Origin and Analysis of the Nano/Micropore Network in the Upper Cretaceous Ozan/Annona Chalks in the Caddo/Pine Island Field in Northwest Louisiana*

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Abstract

The Campanian Annona Chalk is a shallow (1400 to 1700 foot, however it may have been buried deeper) producing reservoir of light oil (API gravity 42 to 44). The reservoir is a fractured, slightly argillaceous lime chalk, as is the Ozan chalk below. Both units were deposited on the Upper Cretaceous drowned shelf in a moderate-depth, aerobic setting as evidenced by numerous burrows and a high ratio of benthic to planktonic foraminifera. Clay-size material (up to 20%) composed of smectite and microquartz is slightly higher in the Ozan than the Annona. Major allochems are benthic and planktonic foraminifera and fragments of echinoids, ostracods, and bivalves in a finer matrix of coccoliths and coccoliths elements. The coccoliths and associated elements range in size from less than 400 nm to a few microns. The pore network resulting from this fine-grain size and burial cementation produces a reservoir composed of nano- to micropores. Pore throats are in the nanometer range. Porosity averages between 23 to 27%. The origin of this extremely fine pore network is depositional. The original pores between the coccoliths and fragments are interparticle. Minor intraparticle pores are associated with the foraminifera and some voids in the coccoliths.

The coccosphere bodies easily breakdown to coccolith plates and individual elements. With the degradation of the polysaccharides (organic matter that hold the coccolith together) the coccoliths fragments separate. This results in finer material and associated finer pores. Later cementation will reduce these early formed pores. The minor amount of clay affects pore size by dividing the interparticle pores into multiple smaller pores. The clay also appears to promote pressure solution and enhanced cementation. The result of all these processes is to produce a porous reservoir with modest permeability. Natural and induced fractures form the collection network for the oil, but the nano- to micropores are the storage component of the reservoir.
References Cited


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General Micropore Types

Aragonite to calcite
(depositional/diagenetic)

Mixed

Coccolith-rich sediment
(depositional)

Mg-calcite to calcite
(diagenetic)

Loucks et al. (2013)
Project Goals

- Present depositional setting of the Annona and Ozan Chalks
- Review lithofacies
- Define pore network and reservoir quality
Correlation of Upper Cretaceous Chalks

<table>
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<tr>
<th>Stage</th>
<th>Age (M.Y.)</th>
<th>Central Western Interior A</th>
<th>Central Texas B</th>
<th>South-western Arkansas C</th>
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<td>Fairport</td>
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<td>Cenomanian</td>
<td>93.9</td>
<td>Greenhorn</td>
<td>Buda</td>
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<td>Gulf of Mexico</td>
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</tbody>
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Modified from Bottjer (1986)
Ages according to IUGS (July 2012)
Regional Paleogeographic Setting

Late Cretaceous (75 Ma) Campanian

Upper Cretaceous Drowned Shelf

Western Interior Seaway

30 N

R. Blakey (2013)
Study Area

Caddo/Pine Island Field

Thrash #1

Jolly Heirs

Caddo/ Pine Island

Drilled 1962

Texas

Akansas

Louisiana

Caddo

Co.
Stratigraphic Section

Nacatoch

Saratoga

Marlbrook

Annona

Annona

Ozan

Ozan

1500'

1600'

1700'

1800'
Ozan Marl

Annona Chalk

Marlbrook

1650

1700

1750

1800

Annona Chalk

Core slabs

1 in

1 in

1 in

Argillaceous
Rich seams

Burrows

Hardground clasts

Inoceramid

Burrow
Examples of Biota

Thin sections

**Globigerinelloides sp.**

*Heterohelix cf. globulosa*

**Globotruncanid**

**Thin sections**

**Nonionella austinana ?**

*Lenticulind*

Wide variety of benthic and planktonic fauna

**Planktonic foraminifera**

**Globigerinelloides sp.**

**Globotruncanita stuartiformis**

**Heterohelix**

**Pseudotextularia sp.**

**Benthic foraminifera**

**Ammobaculites sp.**

**Tritaxia ellisorae**

**Heteroelix**
Coccolith Hash Matrix

Whole coccosphere

Coccoliths

Coccolith-rich limestone with cementation

SEM chips
Predominant allochems are foraminifera and coccoliths.
Mineralogy

Secondary electron photo

1827 ft: SEM polished thin section (Ozan)

Calcium and aluminum EDX map

Calcite (coccolith elements)

Smectite

Coccolith elements

Interparticle pores
Slight differences in mineralogy between the formations is important to reservoir quality.
General Diagenesis of Chalks

- Compaction (~75% → ~50%*)
- Segmentation
- Cementation
- Effects of clay

*Based on diagrams from Scholle (1977)
Segmentation of Coccospheres

- Coccosphere (unicellular planktonic algae)
- Partly held together by CAPs (coccolith-associated polysaccharides)
- Mechanical compaction and bioturbation may aid in segmentation
Cementation

Overgrowth/syntaxial cementation producing interlocking coccolith platelets

Pore-fill cementation

Overgrowths/syntaxial cementation

Coccoliths

Coccolith platelets

Early interlocking overgrowths with crystal growth competition

Advanced cementation
Cementation

Cemented coccolith

Pore-fill cement

Calcite overgrowths on coccolith elements

Calcite overgrowths on coccolith elements

Cements nucleate on the coccolith elements

Indentations produced by plucked crystals

SEM chips
Effects of Clay

Clay appears to promote cementation

SEM chips
Thin-Section View: Micropores

Continuous micropores in matrix

Blue fluorescent dyed thins section
Thin-Section View: Micropores

Large, patchy areas of micropores; patches may be associated with peloids

Blue fluorescent dyed thins section
Pore Network (FSEM Ar-Milled)

Spined globigerinid with cemented intraparticle pores

Micropores

Coccoliths

Ozan nanometer- to micron-scale pores

SEM Ar-ion milled stub
Pore Network (FSEM Ar-Milled)

Interparticle pores

Calcisphere or small globigerinid chamber

Intraparticle pore

~30 nm

~20 nm

~70 nm

~40 nm

Annona nanometer- to micron-scale pores

SEM Ar-ion milled stub
Pore Network (FSEM Ar-Milled)

Less compaction of coccolith elements inside globigerinid

Nanoporous globigerinid wall

Less compaction in protected area

Less compaction of coccolith elements inside globigerinid
Pore Network (FSEM Ar-Milled)

- Ozan nanometer- to micrometer-scale pores with clay
- Clay reduces pore connectivity

Microporous coccolith hash

Globigerinid with cemented intraparticle pores

SEM Ar-ion milled stub
Minipermeability Analysis

Annona
Mean porosity = 23.8%
Mean permeability = 7.10 md

Ozan
Mean porosity = 17.4%
Mean permeability = 23.80 md
Conclusion

- Deposited as chalk on an oxygenated, drowned shelf
- Predominately calcite with 2 to 8 percent clay and microquartz
- Pore network mainly primary interparticle micropores and intercrystalline nanopores within coccolith hash reduced by compaction and cementation
- Will nanopores affect $S_w$ relative to micropores?