Conventional Fossil Fuels

JMA

Coal

JMA

Coal

Coal is a fossil fuel formed in swamp ecosystems where plant remains were saved by water and mud from oxidization and biodegradation. It is composed primarily of carbon along with assorted other elements, including sulfur. It is the largest single source of fuel for the generation of electricity world-wide, as well as the largest source of carbon dioxide emissions, which have been implicated as the primary cause of global warming. Coal is extracted from the ground by coal mining, either underground mining or open-pit mining (surface mining).

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Coal Energy Density

- 24 Megajoules per kilogram or 6.67 kW-h/kg
- Thermodynamic efficiency of coal powerplants is about 30%
- Coal power plants obtain approximately 2.0 kW-h per kg of burned coal

JMA

As an example, running one 100 Watt computer for one year requires 876 kW-h (100 W × 24 h × 365 {days in a year} = 876000 W-h = 876 kW-h).

$$\frac{876 \text{ kW} \cdot \text{hours}}{2.0 \text{ kW} \cdot \text{hours/kg}} = 438 \text{ kg of coal} = 967 \text{ pounds of coal}$$

It takes 438 kg (967 pounds) of coal to power a computer for one full year. One should also take into account transmission and distribution losses caused by resistance and heating in the power lines, which is in the order of 5 - 10%, depending on distance from the power station and other factors.

JMA

Carbon Cost

- Coal is 50% carbon (C) by mass so 1 kg of coal = 0.5 kg of C = 1/24 kmol C
- By burning C combines with O2 in the atmosphere the result is 1/24 kmol CO2 is produced from every 1/24 kmol C
- 1/24 kmol CO2 * 44 kg / kmol = 1.83 kg

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Running a computer on coal for one year releases to the atmosphere about 802 kg of CO_2.

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Energy density

Fission of U-235	2.5 $\times 10^{10}$	Wh/kg
Coal	6,670	Wh/kg
Diesel	13,762	Wh/kg
Gasoline	12,200	Wh/kg
LNG	12,100	Wh/kg
Propane (liquid)	13,900	Wh/kg
Ethanol	7,850	Wh/kg
Liquid H2	39,000	Wh/kg
Wood	1,600 - 4,709	Wh/kg

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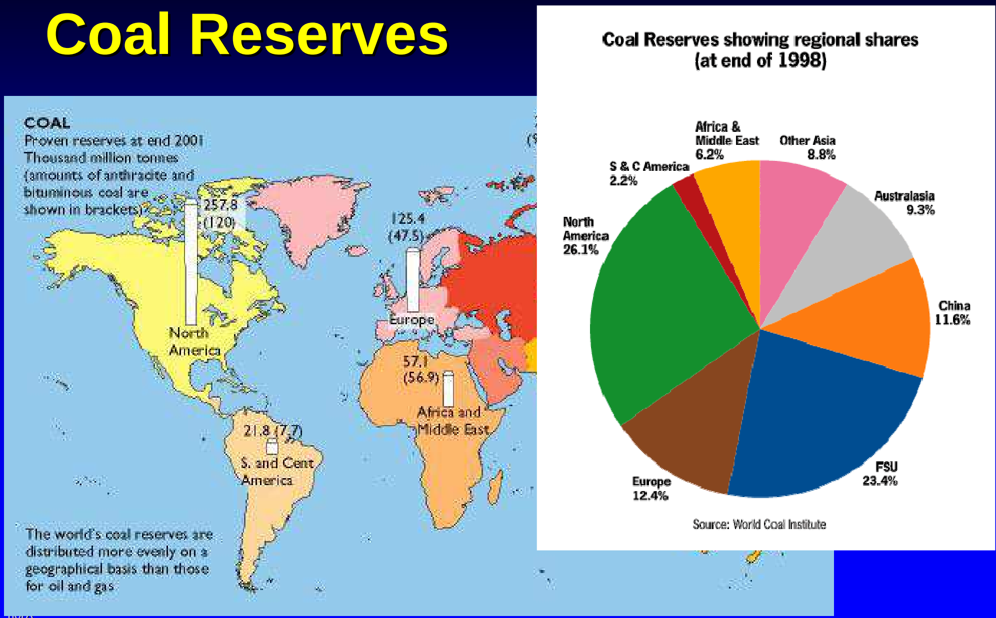
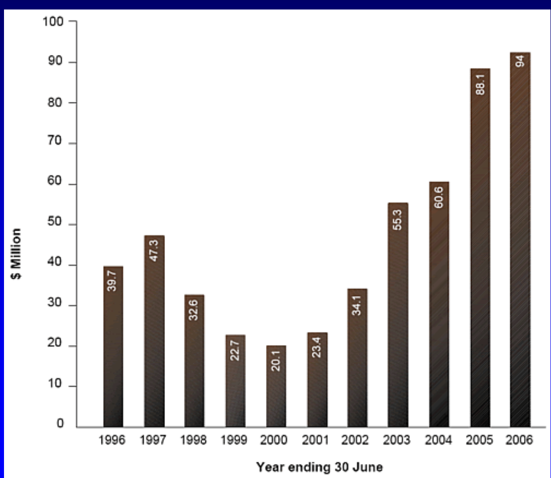
Coal Reserves



JMA

Coal Exploration in Australia

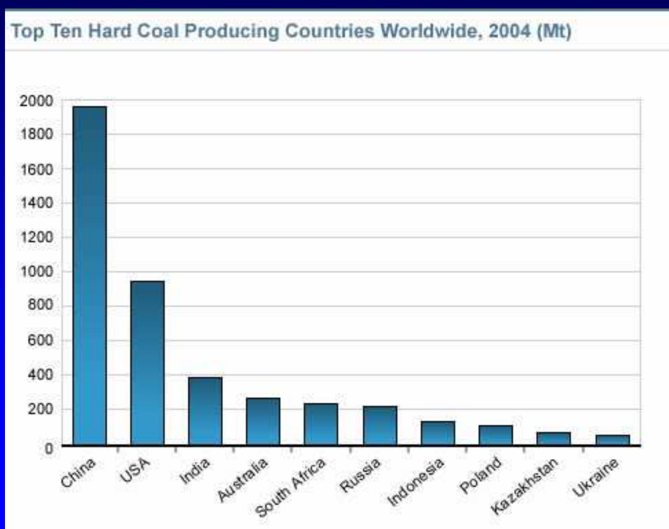


JMA

Coal Production Today

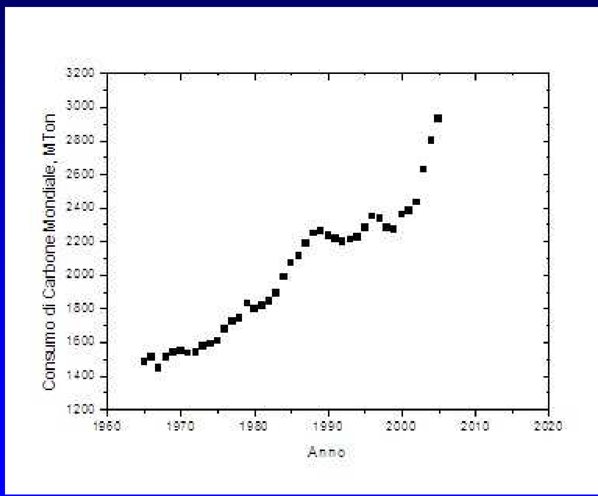
JMA

Coal Production Today



JMA

Coal Production Trend Reversal



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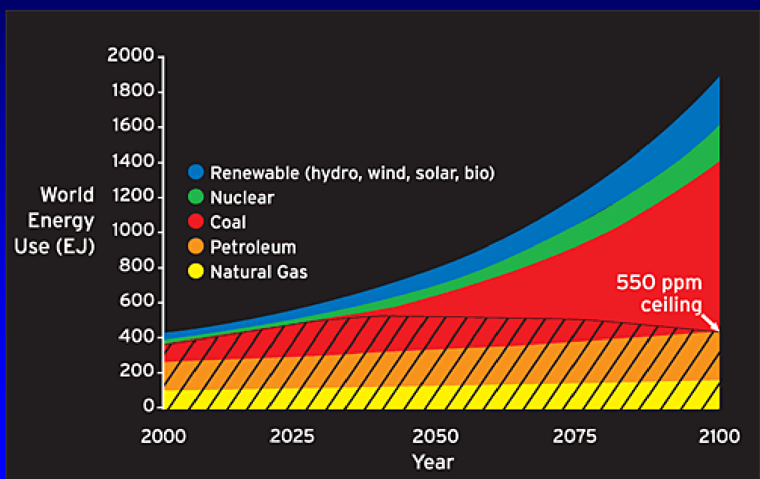
Coal Future



JMA

FutureGen - Tomorrow's Pollution-Free Power Plant

JMA

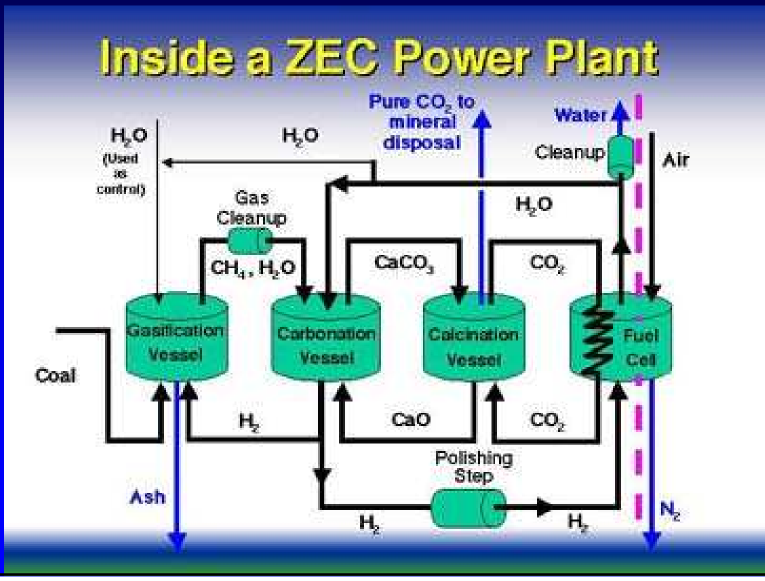
FutureGen
Electrical Power and Hydrogen

The prototype plant will establish the technical and economic feasibility of producing electricity and hydrogen from coal (the lowest cost and most abundant domestic energy resource), while capturing and sequestering the carbon dioxide generated in the process.

The project will employ coal gasification technology integrated with combined cycle electricity generation and the sequestration of carbon dioxide emissions. The project will require 10 years to complete and will be led by the FutureGen Industrial Alliance, Inc., a non-profit industrial consortium representing the coal and power industries, with the project results being shared among all participants, and industry as a whole.

JMA

Clean Coal Technology



JMA

Coal is not problem free ….

Oil and Gas

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What is Petroleum?

- Hydrocarbon: an organic compound made up of carbon and hydrogen atoms
- Petroleum: a natural yellow-to-black flammable liquid hydrocarbon found beneath the earth's surface

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The Goal - 'Black Gold'

Petroleum Supplies our Energy Needs

Light Texas Crude	Heavy Texas Crude
Palo Pinto Field North Texas	Humble Oil Field Southwest Texas

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The chemical structure of petroleum is composed of hydrocarbon chains of different lengths. These different hydrocarbon chemicals are separated by distillation at an oil refinery to produce gasoline, jet fuel, kerosene, and other hydrocarbons. The general formula for these alkanes is C_nH_{2n+2}. For example 2,2,4-Trimethylpentane, widely used in gasoline, has a chemical formula of C_8H_{18} which reacts with oxygen exothermically:

Incomplete combustion of petroleum or gasoline results in emission of poisonous gases such as carbon monoxide and/or nitric oxide.

Formation of petroleum occurs in a variety of mostly endothermic reactions in high temperature and/or pressure. For example, a kerogen may break down into hydrocarbons of different lengths.

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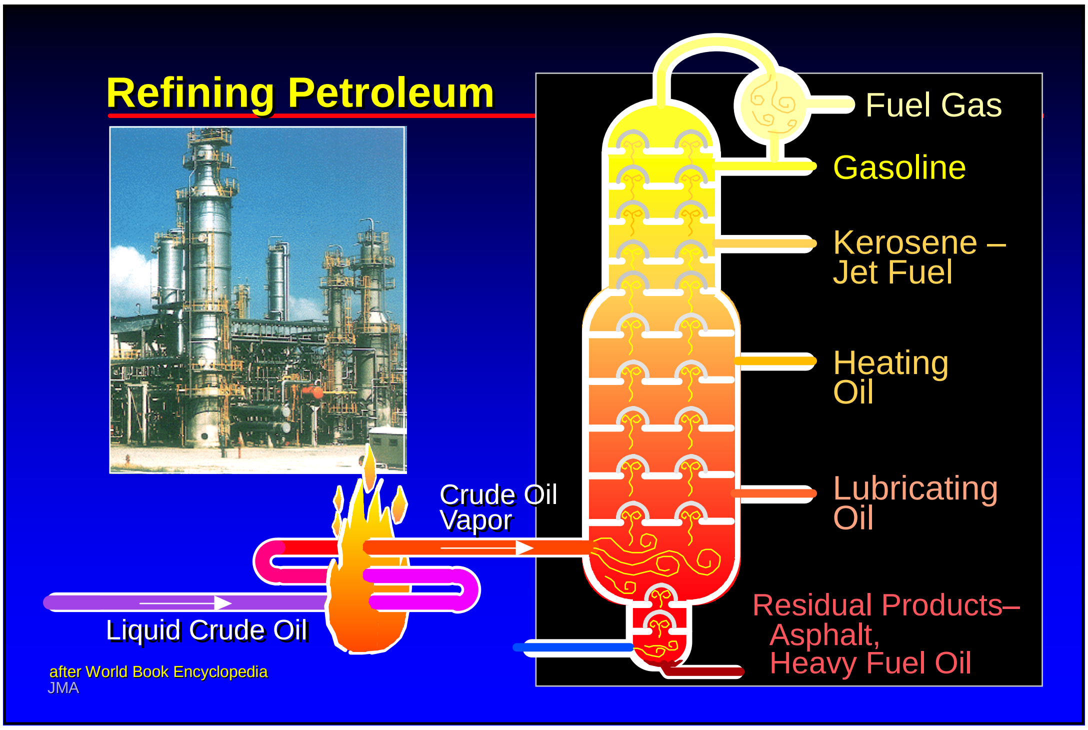
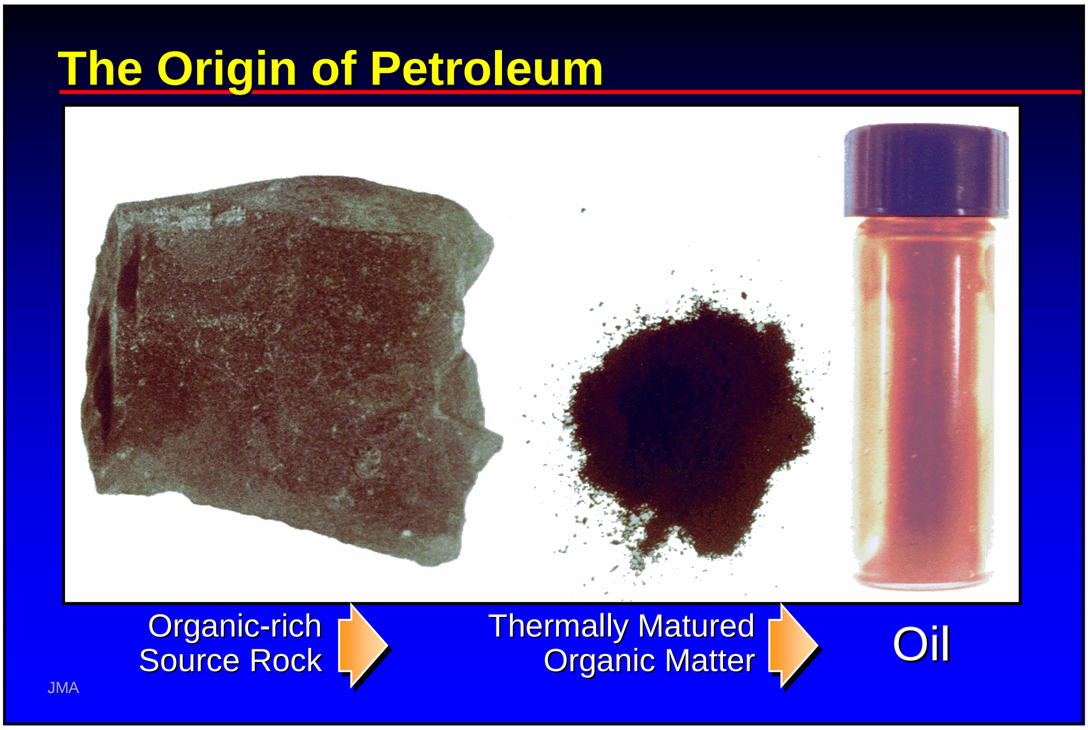

Refining Petroleum
Fuel Gas
Gasoline
Kerosene –
Jet Fuel
Heating
Oil
Lubricating
Oil
Crude Oil
Vapor
Residual Products–
Asphalt,
Heavy Fuel Oil
Liquid Crude Oil
after World Book Encyclopedia
JMA


The Origin of Petroleum
Organic-rich
Source Rock
Thermally Matured
Organic Matter
Oil
JMA

Geologists often refer to an "oil window" which is the temperature range that oil forms in—below the minimum temperature oil remains trapped in the form of kerogen, and above the maximum temperature the oil is converted to natural gas through the process of thermal cracking. Though this happens at different depths in different locations around the world, a 'typical' depth for the oil window might be 4–6 km.

JMA

Classification

The oil industry classifies "crude" by the location of its origin (e.g., "West Texas Intermediate, WTI" or "Brent") and often by its relative weight or viscosity ("light", "intermediate" or "heavy"); refiners may also refer to it as "sweet," which means it contains relatively little sulfur, or as "sour," which means it contains substantial amounts of sulfur and requires more refining in order to meet current product specifications. Each crude oil has unique molecular characteristics which are understood by the use of crude oil assay analysis in petroleum laboratories.

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Crude oil benchmarks (same characteristics) for pricing:

•Brent Crude, comprising 15 oils from fields in the Brent and Ninian systems in the East Shetland Basin of the North Sea. The oil is landed at Sullom Voe terminal in the Shetlands. Oil production from Europe, Africa and Middle Eastern oil flowing west tends to be priced off the price of this oil, which forms a benchmark.

•West Texas Intermediate (WTI) for North American oil.

•Dubai, used as benchmark for Middle East oil flowing to the Asia-Pacific region.

•Tapis (from Malaysia, used as a reference for light Far East oil)

•Minas (from Indonesia, used as a reference for heavy Far East oil)

•The OPEC Reference Basket, a weighted average of oil blends from various OPEC (The Organization of the Petroleum Exporting Countries) countries.

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History of Petroleum

First Use:
- Egyptians: oil to preserve mummies
- Chinese: natural gas for fuel
- Babylonians: oil to seal walls and pave streets
- Americans: tar to seal canoes

First Drilling:
- Chinese using bamboo: to 800' in 347 AD
- Americans using cable tool: to 70' in 1859 AD

First Product:
- Kerosene for lamps
- Gasoline was unwanted by-product

Demand Increase:
- Industrial Revolution
  - Internal Combustion Engine (1885)
  - Global Economic Growth

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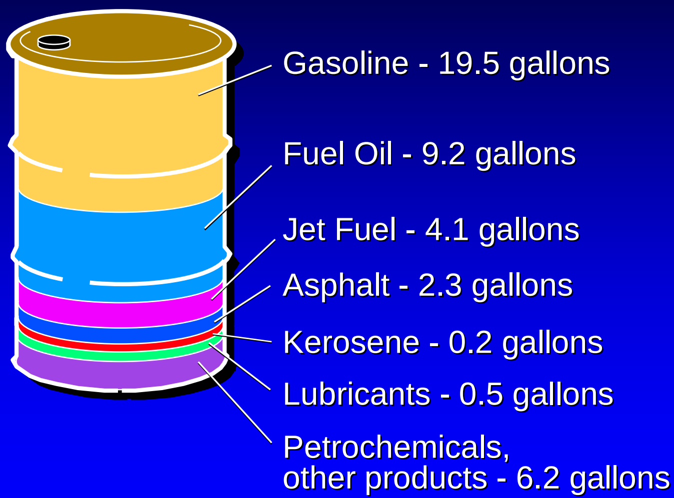
Petroleum Products

A Barrel of Crude Oil Provides:

One Barrel = 42 gallons



JMA

American Petroleum Institute, 1999

Petrochemical Products

More Than 3,000 Products

- Detergents - Cosmetics
- Fertilizers - Weed Killers
- Medicine - Antiseptics - Anesthetics
- Plastics - Synthetic Fibers
- Synthetic Rubber
- Rust Preventatives
- Liquid Petroleum Gas

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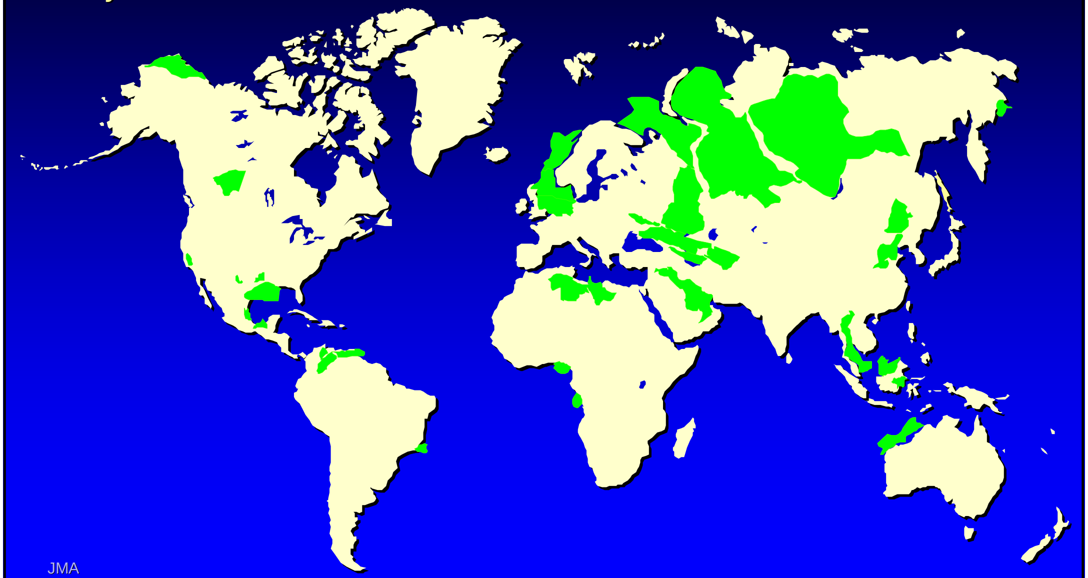
American Petroleum Institute, 1999

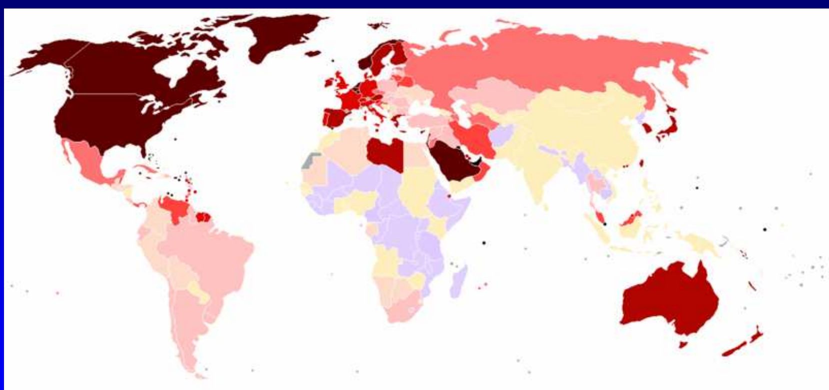
Largest Hydrocarbon Basins

by Ultimate Potential

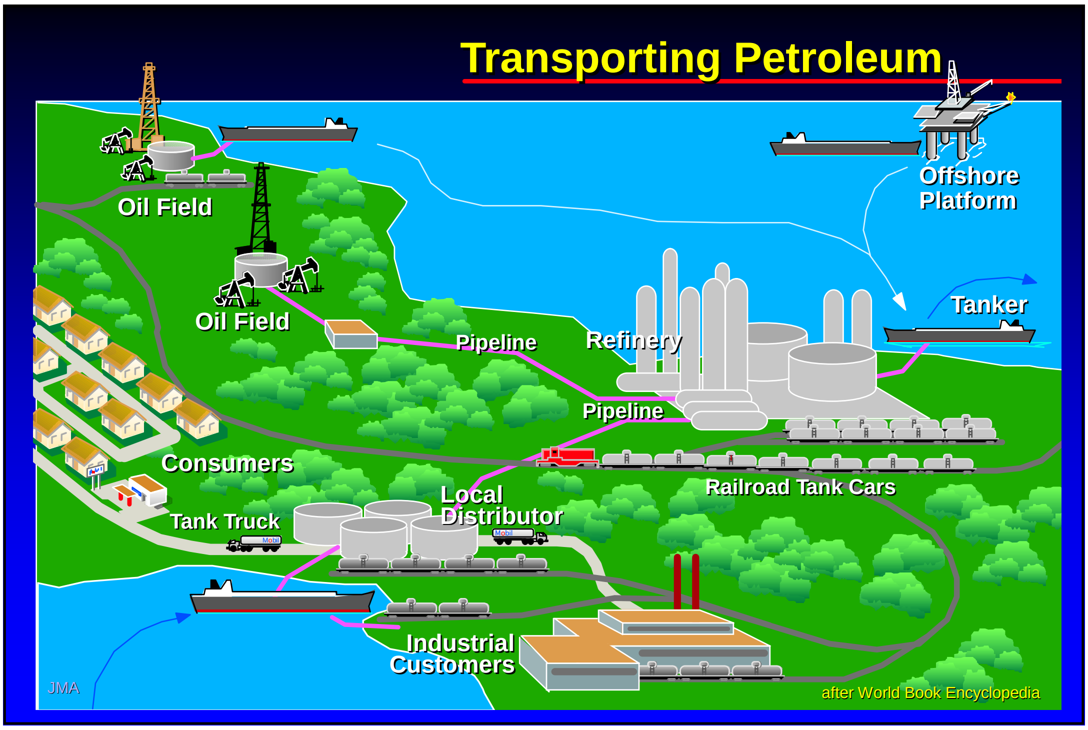


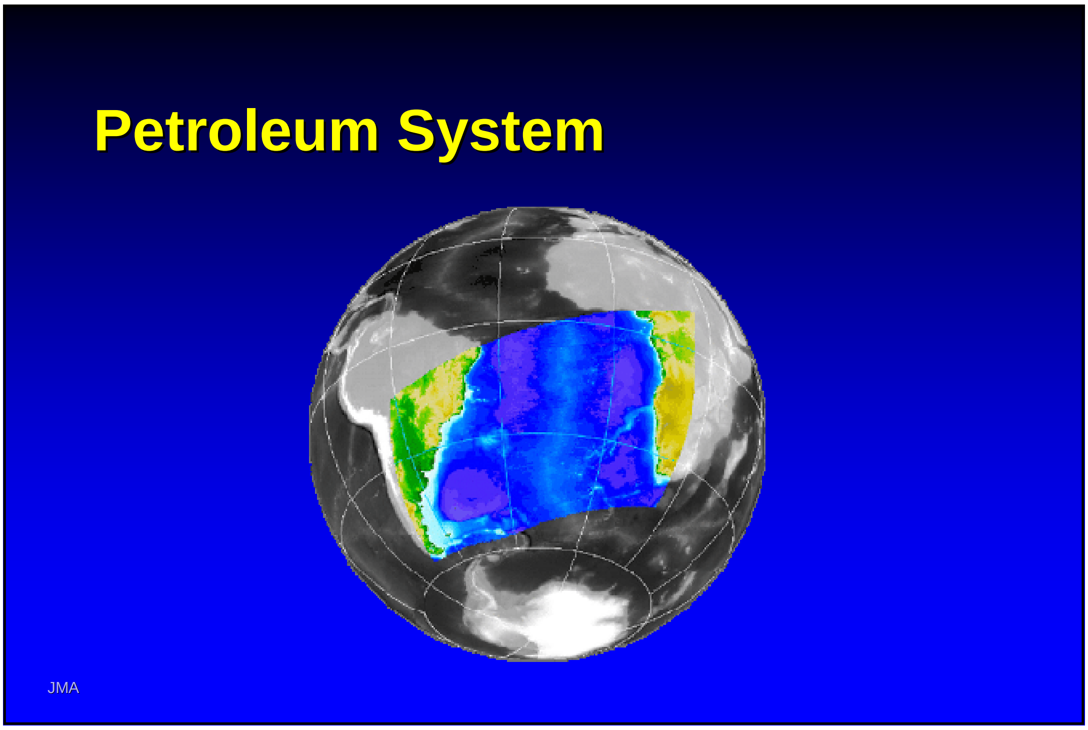
JMA

Oil Consumption Per Capita



JMA


Transporting Petroleum
Oil Field
Oil Field
Offshore Platform
Tanker
Refinery
Pipeline
Pipeline
Consumers
Tank Truck
Local Distributor
Railroad Tank Cars
Industrial Customers
JMA
after World Book Encyclopedia

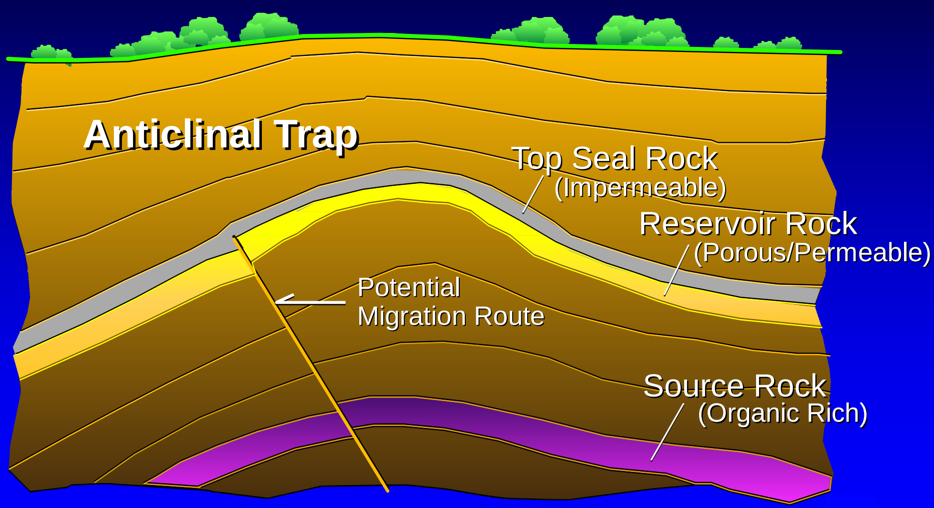

Petroleum System
JMA

Petroleum System Elements

- Source Rock - A rock with abundant hydrocarbon-prone organic matter
- Reservoir Rock - A rock in which oil and gas accumulates:
  - Porosity - space between rock grains in which oil accumulates
  - Permeability - passage-ways between pores through which oil and gas moves
- Seal Rock - A rock through which oil and gas cannot move effectively (such as mudstone and claystone)
- Migration Route - Avenues in rock through which oil and gas moves from source rock to trap
- Trap - The structural and stratigraphic configuration that focuses oil and gas into an accumulation

JMA

Petroleum System Elements



JMA

Source Rock for Petroleum

Organic-Rich

Thin Laminae

Measured Values

Total Organic Carbon	Hydrogen Index
3.39	378

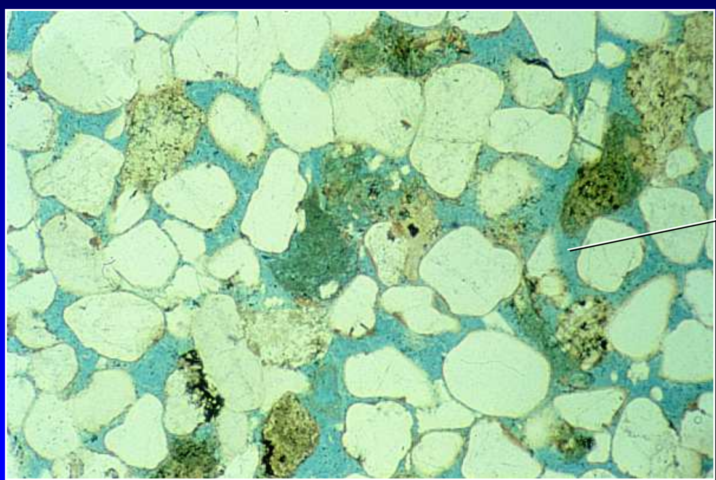
In-Place Petroleum S_1	Pyrolytically Generated Petroleum S_2
2.24	12.80

LOMPOC Quarry Sample
Monterey Formation, CA

JMA

Reservoir Sandstone

Good Porosity = Lots of Space for Petroleum



Pores (blue)

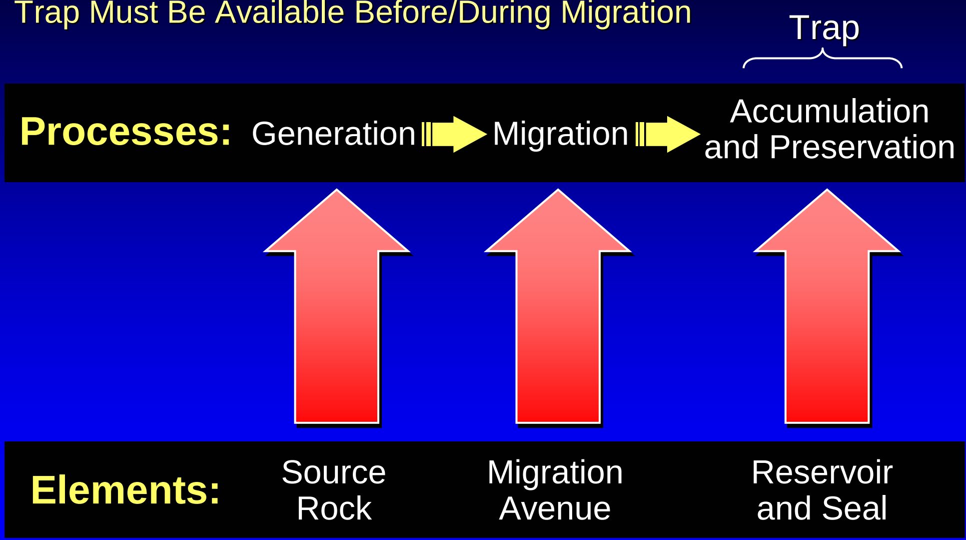
JMA

A Geologic Cross-Section

JMA

Petroleum System: Timing is Critical

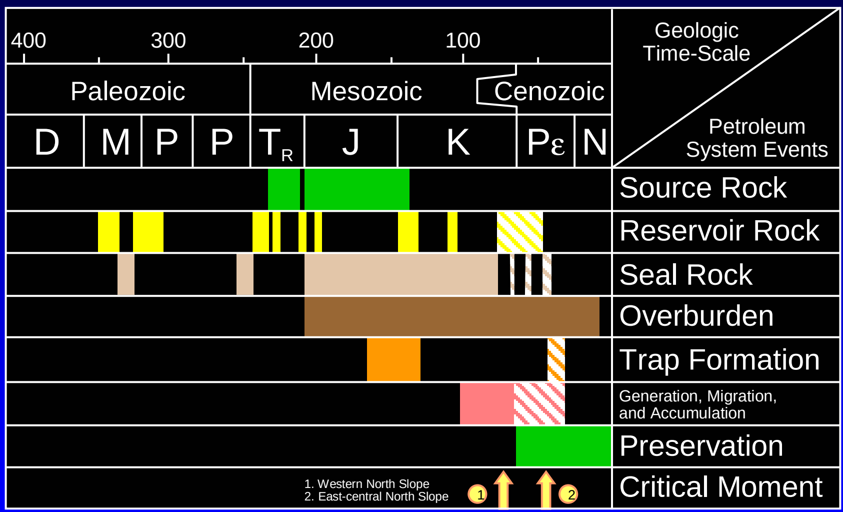
Trap Must Be Available Before/During Migration



JMA

Petroleum System Events Chart

North Slope, Alaska

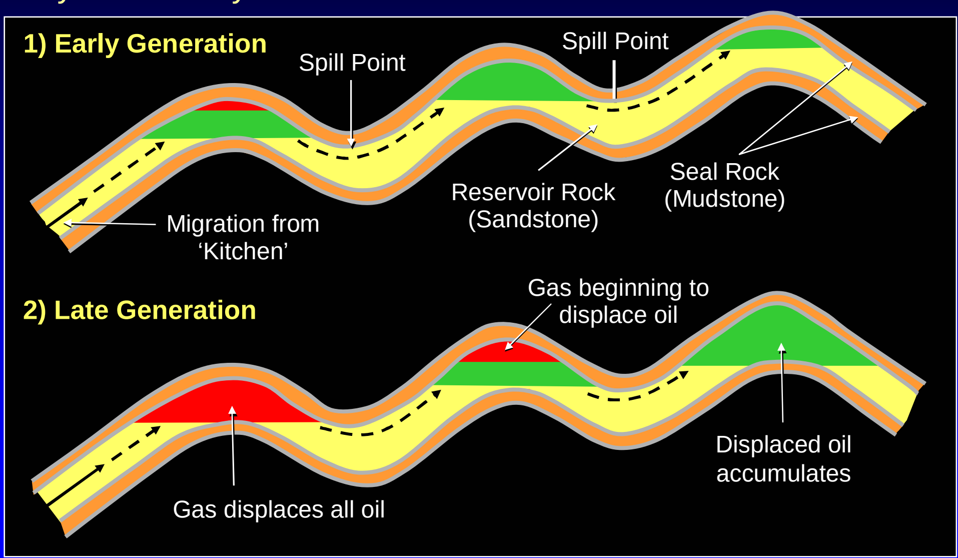


Bird, 1994

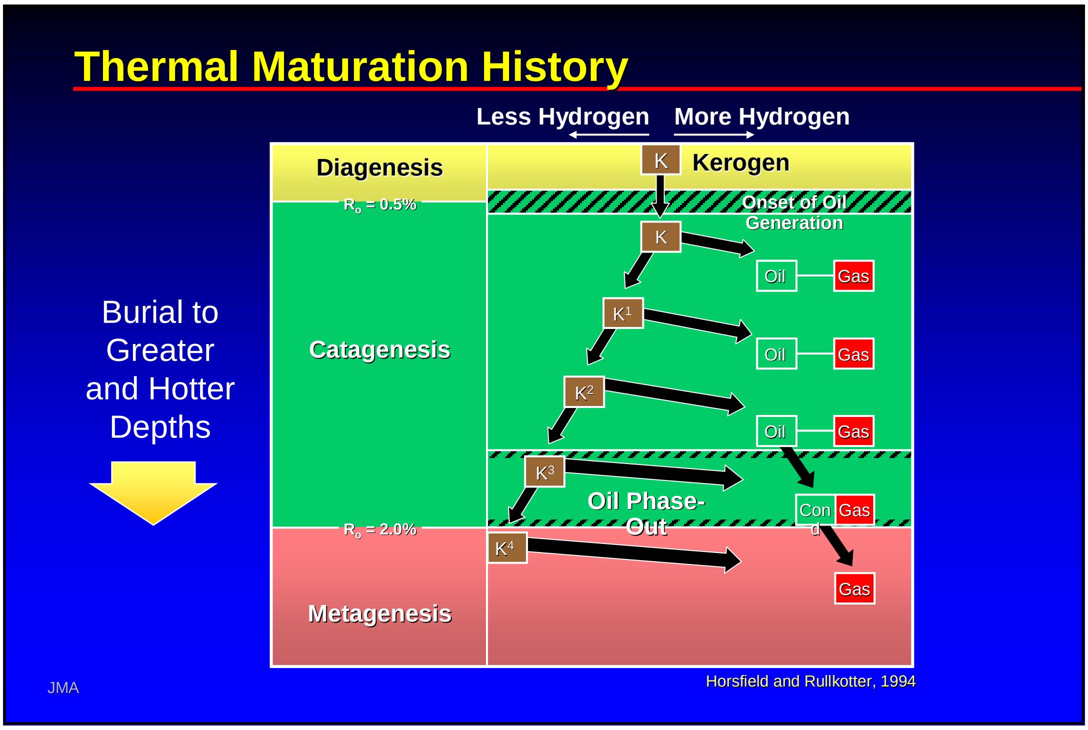
JMA

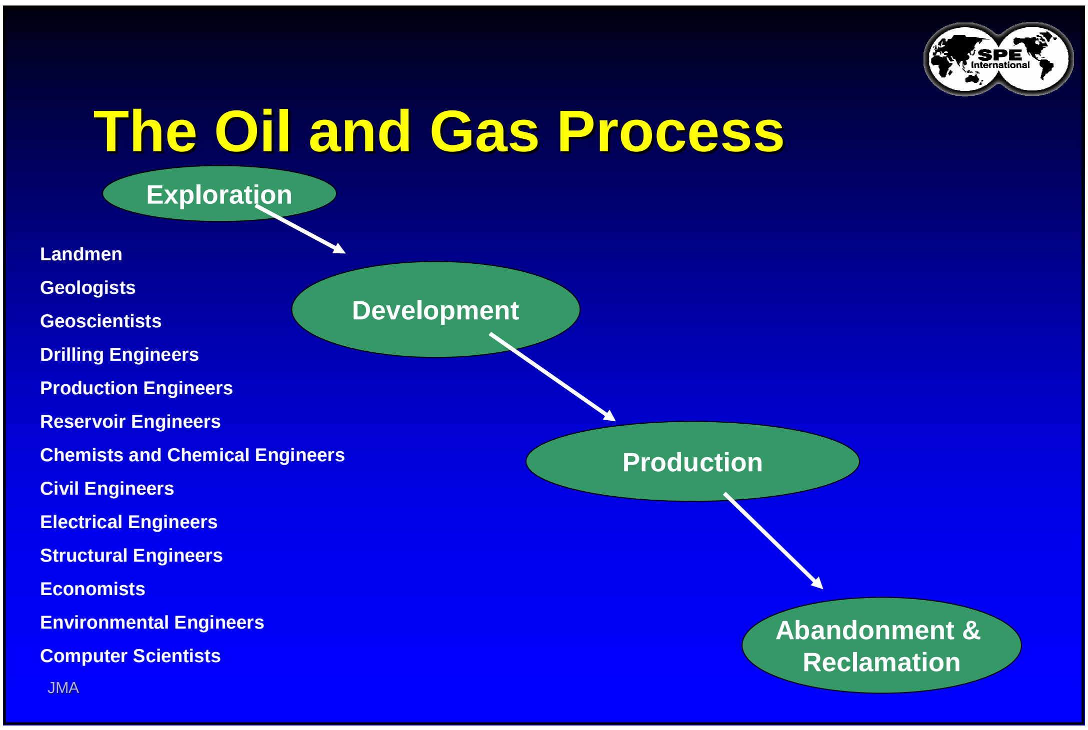
Petroleum System

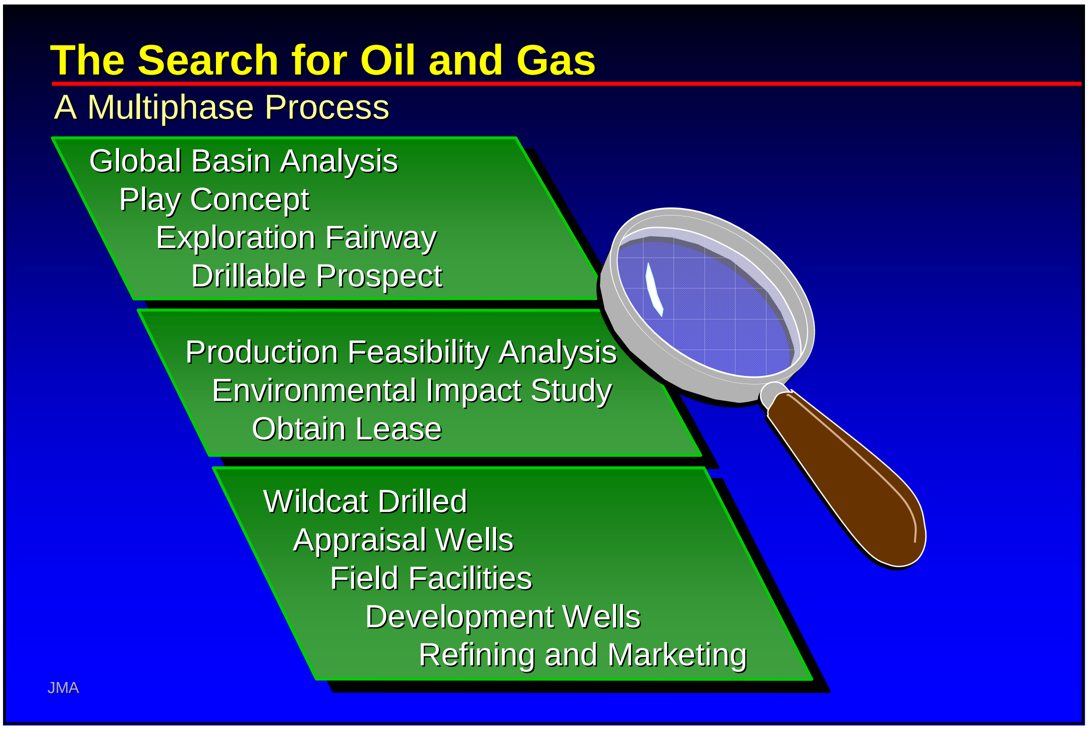
A Dynamic Entity

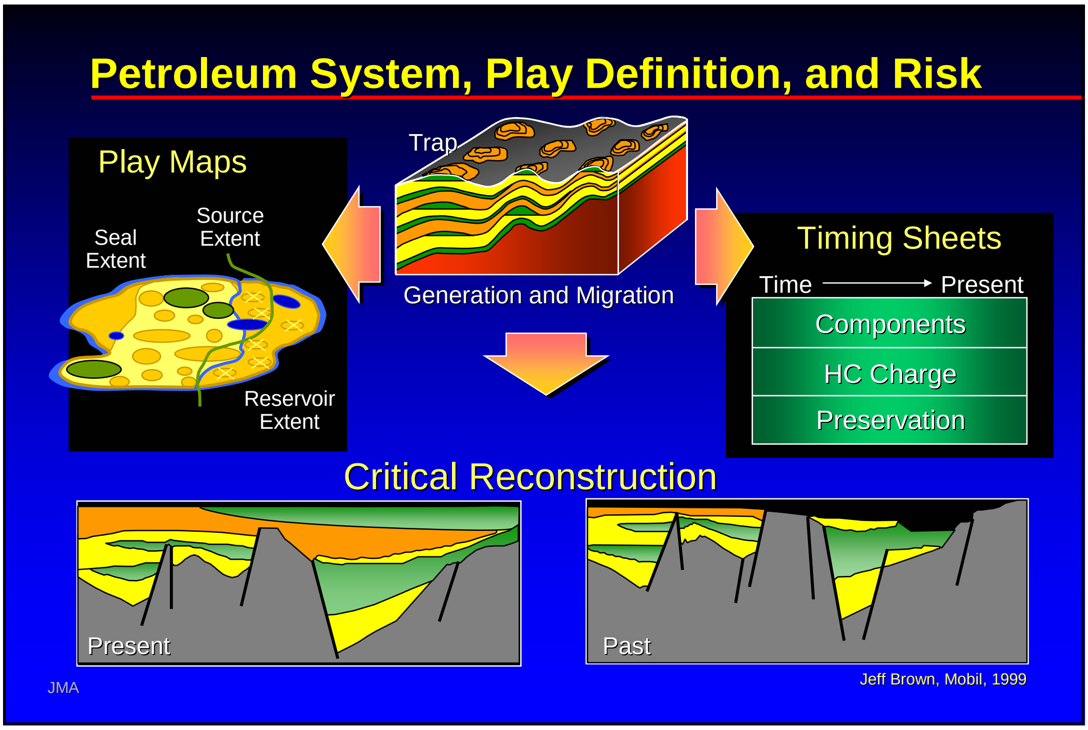


JMA

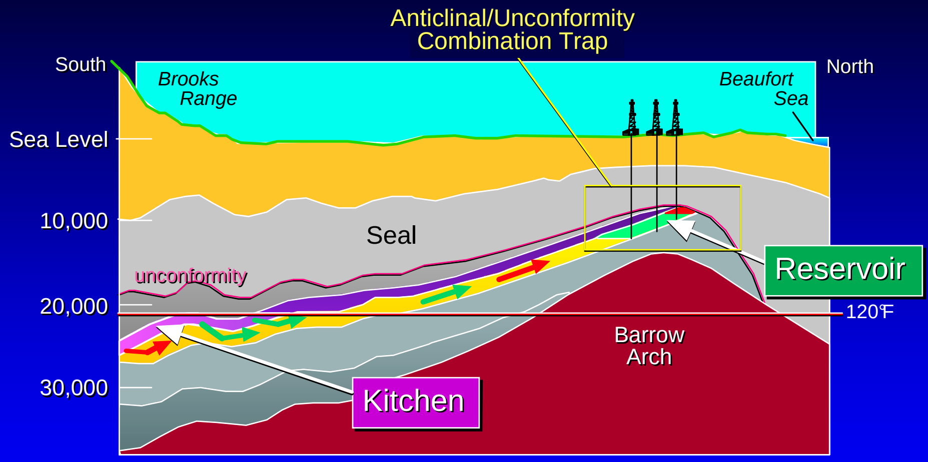

Thermal Maturation History
Less Hydrogen
More Hydrogen
Diagenesis
K
Kerogen
R₀ = 0.5%
Onset of Oil Generation
Burial to Greater and Hotter Depths
Catagenesis
K
K1
K2
K3
K4
Oil
Gas
Oil Phase-Out
Cond
R₀ = 2.0%
Metagenesis
JMA
Horsfield and Rullkotter, 1994


SPE International
The Oil and Gas Process
Exploration
Development
Production
Abandonment & Reclamation
Landmen
Geologists
Geoscientists
Drilling Engineers
Production Engineers
Reservoir Engineers
Chemists and Chemical Engineers
Civil Engineers
Electrical Engineers
Structural Engineers
Economists
Environmental Engineers
Computer Scientists
JMA


The Search for Oil and Gas
A Multiphase Process
Global Basin Analysis
Play Concept
Exploration Fairway
Drillable Prospect
Production Feasibility Analysis
Environmental Impact Study
Obtain Lease
Wildcat Drilled
Appraisal Wells
Field Facilities
Development Wells
Refining and Marketing
JMA


Petroleum System, Play Definition, and Risk
Play Maps
Seal
Extent
Source
Extent
Reservoir
Extent
Trap
Generation and Migration
Timing Sheets
Time
Present
Components
HC Charge
Preservation
Critical Reconstruction
Present
Past
Jeff Brown, Mobil, 1999
JMA

Prudhoe Bay Oil Field (1968)



- Largest North American field
- More than 8 billion barrels recoverable

American Association of Petroleum Geologists, 1990

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Global Oil and Gas Fields

JMA

Oil Exploration

JMA

Petroleum Exploration's Challenge

Interpreting the Unseen

- Surface Geology
  - Aerial photos
  - Geologic maps

- Subsurface Analysis
  - Gravity
  - Magnetics
  - Seismic reflection
  - Wells

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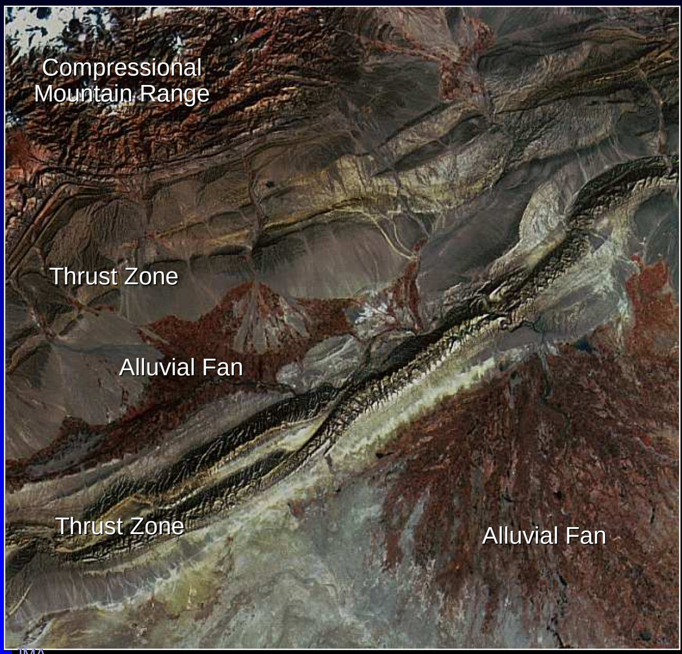
Silicon Graphics

Aerial Photo

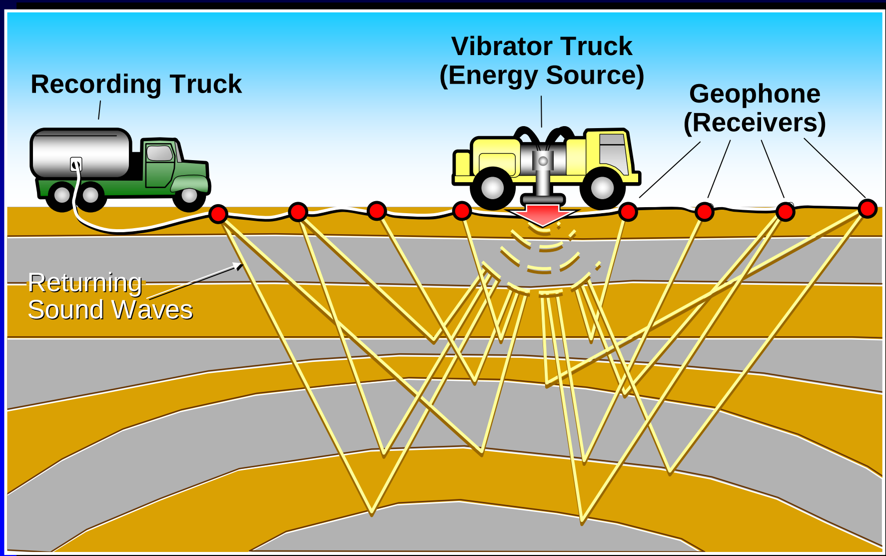
Traditional Tool with Improved Resolution



- Aerial photo for mapping patterns
- Field check for geological detail

JMA

Seismic Imaging of Anticline



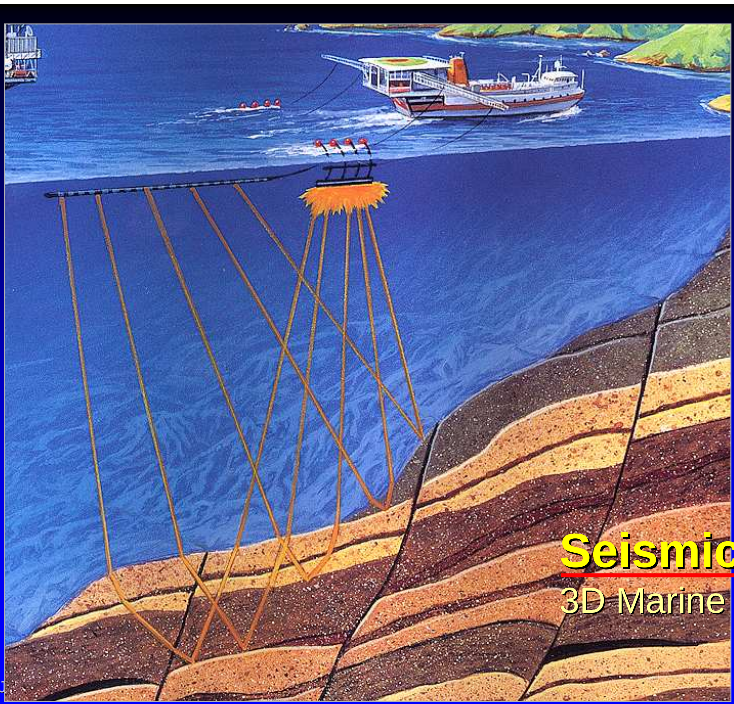
American Petroleum Institute, 1986

JMA

Seismic data acquisition in Gabon

JMA

www.planete-energies.com



Seismic Imaging

3D Marine Data Acquisition

Silicon Graphics

Offshore Seismic Acquisition - Angola

www.planete-energies.com

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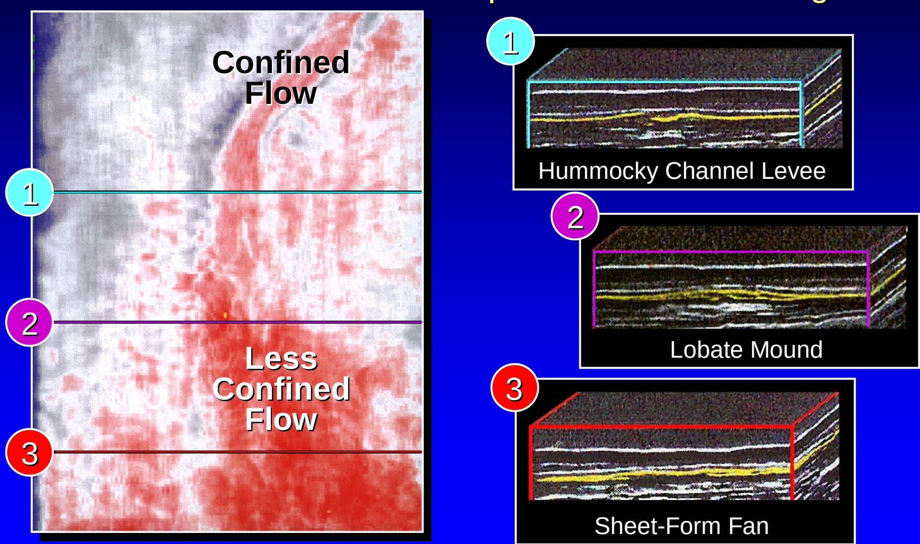
3D Seismic Image - Submarine Fan

New Tools → Better Data → Improved Understanding

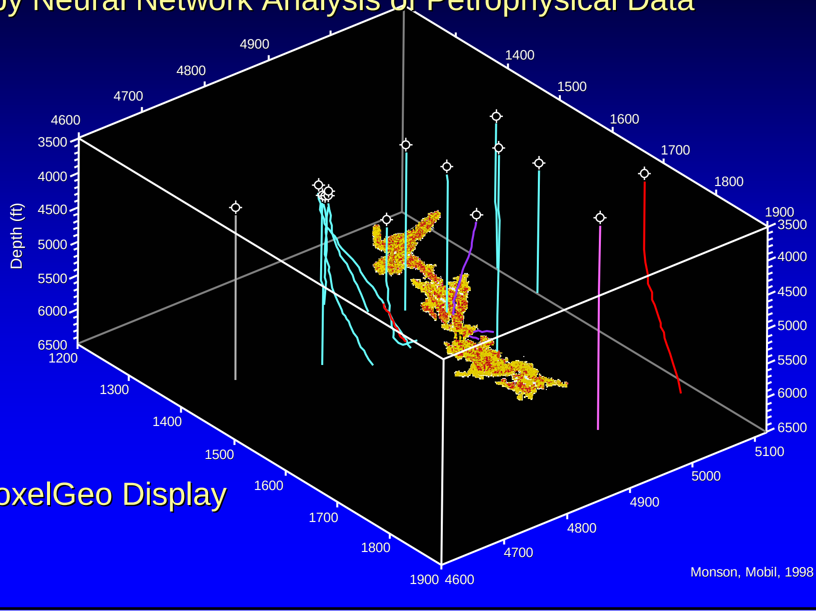


JMA

Armentrout *et al.*, 1996

3D Seismic Image of Channel Sand

Calibrated by Neural Network Analysis of Petrophysical Data



VoxelGeo Display

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Monson, Mobil, 1998

Exploration Costs: 1999

Seismic Surveys

	Alaska North Slope	Gulf of Mexico
2D	\$50,000/mile	\$70 - \$150/mile
3D		\$25,000 - \$80,000/mi^2
3D Proprietary		\$250,000 - \$400,000/mi^2

Wildcat Wells

Alaska North Slope		Texas	Gulf of Mexico		
Offshore	Onshore	Onshore	Shelf	Slope	Deep-Water
\$30 Million	\$16 Million	\$7 Million	\$12 Million	\$25 Million	\$40 Million

January 1999 Estimates

JMA

Different Ways
Industry Pays for Drilling Rights

- Rental - Annual fee for land use while exploring
- Bonus - One-time lump sum paid upfront for right to explore
- Royalty - Percentage payments of oil and gas value produced
- Tax - Governmental ‘fee’ on product value produced

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Cost of Drilling Rigs

Offshore

Daily Rig Cost

1998	$90,000
1999	$40,000

(Single year contract)

Ultra Deep Daily Rig Cost

1998	$180,000
1999	$180,000

(Five year contract)

Onshore

Daily Rig Cost

1998	$60,000
1999	$30,000

(Single year contract)

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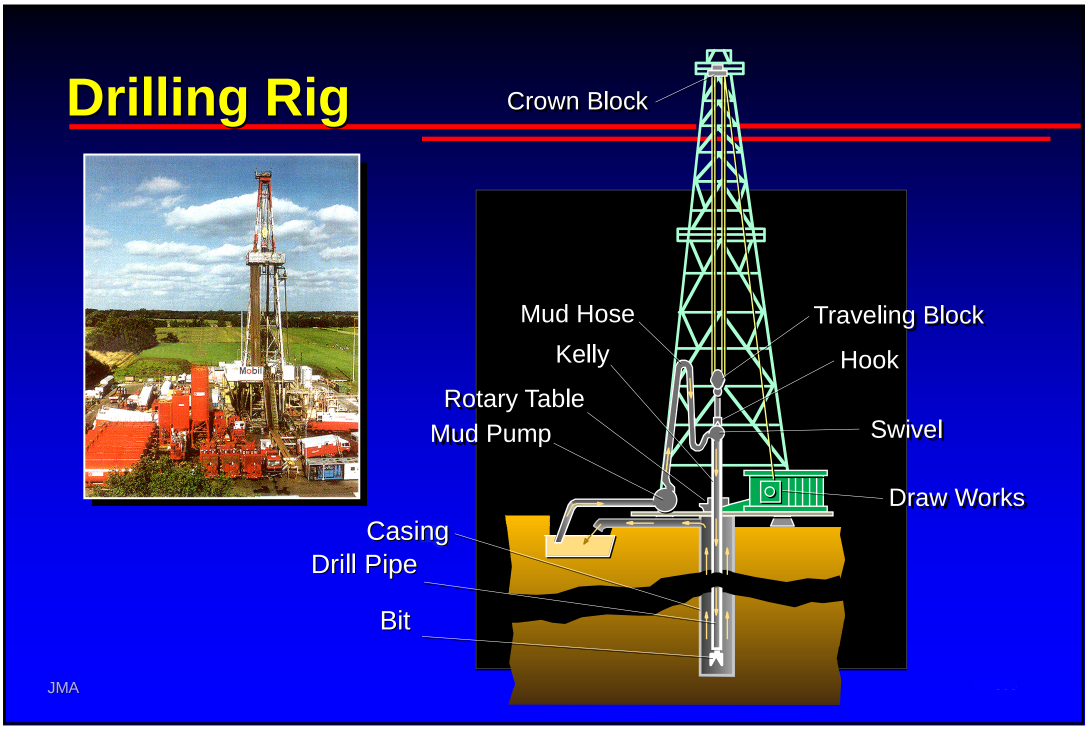
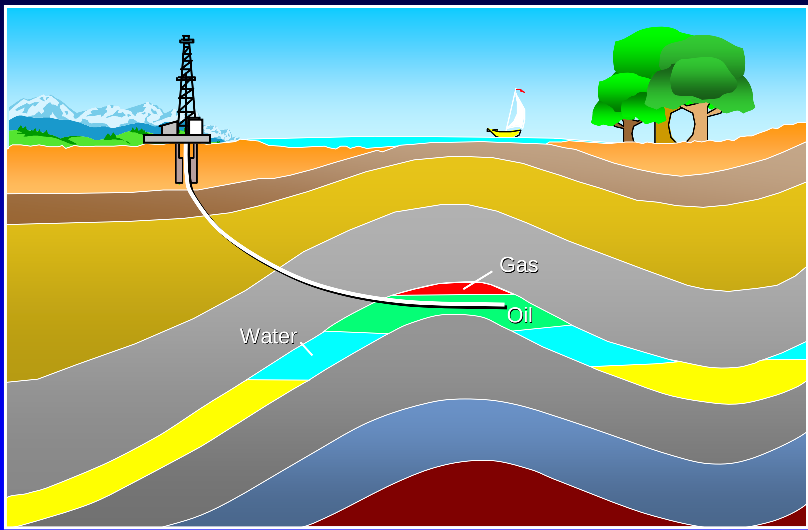

Drilling Rig
Crown Block
Mud Hose
Kelly
Rotary Table
Mud Pump
Traveling Block
Hook
Swivel
Draw Works
Casing
Drill Pipe
Bit
JMA


Drilling
Rock Bit
Cuttings
Core (Diamond) Bit
Core
JMA

Directional Drilling Avoids Surface Hazards



American Petroleum Institute, 1986

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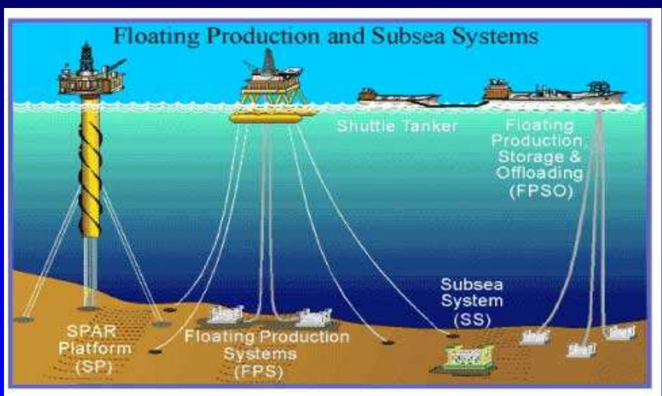
New Offshore Production Structures Enable Development in Deeper Water



Industry has moved fixed to floating structures to develop oil and gas in deeper water

Graphic courtesy of Minerals Management Service

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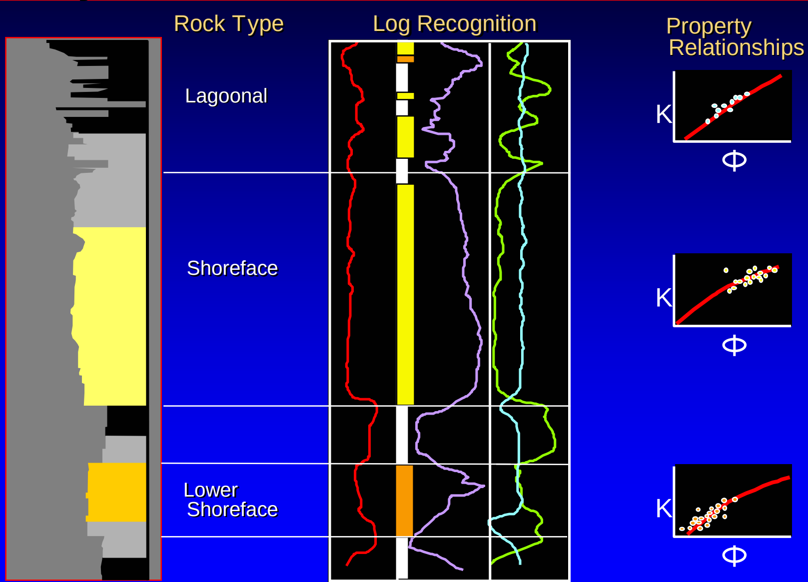
Costlier Deepwater Ventures: New Technology Allows Industry to Access Resources in Deeper Water

The Deepwater Pathfinder drillship and global positioning technology keep the drillship stable, shifting less than 50 feet in any direction. This stability enables the ship to drill in very deep water and in most weather conditions.

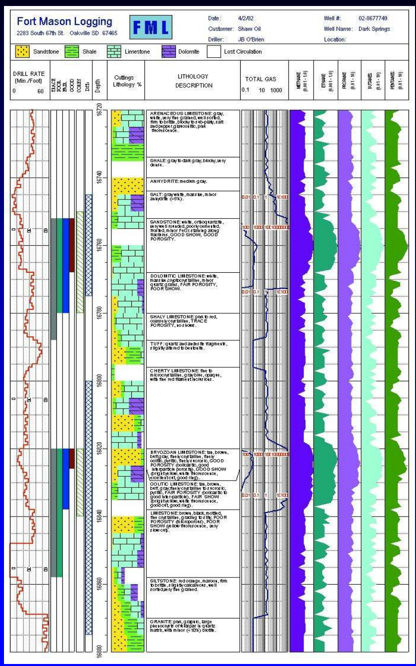
JMA

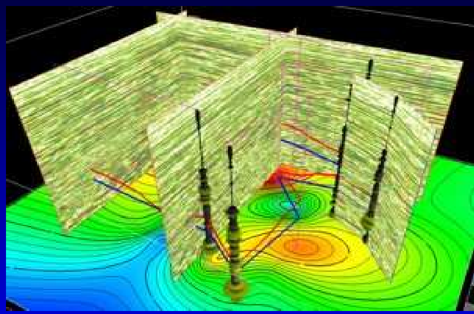
Photo courtesy of ConocoPhillips

Log Analysis for Flow Unit Determination



JMA





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Field Development

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Primary recovery

If the underground pressure in the oil reservoir is sufficient, then this pressure will force the oil to the surface. Gaseous fuels, natural gas or water are usually present, which also supply needed underground pressure. In this situation, it is sufficient to place a complex arrangement of valves (the Christmas tree) on the well head to connect the well to a pipeline network for storage and processing.

Usually, about 20% of the oil in a reservoir can be extracted using primary recovery methods.

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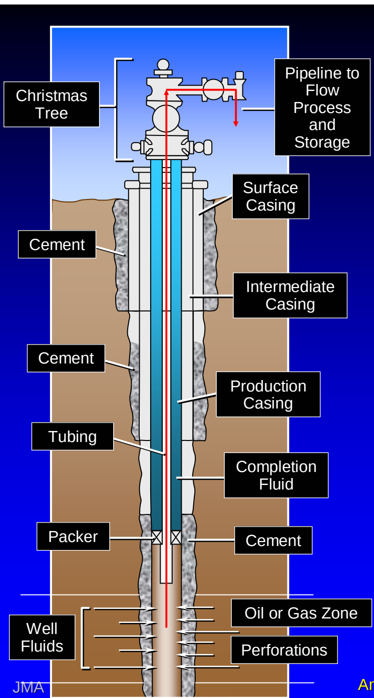

Completed Oil Well

- Water Drive - Hydrostatic pressure pushes oil and gas to surface
- Gas-Cap Drive - Expansion of gas under pressure pushes oil to surface
- Dissolved-Gas Drive - Gas disseminated in oil; usually requires pumping

JMA

American Petroleum Institute, 1986

Secondary recovery

Over the lifetime of the well the pressure will fall, and at some point there will be insufficient underground pressure to force the oil to the surface. If economical, as often is, the remaining oil in the well is extracted using secondary oil recovery methods .

Secondary oil recovery uses various techniques to aid in recovering oil from depleted or low-pressure reservoirs. Sometimes pumps, such as beam pumps and electrical submersible pumps (ESPs), are used to bring the oil to the surface. Other secondary recovery techniques increase the reservoir's pressure by water injection, natural gas reinjection and gas lift, which injects air, carbon dioxide or some other gas into the reservoir.

Together, primary and secondary recovery generally allow 25% to 35% of the reservoir's oil to be recovered.

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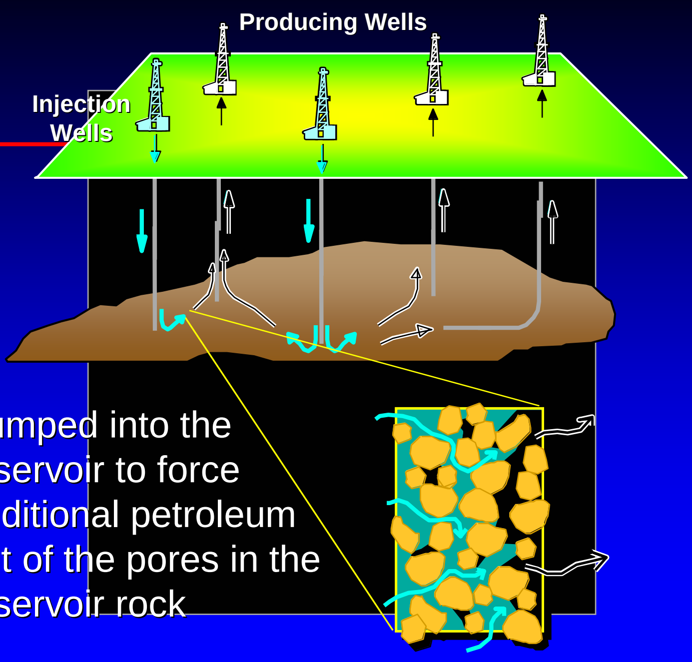
Secondary Recovery

Of 60% Remaining in Reservoir

- Water
- Gas
- Steam
- Chemical
- Fire

Pumped into the reservoir to force additional petroleum out of the pores in the reservoir rock



JMA

Tertiary recovery

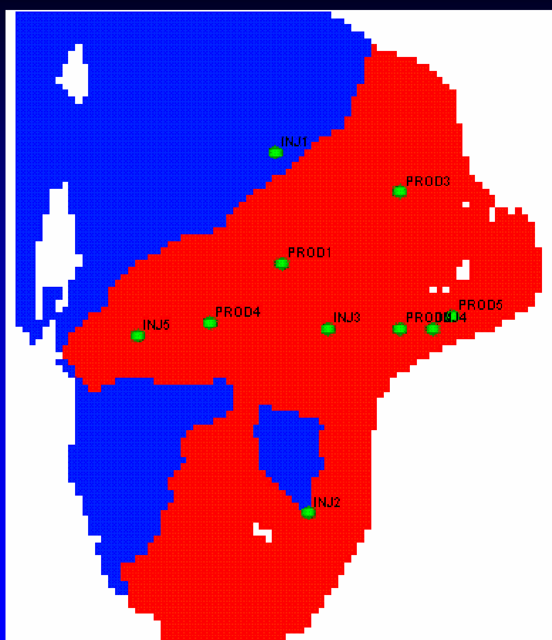
Tertiary oil recovery reduces the oil's viscosity to increase oil production. Thermally enhanced oil recovery methods (TEOR) are tertiary recovery techniques that heat the oil and make it easier to extract. Steam injection is the most common form of TEOR, and is often done with a cogeneration plant. In this type of cogeneration plant, a gas turbine is used to generate electricity and the waste heat is used to produce steam, which is then injected into the reservoir. This form of recovery is used extensively to increase oil production in the San Joaquin Valley, which has very heavy oil, yet accounts for 10% of the United States' oil production. In-situ burning is another form of TEOR, but instead of steam, some of the oil is burned to heat the surrounding oil. Occasionally, detergents are also used to decrease oil viscosity as a tertiary oil recovery method.

Tertiary recovery allows another 5% to 15% of the reservoir's oil to be recovered.

Tertiary recovery begins when secondary oil recovery techniques are no longer enough to sustain production, but only when the oil can still be extracted profitably. This depends on the cost of the extraction method and the current price of crude oil. When prices are high, previously unprofitable wells are brought back into production and when they are low, production is curtailed.

JMA

Non-Optimized Recovery



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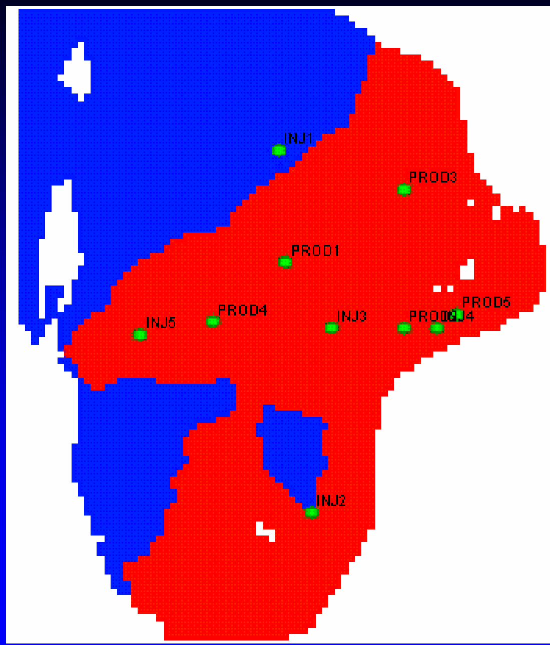
Optimized Recovery



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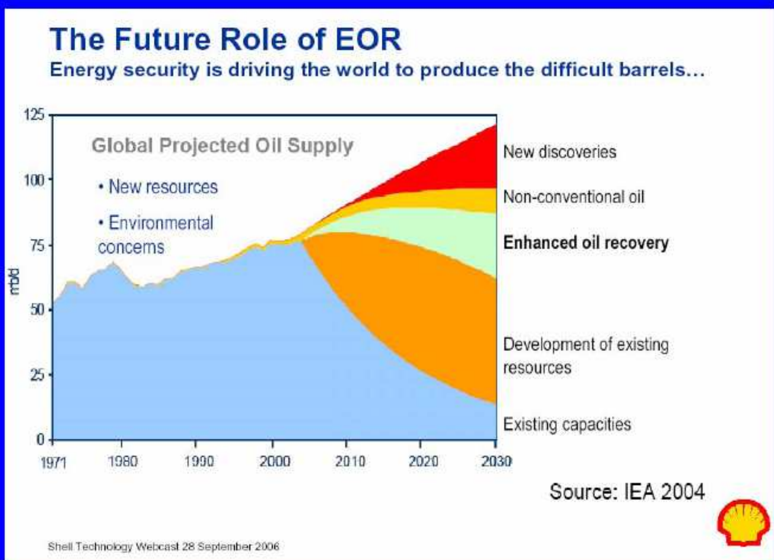

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