Limestone Frequency and Well Performance, Eagle Ford Shale (Cretaceous), South Texas*

John Breyer¹, R.H. Wilty¹, Y. Tian¹, A. Salman¹, K.W. O’Connor¹, B. Kurtoglu¹, R.J. Hooper¹, R.M. Daniels¹, R.W. Butler¹, and D. Alfred¹

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¹Marathon Oil, Houston, TX (jabreyer@marathonoil.com)

Abstract

The Lower Eagle Ford on the southwestern flank of the San Marcos arch consists of cyclic interbeds of thin, brittle, recrystallized limestone and thicker, more ductile, organic-rich calcareous mudstone (marl). The limestones can be recognized, but not fully resolved, by their log signature. The number of limestone beds can be ascertained from the logs and their thickness approximated. The limestone bed frequency can be calculated by dividing the number of limestones in an interval by the thickness of the interval. Mechanical models show that the density of natural fractures increases as bed thickness decreases, suggesting overall fracture effectiveness and complexity will increase as limestone bed thickness decreases. In the North Longhorn area, limestone bed frequency and limestone bed thickness are inversely related, and increased limestone frequency has been identified as a key driver for well performance. Another operator in the play has identified thin limestones interbedded with organic-rich marls as “the most productive and most brittle” facies in the Eagle Ford. Shale reservoirs can be considered in terms of reservoir quality and completions quality. In the Eagle Ford, marl thickness is an important component of reservoir quality and limestone frequency of completions quality. Other factors being equal, the best production will be associated with thick marl sequences with enough interbedded limestone to maximize the complexity of the combined natural and induced fracture network, but not so much limestone as to substantially lower storage of hydrocarbons in the system.
References Cited


Limestone Frequency and Well Performance, Eagle Ford Shale (Cretaceous), South Texas

Presenter: John A. Breyer, Senior Technical Consultant, Marathon Oil

Authors: R. H. Wilty, Y. Tian, A. Salman, K. W. O’Connor, B. Kurtoglu, R. J. Hooper, R. M. Daniels, R. W. Butler, J. A. Breyer and D. Alfred
There are two distinct types of Eagle Ford shale in the Darst Creek field...Both types are fossiliferous, and almost invariably present a rich showing of oil where penetrated. Many tests, however, have proved this showing valueless.

McCallum, AAPG Bulletin 1933
Regional Depositional Setting

- Modified from Ruppel et al. (2012)

- Llano Uplift
- Maverick Intra-Shelf Basin
- "Woodbine" Deltas
- Sierra Diablo Carbonate Platform
- Rio Grande Submarine Plateau
- Albian Shelf Margin
- Aptian Shelf Margin
- San Marcos Arch

Map showing various geological features and depositional settings, including shallow-water carbonate, pelagic carbonate, argillaceous mudrock, and delta plain & delta front.
## Rock Types in the Eagle Ford Shale

![Eagle Ford Shale](image)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Shale</th>
<th>Marl</th>
<th>Limestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abundance</td>
<td>&lt;5%</td>
<td>60-70%</td>
<td>30-40%</td>
</tr>
<tr>
<td>Calcite</td>
<td>&lt;25%</td>
<td>45-55%</td>
<td>75-85%</td>
</tr>
<tr>
<td>Clay</td>
<td>50-60%</td>
<td>10-15%</td>
<td>5%</td>
</tr>
<tr>
<td>TOC</td>
<td>&lt;2%</td>
<td>2-10%</td>
<td>&lt;2%</td>
</tr>
<tr>
<td>Porosity</td>
<td>---</td>
<td>8-12%</td>
<td>3-4%</td>
</tr>
<tr>
<td>Young’s Modulus</td>
<td>--</td>
<td>2-4</td>
<td>4-6</td>
</tr>
</tbody>
</table>
Marls

- Marl: 45% calcite, 15% clay, 40% other
- Foraminiferal Marl: 55% calcite, 10% clay, 35% other
- Foram-Rich Marl: 65% calcite, 10% clay, 25% other
Marls

- Calcite: 45% calcite, 15% clay, 40% other
- Calcite: 55% calcite, 10% clay, 35% other
- Calcite: 65% calcite, 10% clay, 25% other

Marl
Foraminiferal Marl
Foram-Rich Marl

Courtesy of Bigelow Laboratory for Ocean Sciences
Marls

Marl
Foraminiferal Marl
Foram-Rich Marl

Calcite 45% calcite 15% clay
Calcite 55% calcite 10% clay
Calcite 65% calcite 10% clay
Calcite 25% other

Courtesy of Bigelow Laboratory for Ocean Sciences
Marls

- **Calcite**: 45% calcite, 15% clay
- **Other Clay**: 55% calcite, 10% clay
- **Other**: 65% calcite, 10% clay

Foraminiferal Marl

Foram-Rich Marl

Courtesy of Bigelow Laboratory for Ocean Sciences
Replaced and Recrystallized Limestone

500 microns
Replaced and Recrystallized Limestone

500 microns
Basic Assumptions

Reservoir Quality

- Pressure, Porosity, Thickness, Fluid Type

Completions Quality

Faults/Natural Fractures
- From Offset Tops
- From Attributes

Induced Fractures
- Rock “Strength”

Interbedding

Courtesy of CoreLab
Basic Assumptions

Graphic logs courtesy of CoreLab
Numerical Modeling Set-Up

Model 1

Model 2

Model 3

Top Load
Weak Layer
Stiff Layer
Side
Base
Numerical Modeling Results

<table>
<thead>
<tr>
<th>Model 1</th>
<th>41</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 2</td>
<td>84</td>
</tr>
<tr>
<td>Model 3</td>
<td>115</td>
</tr>
</tbody>
</table>
Both 10 ft sections have 70% marl and 30% limestone.

The LS frequency in the example on the left is 0.1/ft.

The LS frequency in the example on the right is 0.3/ft.
Counting Limestones in Outcrop

Upper Eagle Ford
Lower Eagle Ford

Marl

Marl

Marl

Marl

Marl

LS

LS

LS

LS

3 ft.
Counting Limestones on Logs
Counting Limestones on Logs

Graphic logs courtesy of CoreLab
Number of Limestone Beds 1

100-80-60-40
Number of Limestone Beds 2

80-70-60-50
Facies Changes in Lower Eagle Ford

Well A
60% marl
Ls frequency .27/ft

Well B
64% marl
Ls frequency .36/ft

Top of Lower Eagle Ford

6% increase in marl
33% increase in Ls frequency

Top of Buda Limestone

25 km (15 mi)
Lower EGFD Limestone Frequency
Lower EGFD Average Limestone Thickness

15.2 miles
Well Performance vs Limestone Frequency

Production Areas
Possible Solution
Possible Solution

Decrease in RQ > increase in CQ
Possible Solution

Increase in CQ > decrease in RQ
Possible Solution

Decrease in RQ > increase in CQ
An Epiphany

Graphic logs courtesy of CoreLab
Shale Oil and Shale Gas

U.S. tight oil production
million barrels of oil per day

- Eagle Ford (TX)
- Bakken (MT & ND)
- Spraberry (TX & NM Permian)
- Bone Spring (TX & NM Permian)
- Wolfcamp (TX & NM Permian)
- Delaware (TX & NM Permian)
- Yeso-Glorieta (TX & NM Permian)
- Niobrara-Codell (CO, WY)
- Haynesville
- Marcellus
- Woodford (OK)
- Granite Wash (OK & TX)
- Austin Chalk (LA & TX)
- Monterey (CA)

U.S. dry shale gas production
billion cubic feet per day

- Marcellus (PA & WV)
- Haynesville (LA & TX)
- Eagle Ford (TX)
- Fayetteville (AR)
- Barnett (TX)
- Woodford (OK)
- Bakken (ND)
- Antrim (MI, IN, & OH)
- Rest of US 'shale'
The Uncertain Future

U.S. Crude Oil Production 1960-2040

Uncertainty from:
- Well decline
- Drainage area
- Geologic extent
- Technological advances!
The Uncertain Future

Uncertainty from:
- Well decline
- Drainage area
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U.S. Crude Oil Production 1960-2040

MMBOPD