Lecture 1

Introduction to Directional Drilling

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Topics

- Planning directional well profiles
- Directional surveying and directional drilling systems
- Pore pressure and wellbore stability for directional wells
- Principal of Directional Bottom Hole assemblies
- Directional deflection and steering systems
- Torque & Drag and Buckling in directional wells
- Drill bit selection in directional wells and operational parameter selection and simulation for directional wells

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Directional drilling

- Examples of when to use directional drilling
- Directional change, dog leg severity
- Directional well types
- Horizontal wells
- Steerable systems
  - Deflection tools
  - PDM positive displacement motors
  - Rotary steerable systems

Multilaterals

- Infill drilling and geosteering
- (Torque, drag, buckling, directional well design)

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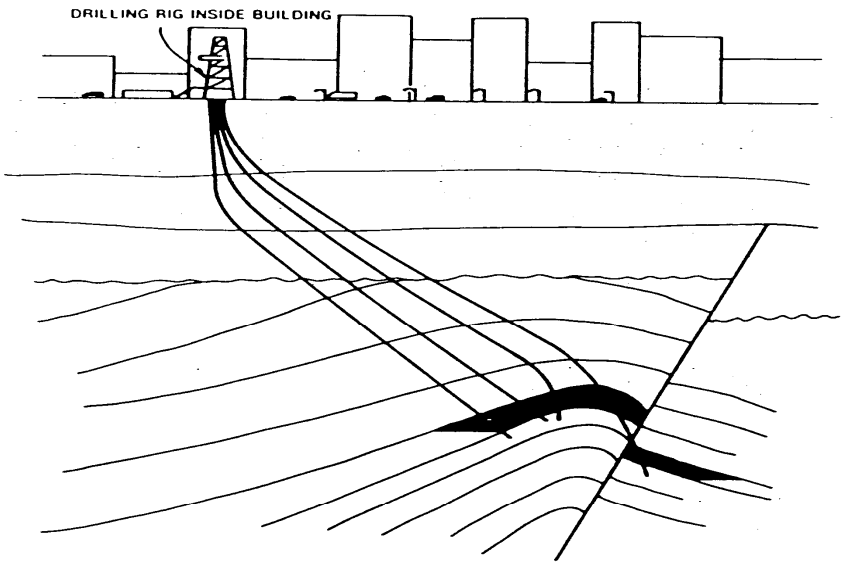


Fig. 8.4—Developing a field under a city using directionally drilled wells.

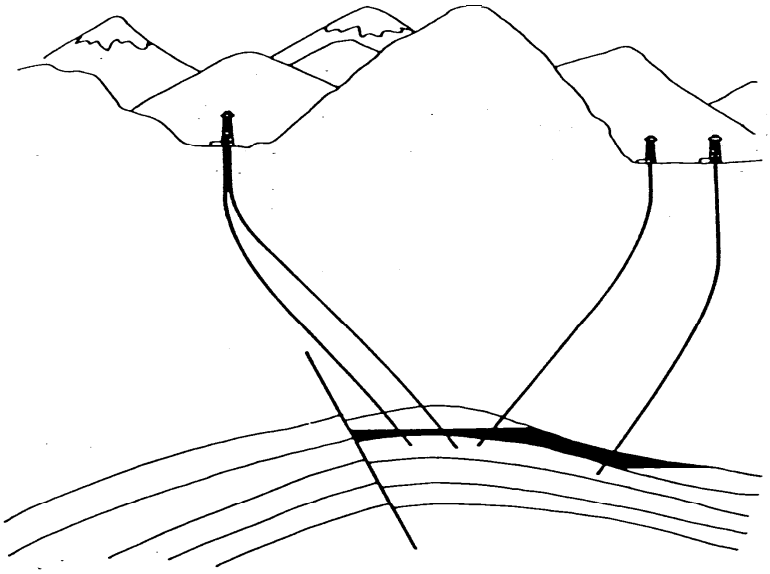


Fig. 8.5—Drilling of directional wells where the reservoir is beneath a major surface obstruction.

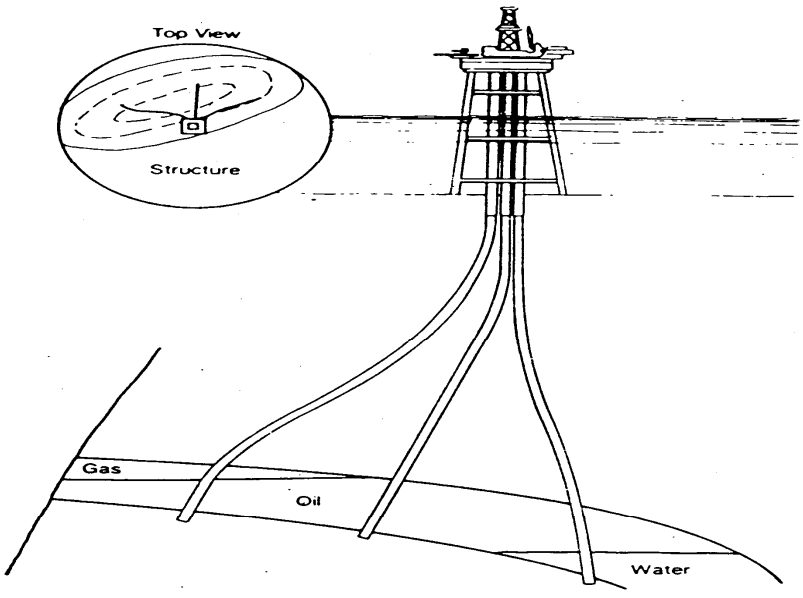


Fig. 8.3—Typical offshore development platform with directional wells.

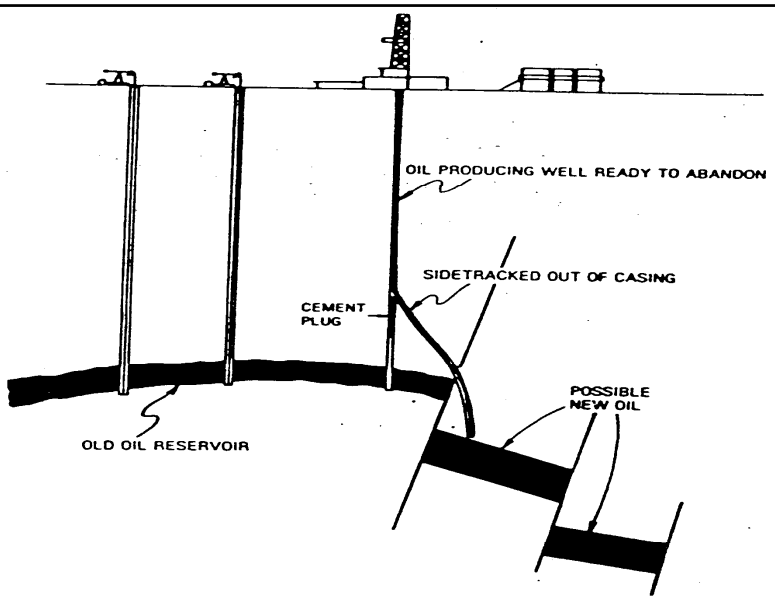


Fig. 8.7—Using an old well to explore for new oil by sidetracking out of the casing and drilling directionally.

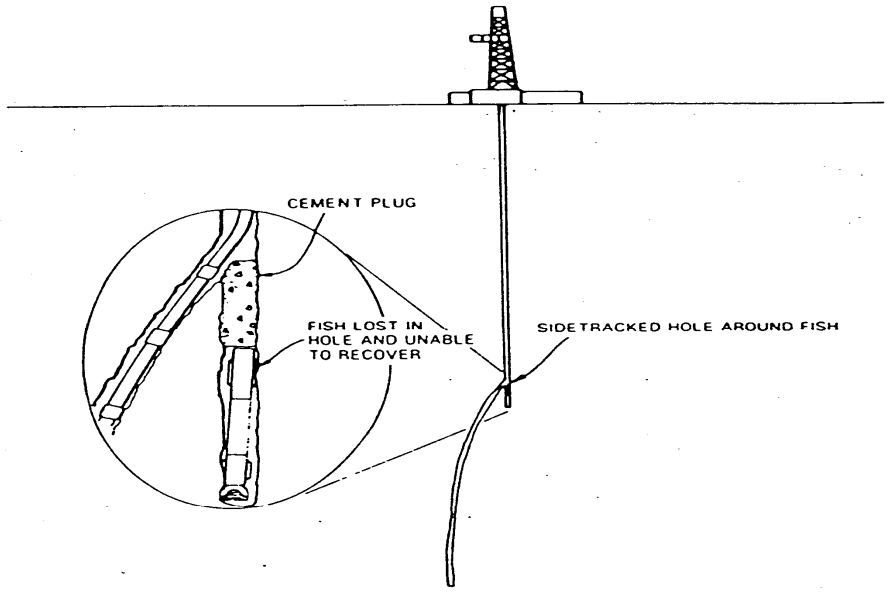
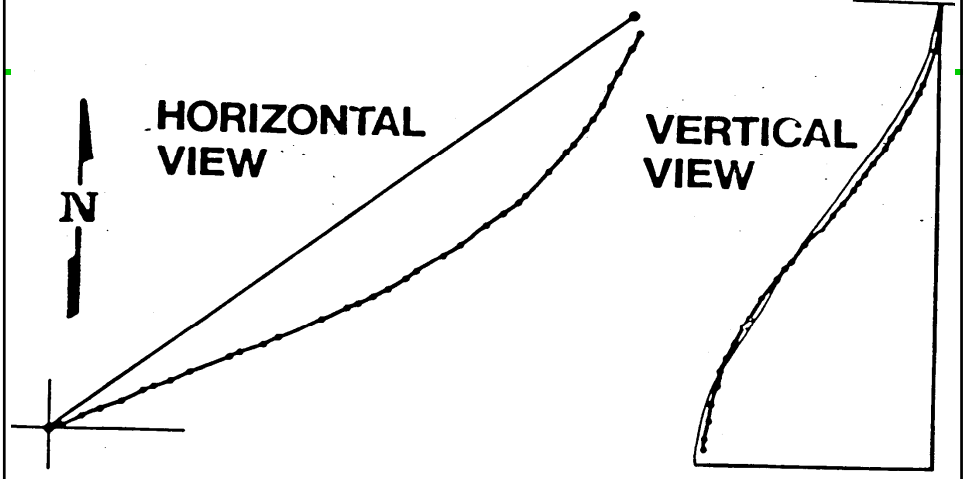


Fig. 8.6—Sidetracking around a fish.



* The actual well path hardly ever coincides with the planned trajectory
* **Important:** Hit target within specified radius

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  - Rotary steerable systems
- Multilaterals
- Infill drilling and geosteering
- (Torque, drag, buckling, directional well design)

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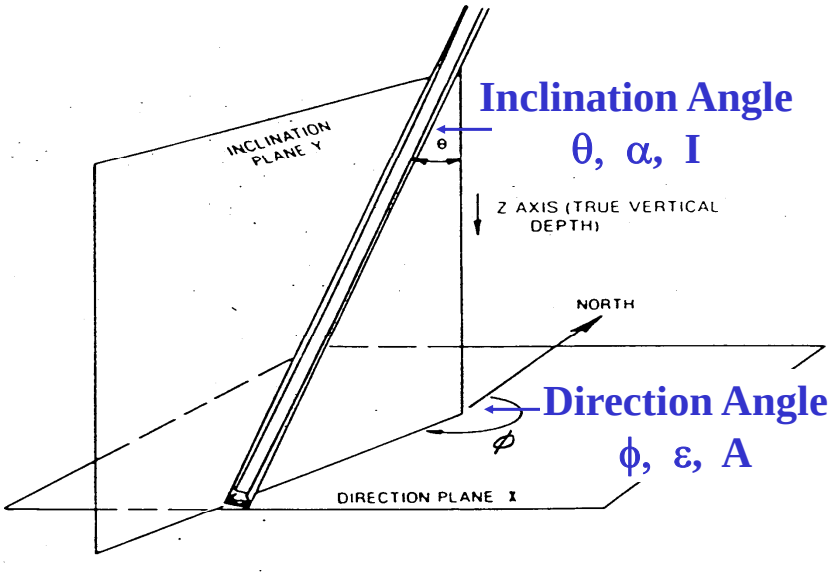
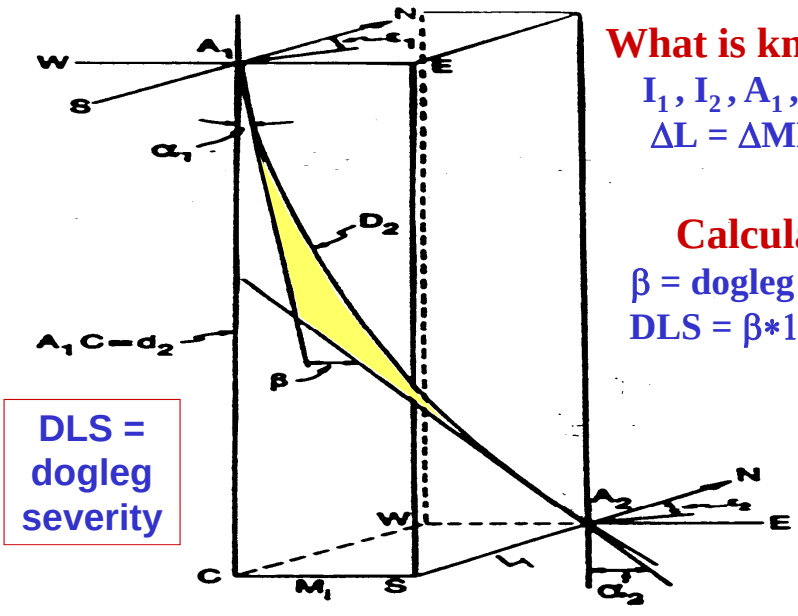


Fig. 8.1—Inclination and direction planes as a wellbore proceeds in the depth plane.



What is known?

$I_1, I_2, A_1, A_2,$
$\Delta L = \Delta MD_{1-2}$

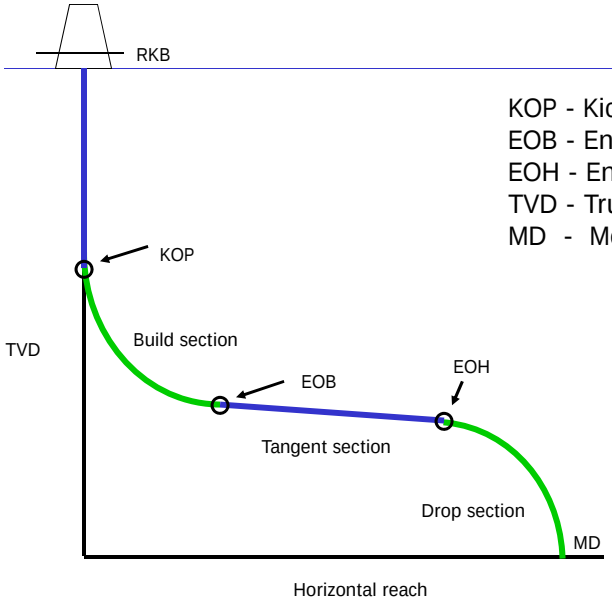
Calculate

β = dogleg angle
DLS = β∗100/ΔL

DLS = dogleg severity

Fig. 8.22—A curve representing a wellbore between Survey Stations A_1 and A_2.

Well profile terminology



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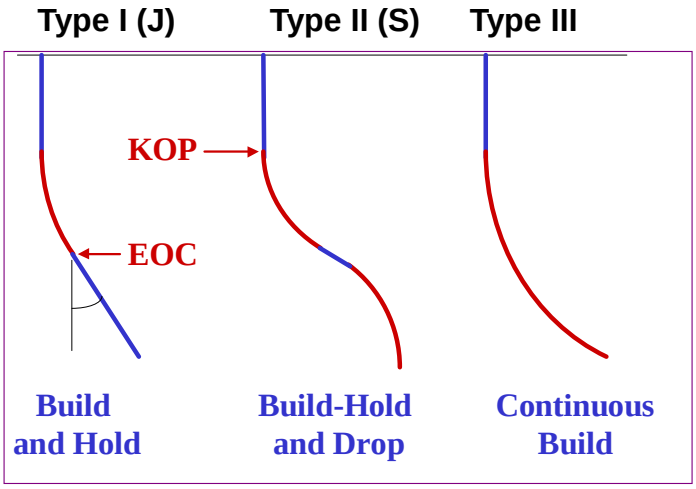
Directional well types



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How to choose a planned well path

- Target locations and boundaries
- Planned casing points
- Natural formation directional tendencies and lithologies in the build up part
- BHA considerations – directional change and performance
- Offset wells or geological features that are to be avoided and to get to close.
- Orientation of the wellbore
- DLS limitations

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Why Drill Horizontal Wells?

- Increase Reserves
- Increase Production Rates
- Control Water Production
- Control Gas Production
- Control Sand Production
- Produce From Thin Reservoirs
- Connect Vertical Fractures
- Produce Methane from Coal Seams
- Increase Injectivity
  - (steam, water, polymers, etc.)

Horizontal wells...

- may produce at 3-5 (or higher) times of vertical wells
- typically cost 1.5-3 times more
- used in reservoir with natural vertical fractures

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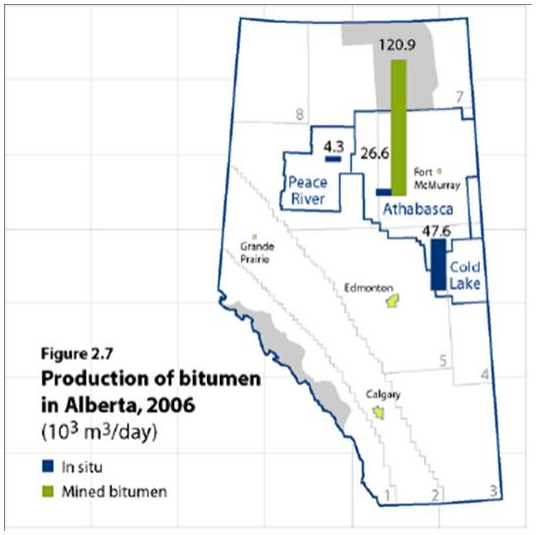
Alberta Oil sands

- 60% production from mining (121,000 m^3/day; 760,000 bpd)
- 40% production from in-situ (78,500 m^3/day; 490,000 bpd)



Source: Canadian Heavy oil association

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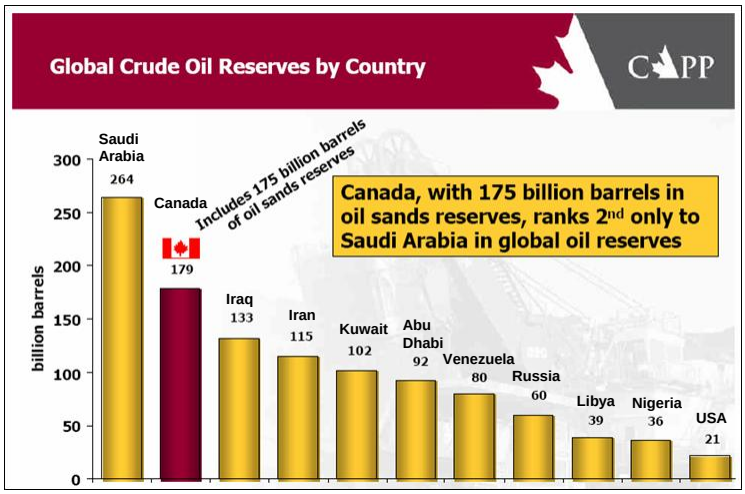
Heavy oil Canada



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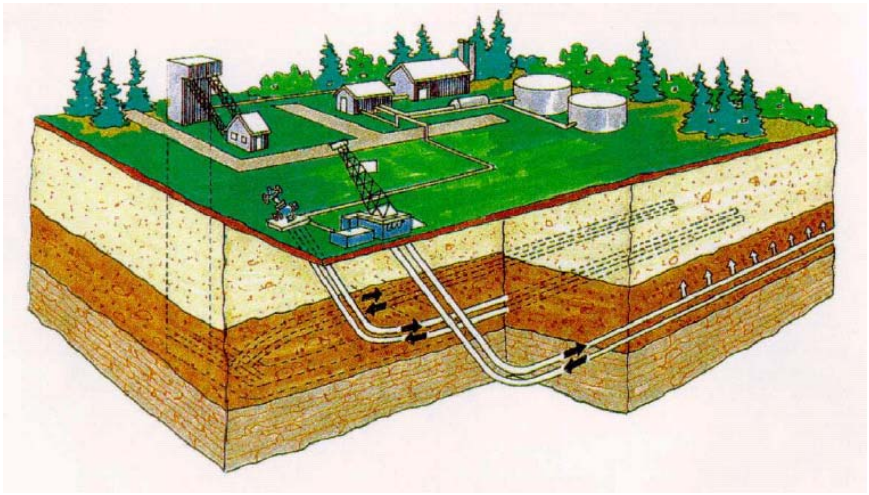

Source: Canadian Heavy oil association

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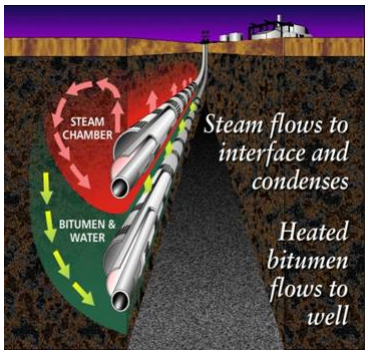
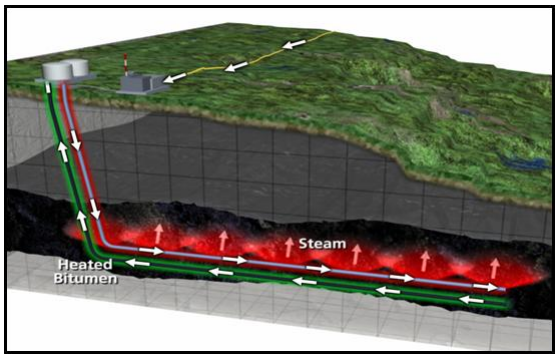
In-Situ

Steam Assisted Gravity Drainage (SAGD)





- Horizontal length: 750 – 1200 m
- Vertical separation: 5 – 6 m
- TVD: 90 – 400 m
- Rate: 100 – 400 m^3/day (700 – 2500 bpd)
- Steam Oil Ratio: 2 – 4
- Current Production: 20,000 m^3/day (125,000 bpd)

Source: Canadian Heavy oil association

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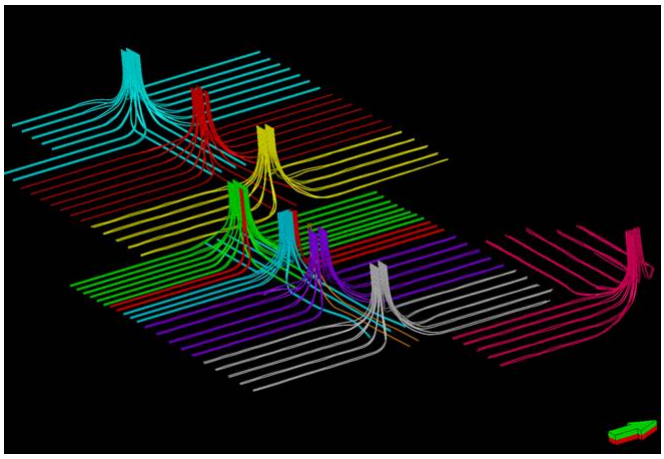
In-Situ

Steam Assisted Gravity Drainage (SAGD) Example of SAGD Pads



Source: Suncor Energy Inc.

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In-Situ

Steam Assisted Gravity Drainage (SAGD)
SAGD Well Pad

Source: Suncor Energy Inc.

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In-Situ

Steam Assisted Gravity Drainage (SAGD)
SAGD Well Pad – Slant Wellheads

Source: Nexen

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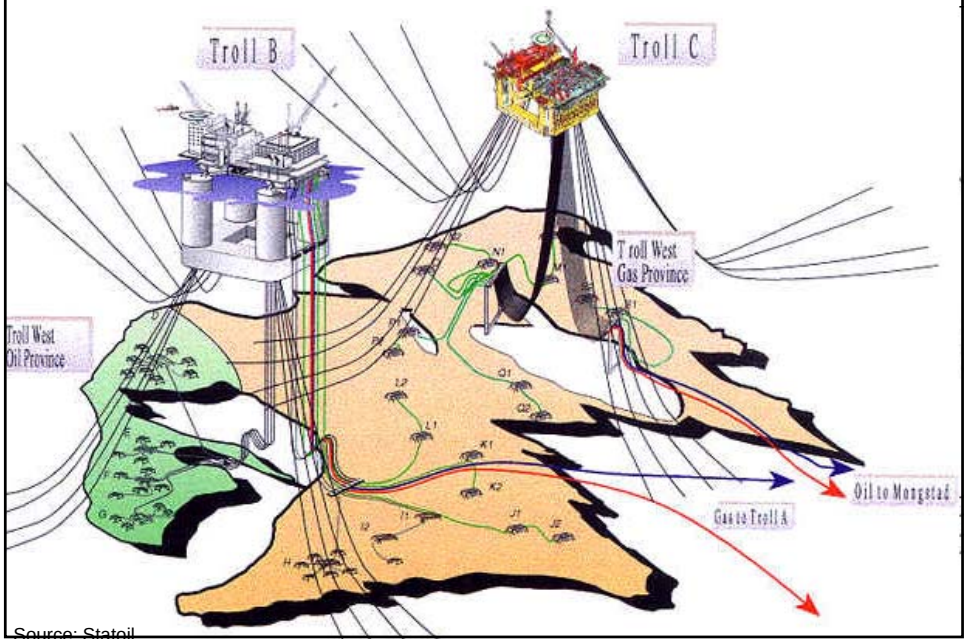
Troll oil field North sea

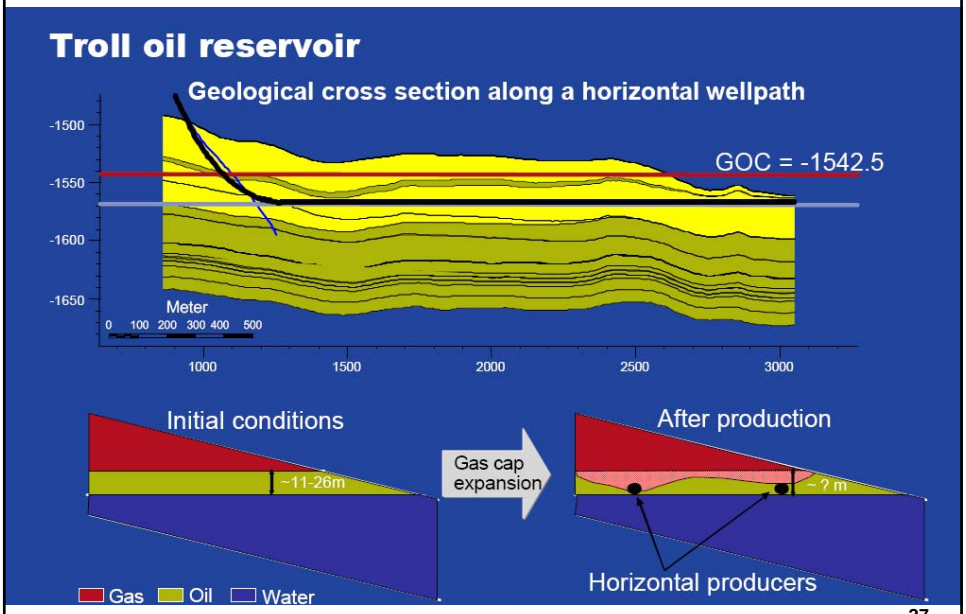
Source: StatoilHydro

Troll oil field



Source: Statoil

Troll horizontal wells



Source: Statoil

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Potential Problems in Horizontal Drilling

- Running equipment in and out of hole
  - drillstring, casing, cables
- Preventing/Remedying differential sticking
- Excessive torque
- Cleaning the hole and preventing cuttings from settling along the hole bottom
- Controlling weight on bit to achieve and maintain directional control
- Cementing casing or liner

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Definition of steerable system

1. A BHA whose directional behavior may be modified from the surface to steer the bit towards the target, without removing the BHA.
2. An MWD system to provide continuous updates of directional parameters while drilling.
3. Surface software capable of predicting the probable trajectory of the wellbore with the current BHA.

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Steerable systems

- Deflection tools
- PDM positive displacement motors
- Rotary steerable systems (RSS)

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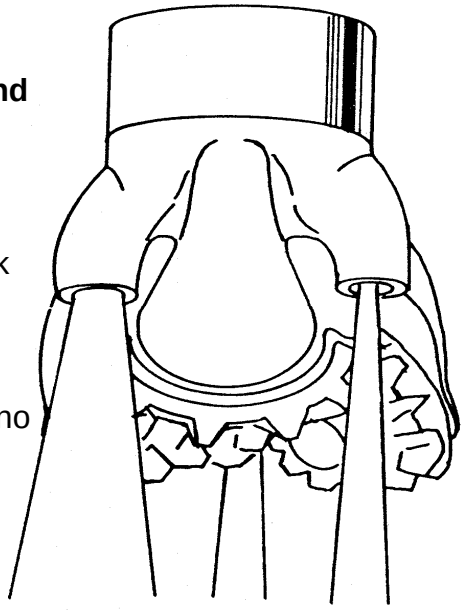
Jetting bit

- A bit with **one oversize and two normal size nozzles** will tend to hydraulically erode the hole on the side of the large nozzle, when drilling in medium soft rock without pipe rotation.
- This causes the hole to change direction.
- When the pipe is rotated, no change in inclination or direction occurs.



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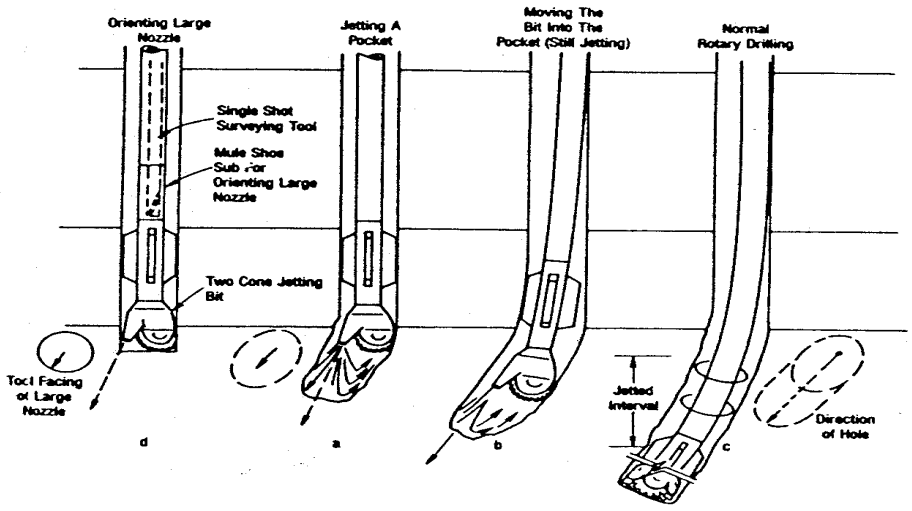
Jetting a trajectory change



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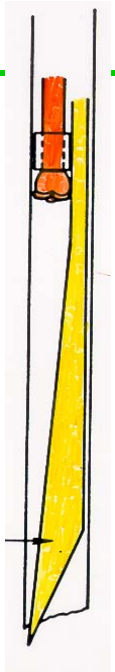
Openhole whipstock

- For kicking off from vertical
- For changing hole direction
- Not for steering.



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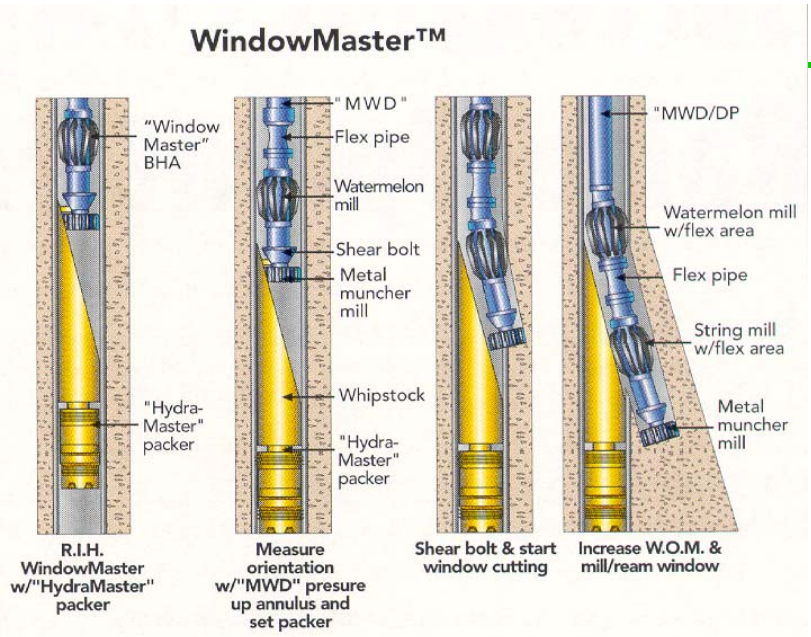

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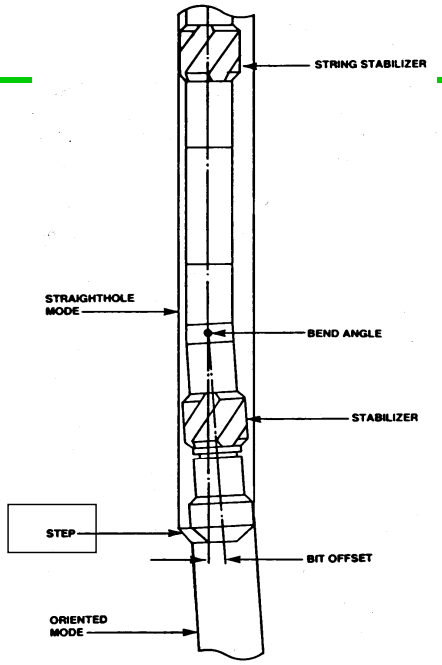
Directional change with Mud motor and bent housing



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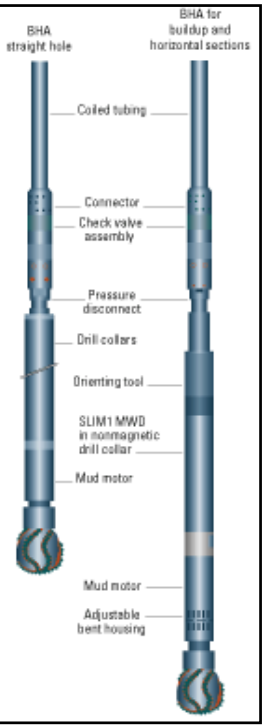
Bottom Hole Assembly

- The lower portion of the drillstring, consisting of (from the bottom up in a vertical well)
- The bit,
- Bit sub,
- Stabilizers,
- Drill collars,
- Heavy-weight drillpipe,
- Crossovers for various thread forms.



BHA cont...

- Mud motor, directional drilling and measuring equipment, measurements-while-drilling tools, logging-while-drilling tools and other specialized devices.
- A simple BHA consisting of a bit, various crossovers, and drill collars may be relatively inexpensive (less than $100,000 US in 2000),
- A complex directional BHA may cost ten or more times that amount.

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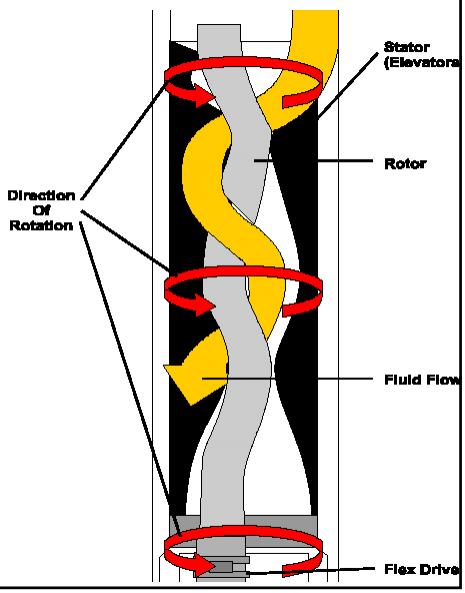
Positive displacement pumps (Mud motor)

- A positive displasement drilling motor that uses hydraulic horsepower of the drilling fluid to drive the drill bit.
- A mud motor incorporating a bent housing
- A steerable motor can be used to steer the wellbore without drillstring rotation in directional drilling operations, or to drill ahead in a rotary drilling mode.



Positive displacement pumps

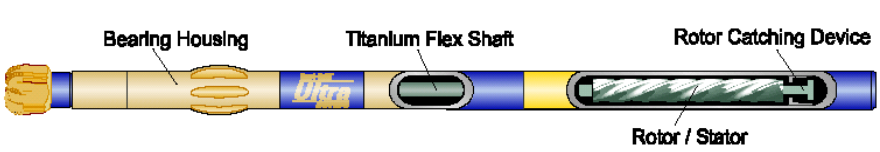
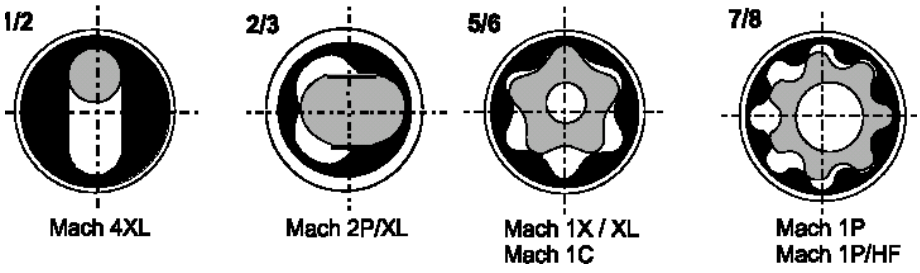


Figure 1-2. Navi-Drill Motor Components



Source: BHI

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3D rotational directional tools

- Push the bit technology and point the bit technology
- Rotational drilling improves cutter transport and thereby hole cleaning
- Rotational drilling improves WOB transfer
- Two most common types is Power drive and Autotrack
- A closer look on Power driwe

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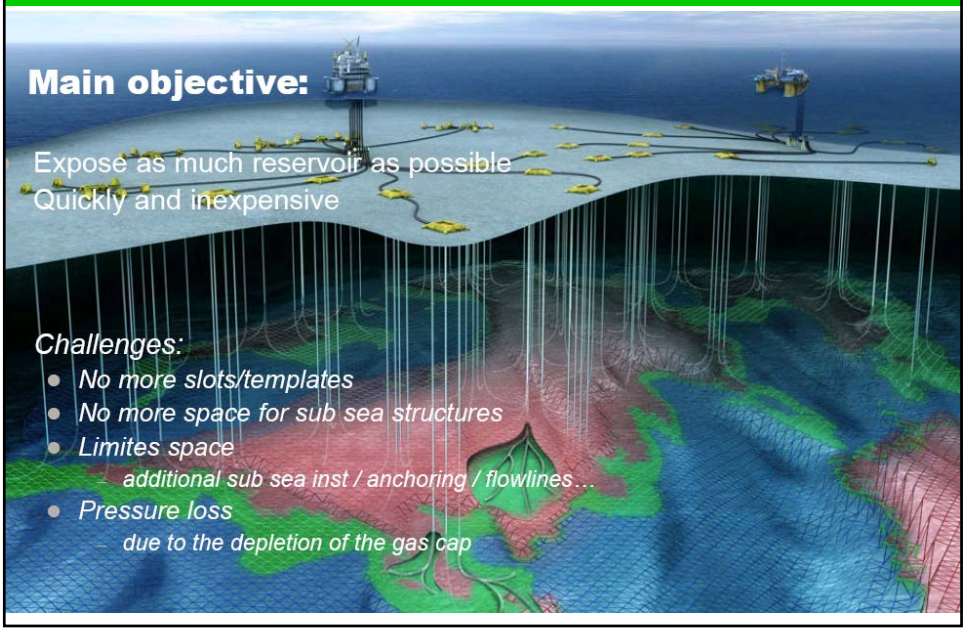
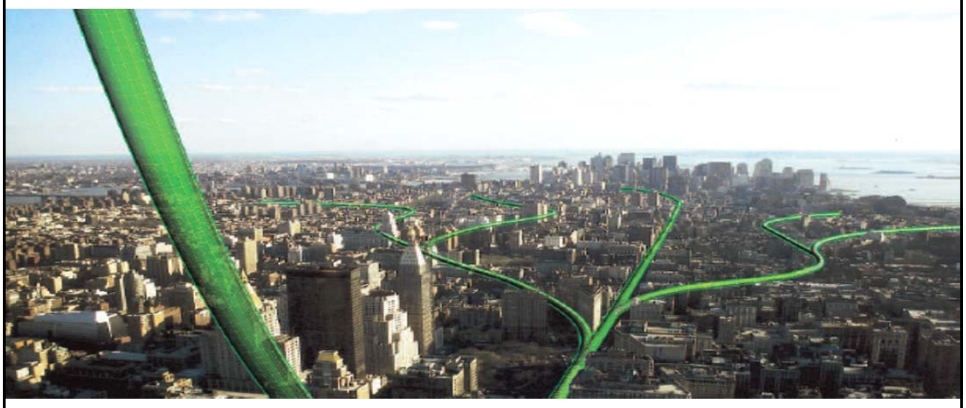
Troll infill drilling



Troll multilaterals



Source: Statoil

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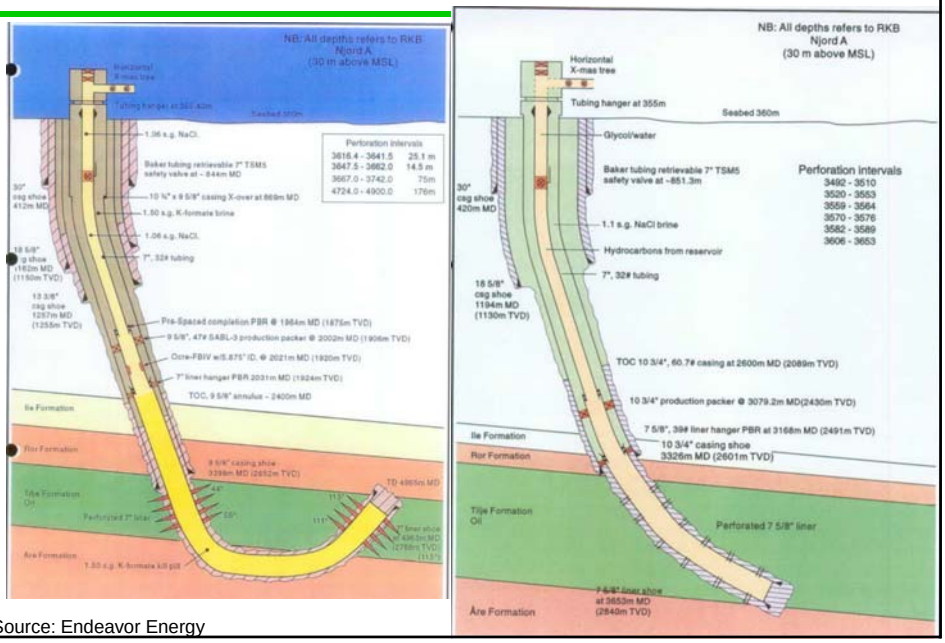
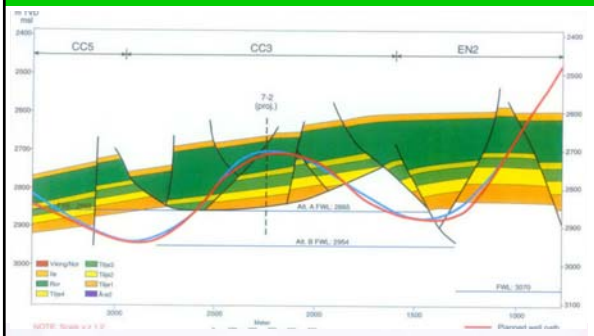
Casing and well design

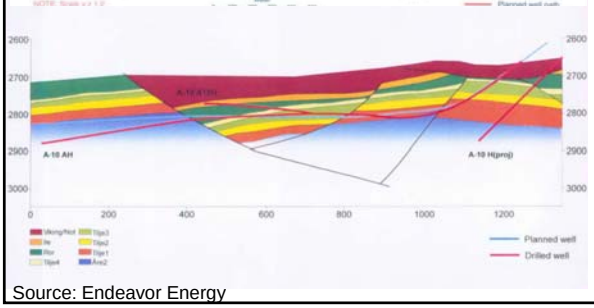


Source: Endeavor Energy

Infill drilling



Well path before geosteering



Well path geosteering

Source: Endeavor Energy

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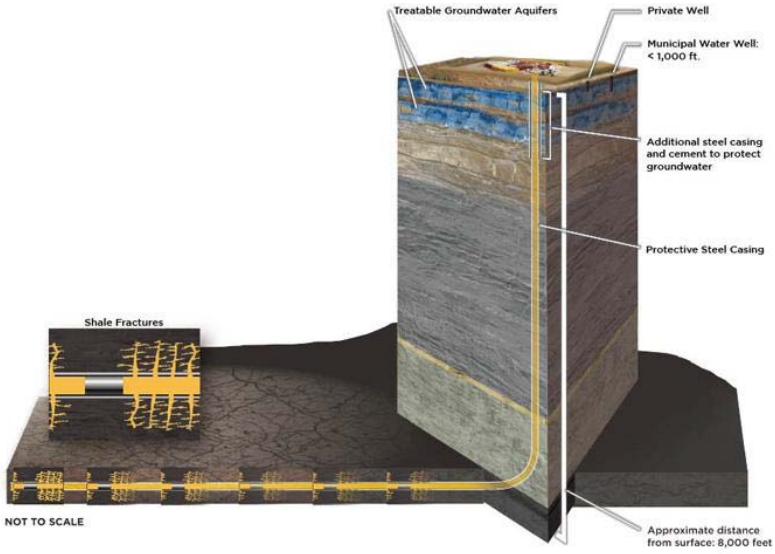
Shale gas fracing



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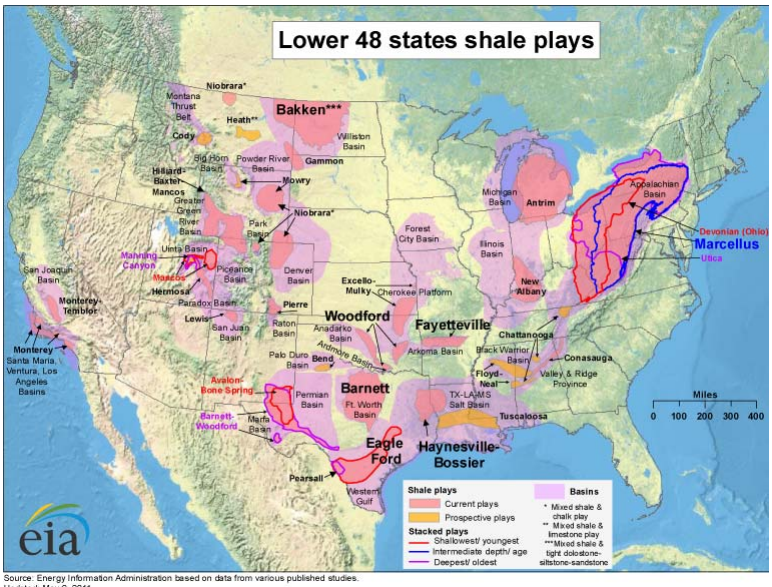
Shale gas



Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

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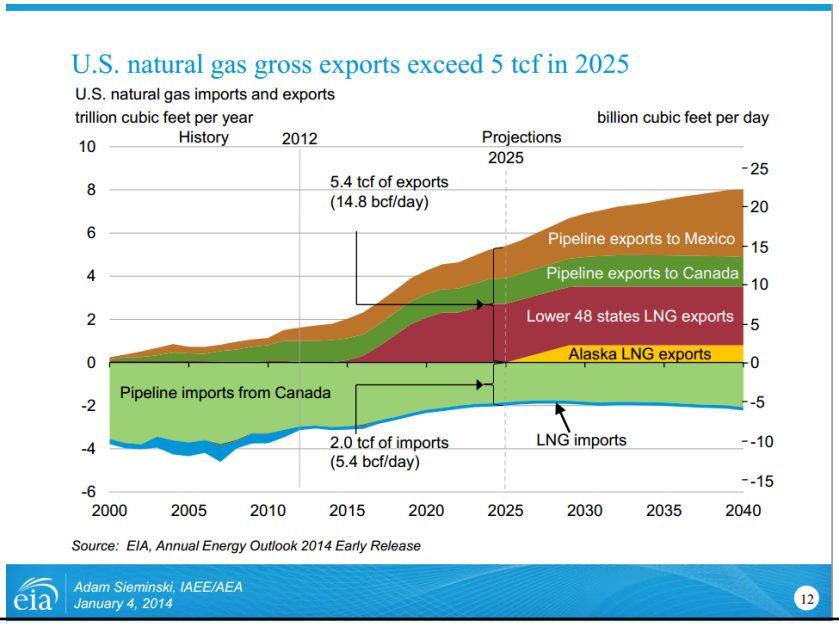
Shale Gas = "Unconventional" Gas



Source: EIA, Annual Energy Outlook 2014 Early Release