Petroleum Geology

Introduction

Prof. Dr. Stefan M. Luthi
Course Data

Course Code: AES3820
Target Group:
1st Year MSc students Petroleum Engineering and Geosciences and Applied Geophysics, also Minor Geosciences

Course Credits: 3 ECTS

Course Material: PPT Presentation on Blackboard; books on reference list
Content

• Why it matters: Some basics
• History of petroleum
• The carbon cycle, organic matter and maturation
• Composition of oil and gas
• Migration from source to reservoir
• Reservoir rock properties
• Trapping
• Basin types and their exploration and development
• Reserves and resources
Course Description

This course aims at introducing the students to the basics of petroleum geology, a vast field that includes geochemistry, structural geology, sedimentology, mineralogy, fluid mechanics, mapping, volumetric calculations, risk and uncertainty analysis, and a vast array of industrial technologies.
Course Description

The course goal is to obtain a basic knowledge of the origins of petroleum and gas, of the accumulation conditions, and of the techniques to find and exploit hydrocarbons.

This should give the students a sufficient basis for further M.Sc. courses in the field, either here at the TU Delft or elsewhere, or to join a company where in-house training is provided.
It is your course

Make the best of it!
Reference Textbooks


Furthermore:

Why it matters
Available online via books.google.com
Quantities of oil are expressed in barrels:

1 barrel = 159 liters
1 cubic meter = 6.37 barrels

1 metric ton = 6.8 to 7.6 barrels (dep. on gravity)

Gas is expressed in millions of cubic feet:

1 MMcf $\approx 3 \cdot 10^4$ m$^3$

Energy-wise, gas can be expressed in oil equivalents:

1 boe $\approx$ 6000 to 6500 cf
Some Numbers

Number of oil and gas wells drilled to date: ~ 7 million
Percentage of wells in the USA: ~50%
Producing wells worldwide: ~ 1 million
Average production of oil wells in USA: 20 bbls/day
Average production of oil wells in Middle East: 7,000 bbls/day

Total number of producing fields: ~40,000

Total number of petroleum geologists: ~ 100,000 (exc. China)
Total number of drill rigs worldwide: ~ 5,000
### More Large Numbers

- **32.4 Gbo**: Annual World Oil Consumption 2012 (proj)
- **4-8 Gbo**: Annual Oil Discovery Rates in 1990s-2000s
- **1175 Gbo**: Total World Oil Consumption 1860-2012
- **850 Gbo**: Conventional World Oil Reserves (P50)<sup>1</sup>
- **1372 Gbo**: Conventional World Oil Reserves (P50)<sup>2</sup>
- **2311 Gbo**: Conventional World Oil Reserves (P50)<sup>3</sup>
- **1900 Gbo**: World Reserves (OIP) of Heavy Oil, Tar Sands, and Oil Shales

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2. BP Statistical Review 2007, includes 164 Gbo of oil sands in Canada
3. USGS, 2000, includes 688 Gbo reserve growth and 732 Gbo undiscovered reserves

1 Gbo = 1 billion barrels of oil
## Oil Companies (International) 2011

<table>
<thead>
<tr>
<th>Company</th>
<th>Prod</th>
<th>Res*</th>
<th>R/P</th>
<th>Revenues</th>
<th>Net</th>
<th>Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exxon/Mobil</td>
<td>3.9 Mboe/d</td>
<td>24.9 Gboe</td>
<td>17.5 y</td>
<td>$486 b</td>
<td>$41.1 b</td>
<td>83,600</td>
</tr>
<tr>
<td>BP</td>
<td>3.4 Mboe/d</td>
<td>17.8 Gboe</td>
<td>14.3 y</td>
<td>$386 b</td>
<td>$25.7 b</td>
<td>79,700</td>
</tr>
<tr>
<td>RD/Shell</td>
<td>3.1 Mboe/d</td>
<td>11.9 Gboe</td>
<td>10.5 y</td>
<td>$470 b</td>
<td>$31.2 b</td>
<td>90,000</td>
</tr>
<tr>
<td>Chevron</td>
<td>2.8 Mboe/d</td>
<td>10.5 Gboe</td>
<td>10.3 y</td>
<td>$254 b</td>
<td>$26.9 b</td>
<td>62,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2.4 Mboe/d</td>
<td>10.4 Gboe</td>
<td>11.9 y</td>
<td><strong>$217 b</strong></td>
<td><strong>$12.3 b</strong></td>
<td><strong>96,100</strong></td>
</tr>
</tbody>
</table>

* Proved

Sources: Annual Reports, Press Releases, Newspaper Reports
## Oil Companies (National + Seminational)

<table>
<thead>
<tr>
<th>Company</th>
<th>Production</th>
<th>Reserves</th>
<th>R/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saudi Arabian Oil Co.</td>
<td>11.0 Mboe/d</td>
<td>303.0 Gboe</td>
<td>75.5 y</td>
</tr>
<tr>
<td>China Nat. Petrol. Co.</td>
<td>4.1 Mbo/d</td>
<td>14.7 Gbo</td>
<td>9.8 y</td>
</tr>
<tr>
<td>Petroleos Mexicanos</td>
<td>2.5 Mboe/d</td>
<td>12.9 Gbo**</td>
<td>14.1 y</td>
</tr>
<tr>
<td>National Iranian Oil Co.</td>
<td>4.0 Mboe/d</td>
<td>300.0 Gboe</td>
<td>205.5 y</td>
</tr>
<tr>
<td>Iraq National Oil Co.</td>
<td>2.7 Mboe/d</td>
<td>134.0 Gbo</td>
<td>136.0 y</td>
</tr>
<tr>
<td>Petroleos de Venezuela</td>
<td>2.6 Mboe/d</td>
<td>129.0 Gbo*</td>
<td>135.9 y</td>
</tr>
<tr>
<td>Kuwait Petroleum Co.</td>
<td>3.7 Mboe/d</td>
<td>111.0 Gboe</td>
<td>82.2 y</td>
</tr>
<tr>
<td>Libya National Oil Co.</td>
<td>2.1 Mboe/d</td>
<td>50.0 Gboe</td>
<td>65.2 y</td>
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<tr>
<td>Abu Dhabi Nat. Oil Co.</td>
<td>2.6 Mboe/d</td>
<td>126.0 Gboe</td>
<td>132.8 y</td>
</tr>
<tr>
<td>Nigerian Nat. Petrol. Co.</td>
<td>2.3 Mboe/d</td>
<td>68.0 Gboe</td>
<td>81.0 y</td>
</tr>
<tr>
<td>Sonatrach</td>
<td>1.3 Mboe/d</td>
<td>39.0 Gboe</td>
<td>82.2 y</td>
</tr>
<tr>
<td>Petrobras</td>
<td>2.2 Mboe/d</td>
<td>15.1 Gbo</td>
<td>18.8 y</td>
</tr>
<tr>
<td>6 largest Russian Oil Co.</td>
<td>9.8 Mboe/d</td>
<td>79.5 Gboe</td>
<td>22.3 y</td>
</tr>
</tbody>
</table>

* Plus 267 Gbo of heavy oil reserves
** Other sources cite >100 Gbo

Claimed reserves based on BP Statistical Review 2011 and other sources.
Oil Production by Region 2011

Source: BP Statistical Review 2007
Oil Consumption per Capita

Source: BP Statistical Review 2012
The world's oil R/P ratio edged lower in 2006, reaching 40.5 years, compared with 41 years in 1996 and 39.8 years in 1986. The level of reserves fell by 1 billion barrels, or 0.1%. Declines in Norway and Mexico were partially offset by increases in Russia and Brazil.
Total World Energy Consumption

In Mtoe = Million tons of oil equivalent.

Source: International Energy Agency (IEA)
Total Energy Consumption per Capita

Consumption per capita 2011
Tonnes oil equivalent

Source: BP Statistical Review 2012
## Reserves/Production

<table>
<thead>
<tr>
<th></th>
<th>Oil</th>
<th></th>
<th>Gas</th>
<th></th>
<th>Coal</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>262.3 Gbo</td>
<td>Saudi Arabia</td>
<td>1680 Tcf</td>
<td>Russia</td>
<td>270.7 billion tons</td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>179.2 Gbo</td>
<td>Canada</td>
<td>974 Tcf</td>
<td>Russia</td>
<td>173.1 billion tons</td>
<td></td>
</tr>
<tr>
<td>Iran</td>
<td>136.3 Gbo</td>
<td>Iran</td>
<td>911 Tcf</td>
<td>China</td>
<td>126.2 billion tons</td>
<td></td>
</tr>
<tr>
<td>Iraq</td>
<td>115.0 Gbo</td>
<td>Iraq</td>
<td>240 Tcf</td>
<td>India</td>
<td>101.9 billion tons</td>
<td></td>
</tr>
<tr>
<td>Kuwait</td>
<td>101.5 Gbo</td>
<td>Kuwait</td>
<td>214 Tcf</td>
<td>Australia</td>
<td>87.2 billion tons</td>
<td></td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>97.8 Gbo</td>
<td>United Arab Emirates</td>
<td>USA</td>
<td>All others</td>
<td>&lt;40.0 billion tons</td>
<td></td>
</tr>
<tr>
<td>Venezuela</td>
<td>80.0 Gbo</td>
<td>Venezuela</td>
<td>204 Tcf</td>
<td>USA</td>
<td>270.7 billion tons</td>
<td></td>
</tr>
<tr>
<td>Russia</td>
<td>60.0 Gbo</td>
<td>Russia</td>
<td>152 Tcf</td>
<td>China</td>
<td>173.1 billion tons</td>
<td></td>
</tr>
<tr>
<td>All others</td>
<td>&lt; 42 Gbo</td>
<td>All others</td>
<td>&lt;100 Tcf</td>
<td>India</td>
<td>126.2 billion tons</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1317.4 Gbo</td>
<td></td>
<td>Total</td>
<td></td>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

R/P = 45.4 y  
R/P = 74.5 y  
R/P = 185.4 y

R/P is a static measure with little predictive value, but it is a simple metric with a message
Historical Development

Prior to 1900

No “petroleum geology”; all oil discovered through seepages (Appalachian, California, Baku, Ploesti, Peru, Egypt, Borneo...)

“Anticlinal theory” known but not used in practice

Many fields located in so-called “geomorphic traps” (where the reservoir rock is truncated by a recent erosion surface)

Drake well in 1859 first to discover oil (Pennsylvania)
Historical Development ctd.

1901-1924

“Anticlinal theory” put in practice with Spindeltop well in Texas

Important discoveries in Lake Maracaibo (Venezuela), Masjid-y-Suleiman (Iran), Trinidad, Borneo, Mexico, Oklahoma, San Joaquin Valley, California (all USA)

Petroleum geology is “American”; foundation of AAPG

Bolivar Coastal field: First in homoclinal trap, first offshore, first large field with heavy oil, launches

SOC becomes first major oil company

Automobiles! Gas stoves!
Historical Development ctd.

1925 - 1945

Important discoveries in La Paz (Venezuela), Kirkuk (Iraq; carbonate reservoir!), numerous fields in Middle East (most also carbonates)

Oil is organic, not inorganic; micropaleontology and organic geochemistry developed as important tools

Technological breakthroughs: Rotary drilling, torsion balance, gravimeter, reflection seismology, electrical well logs, perforations; wells to 3000 meters depth (before: to 1000 m)

World Petroleum Congress founded
Historical Developments ctd.

1945 - 1960

Drilling boom, discovery of major oil fields in Middle East, USA, Western Canada, Russian platform

Drilling depths reach 6000 meters; gas became important

Important insights into hydrocarbon migration and accumulation (e.g. by King Hubbert; Levorsen)

Sedimentology becomes important to understand reservoirs

“Log-normal distribution” of oil fields
Historical Developments ctd.

1960 - 1980

Offshore drilling technology developed

Discovery of North Sea, Libya, Nigeria, Siberia, eastern Mexico oil provinces

“Subtle traps” (e.g. North Dome in Qatar)

Vast improvement of seismic acquisition and processing; becomes vital exploration tool. Further technological improvements in drilling, construction, and logging
Historical Developments ctd.

Since 1980

Passive margins plays discovered (Gulf of Mexico, West Africa, Brazil). Deep to ultra-deep drilling technology developed

Huge carbonate fields in intra-cratonic setting discovered (Peri-Caspian oil province)

3-D and 4-D seismics provide volumetric and dynamic picture of reservoirs; leads to seismic stratigraphy

Integration of petroleum disciplines; computerized workflows

Half of the “easy oil” is produced
Summary: Why it matters

- We depend on energy: In the industrial world every person uses the energy corresponding to about 200 human powers 24 hours per day
- Fossil energy constitutes ±85% of our energy consumption
- Fossil fuels have a high caloric value per volume
- Fossil fuels are finite
- The burning of fossil fuels has undesirable climatic consequences
- But: Energy companies are important for the economy