Sedimentology and Diagenesis of Mississippian (Kinderhookian and Osagean: Tournaisian and Visean) Buildups in Southwest Missouri, Northwest Arkansas, and Northeast Oklahoma*

Beau T. Morris¹, S. J. Mazzullo¹, and Brian W. Wilhite²

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¹Department of Geology, Wichita State University, Wichita, KS 67260 (morrisgeo@me.com)
²Woolsey Operating Co., Wichita, KS 67202

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Abstract

Carbonate buildups are present in the Kinderhookian Compton and basal Osagean Pierson formations in SW Missouri and adjoining Arkansas and Oklahoma. Their depositional origin, biota, and diagenesis are key to evaluating their potential as subsurface petroleum reservoirs. They formed on aggradational to progradational distally-steepened ramps. Those in the Pierson are mainly layered bafflestones; they contain abundant fenestrate bryozoans and crinoids, and are capped by crinoid grainstones. They are interpreted to have been deposited in a relatively shallow, high-energy environment, and locally they are oil-saturated. The older Compton buildups instead are hybrid mud-dominated lithoherms/fenestrate bryozoan-crinoid muddy bafflestones that are associated with nodular-bedded, shaly mudstones. They are interpreted to have been deposited in low-energy, deeper-water environments than the Pierson buildups. One of the Compton buildups is a stromatactis-type “reef” with abundant marine cement-filled vugs. The lithoherm/bafflestone buildups were uplifted and subaerially exposed in mid-Compton time within an EW-trending belt in the study area. Meteoric-dissolution vugs formed and were occluded by detrital dolomite and coarse calcite cement, and then the buildups were dislodged and redeposited to the north within thick sections of upper Compton that downlap an intraformational exposure surface. Such allochthonous buildups might be mappable in the subsurface by thickness trends.
SEDIMENTOLOGY AND DIAGENESIS OF MISSISSIPPIAN
(KINDERHOOKIAN AND OSAGEAN: TOURNAISIAN AND VISEAN)
BUILDUPS IN SOUTHWEST MISSOURI, NORTHWEST ARKANSAS,
AND NORTHEAST OKLAHOMA

Beau T. Morris, Department of Geology, Wichita State University, Wichita, KS 67260
S. J. Mazzullo, Department of Geology, Wichita State University, Wichita, KS 67260
Brian W. Willette, Woolsey Operating Co., Wichita, KS 67202

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STUDY AREA
Southwest Missouri, Northwest Arkansas, and Northeast Oklahoma

LAURUSSIA
GONDWANA

Paleogeographic representation of the study area during middle Mississippian (Kinderhookian and Osagean) time after Blakely (2005). The study area highlighted in red would have been South of the paleo-equator (Gutschick and Sandberg, 1983) within the Paleozoic Ozark Uplift, and to the North of the Laurussia and Gondwana plate-convergence zone.

MISSISSIPPIAN OUTCROP STRATIGRAPHY

St. Joe Group
Compton Group
Boone Group

Mississippian lithostratigraphy in the field area includes Kinderhookian through Chesterian strata, this study is focused on Kinderhookian age, Compton and Osagean age, Pierson formations, which are the two reef bearing formations within the section. Correlatives of these units are present within the subsurface of southern Kansas and northern Oklahoma, and locally are prolific oil and gas reservoirs. They are commonly referred to as the St. Joe, Chouteau, or Gilmore City Ltd in Kansas and/or the St. Joe Group in Oklahoma.

E-W Trending Belt of Anomalous Stratigraphy

Compton and Pierson reefs occur only within an E-W belt of anomalous stratigraphy in the field area

COMPTON
PIERSON

METHODS OF STUDY
17 of 18 total reefs on outcrop analyzed and described in detail
measured reef thickness, sampling beds
underlying, overlying, & adjoining
further outcrop descriptions included
lithologies, biotas, & vertical or lateral changes evident on the outcrop
THIN-SECTION PETROGRAPHIC STUDY
detailed interpretation of biotas, microbials, rock textures, & PRESENCE OF MARINE OR METEORIC CEMENTS

Previous studies of reefs within the field area

Massively bedded, crinoid dominated bioreefs within the St. Joe Member of the Boone Formation, northeast Oklahoma: formed by the growth and accumulation of crinoids.

Waukonsian-type buildups and associated carbonate turbidite facies in central Missouri. Comprised by a dolomitized bioclastic-crinoid, lime mudstone core flanked by crinoidal packstones and grainstones, and having formed along the Burlington Shelf margin in the foreslope to near toe-of-slope depositional settings.

Mudstone cored bioreefs within thin bedded crinoidal limestones in southwestern Missouri and northwest Arkansas: formed by the interaction of physical environmental factors and bathymetry; sediment trapping and stabilizing activities of fenestrate bryozoans; and sediment trapping and stabilizing activities of plants not preserved.

AUTHORS INTERPRETATIONS
Waukonsian and non-Waukonsian reefs developed in the medial ramp settings on aggradational to progradational distally-steepened ramps, some of which have been datoligated due to fore-burul synsedimentary tectonism. They have indicative evidence of synsedimentary submarine cements in synsedimentary marine cements. Both Compton and Pierson reefs have oil staining, and Pierson reefs are locally oil saturated on the outcrop.
COMPTON REEFS
WAULSORTIAN & NON-WAULSORTIAN REEFS

Tabular - Flat Bottom Convex Top Shapes between 5” - 30” thick on outcrop

Beau’s Reef along Highway 71 just north of Jane, Missouri. The Compton Formation at this locality overlies the Devonian Woodford Shale, and the Kinderhookian Bachelor Formation. The Bachelor and the lower Compton comprise a T-R cycle of crinoidal sand (packstones & grainstones) that are overlain by a pronounced carbonate clast conglomerate that represents a regional unconformity within the Compton throughout most of the field area and is even traceable into the subsurface of Kansas. Sandwiched between T-R cycles of the lower and upper Compton are tabular blocks of dismembered reefs and associated shale - muddy downlapping beds. The reefs and their associated facies are all dislodged or downlapping in a northward direction opposite of the supposed basin to the south. We have interpreted this northward progradation to represent syndepositional tectonism in relation to a fore-basement.

Evidence Of Unconformity & FORMATION OF POROSITY

- oxidized haloes and reddish discoloration along fractures and some vugs
- clasts of reef matrix within vugs
- dissolutions vugs and associated fractures
- internal vadose crystal silt within vugs and fractures
- abundant crinoid overgrowths

COMPOSITE SECTION representing out-of-place reefs

COMPOSITIONAL ARCHITECTURE OF COMPTON REEFS

Based upon Lithology and regional stratigraphy and sedimentology, the Compton Formation is interpreted as having been deposited on a very low-relief aggradational to slightly progradational distally-deepened ramp. Comptons consist of muddy carbonates in the proximal and distal ramp settings, with reefs and their associated facies in the median portion.

REELS DEVELOP IN MEDIAL RAMP SETTINGS

REELS WITH 20%-25% POROSITY

RESERVOIR OBJECTIVE

At Compton reefs within the field area are inferred to be OUT-OF-PLACE (DISLODGED) except for the Hey 96 locality South of Brandon, Missouri showing no apparent evidence of being out-of-place.

locally porosity has been occluded on the outcrop

porosity within vugs

place the same reef in the subsurface and strip away all the calcite occluded porosity

result

in place reef
dissolved & redeposited reefs
downlapping strata
Fore-bulge

DIAGENETIC FABRICS

- Bryozan and Crinoid-rich matrix (acting as baffles of sediment)
  - associated biotic constituents include: bryozoans, brachiopods, sponges, and smaller rugose coral
  - textures vary from primarily wackestones to micritic-rich or muddy Micrites
  - cement fabrics include: locally recrystallized micrite to micro and pseudo spar, partially attributed to the semi-lithified nature of these reefs during deposition and diagenesis
  - former high Magnesium Calcite Bladed Marine cements within shells and some vugs; considerable MRC intraparticle cementation during deposition “syndepositional marine cements”
  - METEORIC DISSOLUTION VUGS (related to syndepositional tectonism)
  - vugs locally filled with biotic debris, internal vadose crystal silt, and occluded by coarse pore filling calcite
  - dolomitization of crystal silt filling vugs, locally hematele rimmed

Stromatolite type marine cements, characteristic of Waulsortian Reefs ARE ONLY RECOGNIZED IN ONE Compton reef locality South of Brandon, Missouri.

Along Highway 86 South of Brandon, Missouri exposed along the North side of the road is a 30” + Compton reef, unconformably overlain by shallow water crinoidal sand of the Pierson Formation. This reef bears similar lithologic characteristics to other Compton reefs (i.e. bryozan-crinoid rich bafflestone type facies; meteoric dissolution vugs with crystal silt) however, abundant STRUMATACTIS* occluded by mosaics of radial fibrous calcite marine cements are present throughout. Perhaps genetic difference along with no evidence of being out-of-place represents a unique reef.
PIERSON REEFS

“Hwy. 412 Locality” Panoramic View

- ERODED PIERSON REEF
  burried hill overlying eroded
  Pierson reef (primarily crinoid
crestal deposits exposed), with
  large clasts of reef and debris
  scattered throughout post
  unconformity beds

COMPOSITIONAL CHANGE IN MISSISSIPPIAN
REEFS THROUGHOUT TIME

- CORE FACIES — Bryozoan-crinoid rich layered bafflene
  locally grading from wackestone - packstone textures

- CRESTAL DEPOSITS/ CORE CAPPING FACIES — crinoid grainstones
  LOCALLY OIL SATURATED!!

- CEMENT FABRICS — within these layered bafflenees are
  meteoric dissolution vugs “subaerial exposure” (FORMATION OF POROSITY)
  and ferrous cavities not of meteoric origin, locally occluded with coarse pore
  filling calcite. Vugs also contain abundant former high magnesium calcite
  bladed marine cements of ispahashous, interparticle, and intraparticle
  nature. Distinctive brack radially fibrous crusts of pendant shape within
  meteoric vugs and skeletal fragments along with some internal vadose crystal
  slt are present, however not as not as visible as in Compton reefs. Likewise,
  throughout much of the reef the silicified fabrics such as, chalcedony are
  common. Crinoid overgrowths are prominent throughout much of the crestal depos-
  its as well as in local areas of the core facies, and are generally associated with
  coars finer pseudospin patches when in reef matrix.

FORMATION OF POROSITY
WITHIN CORE FACIES & CRINOIDAL SAND CRESTAL DEPOSITS

★ NO EVIDENCE SUGGEST PIERSON REEFS ARE DISLODGED “OUT-OF-PLACE” ★

DEPOSITIONAL ARCHITECTURE OF PIERSON REEFS

The Pierson like the Compton Formation was deposited on a distally-
steepened ramp, however a major change in ramp settings took place dur-
ing Pierson time shifting from a primarily aggradational to progradational
ramp. At its top the Pierson is marked by a prominent unconformity in areas
of anomalous stratigraphy, with nearshore and shallow-marine carbonates in
the proximal and distal portions and reefs associated with shallow-water
limestones (crinoidal sands) in medial ramp settings.

Mazzullo et al., 2011

Porous
Dolomite
wk-pk
Reef
wk-pk
wk-pk
wk-pk
wk-pk-grnst
Mazzullo et al., 2011

Composite sketch of Pierson Reefs cropping out along the South side of Highway 412, East of Siloam Springs, Arkansas. The Pierson at this locality is upwards of 20ft (+) thick comprised of shallow water limestones and reefs, overlain by roughly 30’ of Reeds Spring Formation. A total of four reefs are present from East to West along the outcrop with the eastern two representing pri-
marily crestal/capping facies (crinoidal sands), and the western two exposing both the reef core
and creatal deposits. There are multiple unconformities throughout the Pierson section, most nota-
ble the upper most Pierson unconformity that locally becomes a composite unconformity at
the East and West ends of the outcrop. This unconformity did not erode as deeply into the Pierson as
it did at the western end, preserving a thicker section of Pierson forming a “BURIED HILL.”

RESERVOIR OBJECTIVES

Porous oil saturated creatal deposits/crinoidal sandstones

Westernmost Pierson reef with core facies and creatal deposits exposed along Highway 412, E. of Siloam Springs, Arkansas

Porous oil saturated creatal deposits

Pierson reef with core facies and creatal deposits exposed along Highway 412, E. of Siloam Springs, Arkansas

No cores or plugs were available to study within the Pierson Reefs, making a reservoir analysis difficult. Therefore, an analogous study of the Compton Formation was made. The Compton is composed of predominantly crinoidal sandstone, with lesser amounts of rhodocystid crinoid facies, bryozoan facies, and crinoid/rods dolomite.
Reefs of tabular to convex top shape of Kinderhookian and lower Osagean age are exposed in an E-W trending belt within the study area, associated with thick "anomalous stratigraphy" in their respective stratigraphic sections.

- **COMPTON REEFS**
  - classified as WAULSORTIAN AND NON-WAULSORTIAN REEFS, and are associated with muddy-shaly limestones
  - they were subaerially exposed during middle Compton time in relation to fore-bulge syndepositional tectonics and developed meteoric dissolution vugs and internal vadose crystal silt
  - all reefs except one (Hwy. 86 Locality) are inferred to be dislodged or redeposited
  - likewise, the Hwy. 86 reef locality is the only "stromatolitic type" reef present is within the field area, and with abundant radiaxial fibrous calcite marine cements

- **PIERSON REEFS**
  - different from Compton reefs, are layered bryozoan-crinoid rich baffelstones comprised of a bryozoan rich core facies and crinoid grainstone crestal deposits, that are locally oil saturated, NOT WAULSORTIAN REEFS
  - they were subaerially exposed forming some meteoric dissolution vugs and associated vadose crystal silt and pendant shape RFC cements
  - former HMC bladed cements of isopachous, interparticle, and intraparticle nature are common throughout
  - they show no evidence of being dislodged or redeposited
  - Pierson reefs occur in a belt further South of Compton reefs indicating overall basinward progradation

This study provides a temporal analysis of reefs in outcrop along with their sedimentary and depositional architectures serving as a model for recognizing reefs and/or reef belts within the subsurface of Kansas and northern Oklahoma.

Within the subsurface of Kansas and northern Oklahoma our analog model suggests that Compton and Pierson reefs are developed within medial ramp settings. As such, these reefs need not be dislodged or out-of-place to develop reservoir characteristics, as this is merely a facies of Compton reefs seen on outcrop. They will however likely be associated with thick anomalous stratigraphy. Hence, these reefs or reef bearing units are mappable within thickness trends and possibly corresponding structure. As Kansas and Oklahoma are mature areas of exploration the use of existing and newly taken core and samples is invaluable tools when such a detailed lithologic recognition and interpretation are needed.