Oil Production Need for In-Situ MEOR

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# The Basics of an Oil Company

## Find It
- **Exploration**
- **Upstream**
- **Acquisition**
- **Processing**
- **Interpretation**

Cost of a “Dry Hole” could be over $100M, harder to find

## Retrieve It

## Move It

## Process It

## Sell It

## The Energy Company in a Single Chart

<table>
<thead>
<tr>
<th>Who Owns the Oil?</th>
<th>25% IOC, 75% NOC</th>
<th>New Techniques and algorithms</th>
<th>Must Build up new reserves</th>
</tr>
</thead>
</table>

**The Cost of a “Dry Hole” could be over $100M, harder to find.**

**New Techniques and algorithms Must Build up new reserves.**

**Who Owns the Oil?**

- 25% IOC
- 75% NOC
Big Fibers
Big Trees
Small plants and animals

Basic Hydrocarbon Resource Formation
Finding Petroleum Should be Easy - Right? Oil is Where You Find It?

But the complication is what happens over time!

Geoscientists are doing forensic science on millions of years of rock formations to determine what happened over those years.
Geologists Make Geological Guesses for Location of New Areas for Investigation
Data is Collected

Multiple types that include

- Remotely sensed geophysical data
  - Magnetic
  - Seismic
  - Gravimetric

- Sample geological and geophysical data
  - Rock data (field samples)
  - Gas data (sniffed)
  - Borehole data
    - Cuttings
    - Liquids
    - Geophysical
      - Electric logs
      - Down hole measurements
    - Biological
Geophysics Remotely Samples the Earth.

They recover the reflected energy transmitted through earth materials.
A Geoscientist Interprets a Seismic Cross Section and Adds Geologic Labels

Seismic section showing target and source for Shell wells 14/05-1 & 14/10-1

- Target
- 2 Shell wells on delta
- SW 85%
- Live oil
- Source
- Mature
- Gas from deep source
- Immature
Another Technique Uses Electro Magnetic (EM) Energy

Data collected by towing e-m source over receivers. Detects resistivity contrasts (oil, coal, salt, igneous rocks).

EM methods can be 100x as costly as seismic methods.
Computer Technology Used to Interpret Data
Drilling Commences to Test Targets

DEPTHS OF THE GULF OF MEXICO

- **Perdido** is the deepest offshore drilling facility at 8,000 feet.
- **U.S. Navy submarines** can go at least 800 feet.
- **Sperm whales'** average depth is 1,968 feet.
- **Scuba divers** max out at 130 feet. (PADI)
- **The Deepwater Horizon wellhead** is in 5,000 feet of water.
- **Relief wells** reached depths of 15,961 feet and 17,810 feet as of July 10.

**Mardi Gras shipwreck**, found in 2002, lies at 4,000 feet.

**The Sigsbee Deep** is the deepest part of the Gulf.

From: CNN.com
Challenge for the Future

- Future Challenge: 400 Billion Barrels
- Cumulative Production: 175 Billion Barrels
- Proved Reserves: 21 Billion Barrels

*Excludes deepwater Gulf of Mexico*
Two Main Challenges for the Upstream Oil Business Today!

New discoveries in New areas

Make the most of mature areas
NPV @9% vs Recoverable reserves - based on constant $50/bbl. More reserves produced from the same location the greater the profit.
Potential for Viscous Oil Recovery (VOR) in Alaska is Great and will add to Reserves

- 23 billion barrels of viscous oil are physically locked underground in Alaska (AK) >50% of original Resource
- This reserve is equal to about the same resource as the initial "oil-in-place" delineated for the prolific Prudhoe Bay oil field
Primary Enhanced Oil Recovery

Water Flood and/or Fracture
- Oil floats on water
- Oil migrates to wells through fractures if necessary
- Need water source that is not potable

Microbiological
- Current methods involve injection of microbes
- No guarantee of compatibility with subsurface environment
- Control of fluids very difficult using present technologies

CO₂ Injection
- Oil is forced out
- Oil is made lighter and flows easier
- Need source of CO₂

Viscosity Reduction is fundamental to and critically needed by all VOR technologies and the methods currently in general use are relatively environmentally insensitive eg.
CO2 and Total % Production from Different Phases

A Representative Oil Field Development Sequence

- Primary
- Secondary
- CO2 EOR

- 10-20% OOIP
- 15-25% OOIP
- 10-15% OOIP

YEARS
CO2 Process Diagram
New Facilities Needed for CO2
Secondary enhanced oil recovery of viscous oil include:

- Steam Flooding; In-situ Combustion; Miscible Gas Injection; CO2/Flue Gas Cyclic Injection; Alkaline-Surfactant-Polymer (ASP) Flooding; Solvent Gas Injection via Horizontal Wells; Post Cold-flow Reservoir Recovery; The common element to all of these methods is that:
  - They are expensive
  - They require additional infrastructure and resources
  - They are environmentally insensitive
  - They sterilize the subsurface environment
Why is the Need Critical for New Approaches Now?

The Petroleum Industry Has Reached a Tipping Point with Respect to Climate Alteration, Environmental Protection and the Need for Energy

- There is a great push in the US to lessen dependence on foreign sources of oil
- Oil from the Colorado Plateau, where oil shales are mined and heated to produce crude, can cost two to three times as much as drilling and production elsewhere and depends upon oil being priced above $100 per barrel.
- 23 billion barrels of viscous oil are physically locked underground in Alaska at Prudhoe Bay which more than the “non-viscous oil in place” or already produced from Prudhoe Bay.
- The availability of CO₂ nearby to viscous reserves may not exist or may have to be purchased from others.
- The infrastructure is already in place where most viscous oil occurs which minimizes new environmental damage, need to acquire new permits, and to install new distribution networks.
Why not Use a Technology That is Environmentally Friendly, Does Not Require an Appreciable Additional Amount of Equipment, and has a Wealth of Microbiological Data Already Available with Respect to Species Identification that Insures Successful Implementation?
Typical Contaminated Soil Remediation
FIGURE 6.1  Microbial approaches for oil recovery. Panels A–C refer to different processes described in the text. (A) Microbial paraffin removal (left side) and microbial well stimulation (right side). Paraffin removal could be applied to either injection (I) or production (P) wells; well stimulations are done in production wells, most often, paraffin removal and microbial well stimulations involved the injection of nutrients and cells. (B) Microbially-enhanced water flooding where the stimulation of microbial metabolism creates useful products to mobilize oil; an inoculum maybe used. (C) Microbial selective plugging blocks high permeability zones (upper region) and redirects the recovery fluid into bypassed regions (lower) of the reservoir; nutrients and inoculum (if used) enter the high permeability zone (upper panel) and in situ microbial growth reduces permeability in this region.
Features of a Data Rich MEOR Approach

- Uses microbiological species indigenous to formation containing the Oil
- Must characterize the heavy oil and its environment in a perspective consistent with MEOR implementation in key locations
- Exploit bacteria influential in improving oil recovery in *TWO* ways:
  - Identify those bacteria that directly or indirectly metabolize heavy components over light components, thereby differentially improving viscosity
  - Identify those bacteria that generate the most surfactant per product consumed
- Utilizes agent based modeling to simulate interactions between the bacteria and subsurface geology before and during field tests
- Method satisfies need by industry for “green technology” for the production of viscous or heavy oil from either current oil fields or new discoveries after Primary Recovery that is not labor or energy consumptive.
So Much Data - So Little Information.
New Data Centric Approach (ASSET 1)

- Acquire data (all data in digital format) and analyze **spatial relationships** between data elements
  - Geophysical, geochemical, and geological data
  - Liquid data analyses
  - Biological data

- Use geo-statistics to predict intervening points

- Knowledge is **built and captured** to ascertain:
  - **Associations** between data at same location
  - **Associations** between data and current models

- **Predict**
  - Using Discovery Based AI and Agent Based techniques
    - What characteristics to look for and where to look for them on the prospect
    - **Understand** rock, mineral and biological reactions to expect

- Display proposed areas that have proper relationships on maps and related displays

- Estimate intervening points to intercept meaningful interactive zones with geo-statistics

- Drill and reassess
MEOR Data Management

• Oil reservoirs and tar sands may contain both heavy and light hydrocarbons.

• MEOR has been proven as a biogeochemical process for remediation hazardous hydrocarbon spills that:
  • Uses nutrient enhancement of in-situ microbiologically preferential species
    • To preferentially mobilize lighter fractions
    • Degrade the heavier fraction
    • Produce surfactants to permit migration

• To do this requires:
  • Sufficient characterization of reservoir to understand spatially the:
    • Organic and inorganic species
    • Permeable pathways
    • Potential geochemical changes that might take place.

• Methods used are:
  • Statistical, AI, and discovery based analytical techniques
  • Simulation using agent based models

• This approach will incur less environmental damage to:
  • Subsurface environments
  • Surface ecology in environmentally sensitive areas

• Less costly because of energy savings and infrastructure reuse
Agent Based Models

- Each agent has a very small program that governs behavior.
  - Example from the wild
    - Sardines
  - Simulation
School of Sardines
Model
Agent Based Models

- Each agent has a very small program that governs behavior.
  - Do not swim out of the water
  - Do not swim into the bottom
  - Remain within x distance of your neighbor
  - Move away from anything bigger than you are.
Geographic Information Systems 
and Geostatistics

Geographic Information Systems (GIS):
- Organize information by its location
- Visualizes Data
  - To improve the understanding of relationships
  - Enables better decision making

Geostatistics
- Class of statistical techniques developed to analyze and predict values of a variable distributed in space or time
- Initially developed as a mining evaluation tool
  - Used in the exploration of minerals, ores, and coals
  - Currently also applied to numerous surface and subsurface disciplines in geology and environmental sciences
Geostatistics
Data Mining and Data Management

- Data Marts
- Enterprise Data Warehouse
- Operational Data Store

Database

Data Mining Process
- Clustering
- Associations
- Sequences
- Classification
- Regression

Master Data Management
- Products
- Customers

Applications, Operational Systems

3rd Party External Data
Data silos result in minimal global data analytics resulting in an incomplete picture. We integrate the data in data warehouse such that all is available for analysis and use in subsurface simulations.

The combination of Spatial Analysis, Data Analytics, Agent Based Modeling and Continuous Monitoring results is an evolutionary step in geological understanding.

This approach brings a resource exploiter one step closer to seeing a complete picture.
Inter-relate
Agents to Understand Changes
Interaction of Agents of Different Species Recognized During Simulations Allows for the Control of the Project During Testing and Running of Well field
Points of Emphasis

- The use of microbiologically enhanced oil recovery using formation indigenous species started during initial water flood recovery extends production dramatically.
  - This MEOR process is not dependent upon the use of exo-formational species injected into the formation but only requires injection of nutrients to the species that are in-situ.
  - This method is a proven technique for remediation of refined product spills and is most successful when in-situ microbiological species are well characterized and their biochemistries understood.
  - The success of MEOR is dependent upon the ability to monitor and understand the progress of extraction of hydrocarbons and monitoring the reservoir health on a continuous basis. The use of sophisticated modeling and simulation associated with ABM and AI is one of the keys to success.
  - The recovery of hydrocarbons from well fields that have undergone either CO2 or thermal methods of secondary recovery is less successful.
  - Little or no additional equipment is necessary to utilize this approach to Oil recovery and the process will be successful when recovering either viscous or non-viscous hydrocarbons.
Questions?