & Early Cambrian) sediments including resistant quartz, feldspar, clay minerals, and trace amounts of zircon, tourmaline and garnet.

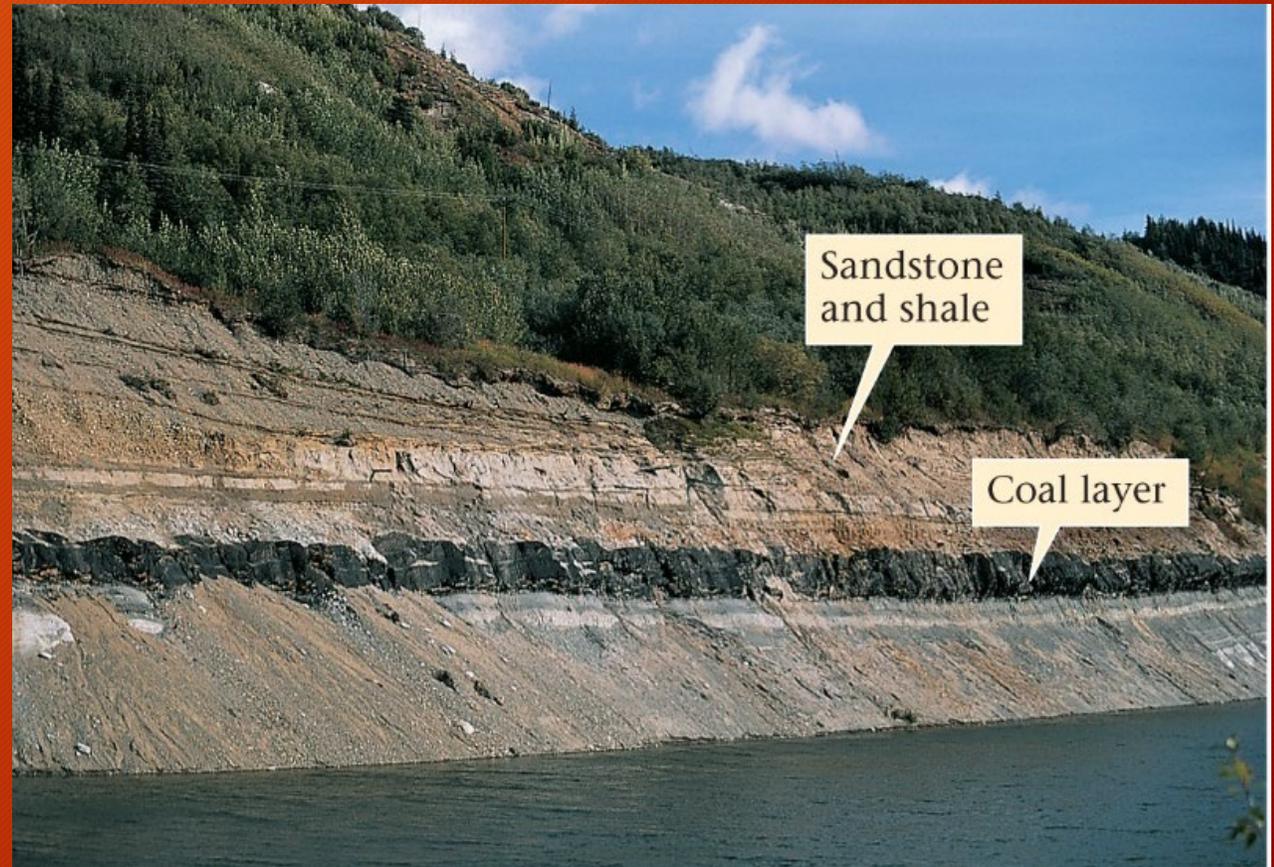


Late Cambrian Sandstone

- Throughout the Midwest there are numerous sandstone formations that are mature:
 - A. Physically
 - Well rounded
 - Well sorted
 - B. Chemically
 - Mostly quartz
 - Some areas rich in feldspar too

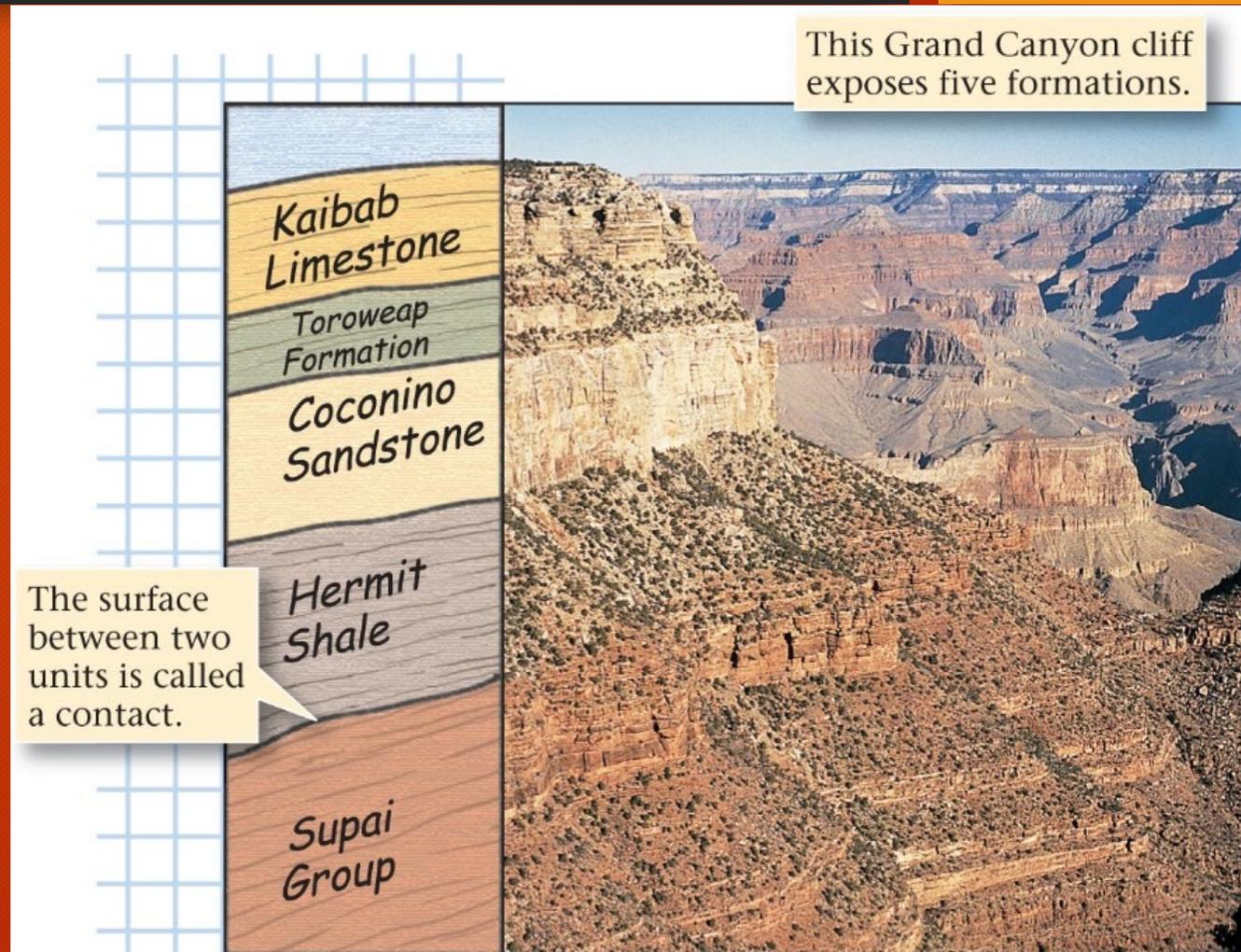
Concept of Geologic *Formations*

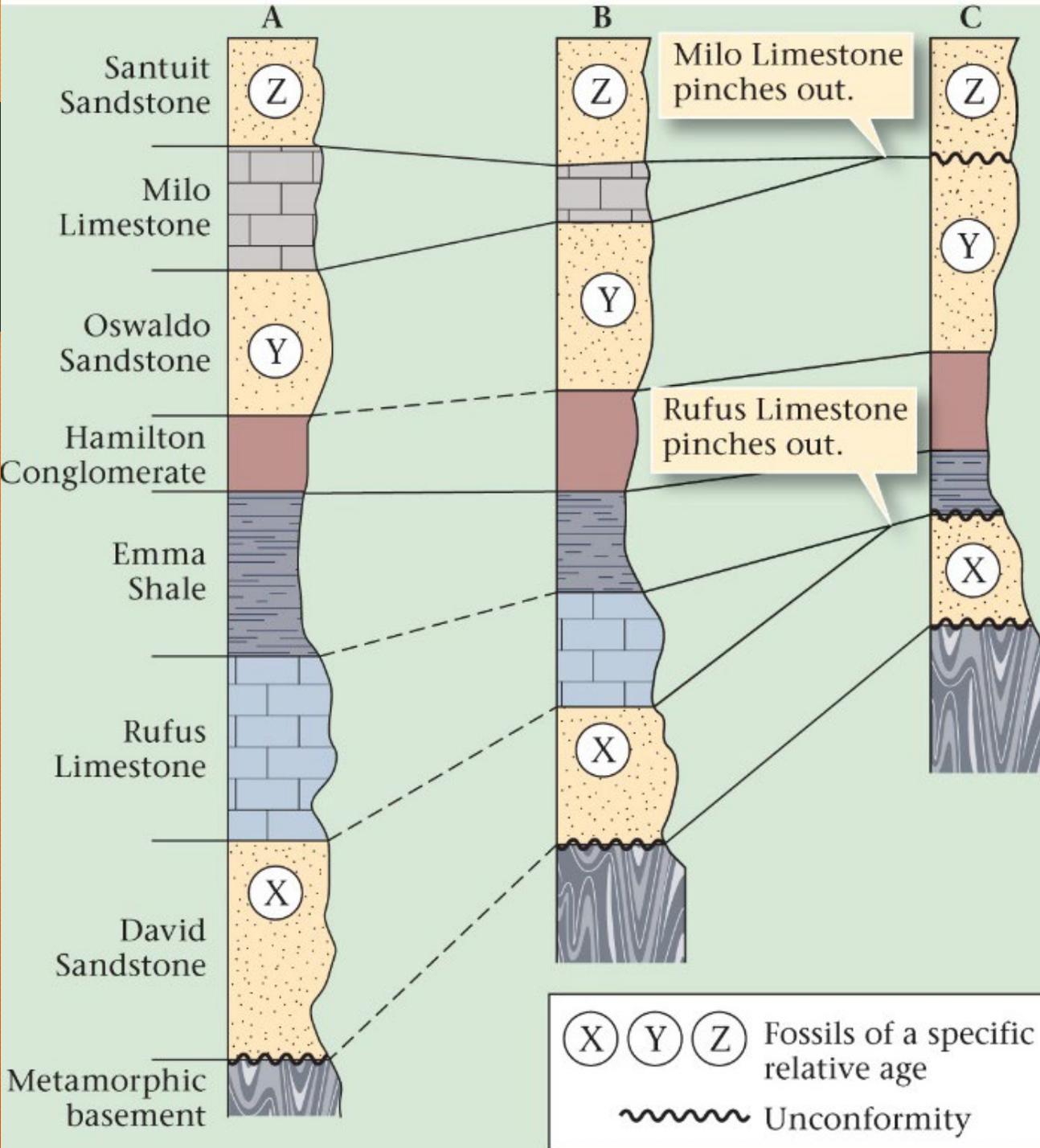
- A body/layer of rock that consists dominantly of a certain lithologic rock type
- Maybe combined into *Groups*
- Or maybe divided into *Members*



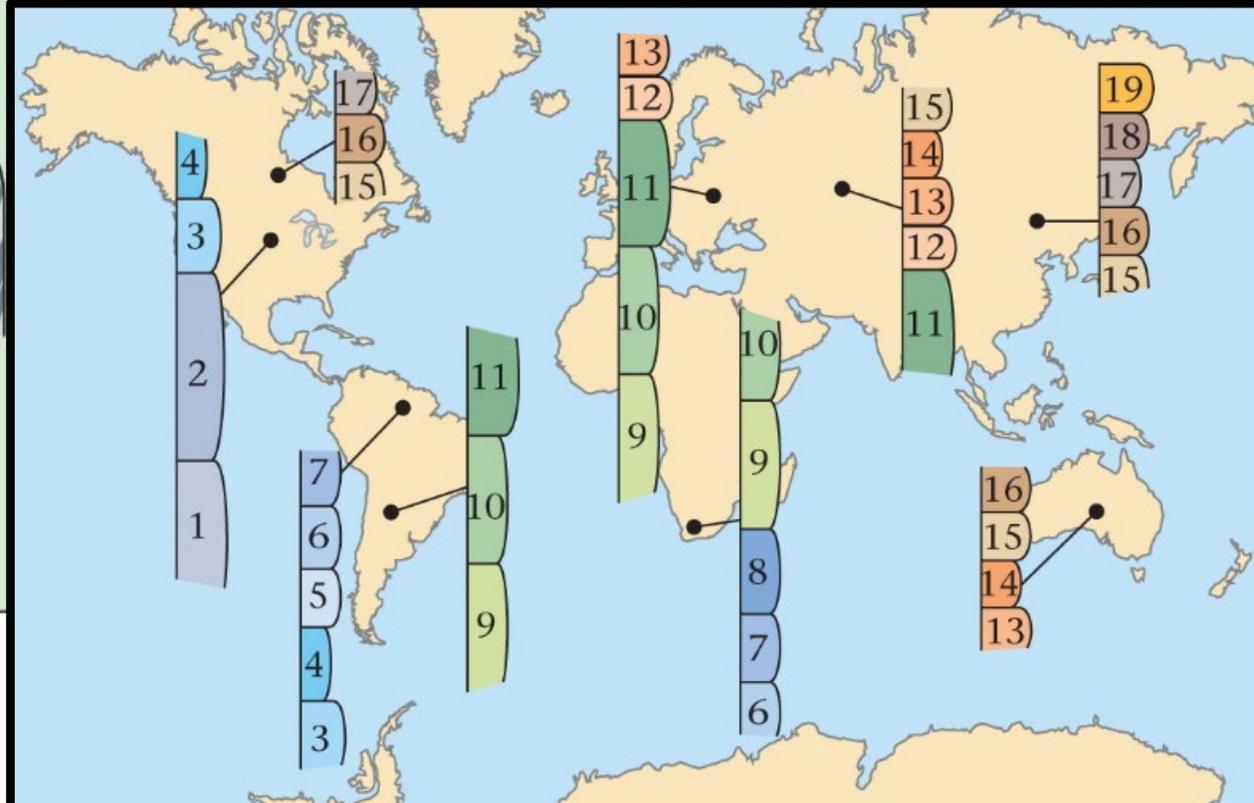
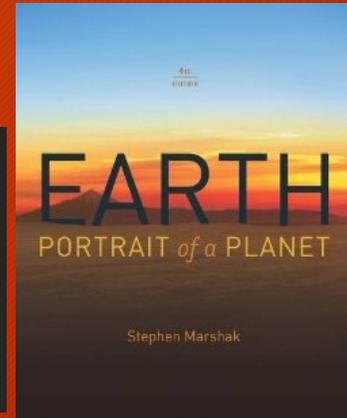
Stratigraphy - The science of rock layers

- Concerned with all characters and properties (physical, chemical and/or biological)
- Enables geologists to trace rock formations from one place to another
- Helps geologists to interpret modes of origin and history

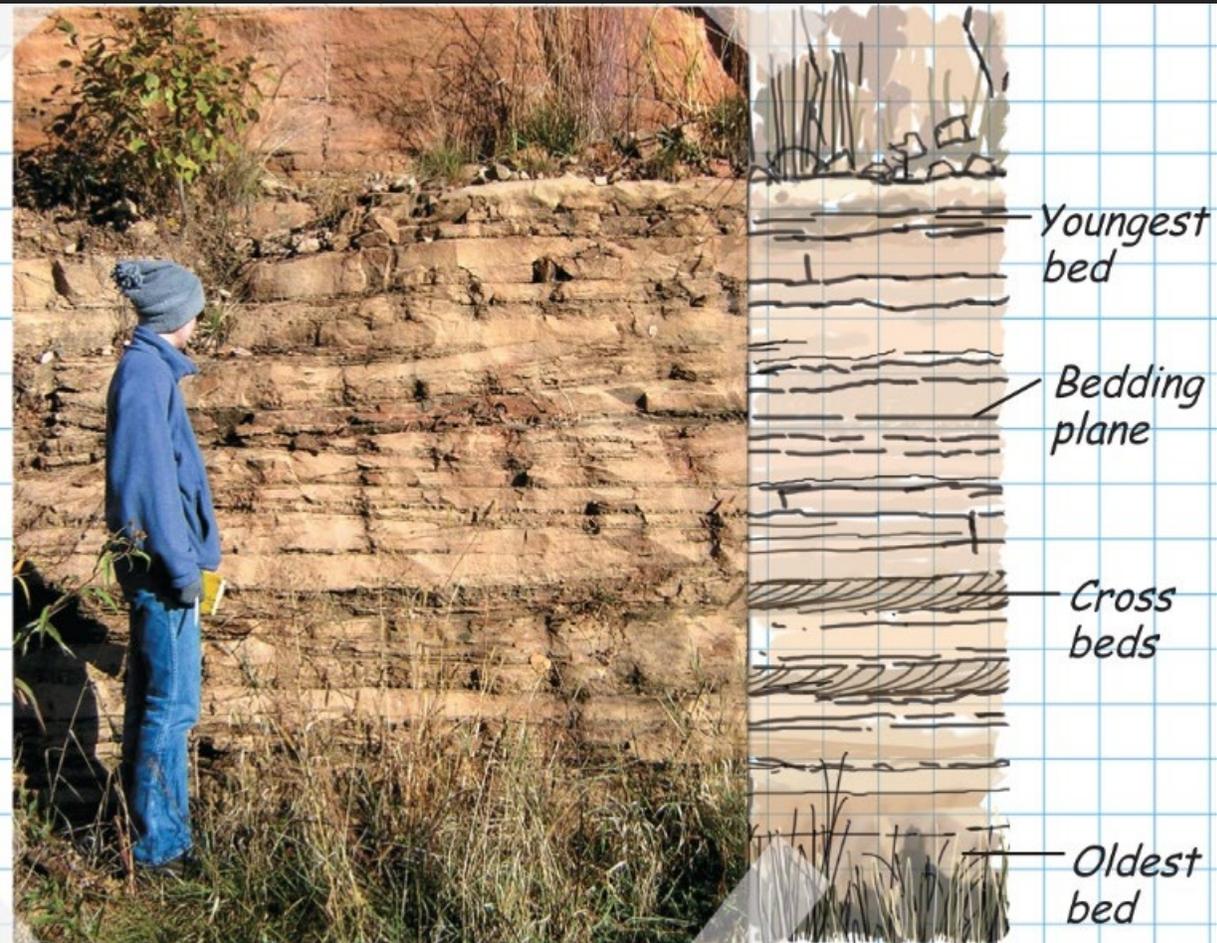
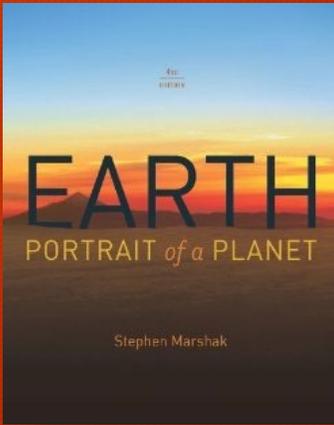




Correlation



Relative dating - Law of Superposition



What a Geologist Sees

The Jordan Sandstone

- Some layers are cemented with dolomite
- Formed on a shallow marine shelf and shoreline
- High porosity and moderate permeability
 - Serves as one of the Iowa's best groundwater/aquifers



Location

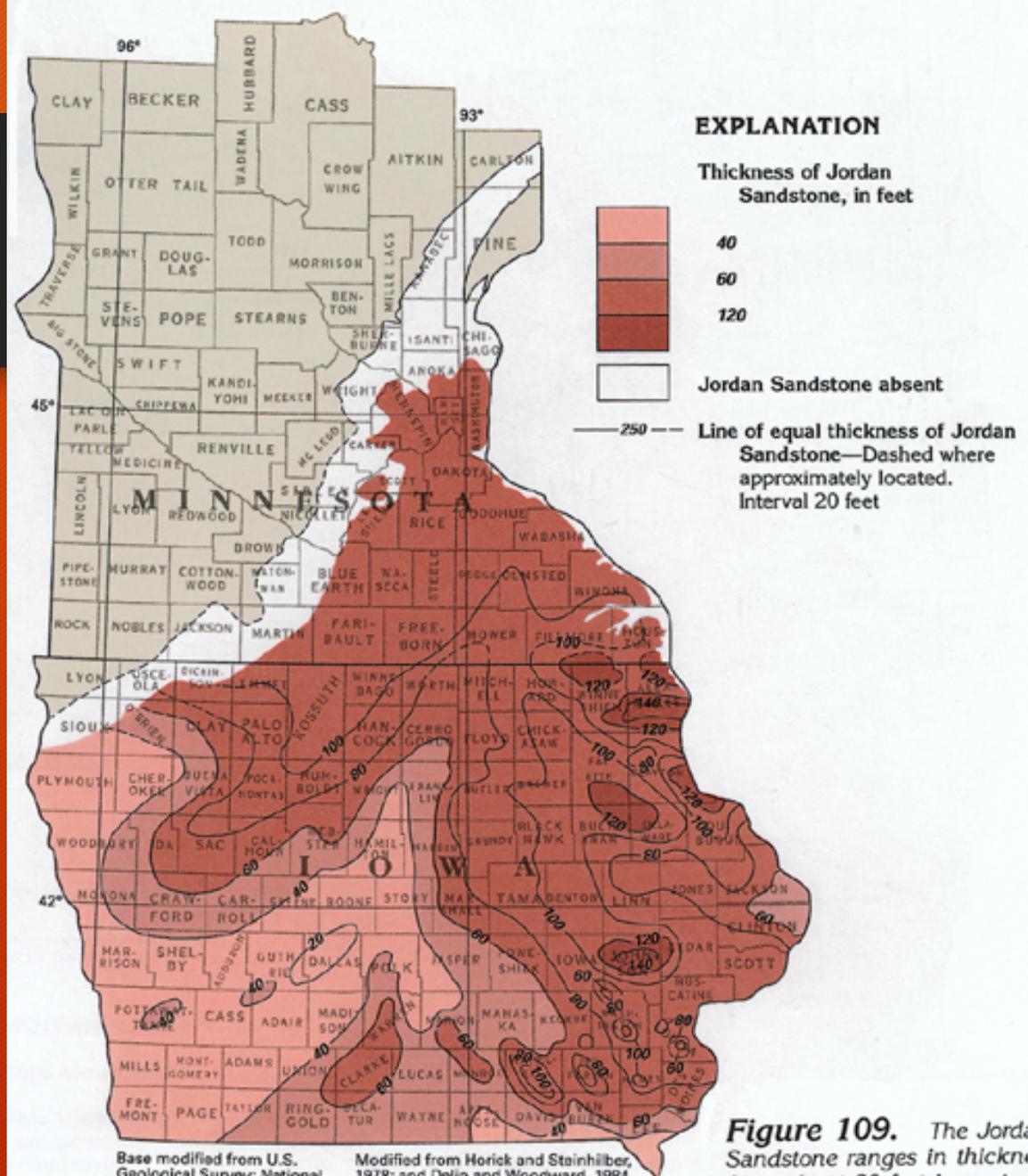
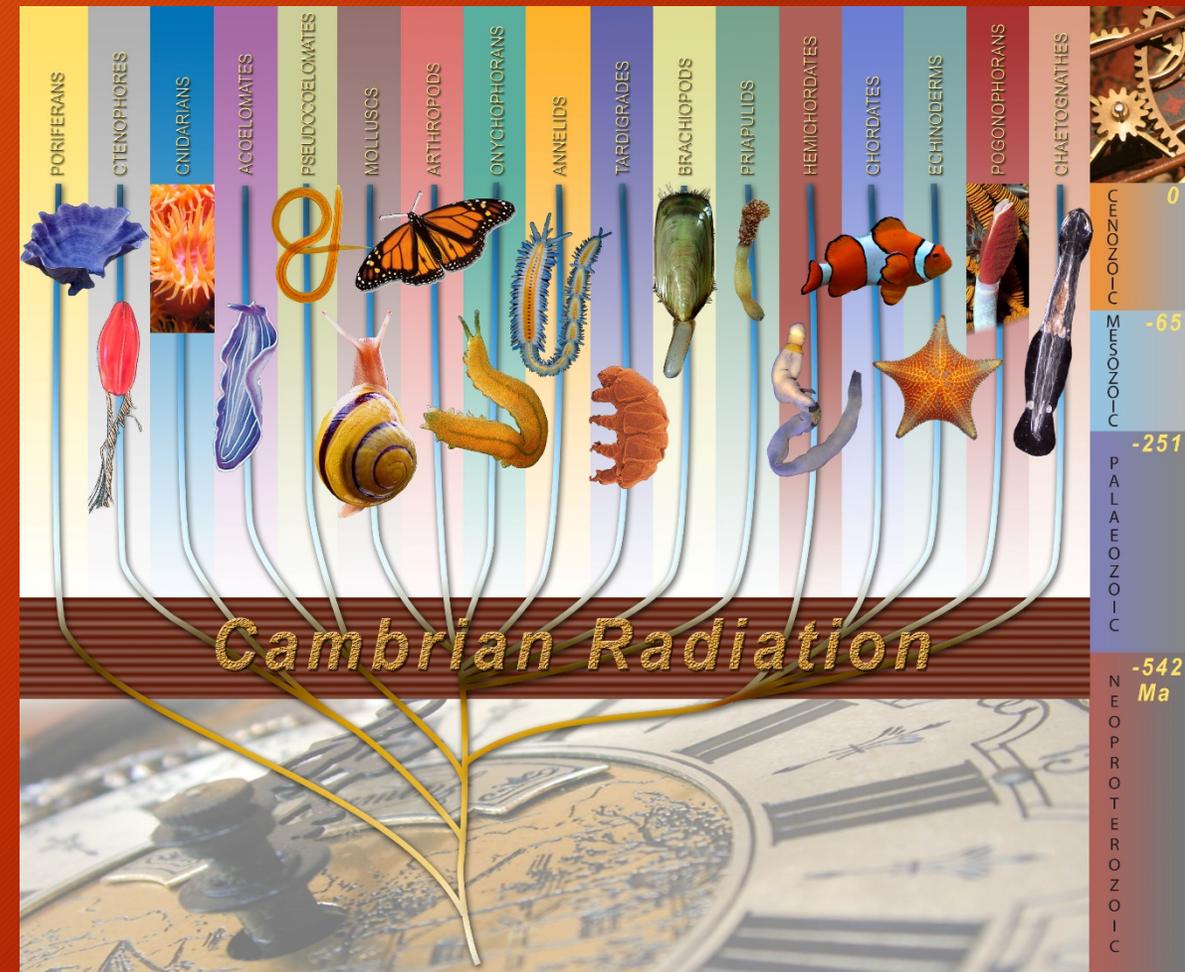


Figure 109. The Jordan Sandstone ranges in thickness from about 20 feet in central Iowa to about 140 feet in northeastern and east-central Iowa.

Cambrian Life

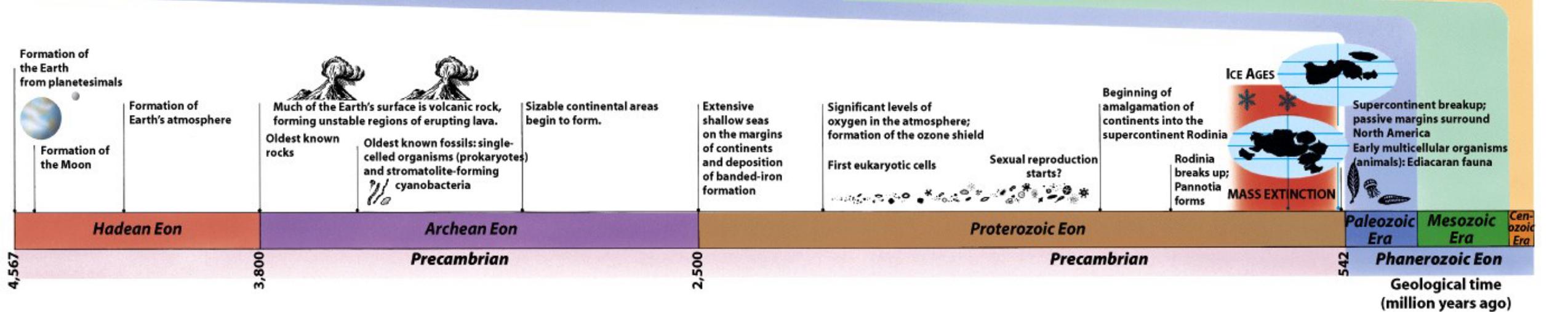
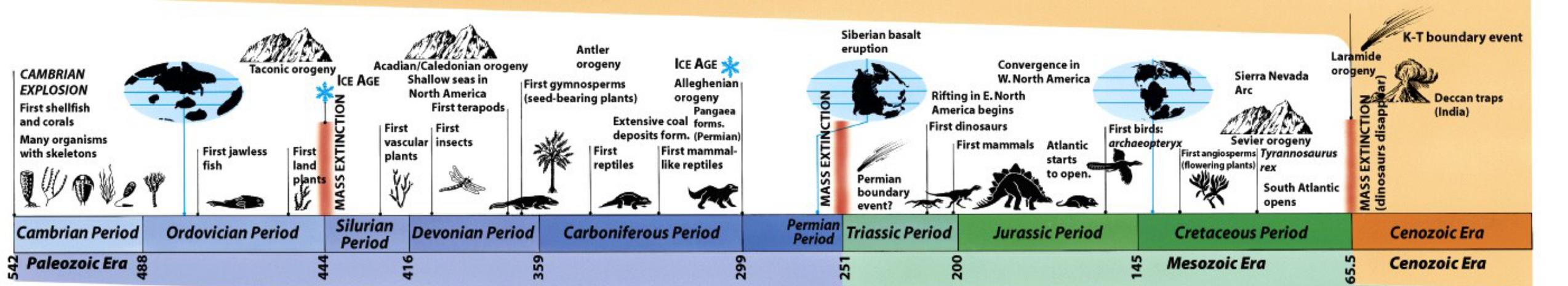
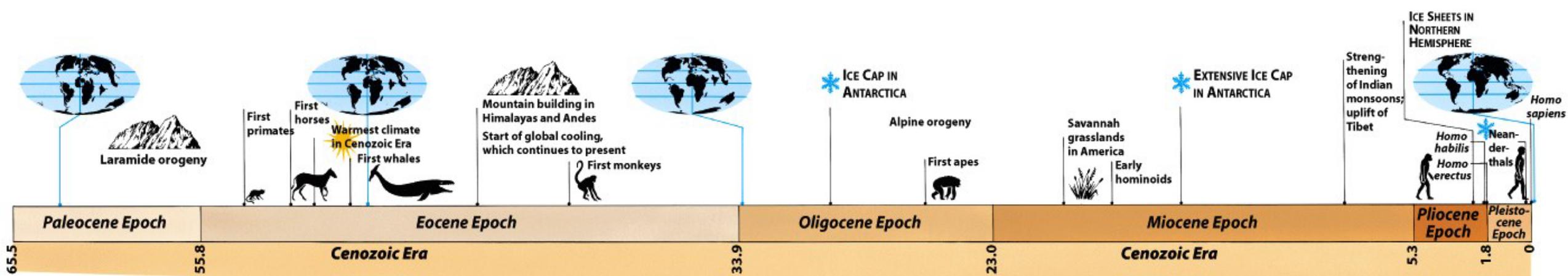
- The age of the Trilobites
- Trilobites and brachiopods are abundant in this period, but not in Iowa.
- Why???
- Iowa's Cambrian record is dominated by SANDY near shore transition environments.



Ordovician - Warm, Shallow Seas

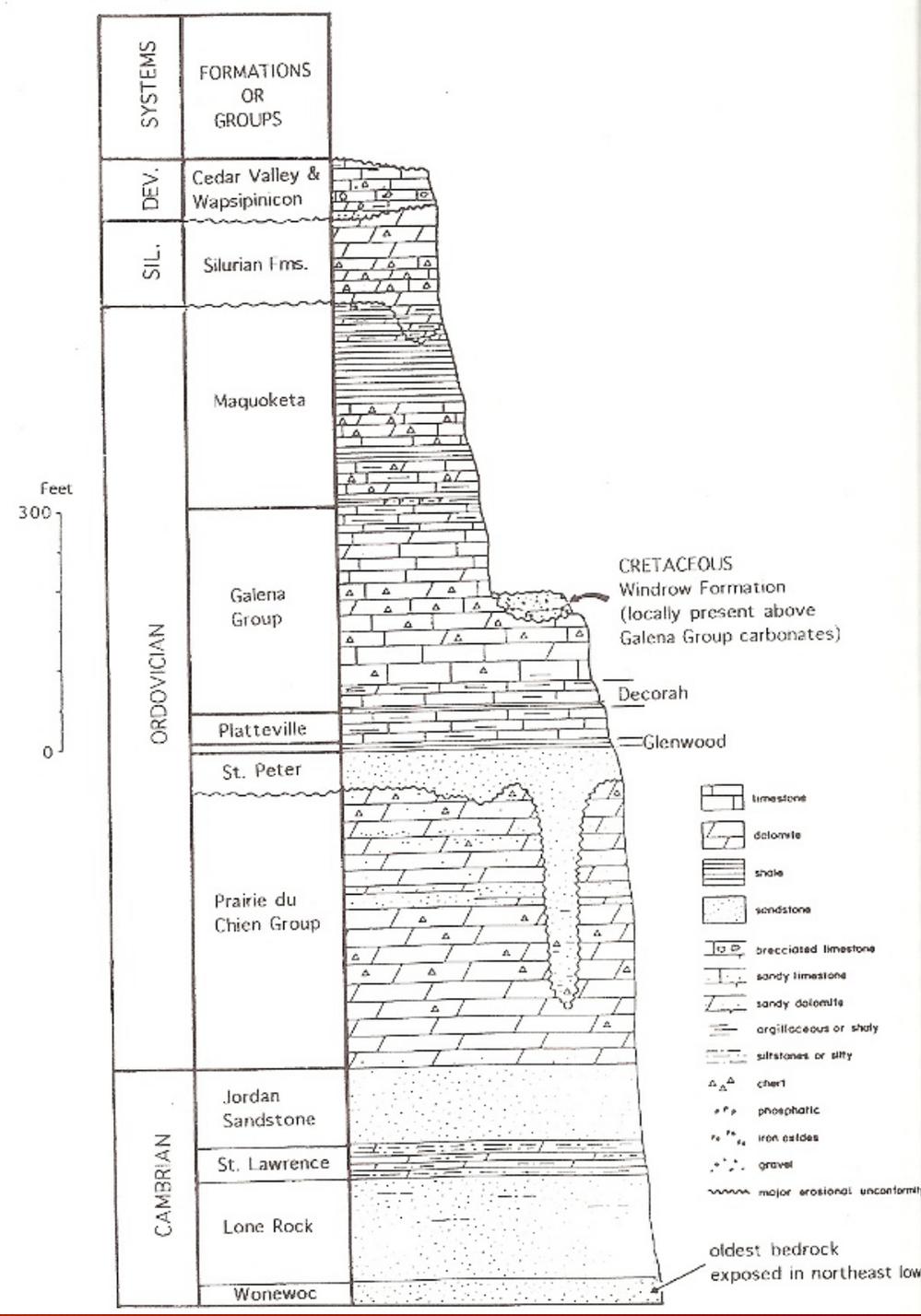
443 Ma
to
485 Ma

- Early Ordovician - Again on the edge of a shallow sea depositing carbonate, sandy carbonate, and quartz sandstones (Prairie du Chien Group) before another series of weathering and erosion!
- Mid-Ordovician - Major sea transgression changed a sandy shallow sea to carbonate shelf. Ash layers appear in the Decorah and Dunleith Formations.
- Late Ordovician - Increasingly muddy depositional environments forming the carbonate-rich shale layers (e.g. the Maquoketa Shale).
- Towards the end of the Ordovician the seas regress and weathering and erosion begin again, creating an ???



Geological time (million years ago)

Ordovician stratigraphy



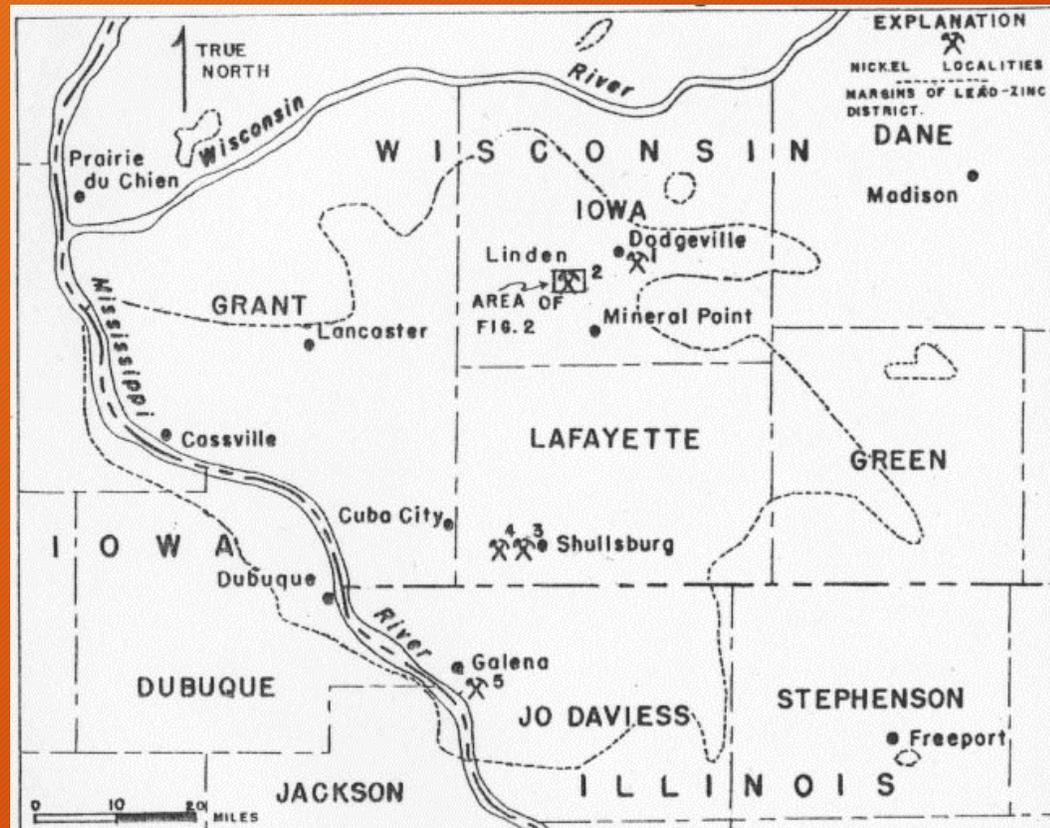
St. Peter Formation

- Quartz Sandstone (super mature)
 - But, In NW Iowa the St. Peter contains a lot of shale from the then exposed Transcontinental Arch
- Well exposed in Pikes Peak St. Park
- An important economic resources for glass and fracking
- 1960's served as a fall out shelter with supplies to meet the needs of 44,000 residents for two weeks

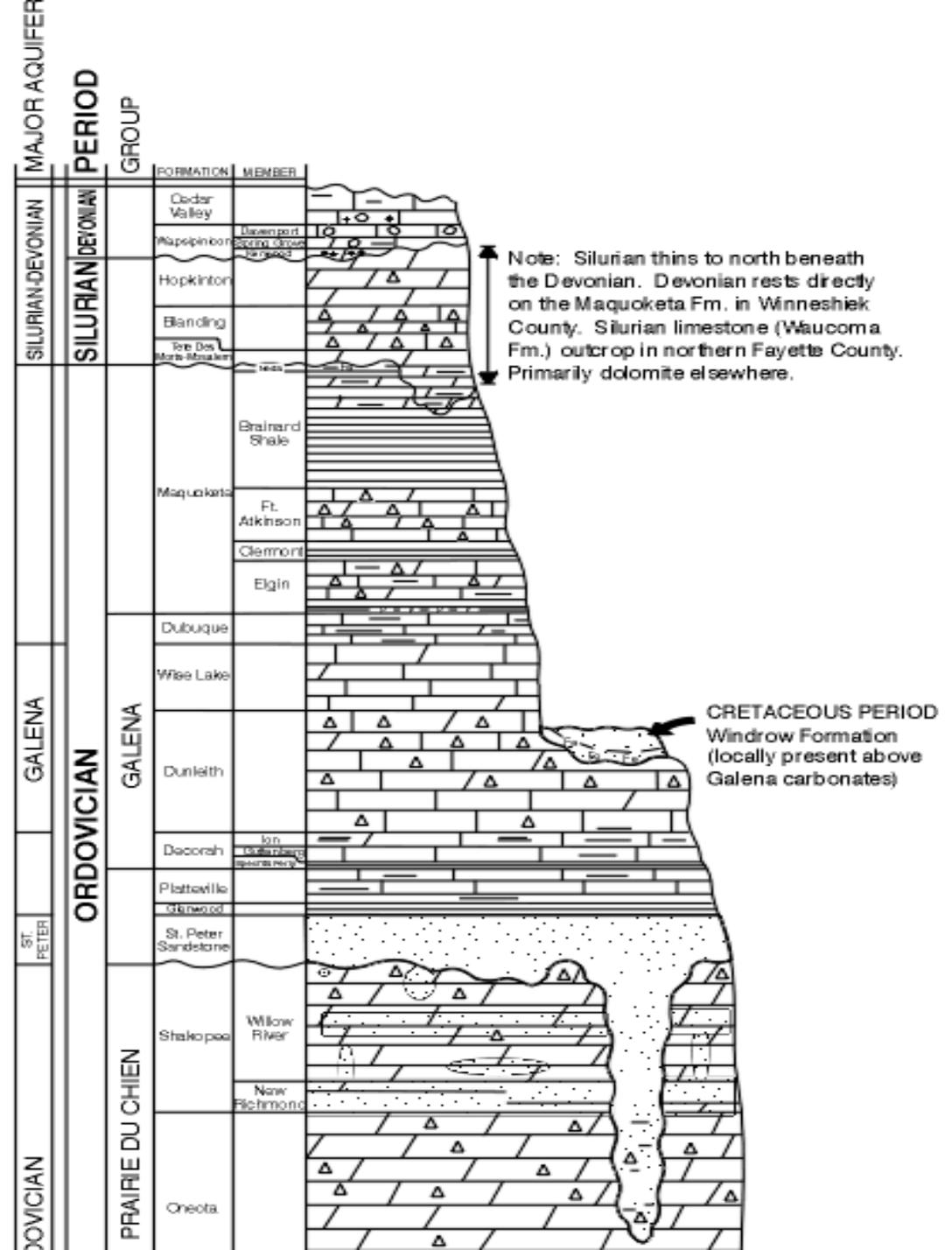


Galena Group

- Dunleith, Wise Lake, and Dubuque Formations

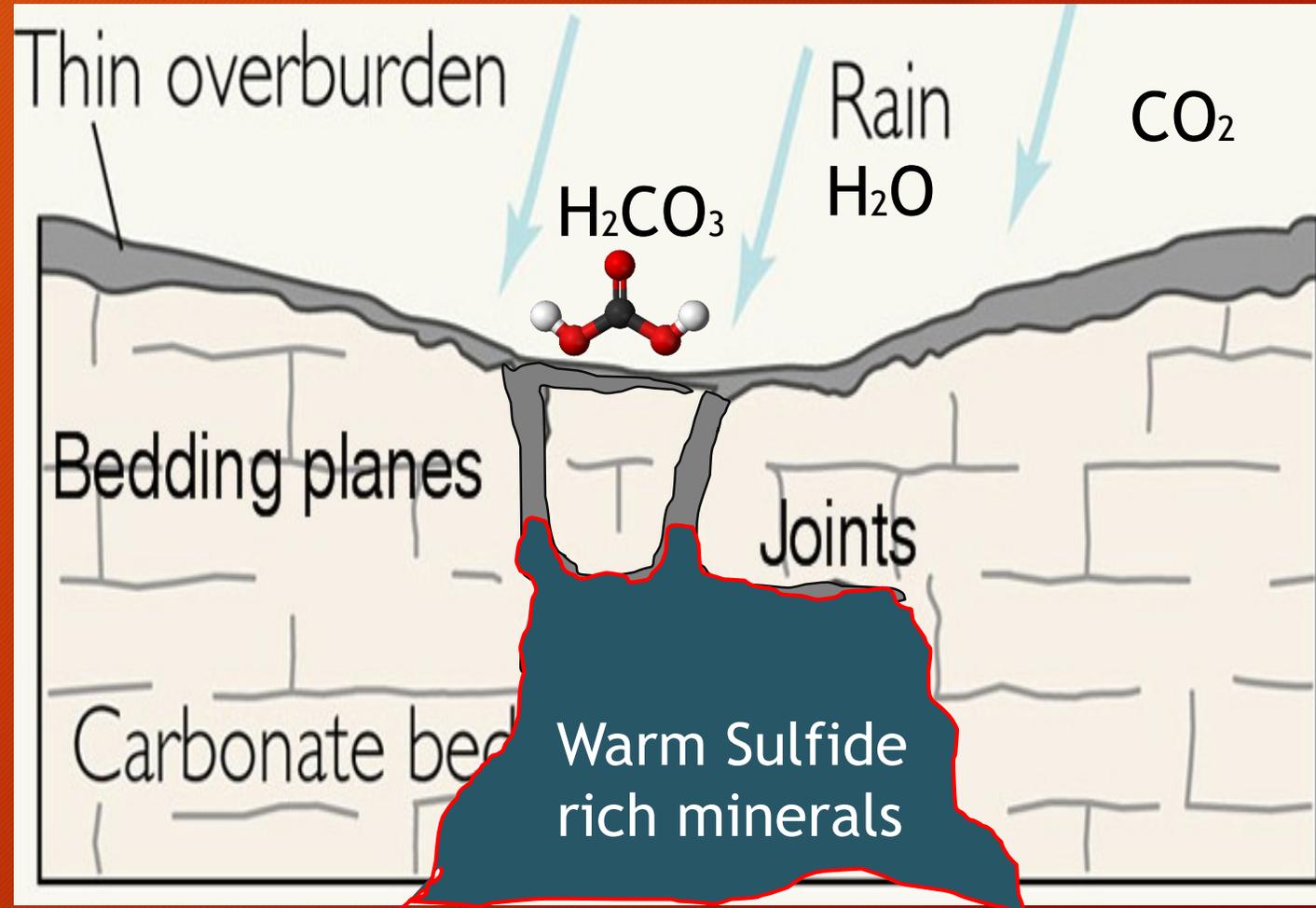


Upper Mississippi Valley Zinc and Lead District



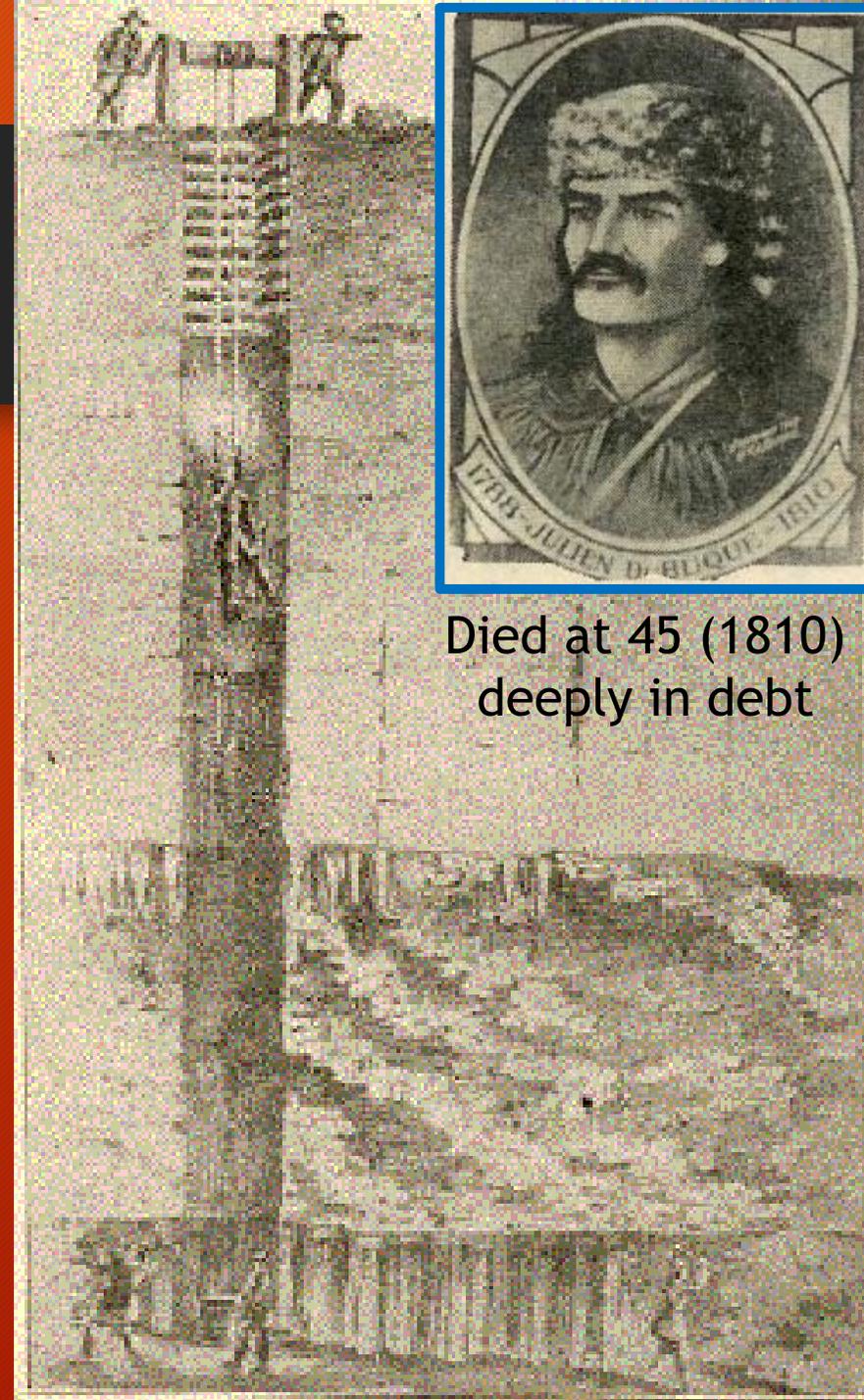
How does Galena & Zinc form in Limestone?

- Space is created, through karst processes
- Warm sulfide-rich solutions migrate upwards and infiltrate the new space
- Sulfide minerals precipitate out of solution and along the edges of these new spaces
- The Mississippi cuts its channel into the landscape and lowers the water table
- Exposing the sulfide minerals, creating Iron sulfide, Lead sulfide, and Zinc sulfides



Lead and Zinc Mining 1788-1810

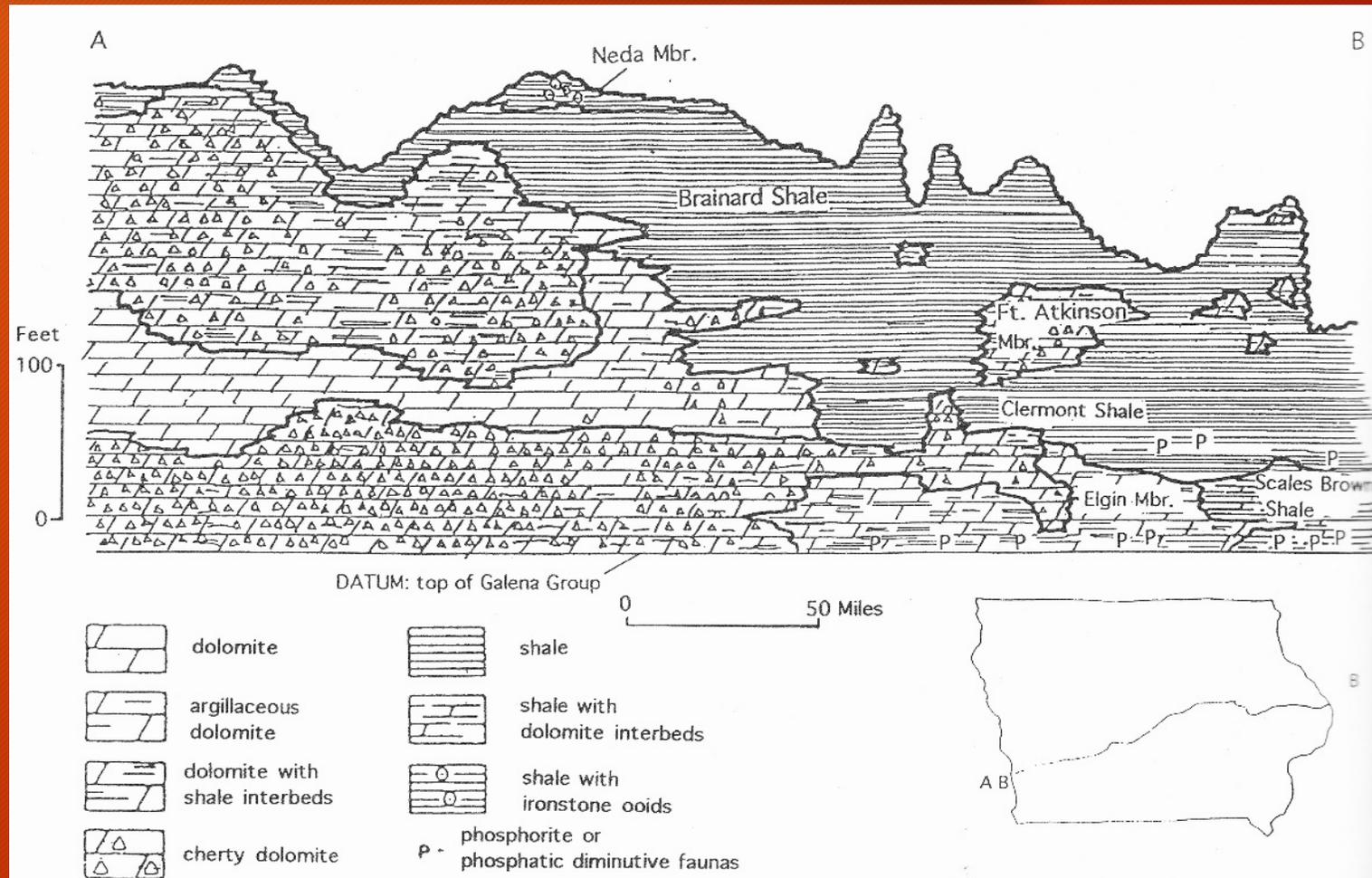
- Spain ruled Iowa via the Treaty of Paris (1763) as a product of the French and Indian War (1756-1763)
- Julien Dubuque became friends with the local Meskwaki, eventually marrying Potosa and entering their culture as *Little Night*.
- Julien, identified the mineral resources and with the Meskwaki's permission began mining
- Julien, requested ownership/confirmation of his land from the Spain, and it was granted in 1796. 'The Mines of Spain'



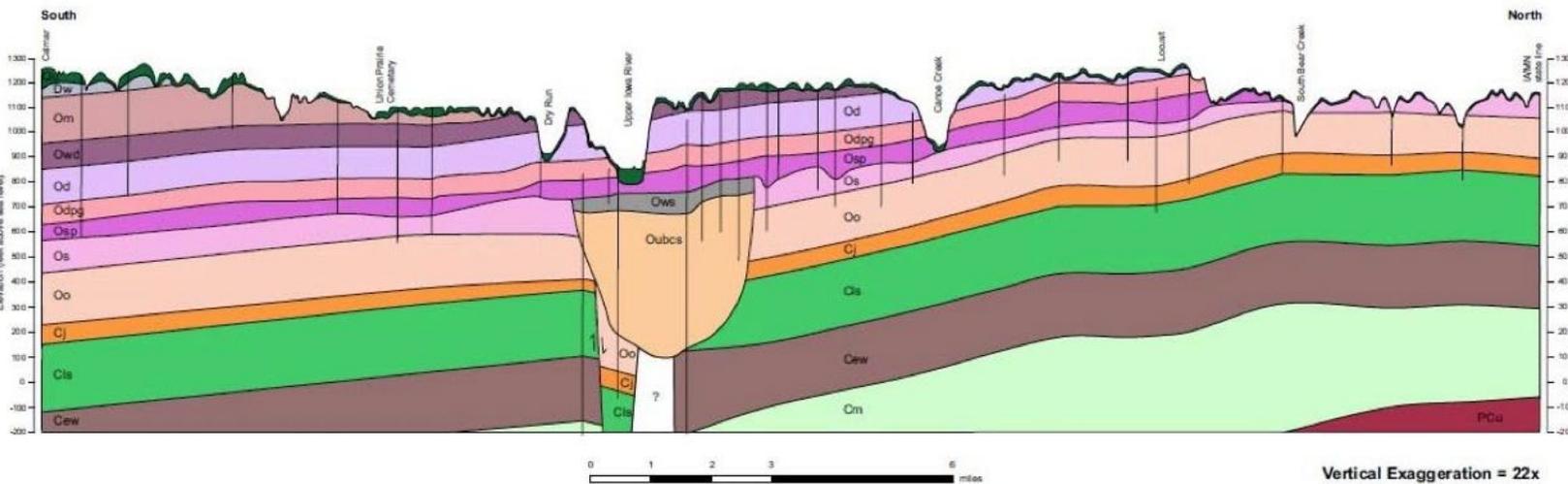
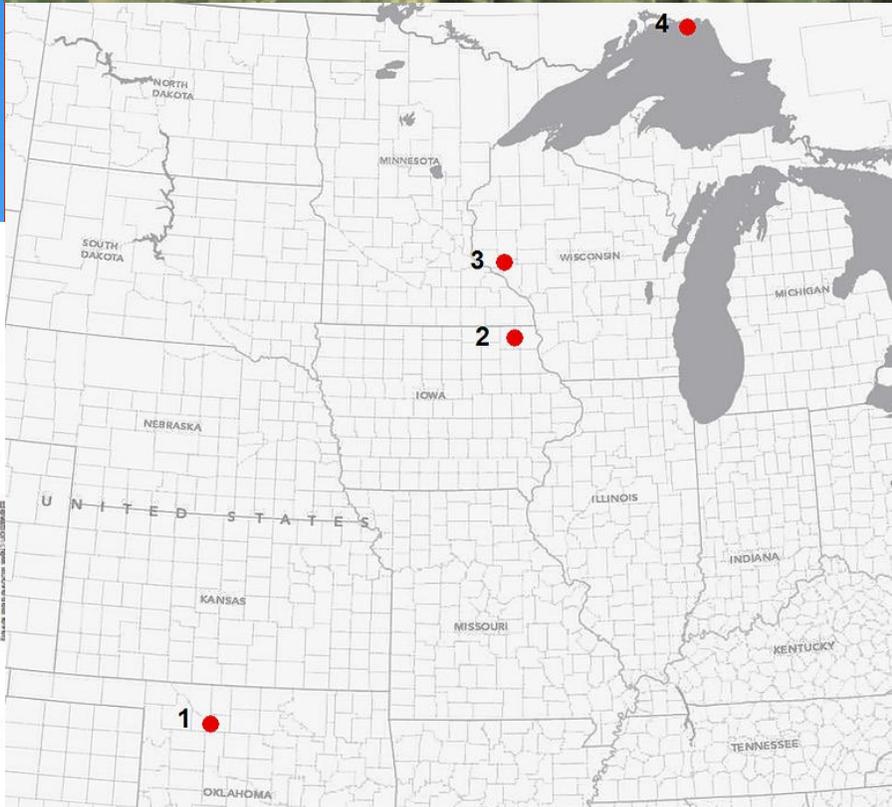
Died at 45 (1810)
deeply in debt

Maquoketa Formation

- Thick impermeable shale
- Large caverns were excavated under Johnson and Polk counties to seasonally store liquefied petroleum gas
- Enables the pipeline industry to store their product so that they can meet demand during the winter



Decorah Structure

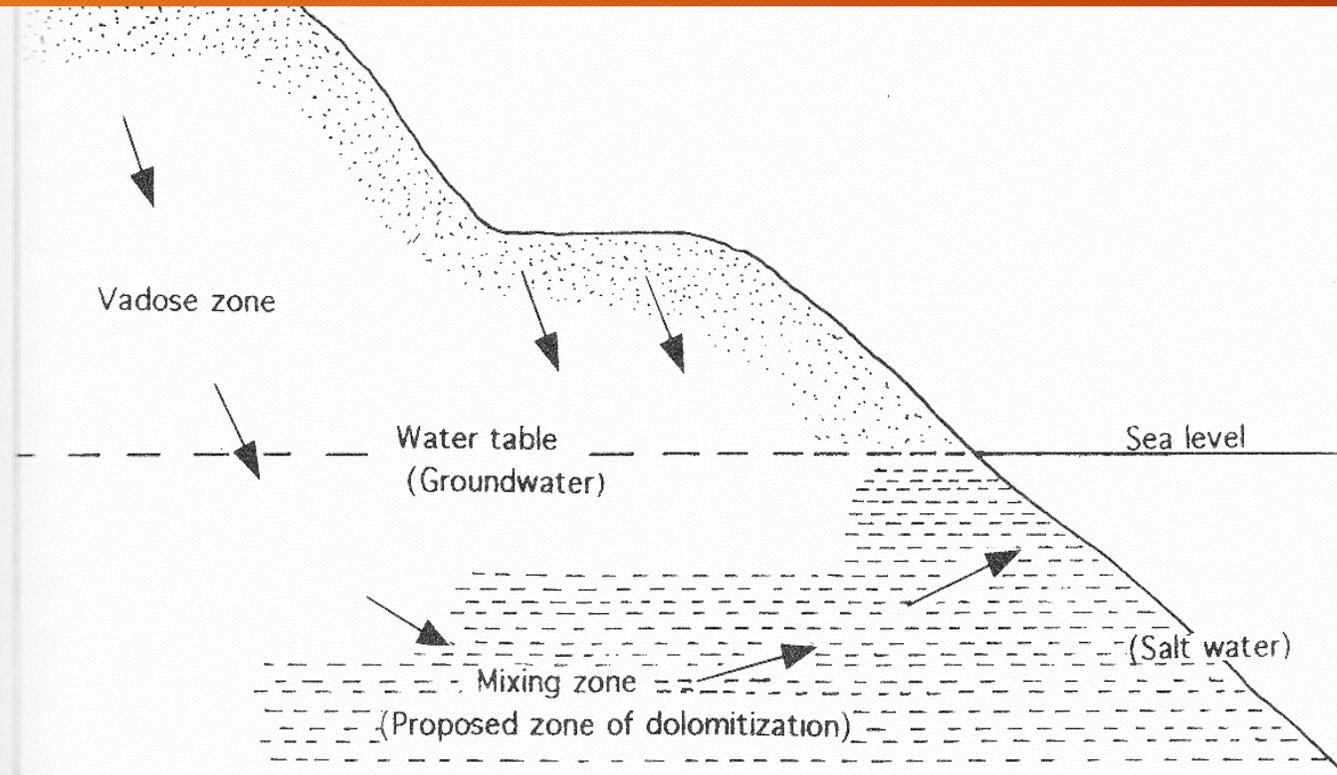


Ordovician Life: Warm shallow seas = ☺ Life

- Brachiopods
- Bryozoans
- Corals
- Receptaculitides
- Mollusks
- Worms
- Arthropods
- Echinoderms
- Graptolites
- Conodonts



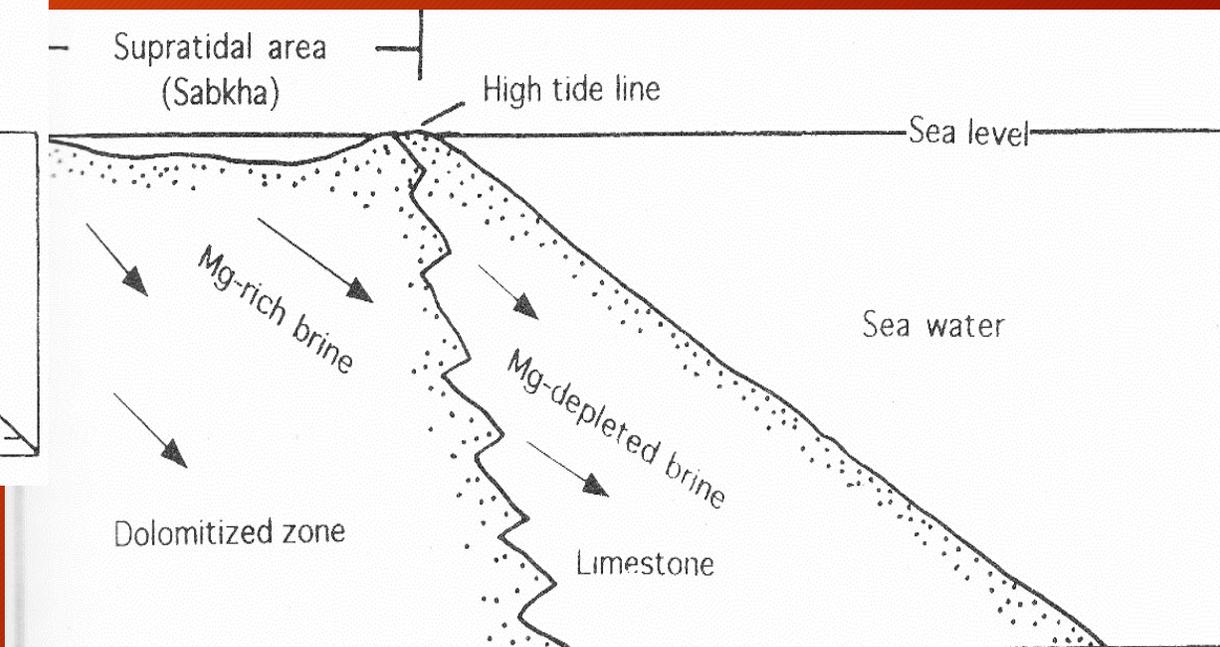
Process of Dolomitization



CaCO_3

Mg replaces some Ca

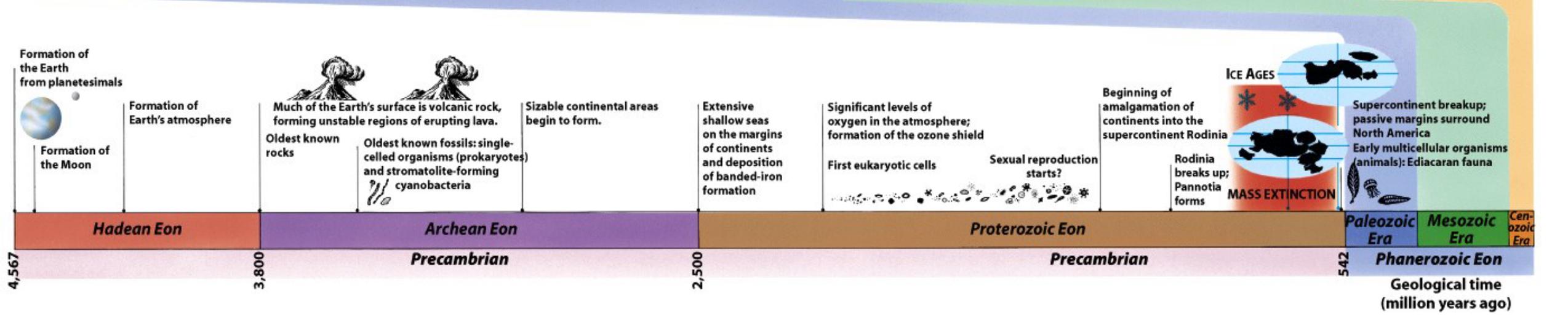
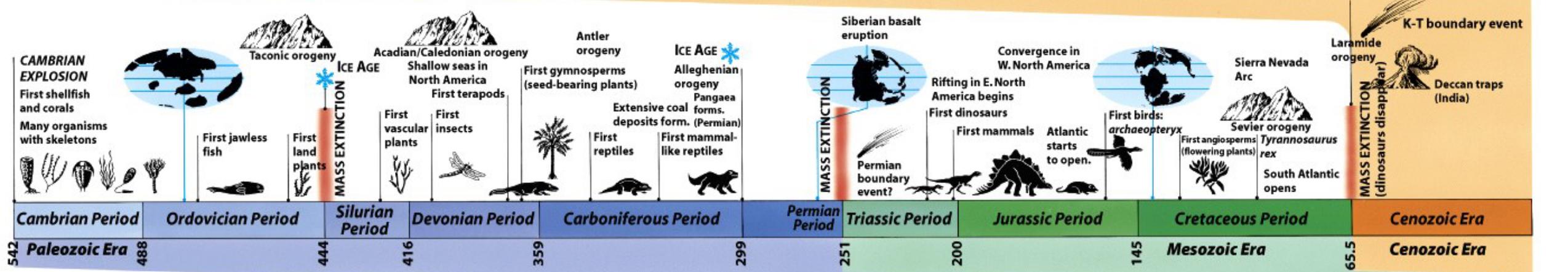
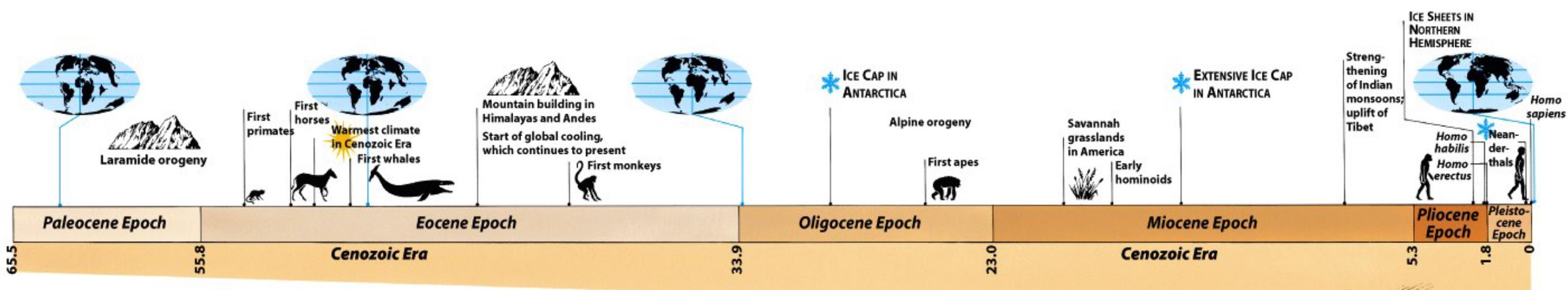
$\text{CaMg}(\text{CO}_3)_2$



Silurian - Dolomite and Carbonate Mounds

419 Ma
To
443 Ma

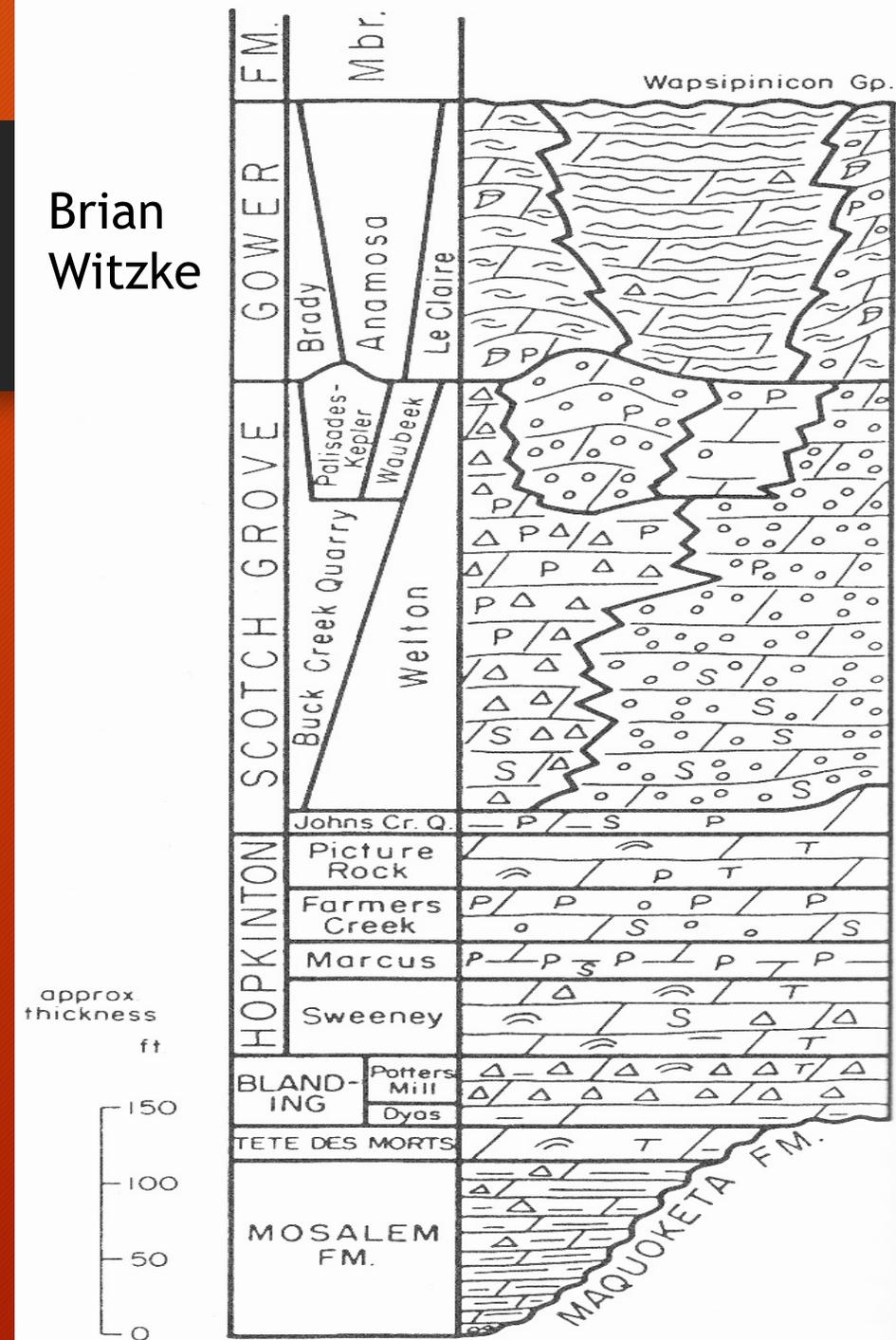
- Six Dolomite and two limestone formations, that provide the foundation for many of Eastern Iowa's State parks.
- There are five marine Transgression to Regression phases recorded in Iowa's Silurian Formations.
- These Silurian rocks have great economic value (agricultural lime, road aggregate, aggregate for concrete, building stone and as bedrock aquifers).
- Towards the end of the Silurian there was another period of weathering and erosion that created an unconformity between the Silurian and Devonian.



Silurian stratigraphy

- Dolostone formations
 - Mosalem
 - Tete des Morts
 - Blanding
 - Hopkinton
 - Scotch Grove
 - Gower
- Limestone formations
 - Waucoma
 - Le Porte City

Brian
Witzke



Hopkinton Formation

- Common in eastern Iowa
- Very-fine to coarsely crystalline dolostones with areas of nodular chert
- Contains four members
 - Sweeney
 - Marcus
 - Farmers Creek
 - Picture Rock



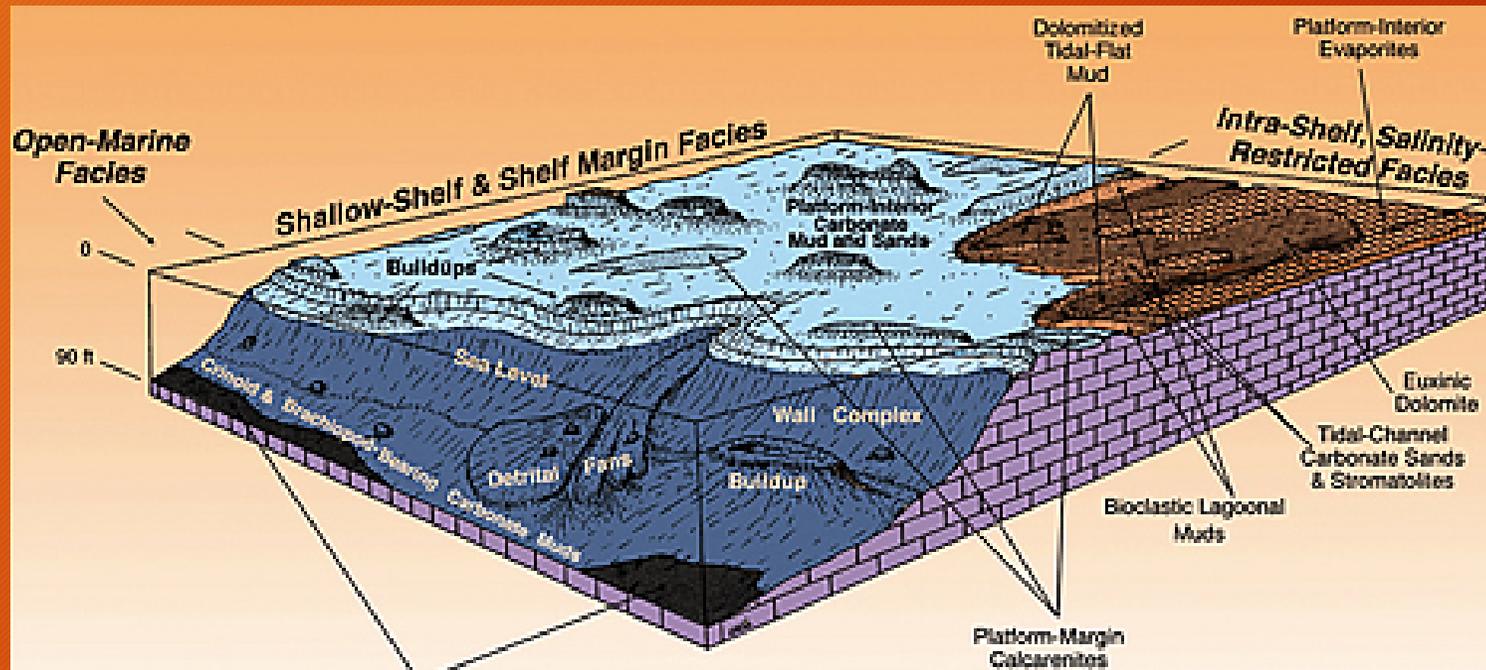
State Parks

- Maquoketa Caves State Park
- Backbone State Park
- Mississippi Palisades State Park
- Picture Rock County Park (Jones Co.)



Scotch Grove Formation

- Overlies the Hopkinton Fm. as dolostone with cherty intervals
- Represented by the natural bridge feature at Maq. Caves State Park



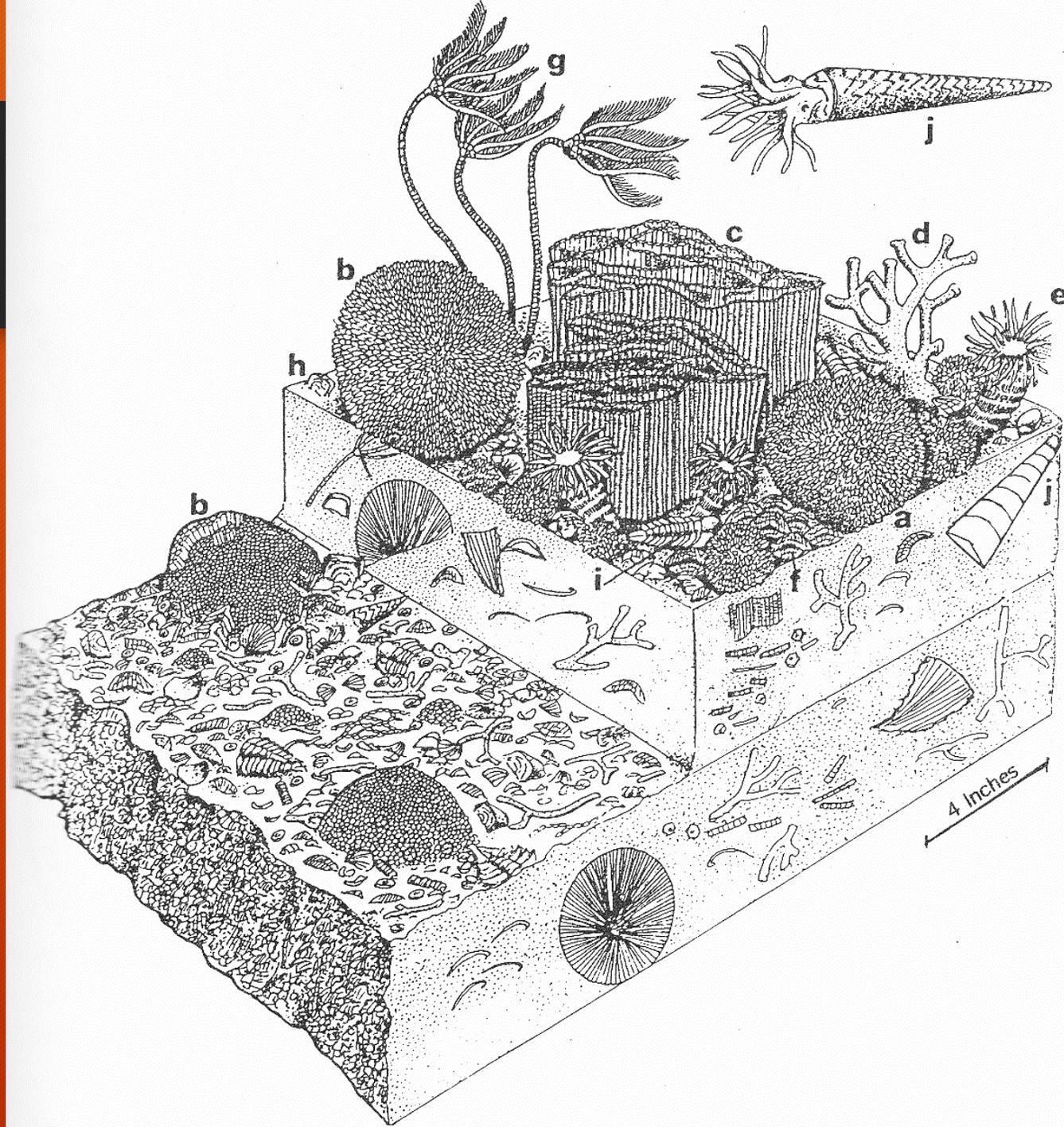
Anamosa Facies - Ideal building stone

- Uniform bedding
- Fine consistent texture
- Used for many of Iowa's early buildings
 - Rock Island Arsenal (IL)
 - Anamosa Prison
 - Stone City, IA
 - Cornell College
 - Herbert Hoover Presidential Lib.
 - Three large buildings in downtown Minneapolis

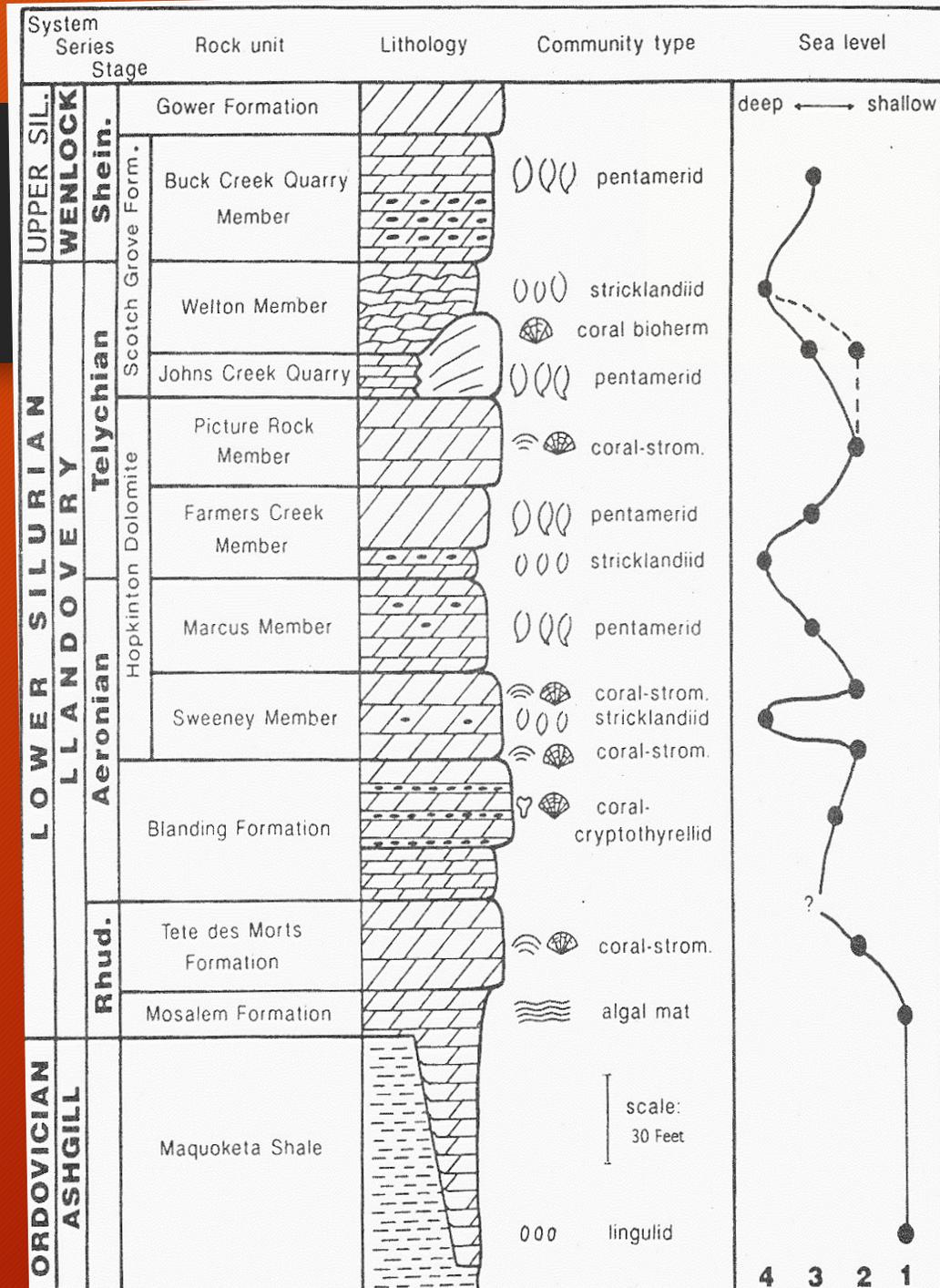


Silurian Life

- Colonial corals
 - Favosites
 - Halysites
- Solitary corals
- Brachiopods
- Algae



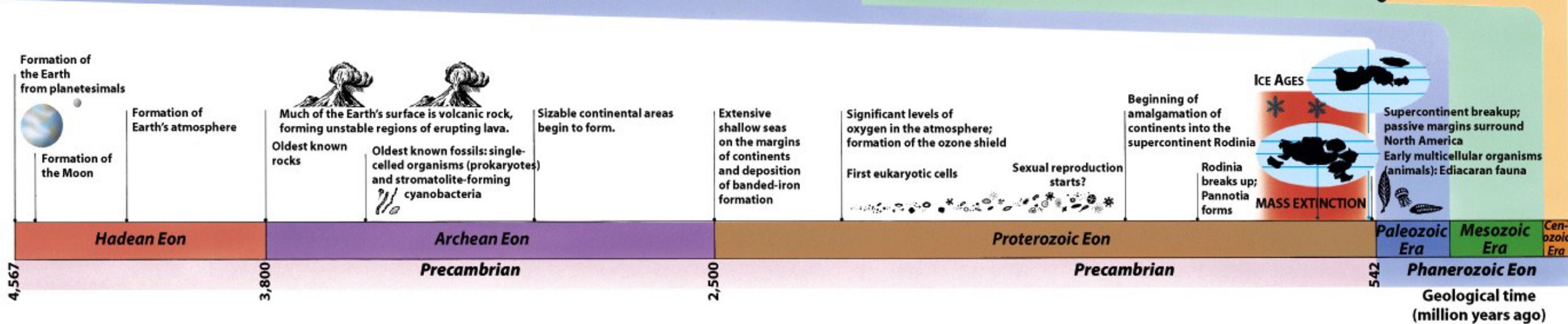
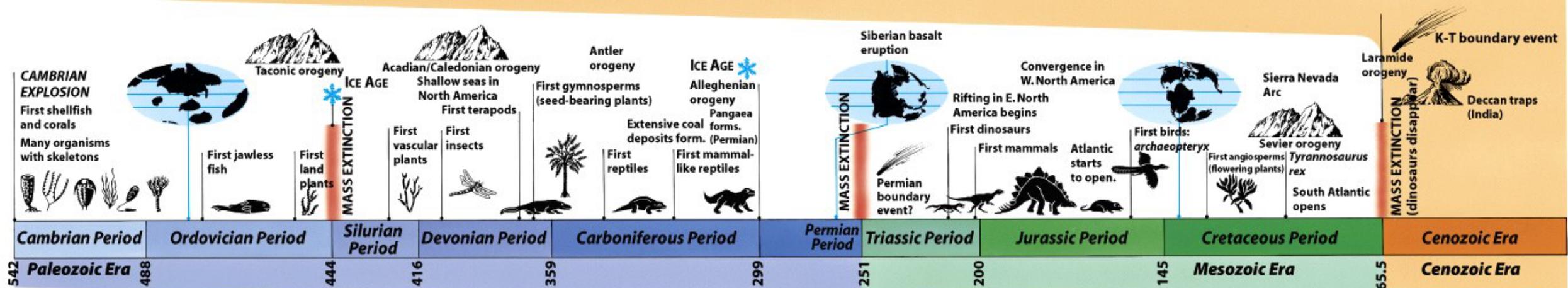
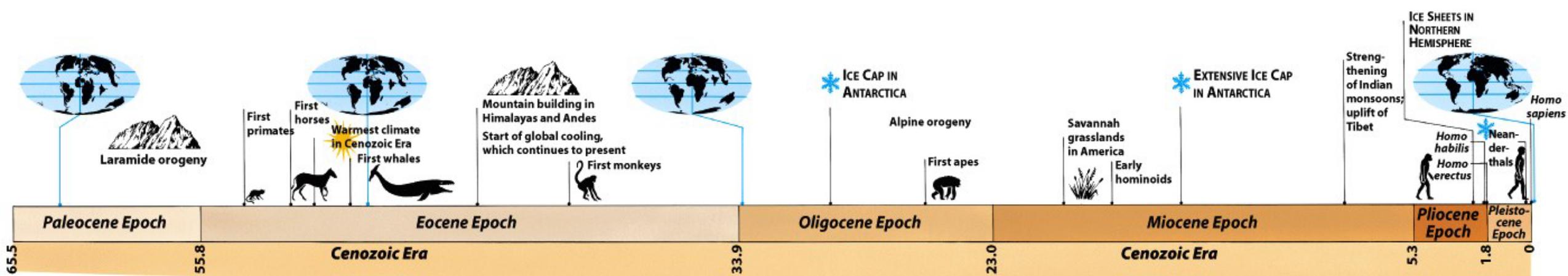
Applied paleontology



Devonian - A Marine Extravaganza 😊

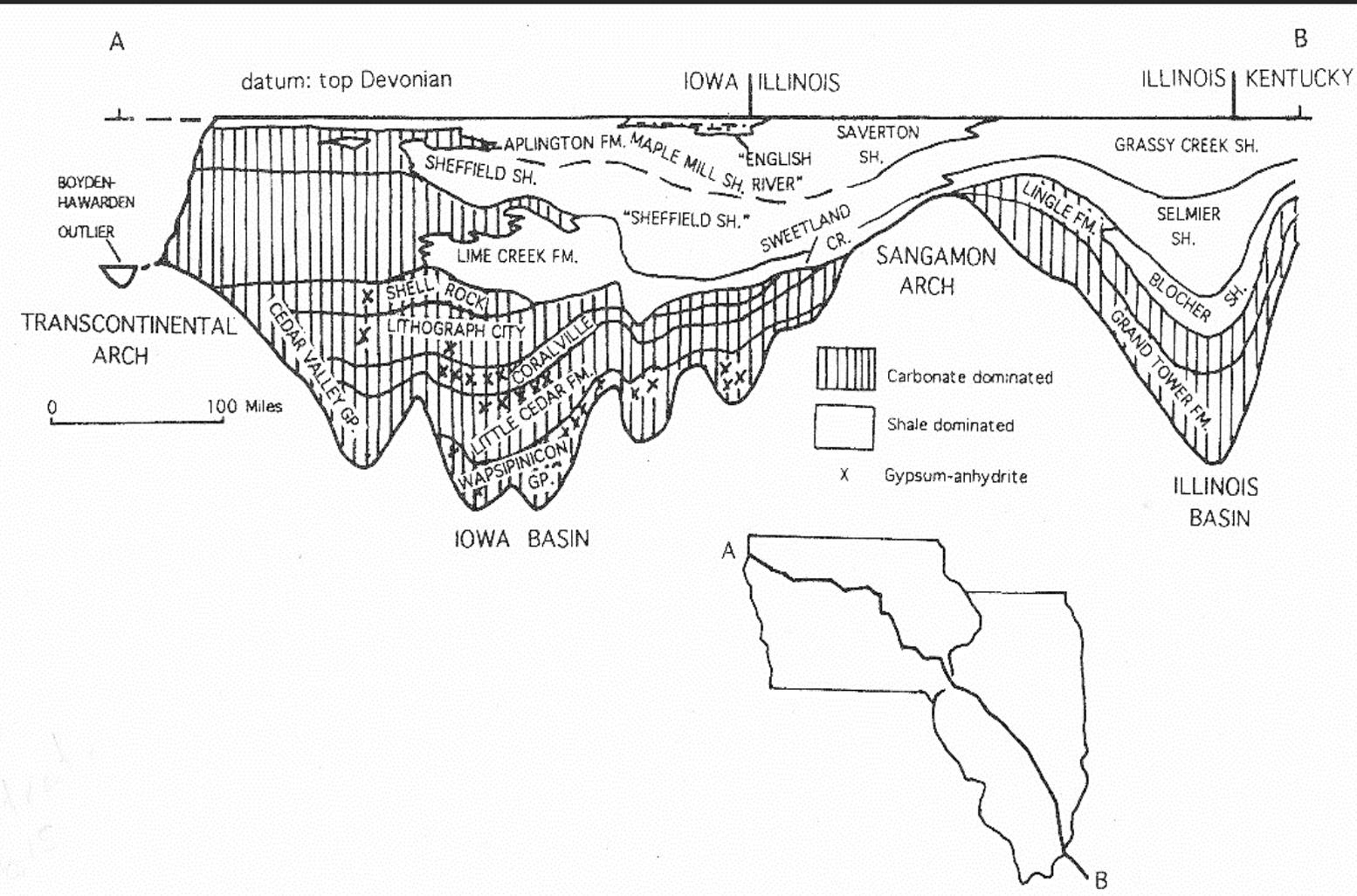
358 Ma
To
419 Ma

- The Devonian System contains 13 formations.
- Economically valuable resource for road and concrete aggregate in eastern Iowa and gypsum is mined southeastern and north-central Iowa for Portland Cement.
- The Devonian System also serves as an important aquifer/water source for eastern and north-central Iowa.
- These formations also contain significant and well preserved fossils



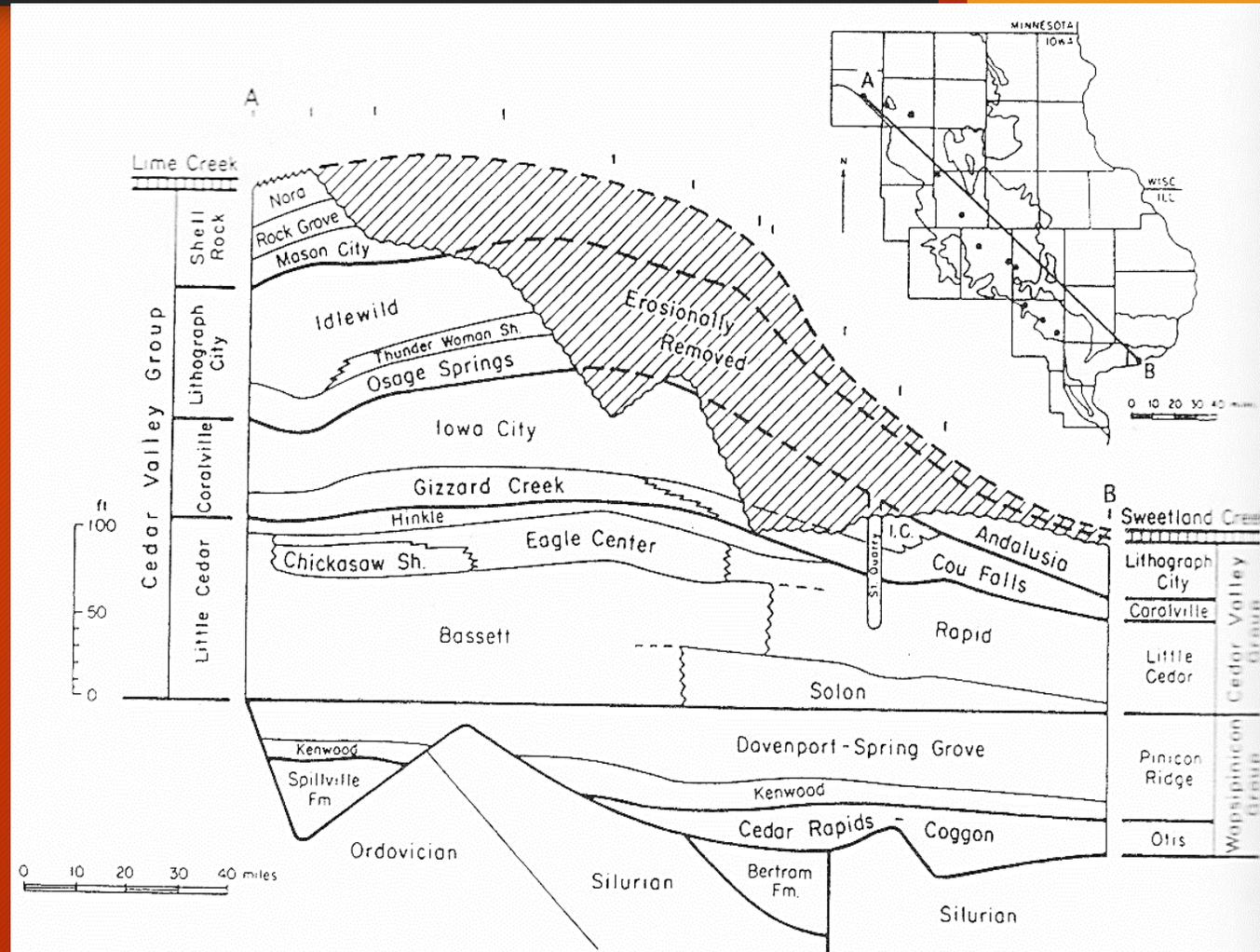
Geological time (million years ago)

Regional stratigraphy



Little Cedar Formation

- Basal Fm. of the Cedar Valley Group
- Solon Member is mostly limestone with abundant fossils
- Rapid Member fine-grained argillaceous limestone that is also fossil rich

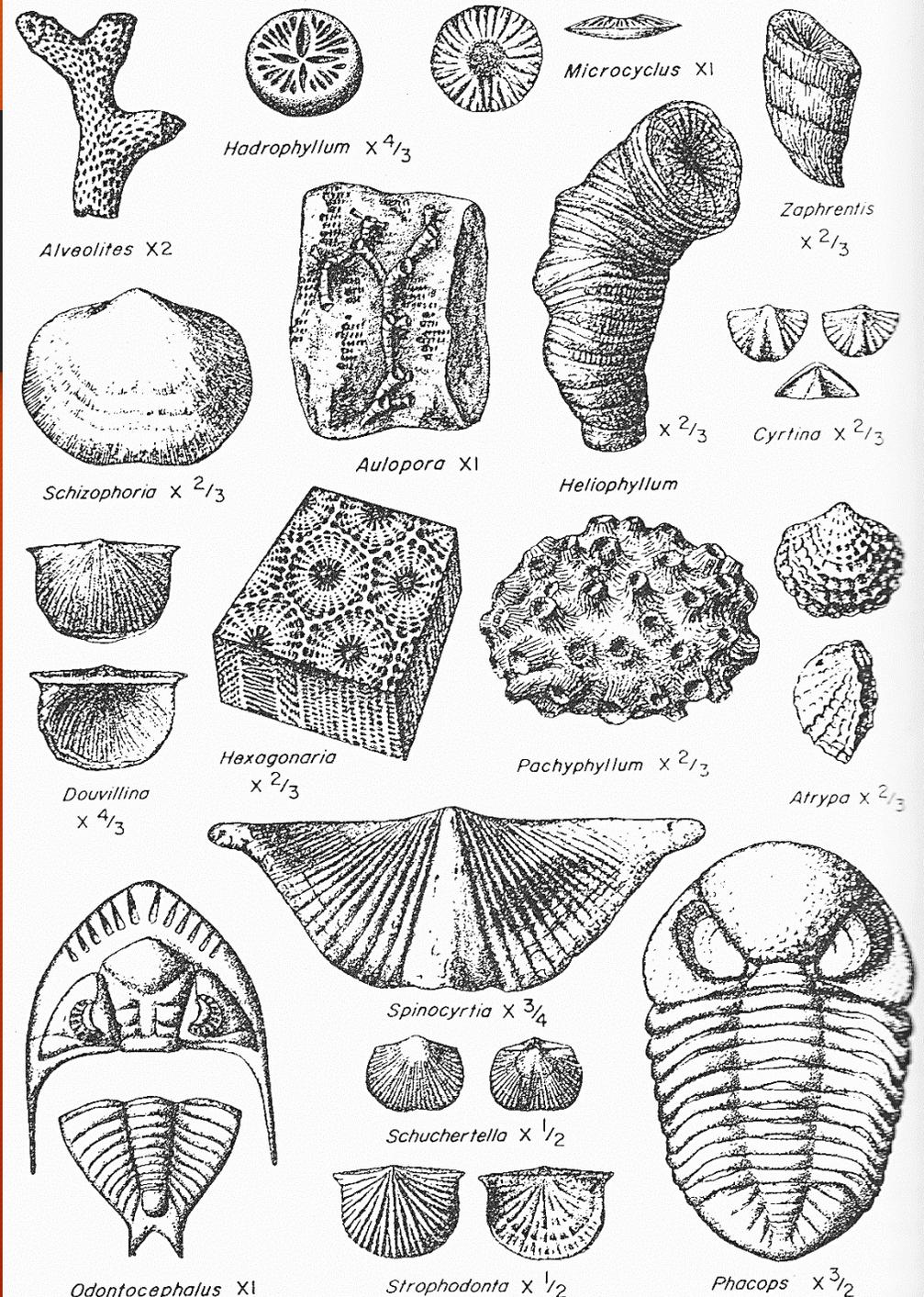
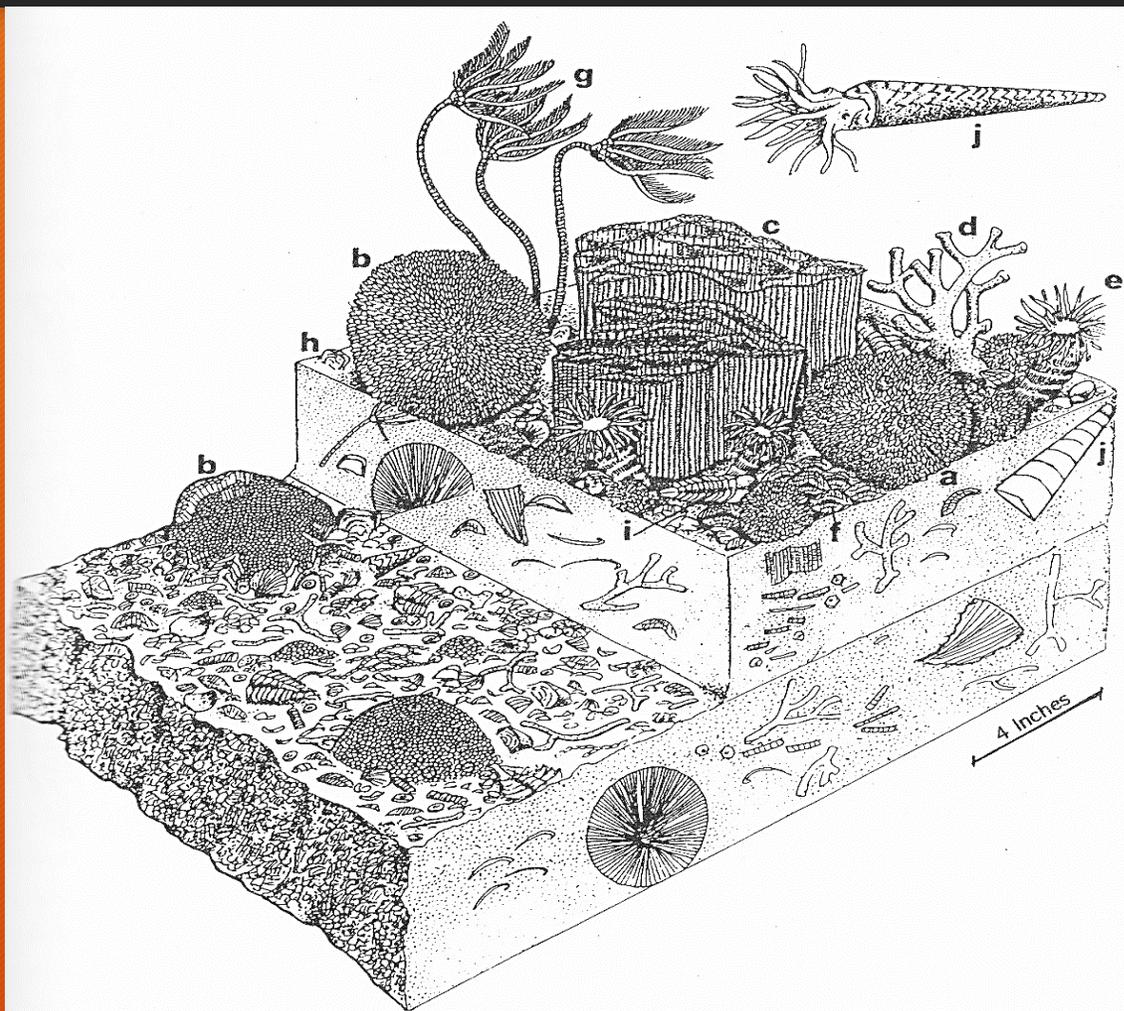


Lithograph City Formation

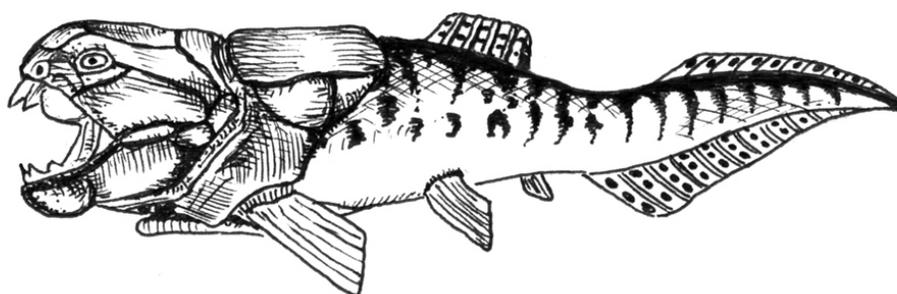
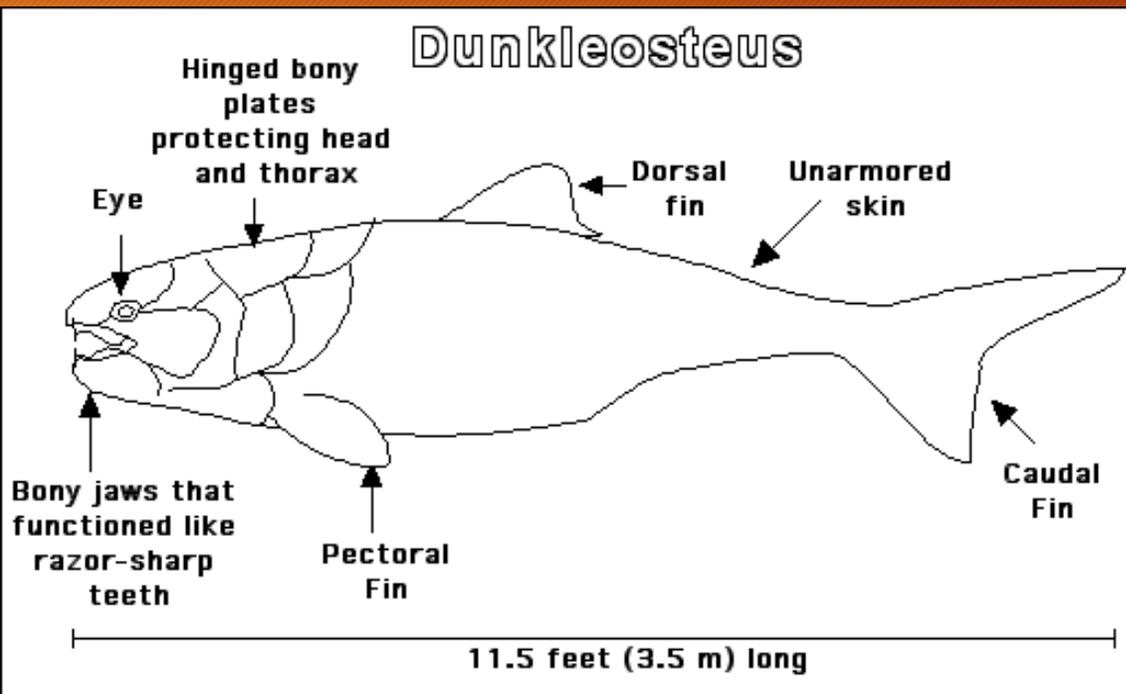
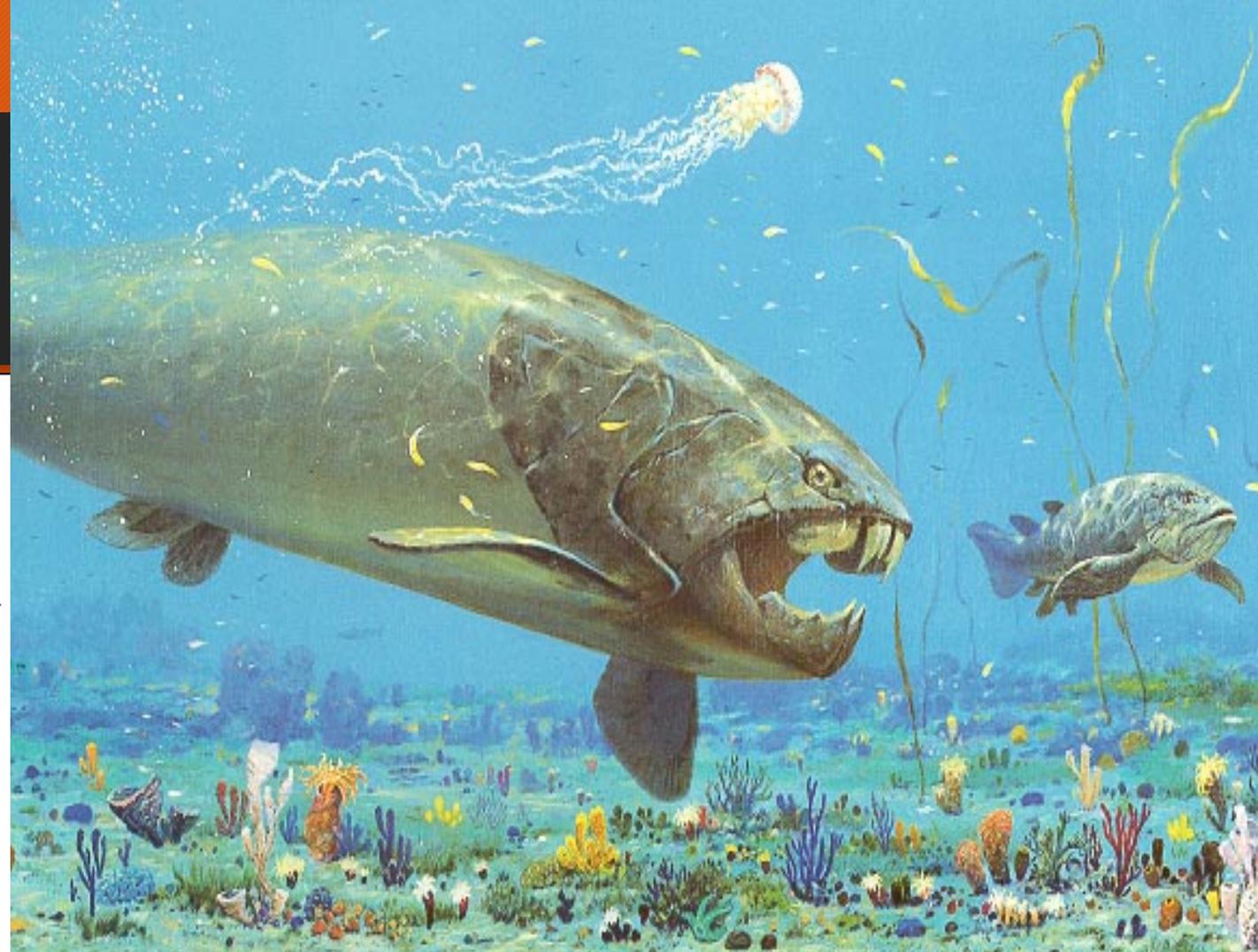
- An extremely fine grained / pure limestone
- Used for Lithography in the early 1900.
Lithography City - Floyd-Mitchell county line
- Quarried extensively for road and concrete aggregate as well as Portland Cement



Devonian Life



Devonian Life



Devonian Life - Via the Devonian Fossil Gorge



Carboniferous - Mississippian - Last major sea

323 Ma
To
358 Ma

