Lower Mississippian Sequence Stratigraphy and Depositional Dynamics: Insights from the Outcrops, Northwestern Arkansas and Southwestern Missouri

Walter L. Manger
Professor of Geology, Emeritus
University of Arkansas
Fayetteville, Arkansas

INSIGHTS

1. The Mississippian Lime section represents a single, third-order (unconformity-bounded), transgressive-regressive, eustatic cycle.
2. Higher order cycles are also present, possibly reflecting climatic signatures.
3. Lower Mississippian lithologies reflect an impoverished, cratonic, carbonate "factory" dominated by crinozoan detritus and carbonate mud produced at very high rates within effective wave base.
4. Apparently, the play is developed in carbonates, potentially including oolite, that were transported down-ramp as lobate bodies and grain flows, and deposited below both effective and storm wave base.

INSIGHTS, cont.

5. Chert characterizes the maximum flooding and highstand/regressive portions of the eustatic cycle.
6. Penecontemporaneous chert – black, nodular, non- to poorly fossiliferous, disrupts bedding - formed below the sediment-water interface before the sediment was indurated during maximum flooding.
7. Later diagenetic chert – white, bedded, fossiliferous, follows bedding – formed by groundwater replacement along bedding planes of lithified carbonate following regression.

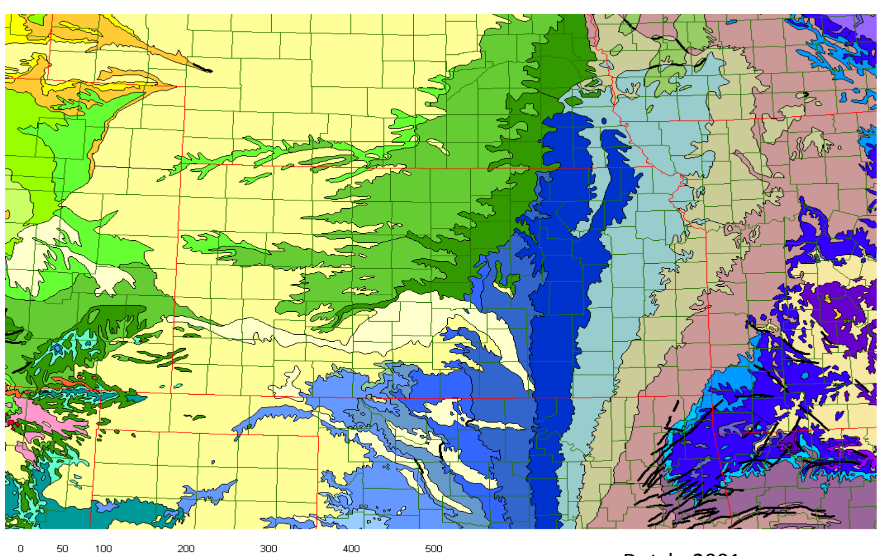
INSIGHTS, cont.

8. Lithostratigraphic nomenclature for the four state region (Missouri, Arkansas, Oklahoma, Kansas) generally recognizes a chert-free, transgressive succession, succeeded by chert-bearing, maximum flooding and highstand/regressive successions.
9. The chert-free interval is thin compared to the chert-bearing interval, and condensed, representing all or part of seven conodont zones and spanning the Kinderhookian-Osagean boundary.
10. The chert-free interval is apparently dolomitized in the subsurface and exhibits matrix porosity, yet in outcrop, it is mud-dominated, for the most part, and tight.
11. For the most part, lithostratigraphic subdivisions of the chert-bearing interval are based on chert development.

INSIGHTS, cont.

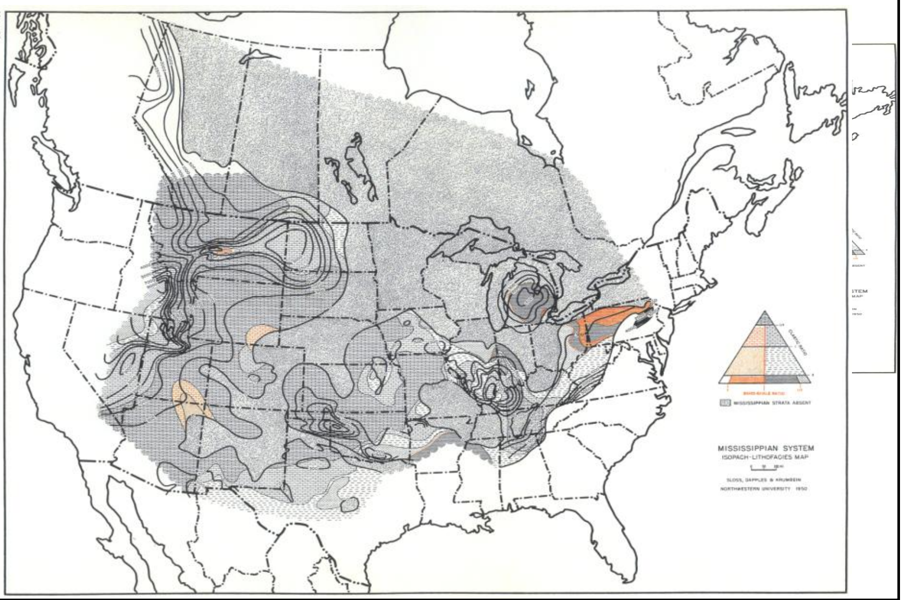
12. Maximum flooding and highstand/regression lithostratigraphic subdivisions have not been mapped and their validity is suspect.
13. Highly fractured zones occur in both the penecontemporaneous chert of the maximum flooding interval, and the later diagenetic chert of the highstand/regressive systems tracts.
14. Tripolitic chert reservoirs appear to be confined to the highstand/ regressive interval. If so, it cannot represent intraformational unconformity development since that chert is a groundwater replacement.
15. The chert-bearing interval was deposited very rapidly, representing only three conodont zones and may span the Osagean-Meramecan boundary in some sections.
16. Where complete, the Lower Mississippian cycle concludes with crinozoan grainstones deposited *in situ* within effective wave base

GEOLOGY OF THE NORTHERN AMERICAN MIDCONTINENT

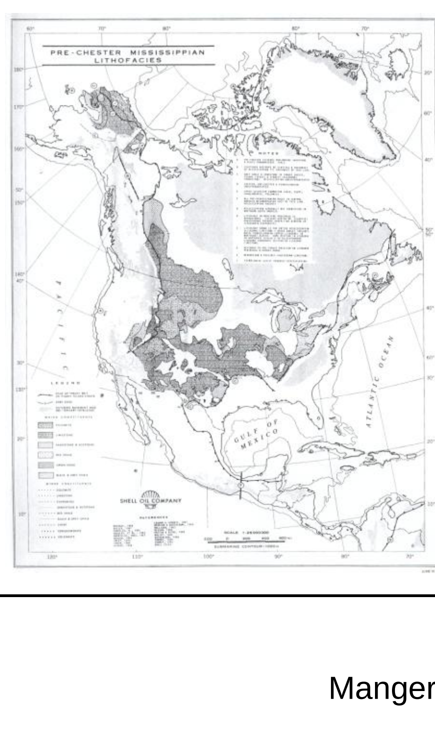


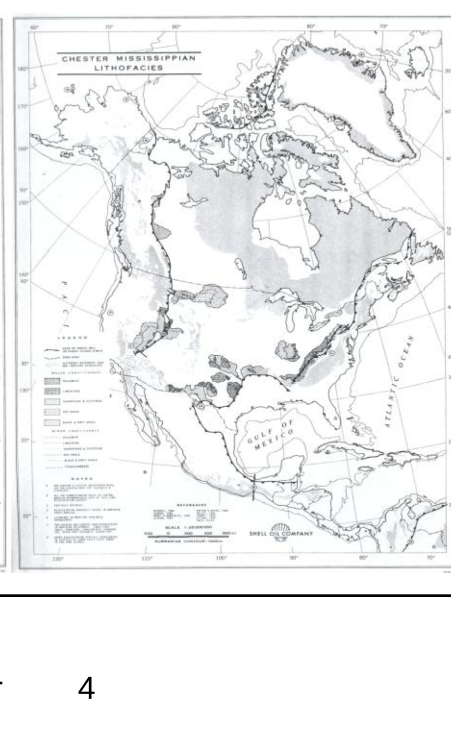
Dutch, 2001

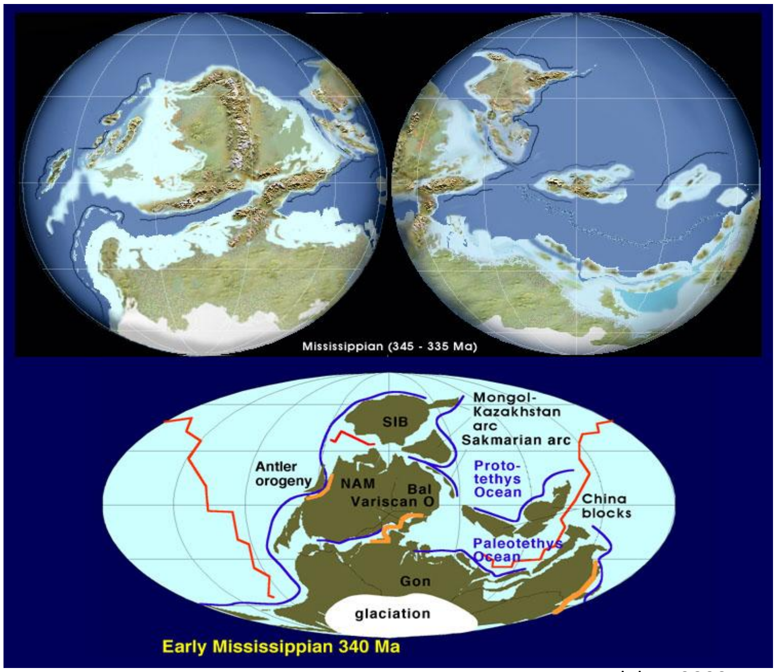
MISSISSIPPIAN LITHOFACIES (SLOSS, DAPPLES, AND KRUMBEIN, 1960)



Pre-CHESTERIAN/CHESTERIAN LITHOFACIES – SHELL, 1970

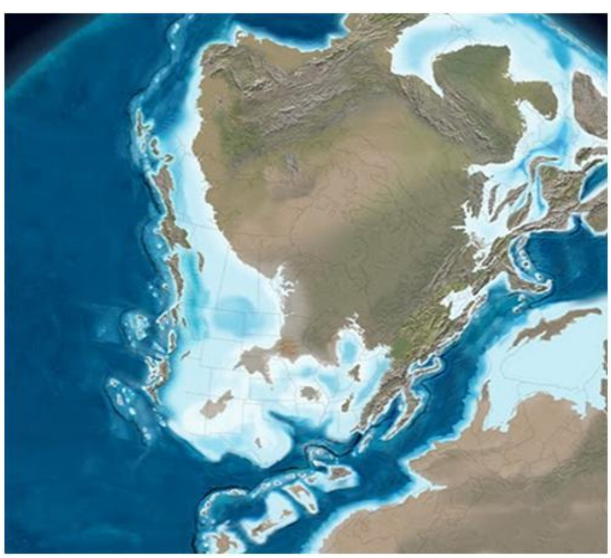




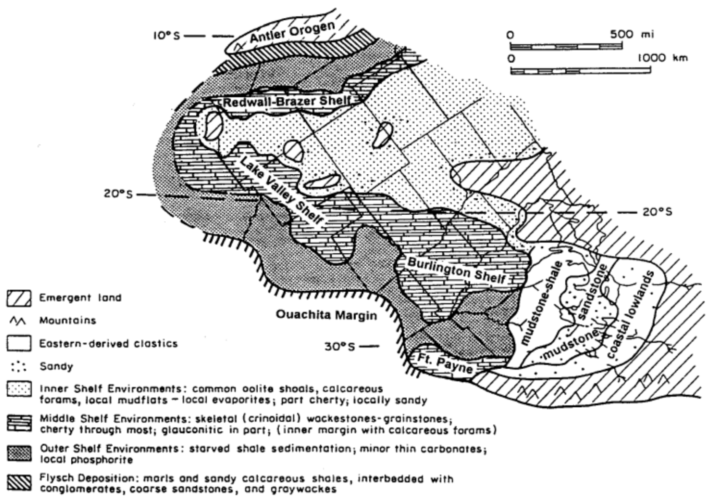


Blakey, 2000

LOWER MISSISSIPPIAN PALEOGEOGRAPHY (BLAKEY, 2009)

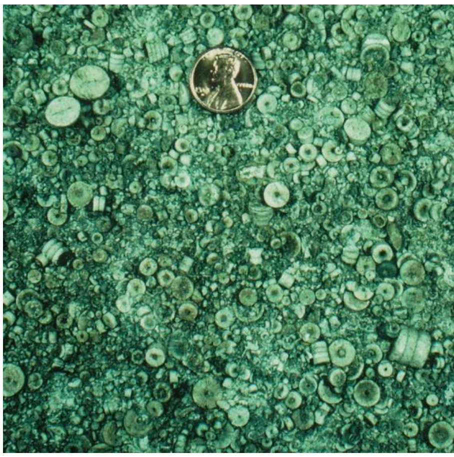


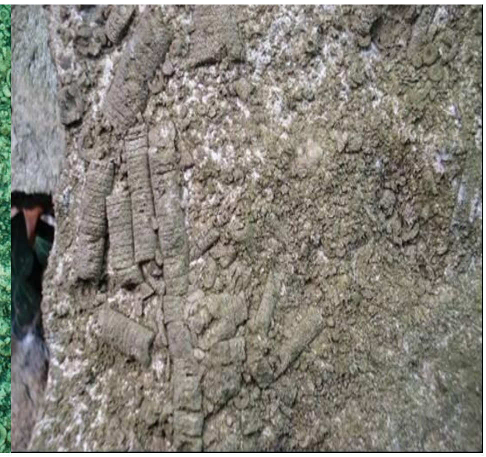
EARLY MISSISSIPPIAN PALEOGEOGRAPHY, SOUTHERN MIDCONTINENT, NORTH AMERICA (WITZKE AND OTHERS, 1990)



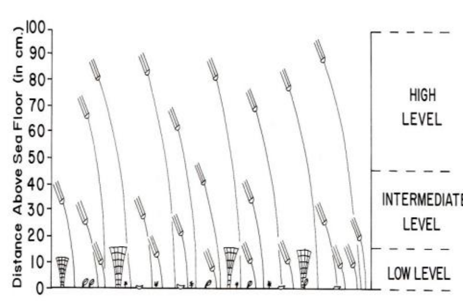
AERIAL VIEW – BAHAMA PLATFORM

CARBONATE FACTORY 1 - CRINOZOANS – LIVING AND FOSSIL



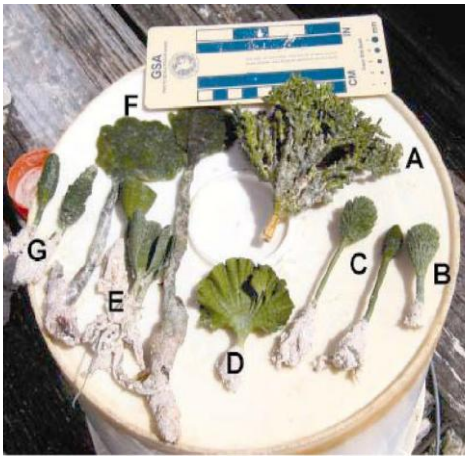


MODERN CRINOIDS AND NICHE TIERING



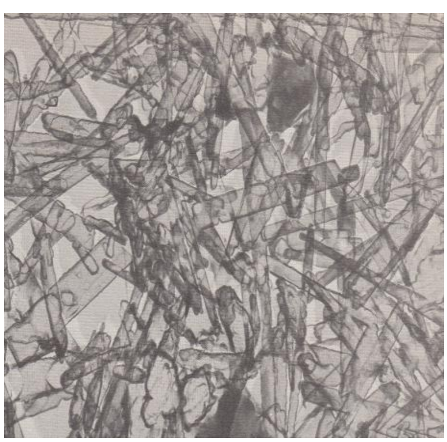
Ausich, 1980

CARBONATE FACTORY 2 – CALCAREOUS ALGAE



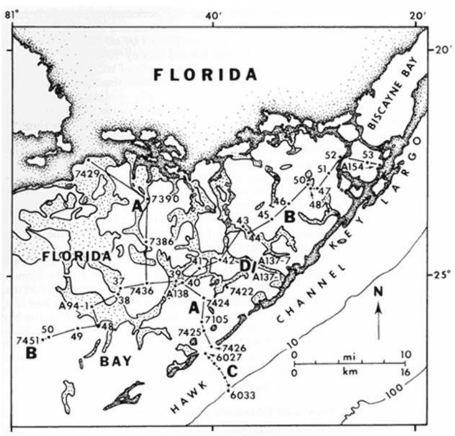
STOCKMAN, GINSBURG AND SHINN, 1967

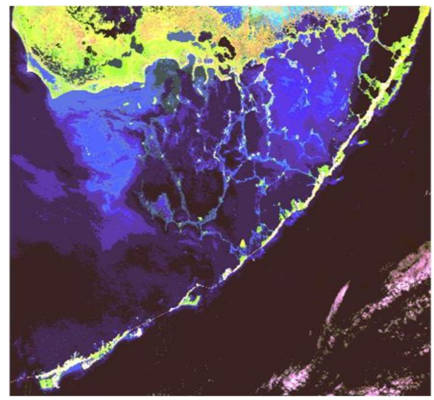
CARBONATE FACTORY 2 - LIME MUDSTONE / MICRITE



FOLK, 1959 – DUNHAM, 1959

AERIAL VIEW - FLORIDA BAY





CARBONATE MUD FACTORY WITH NET LOSS IN MUD VOLUME

CRATONIC SEQUENCES, OROGENIC AND TECTONIC EVENTS IN THE HISTORY OF THE NORTH AMERICAN CRATON (LEVIN, 1991)

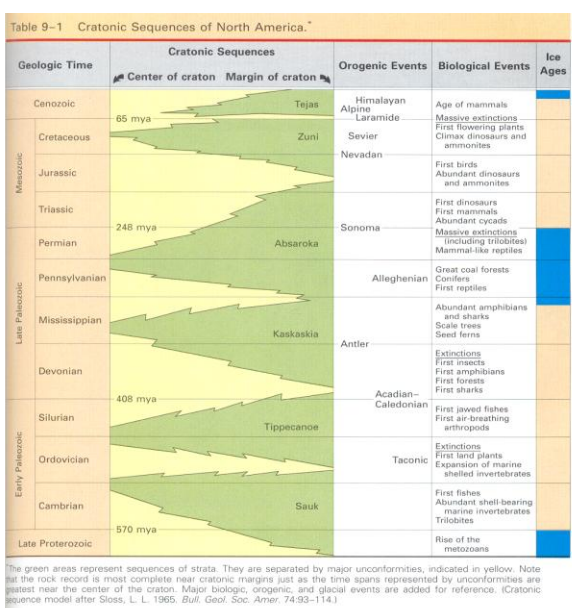
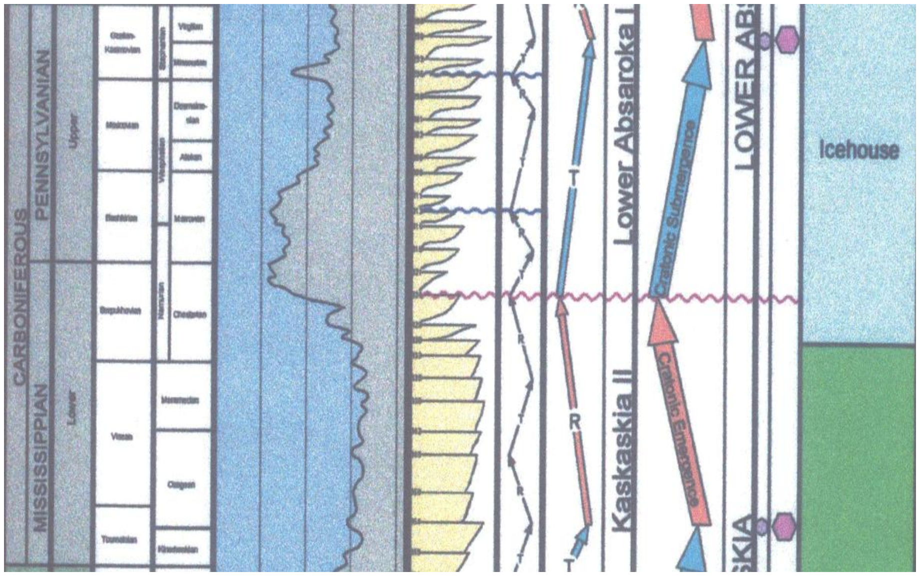


Table 9–1 Cratonic Sequences of North America.*

Geologic Time		Cratonic Sequences (Center of craton – Margin of craton)	Orogenic Events	Biological Events	Ice Ages
Cenozoic		Tejas	Himalayan, Alpine, Laramide	Age of mammals; Massive extinctions	
		65 mya			
Mesozoic	Cretaceous	Zuni	Sevier	First flowering plants; Climax dinosaurs and ammonites	
	Jurassic		Nevadan	First birds; Abundant dinosaurs and ammonites	
	Triassic			First dinosaurs; First mammals; Abundant cycads	
		248 mya	Sonoma		
Late Paleozoic	Permian	Absaroka		Massive extinctions (including trilobites); Mammal-like reptiles	
	Pennsylvanian		Alleghenian	Great coal forests; Conifers; First reptiles	
	Mississippian	Kaskaskia		Abundant amphibians and sharks; Scale trees; Seed ferns	
	Devonian		Antler	Extinctions; First insects; First amphibians; First forests; First sharks	
		408 mya	Acadian–Caledonian		
Early Paleozoic	Silurian	Tippecanoe		First jawed fishes; First air-breathing arthropods	
	Ordovician		Taconic	Extinctions; First land plants; Expansion of marine shelled invertebrates	
	Cambrian	Sauk		First fishes; Abundant shell-bearing marine invertebrates; Trilobites	
		570 mya			
Late Proterozoic				Rise of the metozoans	

*The green areas represent sequences of strata. They are separated by major unconformities, indicated in yellow. Note that the rock record is most complete near cratonic margins just as the time spans represented by unconformities are greatest near the center of the craton. Major biologic, orogenic, and glacial events are added for reference. (Cratonic sequence model after Sloss, L. L. 1965. *Bull. Geol. Soc. Amer.* 74:93–114.)

CORRELATION OF ORDERS OF CARBONIFEROUS EUSTATIC CYCLICITY (Waite, 2002)



MISSISSIPPIAN LITHOSTRATIGRAPHY – SOUTHWESTERN MISSOURI – THOMPSON, 1986

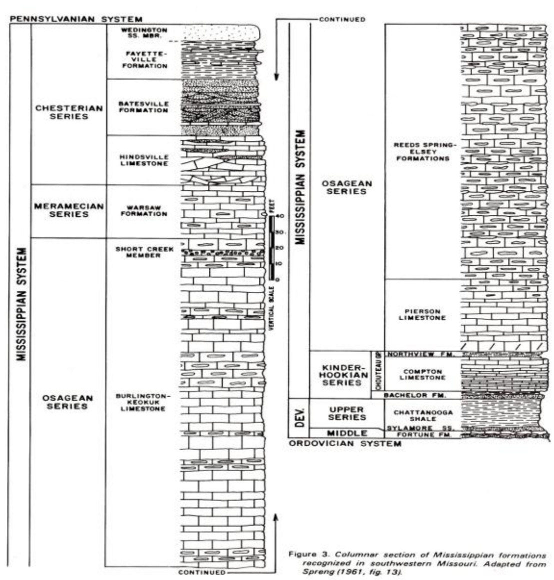
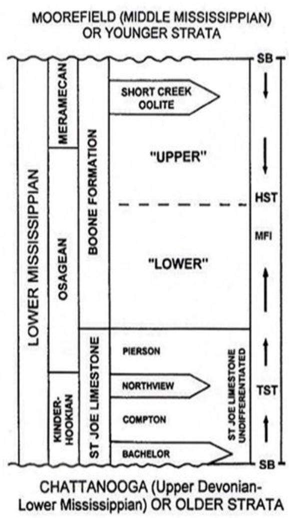
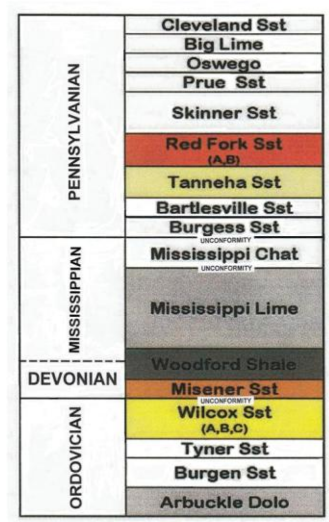


Figure 3. Columnar section of Mississippian formations recognized in southwestern Missouri. Adapted from Spreng (1961, fig. 13).

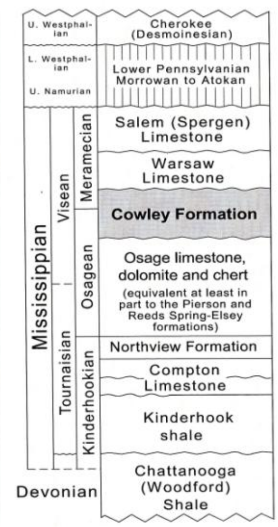
LOWER MISSISSIPPIAN LITHOSTRATIGRAPHY, SOUTHERN MIDCONTINENT



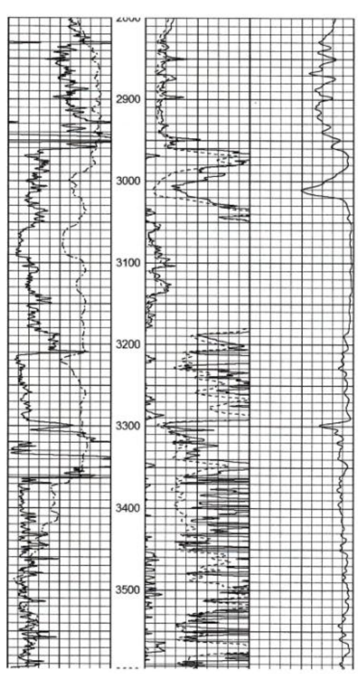
ARKANSAS (Manger and Shelby, 2000)



OKLAHOMA



KANSAS (Mazzullo and others, 2009)



PENNSYLVANIAN SECTION

MISSISSIPPI CHAT ?

UPPER BOONE

CHERT-BEARING CRINOIDAL LIMESTONE

LOWER BOONE

CHERT-FREE DOLOMITIC LIMESTONE
ST. JOE LIMESTONE

WOODFORD

ARBUCKLE

OLSEN #2 WELL
OSAGE CO., OK

LOWER MISSISSIPPIAN OUTCROP, NORTHWESTERN ARKANSAS

TRANSGRESSION TO MAXIMUM FLOODING INTERVAL = ST JOE AND LOWER BOONE

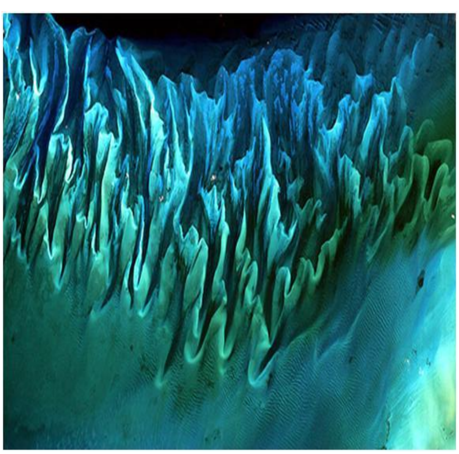
GRAIN FLOW DEPOSITIONAL CYCLES – CLIMATIC SIGNATURE?

HIGH ORDER CYCLES IN COMPTON INTERVAL

FLOATING CRINOZOAN DETRITUS IN MUD MATRIX – PIERSON INTERVAL

AERIAL VIEW – BAHAMA PLATFORM

SEDIMENT MOVEMENT AT SOUTHEASTERN END OF TONGUE OF THE OCEAN, BAHAMAS



This sediment is mostly clean carbonate sand

SEDIMENT MOVEMENT, SOUTH CAT CAY, BAHAMA PLATFORM

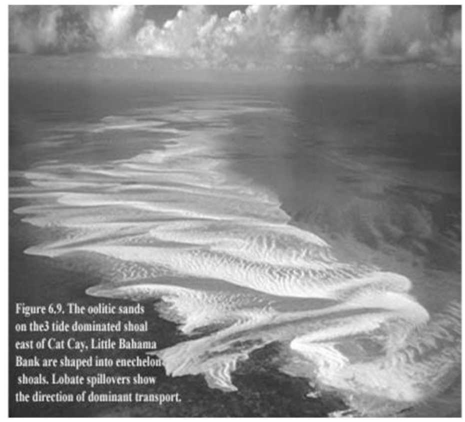
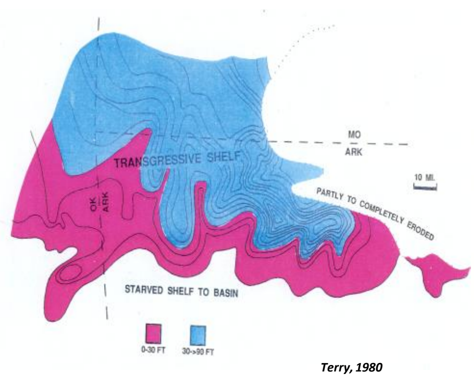


Figure 6.9. The oolitic sands on the3 tide dominated shoal east of Cat Cay, Little Bahama Bank are shaped into enechelon shoals. Lobate spillovers show the direction of dominant transport.

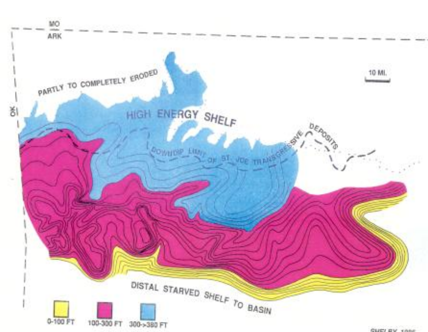
This sediment is clean oolite

LOWER MISSISSIPPIAN ISOPACHOUS MAPS – ST JOE AND BOONE



ST JOE – MIDDLE KINDERHOOKIAN to LOWER OSAGEAN

BOONE – MIDDLE to UPPER OSAGEAN – MERAMECAN?



PENECONTEMPORANEOUS CHERT – LOWER BOONE – MAXIMUM FLOODING INTERVAL

Opal – A ➞ Opal – CT ➞ Chalcedony ➞ Quartz
Shrinkage fractures from de-watering
Fractured chert – reservoir?

LATER DIAGENETIC CHERT – UPPER BOONE – HIGHSTAND AND REGRESSION

Groundwater Replacement Along Bedding Planes

UPPER BOONE MISSISSIPPIAN OUTCROP, NORTHWESTERN ARKANSAS

DEPOSITION WITHIN EFFECTIVE WAVE BASE

REGRESSIVE CARBONATES
WITH DIAGENETIC CHERT REPLACEMENT
ALONG BEDDING PLANES

LOBATE GEOMETRY – UPPER BOONE

WHITE = TRIPOLITIC CHERT/BROWN = LIMESTONE
INTRA-LOBE INCREASE IN DIP, THICKENING, AND
APPARENT GROWTH FAULT

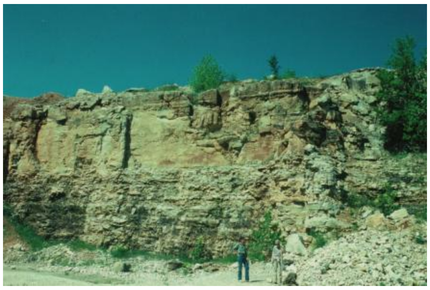
TRIPOLIC CHERT RESERVOIR – HIGHSTAND/REGRESSION – UPPER BOONE

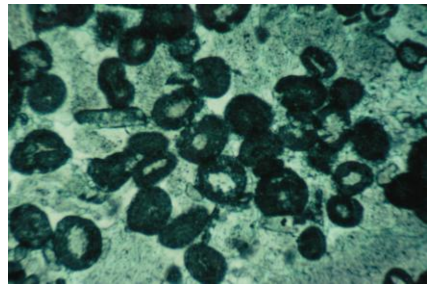
KEOKUK – REGRESSIVE SEQUENCE

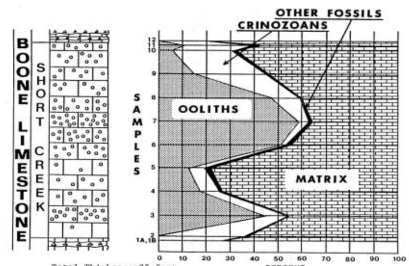
Return to Effective Wave Base

Mobile Skeletal Sand of Crinozoan Detritus

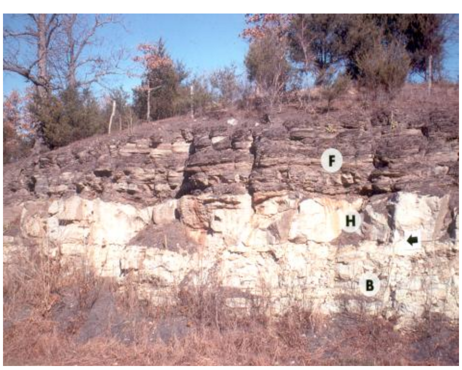
SHORT CREEK OOLITE – GRAIN FLOW DEPOSIT – WAR EAGLE QUARRY - ARKANSAS



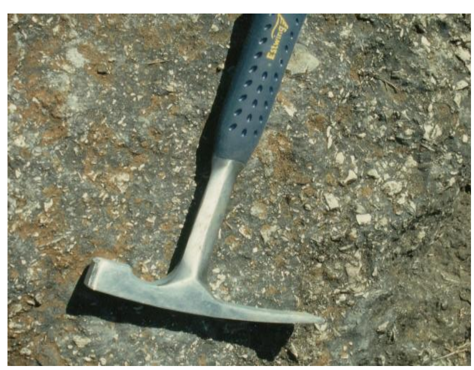




OSAGEAN-CHESTERIAN UNCONFORMITY – THIRD-ORDER SEQUENCE BOUNDARY



BOONE-HINDSVILLE UNCONFORMITY (ARROW)

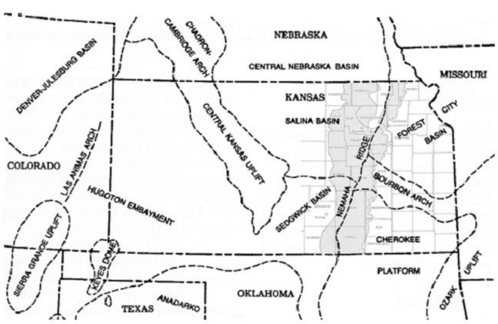


BASAL HINDSVILLE BRECCIA DERIVED FROM UPPER BOONE LATER DIAGENETIC CHERT

A FEW QUESTIONS NEEDING ANSWERS

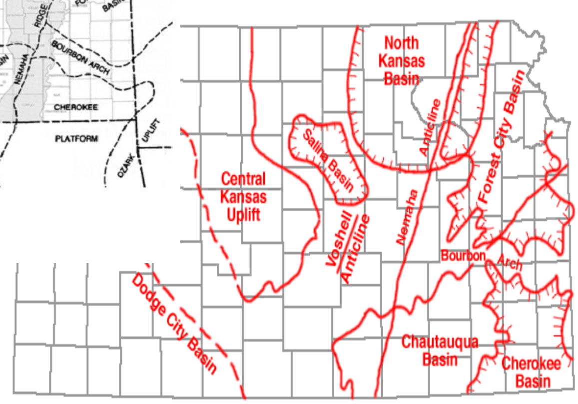
1. Are both the maximum flooding (= Lower Boone) and highstand/regressive (= Upper Boone) intervals productive?
2. What types of reservoir intervals are developed?
3. Can the Lower Boone equivalent be tripolitic?
4. What is the geometry, distribution, and origin of the tripolitic chert intervals?
5. Can lobe, shelf, and carbonate “factory” geometries be determined, and do those geometries influence the distribution of reservoir quality carbonates?
6. What is the history of cratonic basin formation (Chautauqua,Cherokee, Forest City) in the play area?
7. What influence, if any, did basin formation have on the distribution of reservoir quality carbonates?

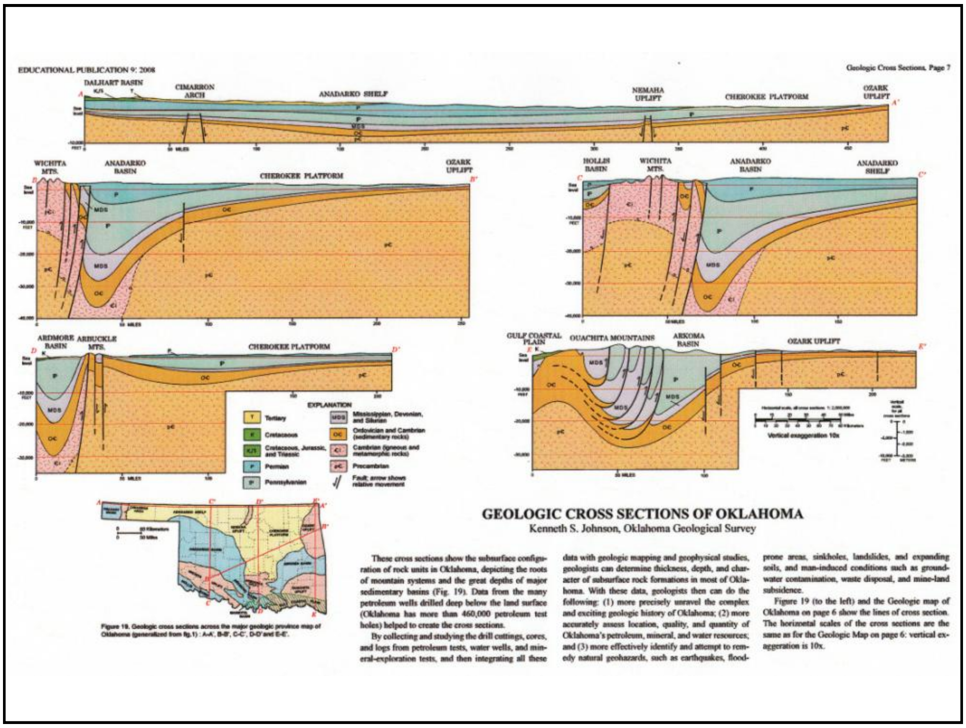
CHEROKEE BASIN THROUGH TIME



PRE-PENNSYLVANIAN (BELOW)
Leatherock, 1945

PENNSYLVANIAN AND LATER (ABOVE)
Chaplin, 1988

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Geologic Cross Sections, Page 7

Figure 19. Geologic cross sections across the major geologic province map of Oklahoma (generalized from fig.1) : A-A', B-B', C-C', D-D' and E-E'.

GEOLOGIC CROSS SECTIONS OF OKLAHOMA

Kenneth S. Johnson, Oklahoma Geological Survey

These cross sections show the subsurface configuration of rock units in Oklahoma, depicting the roots of mountain systems and the great depths of major sedimentary basins (Fig. 19). Data from the many petroleum wells drilled deep below the land surface (Oklahoma has more than 460,000 petroleum test holes) helped to create the cross sections.

By collecting and studying the drill cuttings, cores, and logs from petroleum tests, water wells, and mineral-exploration tests, and then integrating all these data with geologic mapping and geophysical studies, geologists can determine thickness, depth, and character of subsurface rock formations in most of Oklahoma. With these data, geologists then can do the following: (1) more precisely unravel the complex and exciting geologic history of Oklahoma; (2) more accurately assess location, quality, and quantity of Oklahoma's petroleum, mineral, and water resources; and (3) more effectively identify and attempt to remedy natural geohazards, such as earthquakes, flood-prone areas, sinkholes, landslides, and expanding soils, and man-induced conditions such as groundwater contamination, waste disposal, and mine-land subsidence.

Figure 19 (to the left) and the Geologic map of Oklahoma on page 6 show the lines of cross section. The horizontal scales of the cross sections are the same as for the Geologic Map on page 6: vertical exaggeration is 10x.