Paris Basin France

A Potential

Multi-billion barrel

Oil resource

SPEE Luncheon
April 10, 2013
Denver, Colorado
“Progress in prospecting….sometimes seems slow and the results all too meager in proportion to the money that has been spent, but wildcatting is likely to continue for many years because something is always turning up to sustain the interest.”

E. L. Estabrook, 1924
Paris Basin Oil Resource Play

- New oil resource play in Europe
- Rich type II source rock section – basin models suggest over 1,000 BBO generated in basin (high API gravity, low viscosity)
- Stratigraphy and lithology similar to successful analog plays (Bakken)
- Multiple objectives – conventional and unconventional
- Geology and geochemistry of objectives are well documented by regional studies
- Wells drilled for deeper objectives have ubiquitous oil indications in source rock intervals. Recent competitor activity reports positive result.
- Very attractive fiscal and political environment (historically)
- Premium market
- Large contiguous land blocks with excellent term.
- Rural environment – operations feasible
France Facts

- GDP $2.77 Trillion (3rd largest EU)
- Oil Production 72 MBO/day (4.1%)
- Oil Imports 1,666 MBO/day (95.9%)
- Refining Capacity 1,800 MBO/day
- Unemployment 10.9%
- Population 63.1 Million
- 29.6 Million cars
- Over 5 Million trucks
Paris Basin Vision

Unconventional Oil Plays are not possible without application of advanced technology.

The recurring theme among the visionary companies active in these extraordinary plays is revisiting previously maligned areas and applying new drilling and completion techniques.

The key to reach repeatability and economic productivity is when a certain technique fails, we gain new knowledge and try the next innovation.
Paris Basin Geology

- Simple structural setting
- Extensional tectonic regime
- Thick Jurassic source rock section
- Under-explored oily basin
- Unconventional plays unexploited
Liassic Source Rock Characterization

- Thick source rock section (up to 600 meters thick)
- Oil prone kerogen types
- Sufficient burial and thermal history
Paris Basin Regional Geology

- Intracratonic basin formed due to down-warping associated with crustal cooling.

- The Basin was dominated by extensional forces from Permian though Jurassic time, compression shortening began in the Cretaceous and continued into the Tertiary.

- Marine sedimentation began in the Permian and continued into the Tertiary.

- More than 3000m of sediments have accumulated in the Basin center.

- Hydrocarbon exploration began in the mid-20th century.

- Significant oil reservoirs have been discovered in conventional traps, structural and stratigraphic, from the Triassic Keuper sands, Jurassic Bathonian carbonates and Cretaceous Neocomien sands.

- Lightly explored by world standards, there have been less than 1000 exploration wells drilled in the basin. Only 30% have actually penetrated the Liassic. (Paris Basin covers an area the size of Ohio)
Paris Basin Petroleum Development History

1 - CUMULATIVE OIL PRODUCTION VERSUS DISCOVERY DATE

- Neocomian sands
- Portlandian limestones
- Dogger limestones
- Rhaetian sandstones
- Chaunoy sandstones
- Donnemarie sandstones
- Lettenkohle dolomites

The greatest field in France:
- CHAUNOY (CNY)
  ~75 MMBO

~45 MMBO

- VILLEPERDUE (VPU)

- The first discovery:
  - Pays-de-Bray (1954)

- The first discovery of economic size:
  - Goultommes (1958)

- The first Triassic discovery of economic size:
  - Donnemarie (1979)

- The last important discovery:
  - Itteville (1990)

- The latest discovery:
  - La Vieille Borde (1996)

Discovery dates:
- 1950 to 2000
Paris Basin Petroleum Development History

**Number of Wells Drilled (Paris Basin)**

- 1965
- 1966
- 1967
- 1968
- 1969
- 1970
- 1971
- 1972
- 1973
- 1974
- 1975
- 1976
- 1977
- 1978
- 1979
- 1980
- 1981
- 1982
- 1983
- 1984
- 1985
- 1986
- 1987
- 1988
- 1989
- 1990
- 1991
- 1992
- 1993
- 1994
- 1995
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007

**Production (crude oil)**

- Other France
- Paris Basin

Under-explored basin – Conventional and Unconventional Objectives
Paris Basin Hydrocarbon Habitat

(PARIS BASIN)

SCHEMATIC CROSS-SECTION SHOWING THE DIFFERENT RESERVOIRS

(W) PARIS

1000 m

TERTIARY

CRETACEOUS

MALM DOGGER

LIASSIC SOURCE ROCK

TRIASSIC

(After Bacchiana et al., 1994)
Multiple source rock intervals interbedded with carbonates !!!
Notional Evaluation Targets
Paris Basin Liassic Isopach

Thick (up to 2,000’) source rock interval

Total Liassic Isopach
CI = 50 m (164 ft)
Paris Basin Base Jurassic Structure Map

Structure provides proxy for source rock oil maturity window

Liassic “kitchen”
Geochemical data confirms oil generation model and play fairway
Paris Basin Lias Isopach and Thermal Maturity

Isopach map of Lias shale

Thermal maturity appears optimum across Concorde acreage

Exploration Focus

- Thick Lias deposition
- Optimum thermal maturity
- Rich TOC
Paris Basin – Areal Extent of “Kitchen”

<table>
<thead>
<tr>
<th>SOURCE ROCKS</th>
<th>AREAS (Km²) Oil Prod</th>
<th>AREAS (Km²) Oil Expulsion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Toarcian</td>
<td>9500</td>
<td>Immature</td>
</tr>
<tr>
<td>Early Toarcian</td>
<td>11000</td>
<td>1700</td>
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<tr>
<td>“Schistes Cartons”</td>
<td></td>
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<tr>
<td>Lotharingian</td>
<td>19000</td>
<td>6000</td>
</tr>
<tr>
<td>Sinemurian</td>
<td>22000</td>
<td>9000</td>
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</table>

-Source: Poulet, M & Espitalie, J  
“Hydrocarbon Migration in the Paris Basin”  
## Paris Basin Oil Expulsion Model

<table>
<thead>
<tr>
<th>SOURCE ROCKS</th>
<th>Petrol. Pot. (MM T/Km2)</th>
<th>Petrol Generated</th>
<th>Petrol Expelled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Toarcian</td>
<td>3-5</td>
<td>209.0 - 342.0</td>
<td>---</td>
</tr>
<tr>
<td>Early Toarcian</td>
<td>3-5</td>
<td>242.0 – 396.0</td>
<td>37.4 – 61.2</td>
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<tr>
<td>“Schistes Cartons”</td>
<td>3-5</td>
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<tr>
<td>Lotharingian</td>
<td>2-3</td>
<td>277.4 – 418.0</td>
<td>96.0 – 132.0</td>
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<tr>
<td>Sinemurian</td>
<td>2-3</td>
<td>321.2 – 484.0</td>
<td>131.4 – 198.0</td>
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<tr>
<td>Hettangian</td>
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<tr>
<td><strong>TOTALS</strong></td>
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<td>1,049.6 – 1,640.0</td>
<td>264.8 – 391.2</td>
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</table>

**Source:** Poulet, M & Espitalie, J

“Hydrocarbon Migration in the Paris Basin”

<table>
<thead>
<tr>
<th>Well</th>
<th>Date</th>
<th>Toarcian - Domerian</th>
<th>Prunésegagien</th>
<th>Hettangian</th>
<th>Oil, Gas shows, frac</th>
<th>Oil kick/flow</th>
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<td>LUNDIN - Cense Orvat - 1</td>
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</tbody>
</table>
Paris Basin Melarcheze Example

Melarcheze #1Bis
Banc du Roc
Paris Basin Latilly Example

Latilly #1

Hettangian “Shale”
Villemoyen #1
Hettangian “Shale”
Paris Basin XRD and Petrography

- High Quartz content:
  - XRD analysis
  - Thin Sections

- Microfracturation:

- Overpressure indications: Oil & Gas Kicks, 1 Blow Out
Paris Basin Seismic Coverage

Seismic profiles acquired in the Paris Basin since 1970
Paris Basin Seismic Example
Paris Basin Seismic Example
In the Bakken Play, basement block movements can migrate upward and be observed on the surface as lineaments. This character is also observed in the Paris Basin.

Borehole breakout analysis indicates stress anisotropy – Sh max NW-SE
Critical Success Factors
Oil Shale Plays

- **OOIP** .... Need significant resource
- **Thickness** .... Frac Containment- Zonal Sep & Resource
- **Natural Fractures** .... Storage & Transport
- **Maturation** .... Mature Kerogen - Active generation?
- **Catagenesis** .... Kerogen maturation
- **Stress – Anisotropy** .... Orientation(s) of frac vs wellbore
- ** Brittleness** .... High Young’s and Low Poisson’s ... please?
- **Mineralogy** .... Clays, Type-Volume, Pyrite, Calcite fill?
- **Permeability** .... Pore Throats vs Micro Fractures
- **Oil Gravity – Viscosity** .... Fluid flow-recovery efficiency
Paris Basin
Bakken Analog Study
Bakken Analog – Similar Stratigraphic Configuration

Horizontal Bakken/Three Forks

- World Class Oil Shales Sourced Both Bakken and Three Forks Formations
- Bakken Dolomite Average Oil-in-Place 7.0MM Barrels/Section
- Three Forks Estimated Average Oil-in-Place 6.5MM Barrels/Section
Paris Basin – Bakken Comparison

Williston Basin

~ Same Scale

Meters

Feet

Trilbardou 1
Paris Basin-Bakken Burial Depth Comparison

Background adapted from Andrew D. Hindle, Petroleum Migration Pathways and Charges: Concentration: A Three-Dimensional Model. AAPG Bulletin. V. 81, No. 9 (September 1997), P. 1451-1481.

Warning: different scale!
Contour interval: 500 m


Paris Basin – Bakken TOC Comparison

**Schistes Carton**


**Bakken Shale**

From Fred F. Messner and Richard B. Banks, *Computer Simulation of Hydrocarbon Generation, Migration, and Accumulation under Hydrodynamic Conditions*, Oral Presentation at AAPG International Conference and Exhibition, October 15-18, 2000, Bali, Indonesia

*Paris Basin*

*Williston Basin*
Paris Basin – Bakken Tmax Comparison

**Schistes Carton**

**Bakken shale**


**Tmax in °C**


**Tmax corresponds to the temperature of maximum of hydrocarbon formation during the programmed pyrolysis run.**

PARIS BASIN  

WILLISTON BASIN
Micro-fractures in Bakken Formation

Why Maturity Matters

- Catagenesis in mature source rocks
- Large strength anisotropy
- Super-lithostatic pore pressure
- Horizontal micro-fracture propagation

Slabbed sandstone displaying reticulated horizontal fracture network in dry and wet condition. Sample from Bakken Middle Member (Shell 33-23-154 USA, Sec 23 T146N R104W).
Backscatter electron images of polished finely laminated black shale samples showing micro-fractures that have originated within or along the edges of kerogen particles. (Example from Dunkirk Shale – Devonian, New York. After Lash and Engelder 2005)

- Catagenesis in shale source rocks creates its own porosity and permeability.
- Horizontal micro-fractures coalesce and connect with vertical macro-fractures.
- This mechanism accounts for migration of oil from impermeable source rocks.
Whole core example of horizontal oil-filled micro-fractures in mechanical communication with vertical macro-fracture in over-pressured source rock (Tuscaloosa Marine Shale).

(A - 12,325.0-12,325.3') 20% enlargement black light photo of intact vertical fracture and smaller horizontal associated micro-fractures with gold oil fluorescence.

(B- 12,329.5') Gold oil fluorescence along horizontal fractures

(C- 12,329.5') 4" long core section with horizontal fractures and oil fluorescence.

(D- 12,330') 2" long section of highly pyritized core.

(Red arrow = oil fluorescence  White arrow = mineral fluorescence)

From Unocal #1 I.J. Lambert 53-6

**NOTE** Core was photographed 5 days after retrieval and intensity of fluorescence is diminished due to evaporation. Red arrows highlight oil fluorescence.
Thin Sections of Niobrara showing presence of fine grain clastic laminations, natural fractures and oil saturation.

Catagenesis has propagated horizontal micro-fractures.

Pathway and storage for hydrocarbon charge.

Niobrara thin section photomicrograph example.
### Bakken Analogy Summary

#### Rock Types - Deposition

<table>
<thead>
<tr>
<th>Paris Basin Liassic</th>
<th>Bakken</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOC</strong></td>
<td>0-40% (avg 10%)</td>
</tr>
<tr>
<td><strong>Tmax</strong></td>
<td>445 deg C</td>
</tr>
<tr>
<td><strong>Source Rock</strong></td>
<td>Type II</td>
</tr>
<tr>
<td><strong>Organic Matter</strong></td>
<td>Marine Plankton + Anaerobic Bacteria</td>
</tr>
<tr>
<td><strong>Depositional Environment</strong></td>
<td>Marine and Oxygen Restricted</td>
</tr>
<tr>
<td><strong>Adjacent Water Prod Zone</strong></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Lodgepole</td>
</tr>
</tbody>
</table>
### Bakken Analogy Summary

#### Reservoir Characteristics

<table>
<thead>
<tr>
<th>Property</th>
<th>Paris Basin Liassic</th>
<th>Bakken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brittle Layer</td>
<td>Banc de Roc Lime</td>
<td>Mid Bakken Dolomite</td>
</tr>
<tr>
<td>Quartz Content</td>
<td>26 – 58 %</td>
<td>20 – 68 %</td>
</tr>
<tr>
<td>Net Meters (ft)</td>
<td>1 – 40 m (4 - 130 ft)</td>
<td>2 – 20 m (7-66 ft)</td>
</tr>
<tr>
<td>Porosity %</td>
<td>9 - 12% (avg 10%)</td>
<td>3 – 10% (avg 5%)</td>
</tr>
<tr>
<td>Permeability</td>
<td>Up to 5.0 md</td>
<td>0.05 – 0.5 md</td>
</tr>
<tr>
<td>Oil Gravity</td>
<td>34 - 38 deg API</td>
<td>42 deg API</td>
</tr>
</tbody>
</table>
Paris Basin France
Premier Unconventional Resource Opportunity?

• Thick, rich, and mature oil source rock
• Structurally simple basin
• Stratigraphy offers reservoir and mechanical lithofacies favorable for exploitation
• Active hydrocarbon generation and slight over-pressure
• Moderate drilling depths
• Existing petroleum production infrastructure
• Proximal premium market
Paris Basin

- Possible multi-billion barrel oil resource
- 3rd largest modern economy in Europe
- Small vocal environmental faction has successfully urged government to ban hydraulic fracture stimulation
- Government slowly “studying” stimulation to develop policy
- Oil resource exploration on hold
- What’s next????????