Evaluating Mature Fields: Los Angeles Basin as an Analog

AAPG Webinar

October 21, 2010

- Why we are interested
  - 160 billion barrels of oil have been produced in the US to date
  - 330 billion barrels of oil are left How much of this can we produce?

- Opportunities
  - Redevelopments
  - Extension Exploration
  - Frontier Exploration
Don Clarke

- 1974-1981 California State Lands Commission
- 1981-2005 City of Long Beach
- 2005- Present Consultant

Clients include: Occidental Petroleum Los Angeles Basin Business Unit, Tidelands Oil Production Company, Vintage, Terralog Technologies, City of Beverly Hills, City of Hermosa Beach, Signal Hill Petroleum, Glamour Magazine

Publications: 60 papers and abstracts, three guidebooks

Videography: A Crude Awakening, LA’s Hidden Oil Wells, A Gallon of Gas, numerous interviews

AAPG: Chairman of the House of Delegates, Advisory Council
What’s different now?

- New ways to look at the geology
- Computers    Software & Hardware
- Government regulations
- Long reach drilling
- Small foot print
- Oil prices
- Public transparency
New Targets

- Conventional
  - Bypassed oil
  - Missed targets

- Non conventional targets
  - Shales
  - Fractured reservoirs
  - Basement
High Technology

- Computer Mass Storage
- Computational power
- Geologic modeling programs
- Data scanning
- Computer record Management
Modeling Tools

- Structure Models
- Property Models
- Spreadsheet Models
- Cross Sections
Structurally complex core of an anticline
Figure 1. The worldwide ERD database will take on a new profile if BP is successful stepping out 8.3 miles (13.3 km) on its Liberty field development project.
Historical Crude Oil Prices (Year End Average)
## Oil Price History - Annual % Change

<table>
<thead>
<tr>
<th>Year</th>
<th>Change</th>
<th>Year</th>
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<th>Year</th>
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<td>11%</td>
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<td>9%</td>
<td>2001</td>
<td>-32%</td>
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<td>9%</td>
<td>2004</td>
<td>35%</td>
<td>2005</td>
<td>37%</td>
<td>2006</td>
<td>4%</td>
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LA Basin Observation

- Basin Sedimentary Depth (30,000 ft).
- Kitchen is the entire basin.
- Hydrocarbons did not migrate far from source (ref Mobil study).
- Most discoveries date to the 1920’s.
- Past exploration focused on seeps & large faults.
- Existing fields are relatively shallow (3000 to 7000 ft).
- Major Oil Companies began losing interest after WWII and a few sold out.
- Some resurgence of activity following the 1973 oil embargo.
- Remaining Major Oil Companies departed the basin following the 1986 price collapse.
- Most of the fields appear to have potential at elevated oil prices ($100/bbl).
- Small operators are not capable of large scale redevelopment.
- Very few deep wells (> 15,000 ft) ever drilled.
- Three super-giant oil fields
<table>
<thead>
<tr>
<th>Oil Field</th>
<th>OOIP</th>
<th>Cumulative Production</th>
<th>% OOIP</th>
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<tr>
<td></td>
<td>barrels</td>
<td>barrels</td>
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<tr>
<td>Huntington Beach</td>
<td>3,513,513,514</td>
<td>1,300,000,000</td>
<td>37%</td>
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<tr>
<td>Inglewood</td>
<td>1,379,310,345</td>
<td>400,000,000</td>
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<td>Long Beach</td>
<td>3,096,774,194</td>
<td>960,000,000</td>
<td>31%</td>
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<td>Montebello</td>
<td>594,117,647</td>
<td>202,000,000</td>
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<td>Dominguez Hills</td>
<td>1,309,523,810</td>
<td>275,000,000</td>
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<tr>
<td>Brea-Olinda</td>
<td>2,272,222,222</td>
<td>409,000,000</td>
<td>18%</td>
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<tr>
<td>Sansinena</td>
<td>300,000,000</td>
<td>60,000,000</td>
<td>20%</td>
</tr>
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<td>Santa Fe Springs</td>
<td>2,093,333,333</td>
<td>628,000,000</td>
<td>30%</td>
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<td>Torrance</td>
<td>1,036,363,636</td>
<td>228,000,000</td>
<td>22%</td>
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<td>Whittier</td>
<td>257,142,857</td>
<td>54,000,000</td>
<td>21%</td>
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<td>Richfield</td>
<td>2,000,000,000</td>
<td>400,000,000</td>
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<td>Seal Beach</td>
<td>891,666,667</td>
<td>214,000,000</td>
<td>24%</td>
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<td>Rosecrans</td>
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<td>95,000,000</td>
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<td>El Segundo</td>
<td>75,000,000</td>
<td>15,000,000</td>
<td>20%</td>
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<tr>
<td>Totals</td>
<td>19,293,968,224</td>
<td>5,240,000,000</td>
<td>27%</td>
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</table>
Southern California Time Scale

- **Recent**
  - **Now**
- **Pleistocene**
  - 11,000 years ago
- **Pliocene**
  - 1,800,000 years ago
- **Early Miocene**
  - 3,800,000 years ago
- **Miocene**
  - 5,300,000 years ago
- **Late Miocene**
  - 11,200,000 years ago
- **Middle Miocene**
  - 14,800,000 years ago
- **Early Oligocene**
  - 20,500,000 years ago
- **Oligocene**
  - 23,000,000 years ago
Movies of Tectonic Movements
Where do we go from here?

Is there more oil?
If so where is it?
How do we look for it?
Reservoir Description Tools

Core & Log Analyses

Geological Models

Seismic

Cross-Sections

Structure & Isochores

Stochastic Models
Depositional Setting

- Submarine fan deposits
- Shallower zones composed of thick mid-fan lobes
- Deeper zones composed of thinner outer fan sandstones
- Sandbodies exhibit strong off-lapping behavior at multiple scales
Point-Source Turbidite Depositional Model

(Stow et al., 1985)
Typical LA Basin Geologic Description

- Bouma sequences B-D, occasionally A
- Unconsolidated and laterally continuous
- Approximately 120 ft. (37 m) gross interval
- 40% net to gross ratio
- Effective Porosity = 0.27
- Effective Permeability = 500 mD - 1000 mD
- API Oil Gravity = 15-29
- Proximally deposited, amalgamated, turbidite sands
- Swi = 0.15 Average

Permeability barriers (silts/shales) erode off during successive depositional events allowing sands to amalgamate.
Capturing Attic Oil with Horizontal Wells

Horizontal Well
Pass through log

Injected water
Capturing Banked Oil with Horizontal Wells

- OIL SANDS
- WET SANDS
- Fault
- Drilling Island

Fault (40 FT)

OIL SANDS

WET SANDS

Fault
Use of Non-Horizontal Wells

New Wells

Redrills

Plug-backs

Fracture Stimulation
Use of Water Injection Profiles

- Combine sands to form hydraulic layers for material balance
- Most injected water enters higher perm sands in Layer 1
- Little water is injected into other layers
- Layer 1 also has the greatest drawdown
Growth Opportunities from 3-D Seismic

- New fault blocks
- Reinterpreted faults
- Amplitude anomalies
- Horst blocks
- New faults
- Three-way closures against faults
- Sub-thrust rollovers (4-way closures)
- Sub-thrust fault traps
- Sub-thrust pinch-outs

Distance markers:
- SW: 10,000’
- NE: 2,000’, 6,000’, 10,000’, 14,000’
Exploration Methods

- Review old data
- 2D Seismic
- 3D Seismic
  - Reprocess 3D Seismic
- Passive 3D Seismic
- High frequency seismic
- Cross well tomography
- 3D VSP
- Other
Review Old Data

- Compare the new with the old
- Look at the logs and completion intervals
- Compare the production histories
- Talk it up with others
- Do your homework and apply the man hours because a dry hole is expensive.
Bypassed Oil

- Most oil fields have bypassed oil.
- The oil sands have not been produced for many reasons.
- Identify the bypassed oil and design the new well to maximize the opportunity.
- Missed section Look at the logs
- Missed area Look at your maps
Sub Thrust

- Basin compression
- Strike slip faults
- Thrust faults
- Blind thrusts
- Dislocation surfaces
- Flank plays
River Channels

- Any long sinuous sand body.
- These may be ancestral rivers or feeder channels to lobate deposits.
- Tough to spot on seismic.
- Knowledge of the depositional environment will help to spot these.
Turbidite Lobes

- Compensating lobes
- Scour and cutting
- Draping
- Soft sediment deformation
- Reactivation
- Understand the depositional environment
The Details

Los Angeles Basin
Aerial View of Huntington Beach Drill Site
Street View of Huntington Beach Drill Site
San Vicente Drill Site at the Beverly Plaza
The Packard Drill Site in Beverly Hills
Los Angeles Basin Field Example

- Moderate sized oil field (Cumulative production = 200,000,000 bbl.)
- Field had some significant blowouts in the past
- Few mineral rights owners
History

- Discovered 1923 by Unocal and developed systematically through cooperation between the four principal operating companies, including Unocal and Shell.
- Consists of eight major oil reservoirs ranging from 3700 to 7400 feet; also a shallow gas zone between 2650 and 3750 feet.
- Peak oil production around 60,000 bpd 1924-25; peak gas production of 84 million cu.ft/day in March 1925.
- Gas injection 1935-41; waterflood commenced 1946 and extended to all zones by 1960. 20-30,000 bwpd injected throughout 1970’s and 1980’s.
- Oil production and water injection decline sharply in 1997; virtual shutdown of all operations by mid 1998, presumably at behest of landowners.
- Only remaining operator has two wells in the extreme South-East corner of the field, each producing 8 bopd.
Reservoir

- Faulted anticline reflected on the surface by a 150 foot high hill. Vertically stacked reservoirs with 1980 feet of pay at center of formation.
- Estimated 1.3 billion barrels of OOIP.
- Crude oil quality consistent throughout the zones, gravity 29-33 degrees API, low sulfur, high gasoline content and asphalt base.
- Cumulative oil production to date approx. 274 million barrels or 21 % of OOIP.
- Total acreage estimated to be 1,389 acres but main central area of Field approx. 430 acres.
Production History
Production Potential

- Production profile before 1998 virtual shutdown suggests additional 3-5 million barrels proven reserves.
- Based on additional 10% recoverable, additional 130 million barrels possible reserves.
- Good potential in faulted, deeper (Miocene) zones toward East and West flanks
- Possibility of divergent traps along South flank
Other Considerations

- Suitable for CO$_2$ flood in deeper zones.
- No known subsidence concerns.
- Surface area developed primarily for light industry; locations suitable for drilling, treatment and storage.
Conclusion

- This field appears to have been prematurely abandoned considering the substantial increase in oil prices experienced since 2000. Our main caveat concerns the degree of pay thickness variation throughout the measured field acreage and we have tried to take account of this by risking each of the main areas by between 20% and 50% in calculating OOIP.
Evaluating Mature Fields: Los Angeles Basin as an Analog

Don Clarke

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Los Angeles Basin
Geological Overview

The Los Angeles Basin as we know it got started with the subduction of the triple junction off of what is now Mexico around the Miocene times. This caused a rift and a rotation of over 90 degrees of the rocks in the California borderland.
At about 6 million years ago the rift motion was taken up by the San Andreas and other associated transform faults. The transform fault system has taken most of southern California and the Baja Peninsula for a ride north as they move along as part of the Pacific Plate.
During this time the environment and ocean currents were favorable and supported an abundant biota. Simultaneously the tectonic activity broke up a lot of rocks during the right lateral strike-slip movement and associated mountain building. The basin opened as the remains of the biota and the sediments filled it.
It is estimated that there is over 30,000 feet of sediment in the center of the Los Angeles Basin. All of it is less than 24 million years old. Between the layers is a tremendous amount of organic material that has provided the source for the oil. The outwardly visible strike-slip terrain is most likely underlain by thrust faults that complicate the picture.
The Miocene through Recent sediments were derived from the Peninsular mountain ranges and consist of turbidite deposits that produced a complex submarine fan system. The main influx of sediment came from the northeast across what is now known at the Puente and Repetto Hills.
The material spread out into two main lobes. The larger lobe flowed through the Whittier Narrows area and across the center of the basin and the Downey Plain to Long Beach. The western lobe moved west across the basin towards Manhattan Beach where the sediments inter-fingered with deposits coming from the Tarzana Fan area near what is now UCLA.
Folding

During the Pliocene the rotation had ceased and now the Los Angeles Basin became subject to compression.