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Lithostratigraphic Succession and Depositional Dynamics of the Lower Mississippian, Southern Ozarks, Northern Arkansas and Adjacent Areas

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Running Title: Lithostratigraphic and Depositional Dynamics of the Lower Mississippian Succession

Abstract

The Lower Mississippian interval comprises a single, third-order, eustatic cycle subdivided lithostratigraphically into the St. Joe Limestone (Hopkins 1893) and overlying Boone Formation (Branner 1891, Simonds 1891) with type areas in northern Arkansas. Coeval, homotaxial limestones occur in adjacent southwestern Missouri and northeastern Oklahoma, but neither Arkansas name is applied. To eliminate this "state line fault," Missouri formation names for the St. Joe interval are recognized in Arkansas as members (ascending order): Bachelor, Compton, Northview, Pierson. The Boone interval in Missouri is represented by the (ascending order): Reeds Spring, Elsey, Burlington-Keokuk undifferentiated, but utilization of those names in Arkansas is problematic. Chert development and characteristics associated with the Boone Formation in northern Arkansas have not been applied to the equivalent succession in Missouri. Consequently, in northern Arkansas, the Boone Formation is subdivided into informal lower and upper members based on chert development: lower with black to gray, penecontemporaneous chert; upper with white to light gray, later diagenetic chert. In adjacent northeastern Oklahoma, the nomenclature is a mixture of the Arkansas and Missouri names, but chert development is not used lithostratigraphically. The St. Joe Limestone rests unconformably on the Chattanooga Shale (Upper Devonian-Lower Mississippian) or older units marking the initial transgression of the Kaskaskian II Cycle (Vail et al. 1977). Thin-bedded, St. Joe crinozoan packstones represent bioclastic sediment and carbonate mud transported from its origin on the Burlington Platform (now Missouri), and down the adjacent northern Arkansas ramp in a lobate manner. Distal limestones are condensed and replaced by shale beyond the ramp. A brief drop in sea level represented by the terrigenous Northview Member, was followed by continued transgression through Pierson deposition, reaching maximum flooding without a break in the lower Boone (=Reeds Spring) represented by calcisiltites and penecontemporaneous chert. Highstand and regression are recorded in the upper Boone as rapidly deposited crinoidal packstones and grainstones with later diagenetic chert replacement.

Introduction

The Lower Mississippian succession is the thickest post-Ordovician, pre-Middle Pennsylvanian interval deposited across the tri-state area of northern Arkansas, southern Missouri, and northeastern Missouri. Lithostratigraphic nomenclature for this predominantly limestone succession has been applied inconsistently, while chert development, typical of the upper portion of the interval, has been ignored for the most part. In Arkansas, the oldest valid names applied to these strata are the St. Joe Limestone (Hopkins 1893) and overlying Boone Formation (Branner 1891, Simonds 1891) with type areas in northern Arkansas. The St. Joe Limestone rests unconformably on the Chattanooga Shale (Upper Devonian-Lower Mississippian) or older units marking initial transgression. The component carbonates were all produced on the Burlington Platform (now mostly Missouri) (Lane, 1978), and transported down the adjacent northern Arkansas ramp in a lobate manner. Initial deposition was condensed, followed by maximum flooding that occurred in the lower Boone Formation followed by highstand and regression recorded in the upper Boone as the rate of deposition increased.

Geologic Setting

The tri-state region of the southern Ozarks includes portions of northwestern Arkansas, southwestern Missouri, and northeastern Oklahoma exposing Paleozoic strata at the surface. This area includes portions of three broader geologic provinces: the Ozark

Dome and Arkoma Basin of northwestern Arkansas, and the Cherokee Platform in northeastern Oklahoma (Fig. 1). The south flank of the Ozark Dome comprises three plateau surfaces: Salem, Springfield and Boston Mountains, capped by Lower Ordovician, Lower Mississippian and Middle Pennsylvanian strata respectively (Fig. 1).

The Ozark Dome is a broad, asymmetrical, cratonic uplift cored by Precambrian granite and rhyolite exposed in the St. Francois Mountains region of southeastern Missouri (Fig. 1). The Paleozoic sedimentary record surrounding the core is dominated by thick carbonate intervals with subordinate terrigenous clastics punctuated by unconformities reflecting occasional domal uplifts. The Arkoma Basin forms the southern margin of the Ozark Dome as a foreland basin that formed in response to the Ouachita Orogeny beginning in the Middle Pennsylvanian. The western margin of the Ozark Dome is continuous with the Cherokee Platform in eastern Oklahoma that reflects a cratonic setting with a transgressive-regressive history of deposition by epeiric seas, but preserves little evidence of Ozark Dome diastrophism.

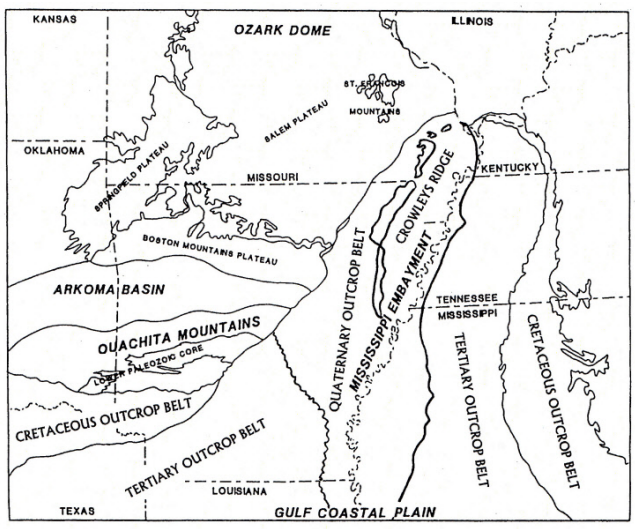

Fig. 1. Geologic Provinces of Arkansas and Adjacent Areas, Southern Midcontinent (modified from Manger, et al. 1988).

Sequence History

The Kaskaskia Sequence of the North American midcontinent essentially encompasses the Devonian and Mississippian Periods (Sloss 1963, 1982, Vail et al. 1977). Later, Sloss (1982) subdivided the Kaskaskia sequence into two second-order sequences: Kaskaskia I - Middle Devonian through the Lower Mississippian Kinderhookian Series, and Kaskaskia II – Osagean through the upper Chesterian Series. Subsequent usage has restricted the Kaskaskia I to the Devonian, and Kaskaskia II to the Mississippian (Vail et al. 1977; Ross and Ross 1987). The maximum flooding events of the first and second order Kaskaskian cycles occurred at about the Kinderhookian-Osagean boundary. The Kaskaskia II second order cycle encompasses two third-order cycles. The maximum flooding event of the lower Kaskaskia II third-order cycle also occurs at about the Kinderhookian-Osagean boundary (Ross and Ross 1987, Fig. 2). The lower Kaskaskia II third-order cycle may comprise as many as five fourth-order cycles (Ross and Ross 1987). Type 1 unconformities, produced when sea level drops below the edge of the continental shelf (Vail et al. 1977), mark the coeval first through third order cycle boundaries, and serve as the basis for the differentiation of the Kaskaskia I and II cycles. In the southern Ozarks, the third-order cycle comprising the St. Joe – Boone interval (Lower Mississippian) rests unconformably on the Chattanooga Shale (Upper Devonian-Lower Mississippian) or older units marking

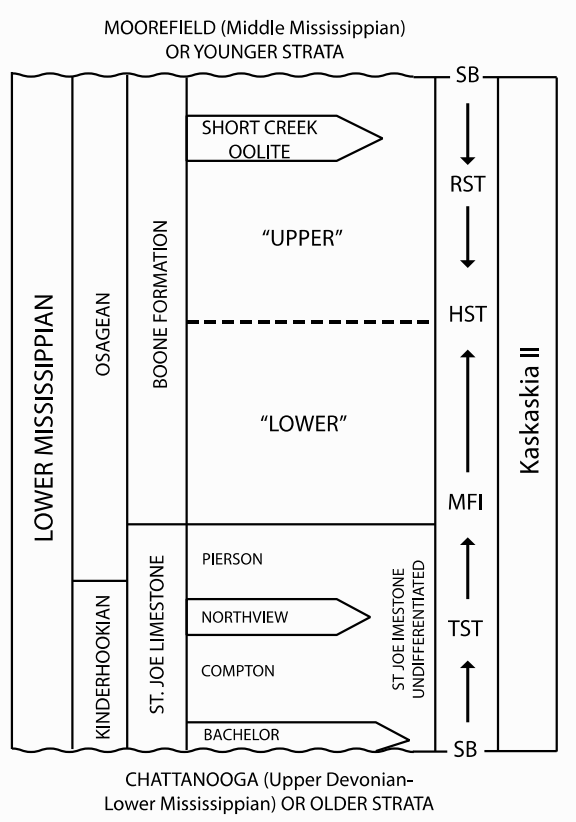

Fig. 2. Lithostratigraphy and Sequence History of the Lower Mississippian Interval, Southern Ozark Region, Northern Arkansas (modified from Manger and Shelby 2000).

the initial transgression of the Kaskaskian II Cycle (Fig. 2). The regressive phase of the Kaskaskia II cycle at the top of the Boone Formation produced a Type 1 unconformity overlain by Meramecian or younger strata in the tri-state region (Fig. 2).

Lithostratigraphy

The lithostratigraphic nomenclature for the Lower Mississippian succession in the tri-state area of northern Arkansas, southwestern Missouri, and northeastern Oklahoma have traditionally recognized a chert-free limestone interval succeeded by a chert-bearing limestone interval (= St. Joe-Boone). However, application of lithostratigraphic nomenclature is inconsistent, making the understanding of St. Joe-Boone interval difficult.

St. Joe Limestone – The St. Joe Limestone was proposed by Hopkins (1893) as the basal, chert-free member of the Boone Formation for railroad cut exposures in the vicinity of St. Joe, Searcy County, Arkansas, but no type locality was designated. Historically, the interval was regarded as a formation (Cline 1934, Kaiser 1950), and a group (Beveridge and Clark 1952, Huffman, 1958), but the Arkansas Geological Survey continues usage as a member, even though the St. Joe was mapped as a discrete interval on the first Geologic Map of Arkansas (Miser and Stose 1929). Thompson and Fellows (1970) proposed a primary reference section at an abandoned quarry along the abandoned St. Louis-North Arkansas railroad, two miles northwest of St. Joe, Searcy County, Arkansas.

The St. Joe Limestone represents the base of the Mississippian interval in northern Arkansas and northeastern Oklahoma, however in adjacent southwestern Missouri, the name has been abandoned. Instead, the interval in Missouri has been subdivided into the Bachelor, Compton, Northview and Pierson Formations (in ascending order) (Thompson and Fellows 1970, Thompson 1986). Although condensed, the southwestern Missouri lithostratigraphic divisions can be recognized across most of the Lower Mississippian outcrop belt in Arkansas, but nomenclaturally, there is a significant "state-line fault" between northern Arkansas and southwestern Missouri. To clarify regional relationships, the St. Joe should be elevated to formational rank with the Missouri units as members (Manger and Shanks 1977, Manger, Shelby, and Farris 1988, Manger and Shelby 2000).

Along the Mississippian outcrop belt in northern Arkansas, the St. Joe thins and condenses to the east, represented by only 3ft 8in at Walls Ferry, Independence County, yet containing a Kinderhookian-Osagean boundary based on conodonts (Thompson and Fellows 1970, Manger et al. 1988). It also pinches out down-ramp and cannot be identified in the subsurface south of the latitude of Washington-Crawford County line (Shelby 1986, Manger and Shelby 2000). Within the interval, both the Bachelor and Northview also pinch-out eastward along the outcrop belt and into the subsurface (Shelby 1986, Manger and Shelby, 2000). The base of the Middle Kinderhookian Bachelor Member is an erosional disconformity. Where it succeeds the Chattanooga Shale, it occurs as green, calcareous shale, while it is an orthoquartzitic sandstone, commonly with a gravel fraction of phosphate-replaced limestone, or occasionally a sandstone-shale couplet, when overlying older strata. The Northview represents a green, calcareous siltstone and shale that briefly interrupted St. Joe limestone deposition, due to a relative drop in sea level. The Kinderhookian-Osagean boundary based on conodonts occurs at the Northview-Pierson contact or within the first foot of the Pierson (Manger et al. 1988). Where the Northview is absent, the Compton and Pierson are indistinguishable, and the St. Joe is undifferentiated (Fig. 3). In northeastern Oklahoma, the St. Joe is accorded group status, and the Missouri formations, except the Bachelor, can be recognized (Huffman 1958). As in Arkansas, where the Bachelor and Northview are absent, the St. Joe is undifferentiated.

Boone Formation – The Boone Formation is the oldest valid formation name applied to the Osagean (Lower Mississippian) interval succeeding the St. Joe in northern Arkansas (Branner 1891, Simonds 1891). The name is credited to Branner by page priority, and is taken from Boone County, Arkansas, although no type section has been designated (Wilmarth 1938). As defined, the Boone Formation is a chert-bearing, crinozoan packstone-wackestone interval, reaching 300-350 feet, and forming most of the Springfield Plateau. In southwestern Missouri, the equivalent interval is divided into formations designated (ascending order): the Reeds Spring, Elsey, Burlington-Keokuk undifferentiated (Thompson 1986). Although chert-bearing, that lithologic characteristic is not utilized in recognizing those lithostratigraphic divisions. Deposition of the Boone interval was significantly faster than that of the St. Joe, which has diluted conodont occurrences making biostratigraphic correlation to southern Missouri difficult and lithostratigraphic assignment problematic. Consequently the name Boone is retained in Arkansas, but the

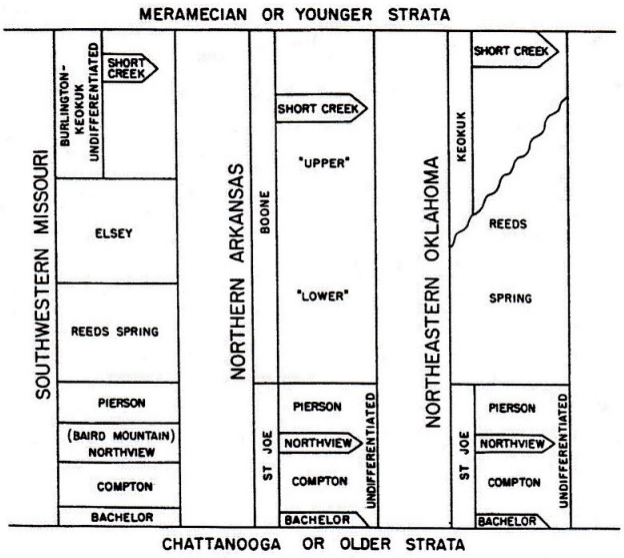

Fig. 3. Lower Mississippian Lithostratigraphic Nomenclature, Tri-State Region, Southern Ozarks (from Manger and Thompson 1982).

interval has been divided only informally into lower and upper members based on carbonate texture and chert development (*e.g.* Manger and Shelby 2000). The lower Boone interval was deposited below effective wave-base and is characterized by calcisiltites, and penecontemporaneous chert - dark, nodular, poorly bedded chert that disrupts bedding, and exhibits compaction features, indicating deposition prior to lithification. The upper Boone limestones were deposited within effective wave-base, and exhibit a framework of bioclastic grains of sand to gravel size, usually crinozoan detritus. The upper Boone is characterized by later diagenetic chert - white-light gray, selectively replacing the finer portions of the component limestones along the bedding planes as a groundwater phenomenon producing an apparently coeval, interbedded limestone-chert succession.

In northeastern Oklahoma, Huffman (1958), based on fossil occurrences, proposed an unconformable relationship without discussion in the Lower Mississippian succession. He assigned an interval of thinly, interbedded dark chert and fine-grained limestone to the Reeds Spring, succeeded by massive crinoidal limestone with mostly white to buff fossiliferous chert, that he assigned to the Keokuk (Huffman 1958). Since he could not recognize the Elsey or Burlington biostratigraphically, he assumed that there was an unconformity in the Osagean portion of the section (Fig. 4). As discussed in the sequence history section, the position of Huffman's unconformity would correspond to the Lower Mississippian maximum flooding-highstand interval, an unlikely place for a regional unconformity.

Oddly, the Short Creek Oolite (Smith and Siebenthal 1907), with a type section in Cherokee County, southeastern Kansas, is a formally named member recognized across the tri-state area, including the Boone Formation in northern Arkansas (McFarland 2004). This distinctive unit, usually thin, but reaching over 25 feet, is also interpreted as a down-ramp grain flow, rather than oolite shoal, that developed during the regressive phase of Boone deposition (Lisle 1984). Few Boone exposures preserve the Short Creek, suggesting brief, localized development of oolite shoals that were destroyed and the ooliths dispersed during the Boone regression.

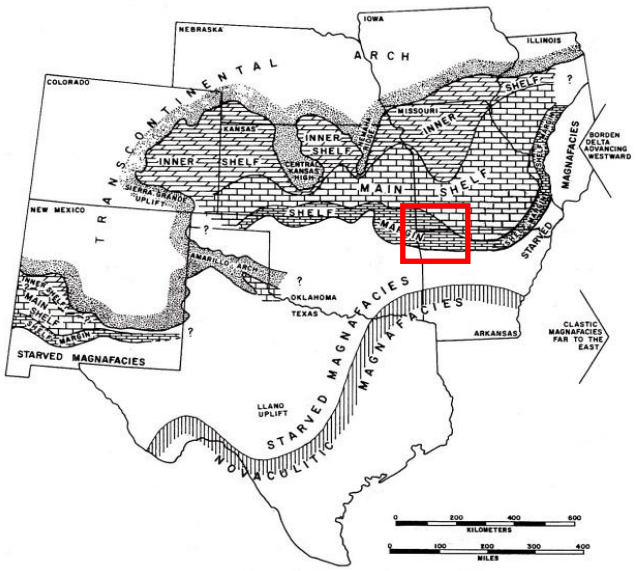

Fig. 4. Osagean Paleogeography and Lithofacies of the Southern Portion of the North American Craton, Burlington Shelf (modified from Lane 1978). This study area in red box.

Depositional Dynamics

The entire Lower Mississippian succession preserved in northern Arkansas represents transported carbonates that originated as the result of biological activity: green algae produced the carbonate mud, while the associated sand and gravel size fractions represent fragmental skeletal remains of invertebrates, particularly, crinozoans, bryozoans and articulate brachiopods. This “Carbonate Factory” occupied most of the North American midcontinent that was covered by warm, shallow seawater. The Burlington Shelf (Lane 1978), which occupied what is mostly the State of Missouri now, produced the carbonate mud and

grains that were transported down-ramp in northern Arkansas. Other similar depositional settings developed across the midcontinent during its greatest covering by shallow, continental seas between the Lower Ordovician and the Cretaceous.

Sunlight most certainly lighted the seafloor promoting the growth of the green algae and the life cycles of microscopic plants and animals that would serve as the food source for the invertebrates that were all filter-feeders. Life and death processes occurred within effective wave-base, which disarticulated both algae and invertebrates, and provided the energy to move this sediment toward the craton margin and down the adjacent ramp in a lobate manner.

Although these Lower Mississippian limestones are bioclastic, the faunal diversity is actually quite limited. Crinozoan detritus comprises nearly all of the bioclasts in most intervals. The abundance of crinoids and absence of other invertebrates reflects the high rate of deposition and instability on the Burlington Shelf. Most Paleozoic invertebrates prefer a low rate of sedimentation and stable substratum, because a constantly moving substratum would bury both sessile and infaunal organisms (Purdy 1963a,b, Ball 1967). If modern analogues can be applied, green algae living on the Burlington Shelf wouldn't be affected by burial because their life spans are too short. They lack roots, but the external thallus can form a holdfast, and they can withstand modest storms. For the crinoids, their long stalks provided protection from burial and allowed them to exploit a food supply higher in the water column. In contrast, smaller sessile invertebrates, such as brachiopods, could easily be covered by modest sedimentation rates and periodic storm activity. Consequently, crinoids and organisms with mutual, commensal, or symbiotic relationships with them would likely be the only invertebrates preserved in the Lower Mississippian sediments.

Conclusions

The Lower Mississippian succession represents an unconformity-bounded, third-order, transgressive-regressive cycle deposited on the southern edge of a broad carbonate platform known as the Burlington Shelf much of which is now physiographically, the Ozark Dome. The St. Joe-Boone interval nomenclature lacks uniformity, but the "stateline fault" with Missouri for the St. Joe interval has been eliminated by recognizing the Missouri formations in Arkansas as members (ascending order): Bachelor, Compton, Northview, Pierson of the St. Joe Formation. The Boone interval in Missouri is represented by the (ascending order): Reeds Spring, Elsey, Burlington-Keokuk undifferentiated, but those names have not been applied with confidence in Arkansas. Instead, Boone is retained as the oldest valid name applied to the interval in Arkansas, divided into informal lower and upper members based on chert development: dark, nodular, penecontemporaneous chert in the lower Boone, and white to gray, later diagenetic replacement chert in the upper Boone.

The Burlington Shelf "carbonate factory" created the carbonate sediments that are seen within the St. Joe-Boone succession in northern Arkansas. The carbonate sediments were produced predominantly by two processes, lime mud from green algae and sand fraction mostly from crinozoan detritus. These sediments were moved from their origin on the Burlington Shelf in present-day Missouri, and transported down ramp in a lobate manner to their site of deposition in present-day northern Arkansas.

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