Petroleum Systems
(Part One)
Source, Generation, and Migration

GEOL 4233 Class
January 2008
Petroleum Systems

**Elements**
- Source Rock
- Migration Route
- Reservoir Rock
- Seal Rock
- Trap

**Processes**
- Generation
- Migration
- Accumulation
- Preservation
Petroleum System Summary

- **Source (Material and Rocks)**
- **Generation (Maturation)**
- Migration
- Trap
- Reservoir
Source Material

Non-Biogenic Origins

Biogenic (Kerogen) – Host rock (Shales and Coals)

Kerogen Types
  Type I – Algal (oil prone) sapropelic
  Type II – Mixed
  Type III – Woody (gas prone) humic
Siljan ‘Ring’
Inorganic Gas Prospect

Drilled to ~22,000’ in 1987
Found abiogenic methane, but no poro-perm
This geologic map shows the rock types and ages found at the Siljan Ring meteorite crater.
Sedimentary Rocks – Where the Action Is
Source Material

Non-Biogenic Origins

Biogenic (Kerogen Types)
- Type I – Algal (oil prone) sapropelic
- Type II – Mixed
- Type III – Woody (gas prone) humic

Host rock (Shales and Coals)
Types of Petroleum

Oil and gas are formed by the thermal cracking of organic compounds buried in fine-grained rocks.

- Algae = Hydrogen rich = Oil-prone
- Wood = Hydrogen poor = Gas-prone
Kerogen Types

Type 1: Algal Oil-Prone
Type 2: Woody Gas-Prone
Type 3:
Ganges Deltaic Sediments
Modern Mahakam Delta Plain
East Kalimantan, Indonesia
(A Rich Source of Kerogen)
Inferred Middle Booch Depositional Environments
Arkoma Basin in Oklahoma
Source Material

Non-Biogenic Origins

Biogenic (Kerogen Types)
- Type I – Algal (oil prone) sapropelic
- Type II – Mixed
- Type III – Woody (gas prone) humic

Host Rock (Shales and Coals)
The Origin of Petroleum

Organic-rich Source Rock → Thermally Matured Organic Matter → Oil
Source Rock for Petroleum

Organic-Rich Thin Laminae

LOMPOC Quarry Sample
Monterey Formation, CA

Total Organic Carbon: 3.39
Hydrogen Index: 378

1 Inch
Woodford Shale (Oklahoma)
Channel-Fill Sandstone Resting on Marine Shale
Red Fork (Oklahoma)
Coals and Coaly Shales
San Juan Basin (New Mexico)
Source rock kerogen can be correlated to oil/gas found in carrier beds and reservoirs.
### Basinal Summary Chart

#### T.O.C.
**Total Organic Carbon**
Petroleum System Summary

- **Source** (Material and Rocks)
- **Generation** (Maturation)
- Migration
- Trap
- Reservoir
The Petroleum Kitchen
Temperature-Pressure-Time

Geothermal Gradient: (thermogenic hydrocarbons)
- Range: <1 to 11 degrees F per 100’
- Typical Sedimentary Basins: 1.0-1.7 degrees F per 100’
- Good average 1.2
  - Oil window of ~ 120-300F (50-150C), or about 5,000-20,000’
  - In practice, oil below 15,000’ rare

Gas – no practical limit to stable depth
Cracking of oil to gas controlled by source kerogen and temperature
Deep basins mostly gas
Practical limits related to maturity of source – not reservoir
# Correlation Chart for Maturation Indices

<table>
<thead>
<tr>
<th>ASTM standards</th>
<th>Vitrinite random reflectance, % R&lt;sub&gt;0&lt;/sub&gt;</th>
<th>Temperatures, °F (°C)</th>
<th>Petrology stages†</th>
<th>Hydrocarbon windows</th>
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† Stage 1: Early porosity destruction
Stage 2: Organic acid dissolution
Stage 3: Late porosity destruction
Incipient metamorphism
Greenschist metamorphism
Over-mature
Hydrocarbon Occurrence & Thermal Maturity
Map of Oklahoma Oil and Gas Fields; Distinguished By GOR and Coalbed Methane Production. From Boyd (2002)
(GOR Cutoffs: Oil <5,000; Oil and Gas 5,000-20,000; Gas > 20,000)
Schematic Cross-section of the Anadarko Basin

Modified from Witt and others (1971).
Regional Stratigraphic Cross-Section
(Hung from Top of Booch)
Oklahoma Arkoma Basin (Booch)

(Present burial depth not necessarily maximum burial depth)
### DIVISIONS OF GEOLOGIC TIME

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*Geologic Time Scale*

Arkoma Basin
Estimated Overburden Removal
Petroleum System Summary

- **Source** (Material and Rocks)
- **Generation** (Maturation)
- **Migration** (Expulsion)
- Trap
- Reservoir
Buried-euxenic-basin model

S.E. Tarim basin prospects

Unconformity

Anticline

Cambrian-Ordovician

Sinian

Devonian

Permian-Triassic

Carboniferous

Jurassic

Cretaceous

Paleogene

Neogene

Buried-euxenic-basin source beds
(350 billion bbl)

K. Hsu
Tarim Associates, Zürich
Source Rock for Petroleum

Organic-Rich Thin Laminae

LOMPOC Quarry Sample
Monterey Formation, CA
Migration Pathways

- Hydrocarbon Expulsion
- Vertical vs. Horizontal Migration
- Residual Saturations
Schematic Interpretation, NM-16 Regional Seismic Line

Western Platform

Northern Taranaki Graben

Manganui Platform

Miocene Volcanics

Top of oil expulsion window (3,600 ms)

Plio-Pleistocene

Oligocene-Miocene

Paleocene-Eocene

Late Cretaceous

Cape Egmont fault zone

Turi fault zone

Sea floor

Taimana-1

Pohokura-2

(see Fig. 1 for location)
Present-Day Petroleum System

-GEOGRAPHIC EXTENT OF PETROLEUM SYSTEM-

-Present-Day-

Presentation of the present-day petroleum system with the following components:

- Trap
- Seal
- Reservoir
- Source
- Underburden
- Petroleum accumulation
- Top of oil window
- Bottom of oil window

Legend:

- Overburden
- Seal
- Reservoir
- Source
- Underburden

Magoon and Dow, 1994
Inferred Middle Booch Depositional Environments
Arkoma Basin in Oklahoma
Petroleum System

1) Early Generation
- Migration from 'Kitchen'
- Spill Point
- Reservoir Rock (Sandstone)
- Seal Rock (Mudstone)
- Gas beginning to displace oil
- Displaced oil accumulates
- Gas displaces all oil

2) Late Generation
- Spill Point
- Gas displaces all oil
- Displaced oil accumulates
GUSSOW'S PRINCIPLE

(WITH EXAMPLES FROM THE BADIN CONCESSION)

NO PETROLEUM

ARBI

MINOR OIL

TAJEDI

OIL

N. AKRI

GAS MINOR OIL

GOLARCHI

GAS

MAKHUMPUR

LIMIT OF COMPLETE CHARGE

Author: D. BOYD  Drafted by: TAJAMUL  Date: NOV. 94
The Leaky Trap
Petroleum System Processes

- Generation
- Migration
- Accumulation
- Source Rock
- Reservoir Rock
- Seal Rock
- Gas Cap
- Oil
- Water

Temperature Levels:
- 120° F
- 350° F
Schematic Migrational Pathways
From Basin to Shelf

SIMPLIFIED MIGRATION PATHWAYS
FROM BASIN TO SHELF

TOP OIL WINDOW
PERMEABLE SANDSTONE
BLACK SHALE

POSSIBLE OIL TRAP
IMMATURE SOURCE
OIL TRAP
IGNEOUS BASEMENT
Asphalt Seep
Viola Limestone (Oklahoma)

The End of the Road
On to the Trap
One More Thing……

Basin Assignments

- North American
  - San Juan
  - East Texas
  - Gulf Coast
  - Anadarko
  - Arkoma
  - Powder River
  - Wind River
  - Green River
  - Williston
  - Delaware
  - Midland
  - Black Warrior
  - Fort Worth
  - Others………..
Facts to Consider

Basin
Location, Size, Maximum Depth, Age (from basement to outcrop + max subsidence), Stratigraphy
Other items; eg - Structure (extensional, compressional)

Petroleum System
Source Rocks: Name(s), kerogen type(s), TOC, depth to top of oil window, kitchen location

Migration Pathways: Carrier bed(s), faults, distance (vertical and horizontal)

Traps: Structural, Stratigraphic, Combination (dominant type)

Reservoirs: Names, Rock types (both reservoir and seal)

Representative Fields (The biggest ones)
OOIP, OGIP, RF, Cum Prod

Other notable Facts – anything else you want to add (history, technology, companies, etc)

Powerpoint presentation: 10-12 slides (or more), approach as management presentation in which object is to highgrade future exploration opportunities for your company. For any answers you cannot find, treat as source of increased risk of entry.
1-Williston Basin  
2-Powder River Basin  
3-Denver Basin  
4-Salina Basin  
5-Forest City Basin  
6-Kennedy Basin  
7-Big Horn Basin  
8-Wind River Basin  
9-Laramide Basin  
10-Washakie-Red Desert B.  
11-Green River Basin  

Figure 1. Map of the United States showing basins containing sedimentary rocks more than 15,000 ft (4,572 m) deep. Shading indicates entire basin area, in which some of the sedimentary rocks are at shallow depths.
Tertiary Basins of Southeast Asia

*Most hydrocarbon production from carbonate reservoirs occurs in rift margin, back-arc, and foreland basins.

Source: Adapted from Packham and Shaw, 1991