Unconventional Upper Jurassic Petroleum Resource System, Tampico-Misantla Basin, East Central Mexico*

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Search and Discovery Article #80711 (2020)**
Posted January 20, 2020

*Adapted from oral presentation given at 2019 International Conference and Exhibition, Buenos Aires, Argentina, August 27-30, 2019
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Abstract

Unconventional resource systems are currently being drilled in the Tampico-Misantla Basin (TMB), Mexico. Pemex has drilled multiple wells into the Upper Jurassic source rock system that is the major source of petroleum in the Golden Lane, Deepwater Gulf of Mexico, and onshore in the East Texas, West Louisiana Salt basin. The Tithonian, Kimmeridgian, and Oxfordian are the principal zones of interest for unconventional tight oil development. Hydraulic stimulation and lateral drilling have been used for decades to extract oil from the tight oil sands in the Chicontepec Formation, so such application of such technology is not new to Mexico.

Drilling results have proven the resource potential of the Upper Jurassic in Mexico. The Pemex Corralillo-157 was drilled with a short lateral yielding an initial flow rate of about 650 barrels of 38° API oil per day with a gas-to-oil ratio (GOR) of about 1000 scf/stb. In the Burgos Basin the Tithonian interval has flowed 10 to 12 million cubic feet of gas per day proving the high retention of oil that was cracked to gas under the higher thermal maturity in that northern Mexico basin.

The Upper Jurassic source rock system is a thick (200+ m), carbonate hybrid with various juxtaposed intervals charged with petroleum. As such it is akin to the carbonate-rich Eagle Ford system in south Texas with a hybrid nature and thickness of the Wolfcamp Formation in the Permian Basin, West Texas-New Mexico. Such analogs provide additional support for a prolific tight oil resource system.

Geochemical assessment of archived cuttings and core permit the calculation of the resource potential as well as the windows of optimum petroleum production. The goal for such analysis is to predict accurately the light oil window with high gasoline content. Using highly reproducible quantitative aromatic hydrocarbon maturity data with correlation to production enables prediction of the optimum areas and intervals for favorable economic results. Combined with specialized pyrolysis conditions and fingerprinting data, prediction of petroleum saturations, API gravity, and GOR may be achieved. Secondary charges or other alteration effects can affect such predictions so such effects must be included in the assessment.
Successful drilling results require good targeting of prospective intervals in the thick Upper Jurassic section including determination of zones with the highest mobility petroleum, but also the presence of stimulation barriers or baffles.

**Selected References**


Unconventional
Upper Jurassic Resource System,
Tampico Misantla Basin,
East-central Mexico

Daniel M Jarvie, Wildcat Technologies/TCU Energy Institute
Alfredo Guzman, Mexico Petroleum Company
Outline

• Introduction

• Background

• U. Jurassic Unconventional Petroleum Systems
  • Organic richness and petroleum generation potential
  • Thermal maturity
  • Petroleum generation
  • Oil content as measured
  • Oil content and properties as restored

• Synopsis
Introduction
### Tampico-Misantla Super Basin

<table>
<thead>
<tr>
<th>Permian Basin</th>
<th>Tampico – Misantla Basin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Original Oil and Gas in Place</strong></td>
<td><strong>Original Oil and Gas in Place</strong></td>
</tr>
<tr>
<td>&gt; 150 Bboe</td>
<td>&gt; 107</td>
</tr>
<tr>
<td><strong>Daily Production</strong></td>
<td><strong>Daily Production</strong></td>
</tr>
<tr>
<td>3.6 MMbo</td>
<td>0.08 MMbo</td>
</tr>
<tr>
<td><strong>Cumulative Production</strong></td>
<td><strong>Cumulative Production</strong></td>
</tr>
<tr>
<td>&gt; 37 Bboe</td>
<td>7.4 Bboe</td>
</tr>
<tr>
<td><strong>Recoverable</strong></td>
<td><strong>Recoverable (Reserves)</strong></td>
</tr>
<tr>
<td>&gt; 122 Bboe</td>
<td>6.9 Bboe</td>
</tr>
<tr>
<td><strong>Conventional and Unconventional Recoverable (Resources)</strong></td>
<td>&gt; 44 Bboe</td>
</tr>
<tr>
<td>37.2 Bboe</td>
<td></td>
</tr>
</tbody>
</table>

### Midland Sub basin

<table>
<thead>
<tr>
<th>Daily Production</th>
<th>Daily Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 2 MMbo</td>
<td>0.04 MMbo</td>
</tr>
<tr>
<td><strong>Cumulative Production</strong></td>
<td><strong>Cumulative Production</strong></td>
</tr>
<tr>
<td>&gt; 2 Bboe</td>
<td>&lt; 0.300 Bboe</td>
</tr>
<tr>
<td><strong>Active Rigs</strong></td>
<td><strong>Active Rigs</strong></td>
</tr>
<tr>
<td>~ 500</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total wells</strong></td>
<td><strong>Total wells</strong></td>
</tr>
<tr>
<td>&gt; 130,000</td>
<td>&lt; 3,000</td>
</tr>
</tbody>
</table>

### Guzman (2018, 2019)

- Hydrocarbon resources:
  - 107 Bboe discovered
  - 2.4 Bboe conventional YTF
  - 34.8 Bboe shale
  - **144.3 Bboe**
Comparison of Play Types in terms of Porosity

Organic-rich system often shows positive slope of porosity to TOC

Organic-rich hybrid system often shows negative slope of porosity to TOC
Change in Original TOC and Petroleum Characteristics with increasing thermal maturity

API Gravity:  
- TOC=5%: 25
- TOC=4%: 35
- TOC=3%: 45
- TOC=2%: 50+

GOR:  
- TOC=5%: 500
- TOC=4%: 1000
- TOC=3%: 2500
- TOC=2%: 20000

Maturity:  
- TOC=5%: 0.70
- TOC=4%: 0.85
- TOC=3%: 0.95-1.20
- TOC=2%: 1.20-1.30

TOC=3%: Volatile (light) Oil
TOC=2%: High BTU Gas
TOC=5%: Low Maturity Black Oil
TOC=4%: Peak Oil Black Oil
TOC=2%: Low BTU Gas
Select Factors to Consider in a Tight Oil System

PRODUCIBILITY

- OIL CONTENT (So, Sw)
- POR/PERM
- OIL QUALITY and PHASE
- SYSTEM TYPE
- BRITTLENESS and Fracture Network
- FRAC BARRIERS or BAFFLES
- PRESSURE
- TOM TOH
Change in Petroleum Composition with maturation

• **GOC is Generative Organic Carbon portion of TOC**
  
• **NGOC is Non-Generative Organic Carbon portion of TOC**

Products:

- OIL
- GAS
- SARA

Kerogen

- GOC
- NGOC

Saturates (C₆+)

Aromatics (PAHs)

Resins

Asphaltenes

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Total Petroleum = S1 measured + (S2 whole rock – S2 extracted rock) + Evaporative Loss

Evaporative losses of oil can range from 5 to 90% depending on oil phase, por/perm, sampling/handling, pressure
Background
## Oil Types in Mexico

<table>
<thead>
<tr>
<th>Crude-Oil Type</th>
<th>Heavy</th>
<th>Light</th>
<th>Volatile</th>
<th>Very Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maya</td>
<td>21.0-22.0</td>
<td>32.0-33.0</td>
<td>38.0-39.0</td>
<td>15.5-16.5</td>
</tr>
<tr>
<td>Isthmus</td>
<td>320</td>
<td>60</td>
<td>38</td>
<td>1280-1750</td>
</tr>
<tr>
<td>Olmeca</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Altamira</td>
<td>3.4-3.8</td>
<td>1.8</td>
<td>0.73-0.95</td>
<td>5.5-6.0</td>
</tr>
<tr>
<td>°API (Gravity)</td>
<td>6.0</td>
<td>6.0</td>
<td>6.2</td>
<td>3.0</td>
</tr>
<tr>
<td>VISCOSITY (SSU 100 °F)</td>
<td>-25</td>
<td>-35</td>
<td>-55</td>
<td>32</td>
</tr>
</tbody>
</table>
Differences in Biomarkers among various oils by period or age

Tithonian data and other fields from Guzman-Vega and Mello, 1999

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Thermal Maturity:
Quantitative Aromatic Hydrocarbons

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Relationship of GOR to API Gravity, Sureste Basin, Mexico

Data from Magoon, 1995

\[ y = 6.9709e^{0.1379x} \]
\[ R^2 = 0.734 \]
Upper Jurassic Tight Oil Systems,
Tampico-Misantla Basin,
Onshore, Mexico
Location Map and Generalized Stratigraphic Column

- Bossier, Haynesville, Smackover age equivalents onshore USA
- Also these age are major source rocks in Deepwater Gulf of Mexico

60 billion boe
J.A. Escalera, Pemex

J.A. Escalera, Unconventional Tight Oil System, U. Jurassic, Tampico-Misantla Basin, Mexico

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Well Locations for Geochemical Study

Comaitalan-1,2
Horcones-8127
Coyotes-3

Amatitlan-1

Profeta-1

Huehuetepex-1

Limonaria-2

Corralillo-157

Huizotate-8

(rocks + oil 37°API)

Aqua Nacida-103

Miquetla-121

Defensa-101

Independencia-3
Comparison of U. Jurassic, Tampico-Misantla Basin, Mexico to Eagle Ford Shale and Wolfcamp Shale

U. Jurassic, TMB, Mexico is similar to Eagle Ford shale lithofacies and TOC

Wolfcamp Shale is much lower carbonate content, i.e., more siliciclastic
Marine carbonate/marly shale source rock affected by carbonic and other organic acids

$\text{CO}_2$ and water released from kerogen forming carbonic acid that can cause partial dissolution of carbonate matrix, i.e., ‘etching’

Organic acids are also released from kerogen that can also cause partial dissolution of carbonate matrix

Potential for secondary porosity creation in matrix

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Best Area in Eagle Ford Shale is modest TOC (2-4 wt.%)

Best producing area of Eagle Ford Shale (mudstone) has modest TOC, good pressure, and good por/perm.
<table>
<thead>
<tr>
<th>Location</th>
<th>Characteristics</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pimienta, Taman, Santiago</td>
<td>Marine carbonate</td>
<td>500-1000 ft</td>
</tr>
<tr>
<td>Tampico-Misantla Basin,</td>
<td>Sulfur wt% 0.50 – 4.00%</td>
<td></td>
</tr>
<tr>
<td>Mexico</td>
<td>Original TOC ca. 5%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Original HI ca. 600 mg/g</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Porosity: ca 7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>U. Jurassic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thickness: 500-1000 ft</td>
<td></td>
</tr>
<tr>
<td>Eagle Ford</td>
<td>Marine carbonate</td>
<td></td>
</tr>
<tr>
<td>Gulf Coast Basin, South</td>
<td>Sulfur wt% 0.50 – 4.00%</td>
<td></td>
</tr>
<tr>
<td>Texas</td>
<td>Original TOC ca. 5%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Original HI ca. 600 mg/g</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Porosity: ca 7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cretaceous</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thickness: 200-250 ft</td>
<td></td>
</tr>
</tbody>
</table>
U. Jurassic Tight Oil System, TMB:
Present-day S2-kerogen and TOC Yields

Data from Morelos, 1992; Santamaria, 1996

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Present-day Source Potential U. Jurassic reduced by level of maturation

Note:
Petroleum Generation Potential is a combination of HI and TOC

1.00% TOC with HI = 600 Total Yield is only:
~ 138 boe/af (sub-commercial)
Geochemical Data used to Restore Original U. Jurassic Petroleum Potential

Geochemical data were used to restore the original U. Jurassic petroleum potential.

**Sigmoidal Fit**

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**Predicted Original HI:**

- P90 HI₀ = 394 mg/gT
- P50 HI₀ = 536 mg/gT
- P10 HI₀ = 602 mg/gT

\[ HI₀ = \frac{652.57}{1 + \exp\left(-\frac{(427-433)}{-8.44}\right)} \]
U. Jurassic Restored Source Potential
Why a Super Basin?

Barrels of Oil Equivalent/Section

- Pimienta: Total 104, Expelled 67, Retained 36
- Taman: Total 81, Expelled 53, Retained 28
- Santiago: Total 28, Expelled 28, Retained 10
- Total U. Jurassic Mexico: Total 213, Expelled 138, Retained 74
- Eagle: Total 98, Expelled 67, Retained 31
- Ford: Total 124, Expelled 83, Retained 31
- Wolfcamp: Total 207, Expelled 124, Retained 83
- Barnett Shale: Total 54, Expelled 31, Retained 23

Total Petroleum Generated at 1.0%Ro
Est. Expelled Oil
Est. Retained Oil
Retained, Expelled, and Total Petroleum Generated

An advantage of this system, much expelled oil in this system is that much oil is retained in the hybrid portions of the U. Jurassic ~ Permian Basin.
Prediction of Fluid Saturation
U. Jurassic, TMB, Mexico

HAWK-PAM
Light Oil to Heavy Oil and Kerogen

Maende, 2015

Pepper, 2019

Fluid saturation by volume (sum of Oil-1(Py1.1), Oil-2 (Py1.2), Oil-3(Py1.3) & Oil-4(Py1.4)

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High Aromaticity Ratio in Carbonate Source Rocks

Fractionation results in lower values in oils

Expelled oils are lower in aromaticity

Not indicative of evaporative fractionation, but rather a marine carbonate source rock with low pristane/phytane ratios

Evaporative fractionation would suggest loss of gas pressure, but in this case indicative of a carbonate source rock

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Thermal Maturity
and
Relationship to Oil Quality
Sulfur Contents decrease with increasing maturity

(y = -0.09x + 4.59, R² = 0.69)

(conventional reservoir data from Vargas, 2000)
Oil Cracking of Resins Results in increased saturates and higher API oils

Data from Santamaria, 1996

Saturates increase with decrease (cracking) of resins

API gravity increases with increase in saturated hydrocarbons

API gravity increases with decrease in resins

Data from Santamaria, 1996
Correlation of Aromatic Hydrocarbons to Oil Quality

Data from Santamaria, 1996

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Calibrating Optimum Maturity to Oil Quality essential for locating best producible oil

Pemex Corralillo-157 produced from U. Jurassic, Pimienta Formation

Optimum API window: 40-49 API

Optimum GOR window: 1000 – 3500 scf/stb
Rock GC Fingerprints allow prediction of light oil fairways

GC=gas chromatographic

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Light hydrocarbon correlation from oils and rock extracts to in situ GOR

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**Eagle Ford Oils**

GC predicted GOR values

**U. Jurassic (Mexico) rock extracts**

GC predicted GOR values

![Graph showing the correlation between reported GOR values and calculated GOR values with the equation $y = 0.9611x + 782.6$ and $R^2 = 0.9351$.]

- **Pimienta-1**: 849
- **Pimienta-2**: 921
- **Pimienta-3**: 1422
- **Pimienta-4**: 1947
- **Pimienta-5**: 3422
- **Taman-1**: 1844
- **Taman-2**: 1920
- **Santiago-1**: 2143

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Using Geochemical Data for Prospecting and Targeting

Best Production Potential = Volatile Oil (other factors being equal)

Fair Production Potential (other factors being equal)

Poor Production Potential (other factors being equal)

API Gravity

Oil Compositional Factors

\[ y = -0.2225x + 47.217 \]

\[ R^2 = 0.9219 \]
Production Projections suggest early results comparable to Eagle Ford

**Eagle Ford Oil Well Productivity**

<table>
<thead>
<tr>
<th>Year</th>
<th>Initial Prod Bbl/d</th>
<th>Recovery Bbls</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011 Original Wells</td>
<td>600</td>
<td>300,000</td>
</tr>
<tr>
<td>2016 Modern Wells</td>
<td>900</td>
<td>800,000</td>
</tr>
</tbody>
</table>

**Upper Jurassic Well Productivity**

<table>
<thead>
<tr>
<th>Year</th>
<th>Initial Prod Bbl/d</th>
<th>Recovery Bbls</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014 Original Test Well</td>
<td>650</td>
<td>300,000</td>
</tr>
<tr>
<td>2018 Targeted Amatitlan Wells</td>
<td>1,200</td>
<td>1,000,000</td>
</tr>
</tbody>
</table>

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*AAPG ICE, Buenos Aires, Argentina, 2730 September 2019 38*
Synopsis

• U. Jurassic Petroleum System in Tampico-Misantla Basin, Mexico has excellent potential for tight oil production when drilled in appropriate areas and completed using advanced technologies

• Oil quality improves (higher API and GOR, lower sulfur) with thermal maturation

• U. Jurassic system is comparable to Eagle Ford Shale in organofacies and lithofacies except it is 3-5x thicker

• Best production areas have been optimized by calibration to produced oil and analysis of rock and rock extracts across the basin

• Available production result from Pimienta suggest comparable yield as early Eagle Ford well production
Gracias!

Thank you!

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