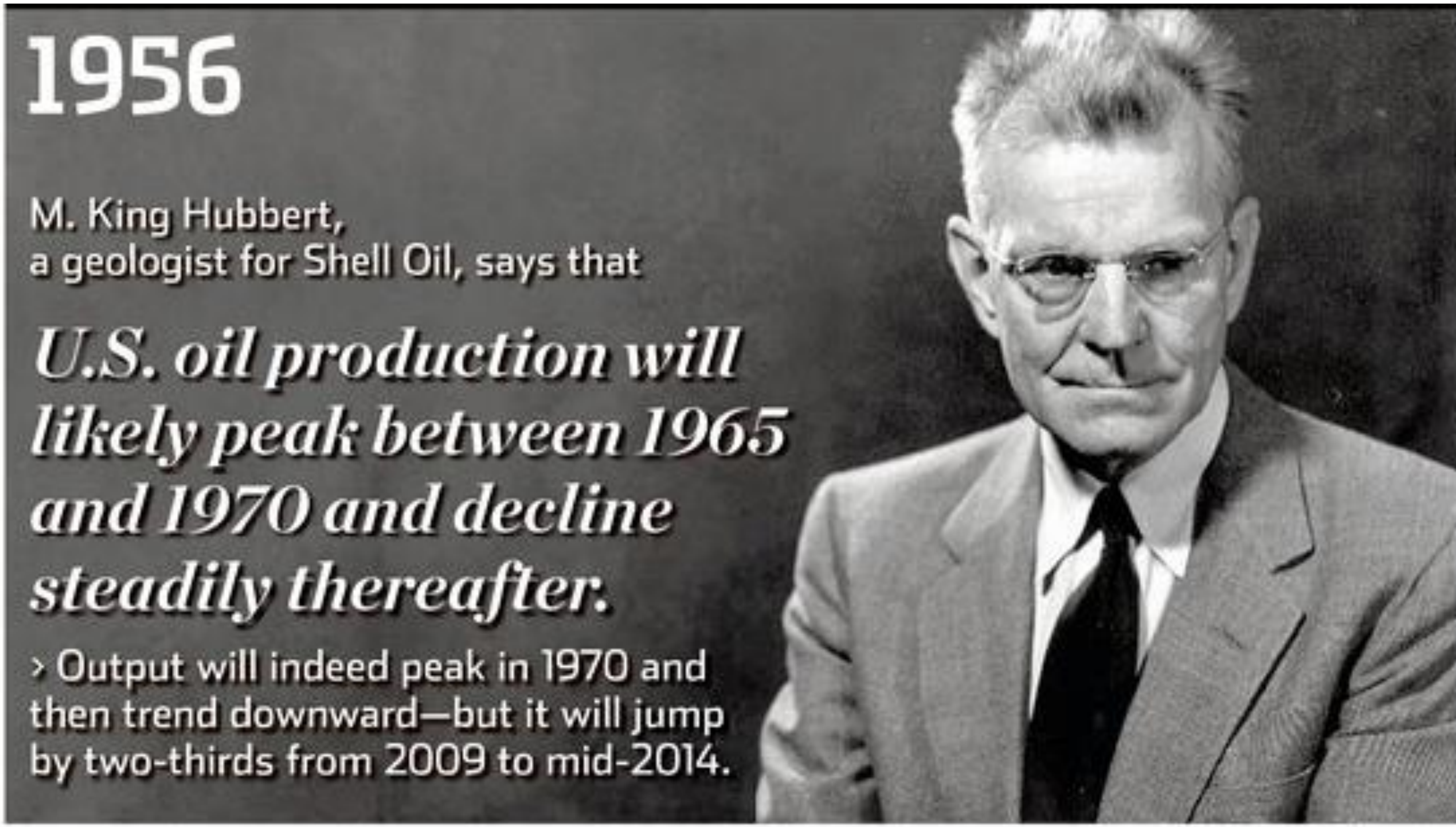
Part I: Oil and gas fuel chain

Oil and Gas Exploration

Jan Osička

What is peak oil?

Peak oil


1956
M. King Hubbert,
a geologist for Shell Oil, says that
U.S. oil production will likely peak between 1965 and 1970 and decline steadily thereafter.
› Output will indeed peak in 1970 and then trend downward—but it will jump by two-thirds from 2009 to mid-2014.

Peak oil

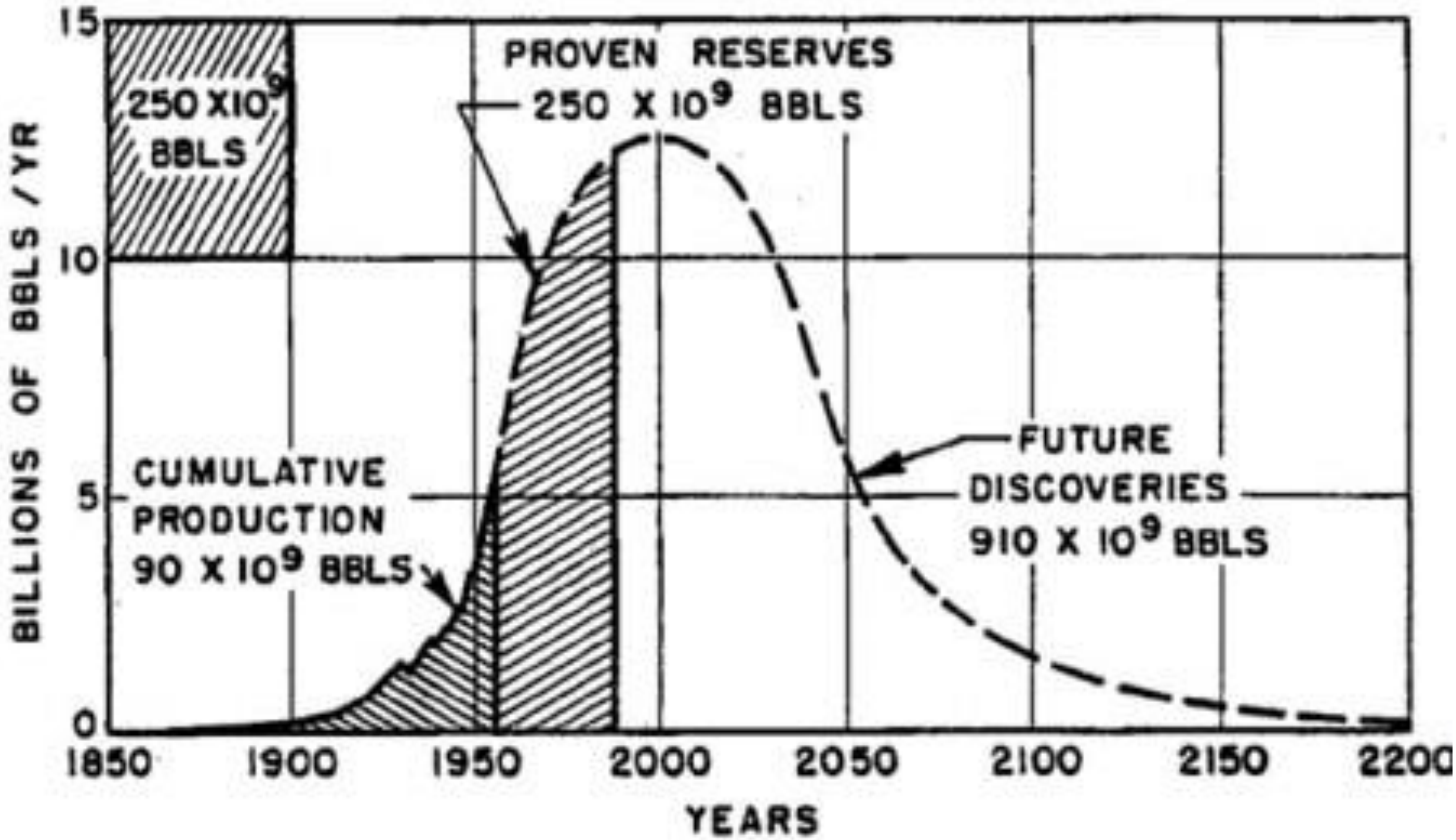


Figure 20 – Ultimate world crude-oil production based upon initial reserves of 1250 billion barrels.

Lecture outline

- Oil and gas characteristics
- Exploration process and techniques
- Reserves
- Concluding remarks on the peak oil concept

Oil

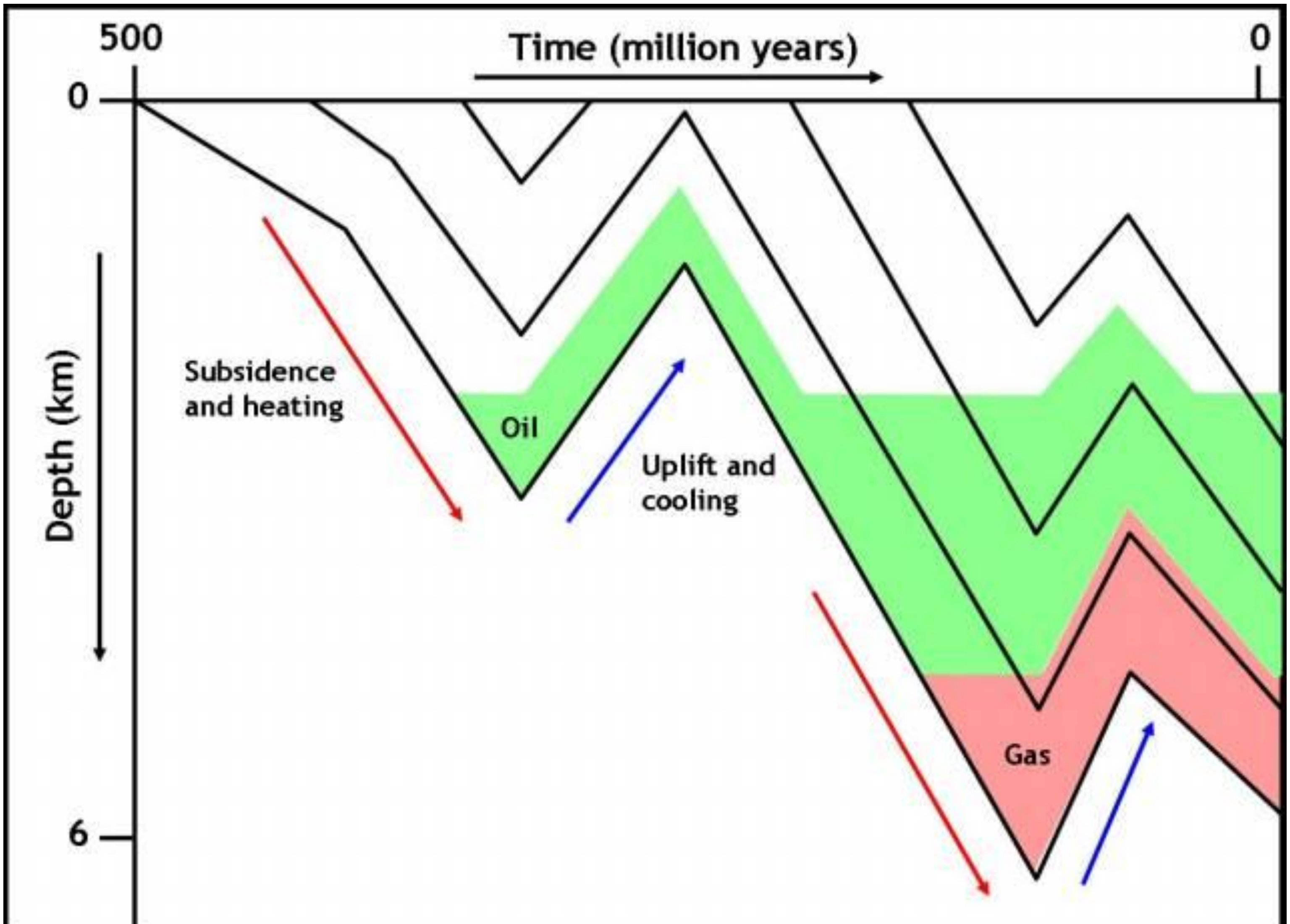
- Dark and flamable liquid
- Lighter than water (**density 800-990 kg/m^3**)
- Content: 84-87 % C, 11-14 % H, up to 4 % S and 1 % N
  - Gases: methane, ethane, propane, butane, carbon dioxide
  - Liquids: alkanes, iso-alkanes, cyclo-alkanes, aromates
  - Solids: resins, asphalt, **sulphur**

  - Marginally nitrogen, oxygen, heavy metals

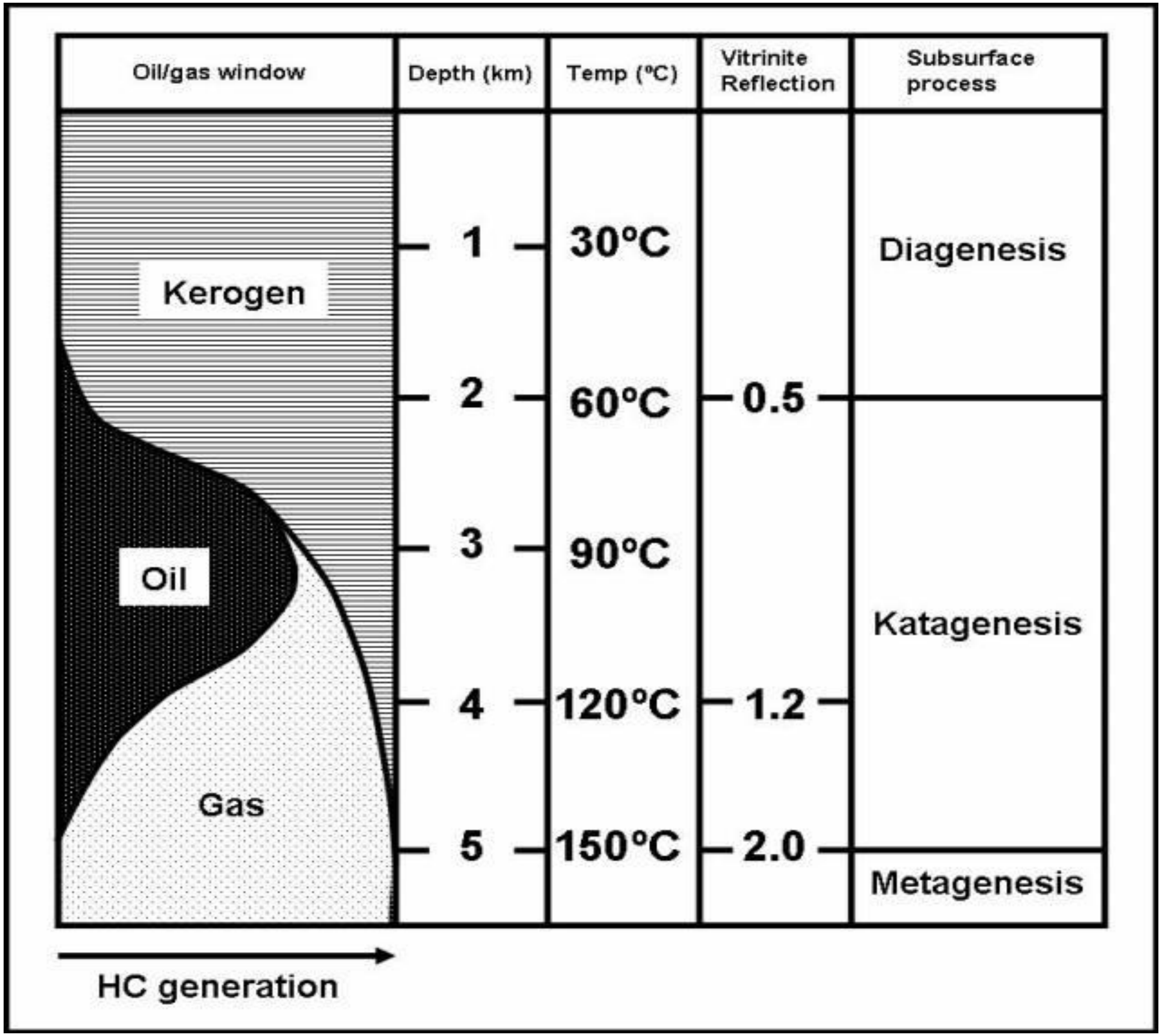
Natural gas

- Colorless and odourless
- Lighter than air (0,6 kg/m^3 at 25 °C x 1,2 kg/m^3)
- Content
  - Methane 70-90%
  - Ethane , propane, butane 0-20%
  - Carbon dioxide, oxygen, nitrogen, sulphide up to 1 %
  - Marginally noble gases

Origins of oil and gas



Origins of oil and gas



Exploration: profit is the key

- Geology, geochemistry, geophysics = sciences
- Exploration = business activity
- The price:
  - 10 bn barrels of oil
  - 2 bn cubic meters
  - ~ 1 500 000 000 000 USD

Risk: between profit and loss

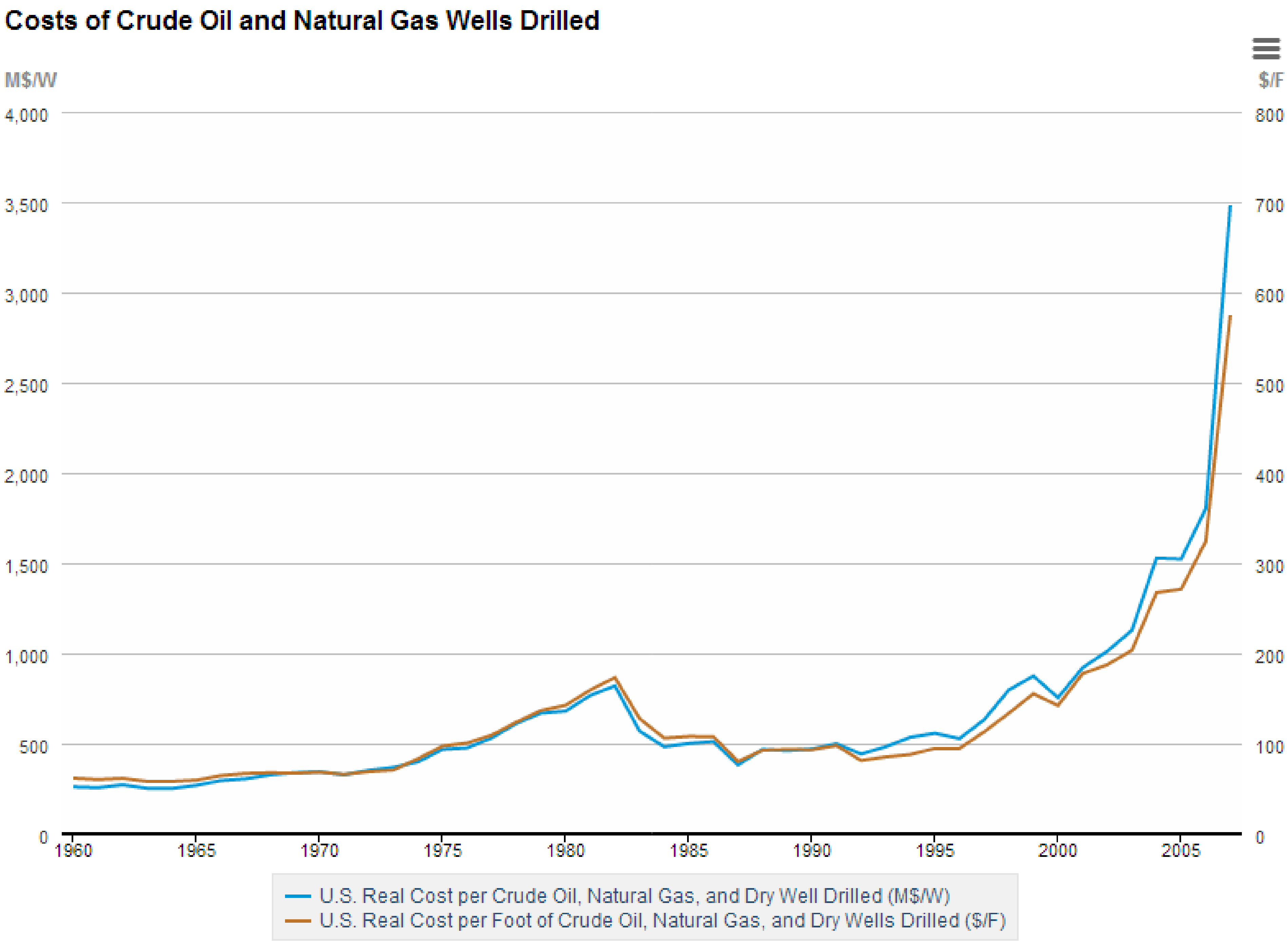
1983 Mukluk Island, Alaska

Drilling rigs rental prices (March 2014)

- Jackup IC 300'+ WD (201 pieces): 166 000 USD/day
- Semisub 4000'+ WD (117 pcs): 432 000 USD/d
- Drillship 4000'+ WD (94 pcs): 499 000 USD/d

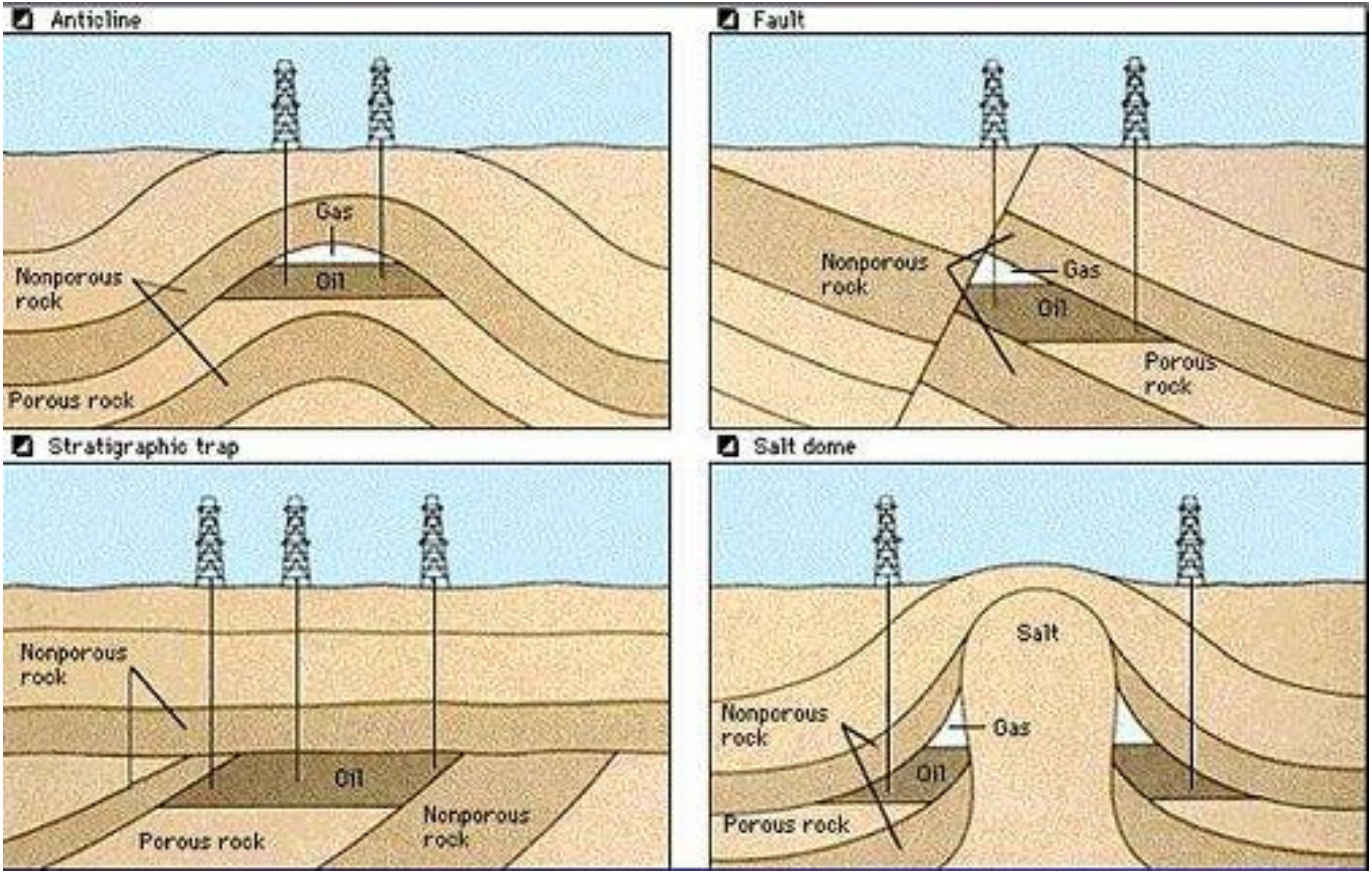
Costs of average exploratory well

- Arizona: 0.4-1 milion USD
- North Sea: 10-17 milion USD
- Angola (offshore): 25-60 milion USD
- Deepwater (several kilometers): ca 100 milion USD


Costs of Crude Oil and Natural Gas Wells Drilled
M$/W
$/F
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
800
700
600
500
400
300
200
100
0
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
U.S. Real Cost per Crude Oil, Natural Gas, and Dry Well Drilled (M$/W)
U.S. Real Cost per Foot of Crude Oil, Natural Gas, and Dry Wells Drilled ($/F)

Phases of exploration

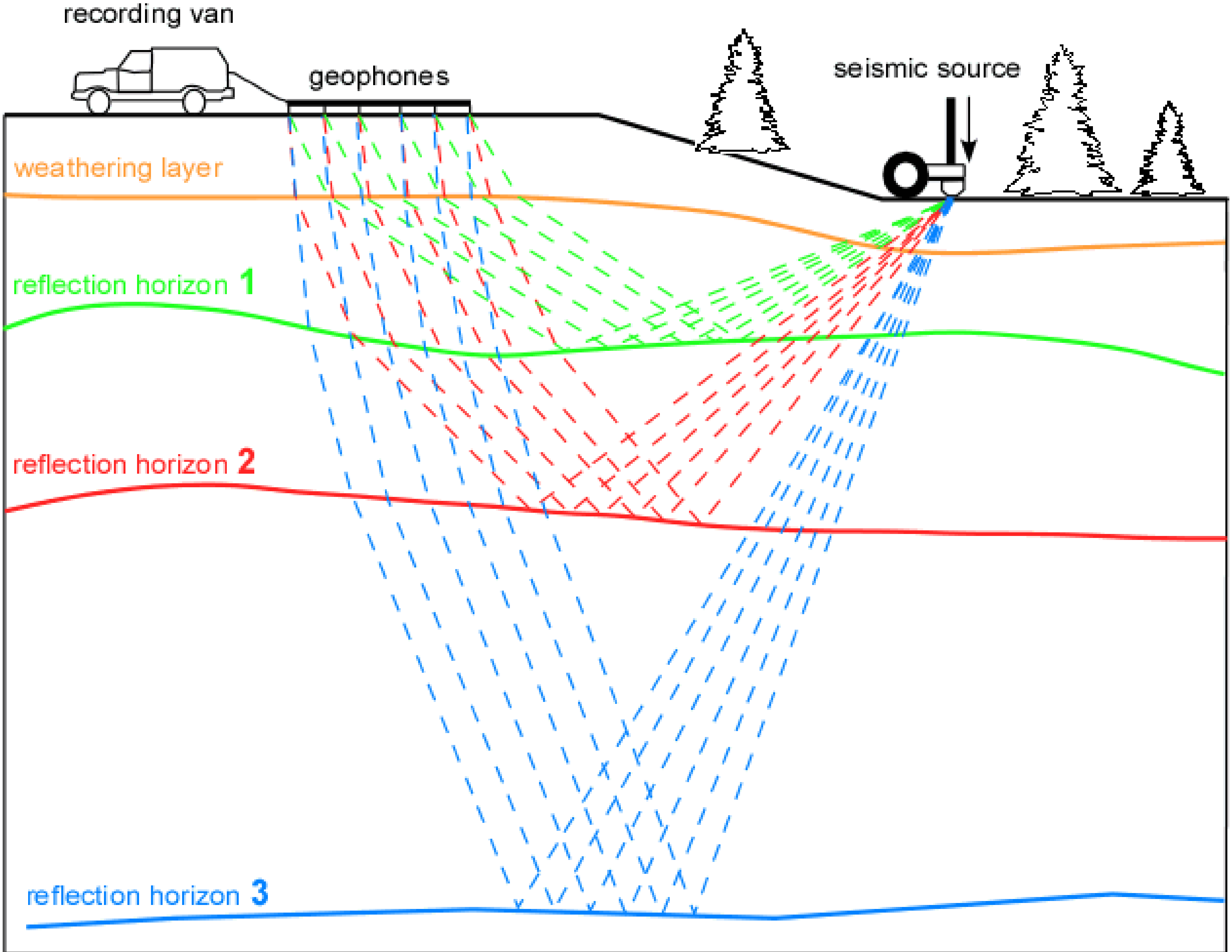
1. Area identification – based on existing knowledge, new technology, changed situation on the market..
2. Exploration licensing proces (+ license auction)
3. Exploration proces
    1. Where are the carbon-rich layers?
    2. What is their structure and thickness?
    3. Where and when were they subject to sufficient temperature and pressure?
    4. Are there any traps to form a reservoir?
4. Evaluation – are there suitable spots for exploratory drilling?


Anticline
Gas
Oil
Nonporous rock
Porous rock
Fault
Nonporous rock
Gas
Oil
Porous rock
Stratigraphic trap
Nonporous rock
Oil
Porous rock
Nonporous rock
Salt dome
Salt
Nonporous rock
Gas
Oil
Porous rock

Geophysical exploration

Seismic exploration

- The most frequent technique
- Accustic wave stimulation and reflection
- Outcomes
  - The presence of hydrocarbons (since 1960s)
  - Thickness and constitution of layers
  - 2D, 3D, 4D graphics

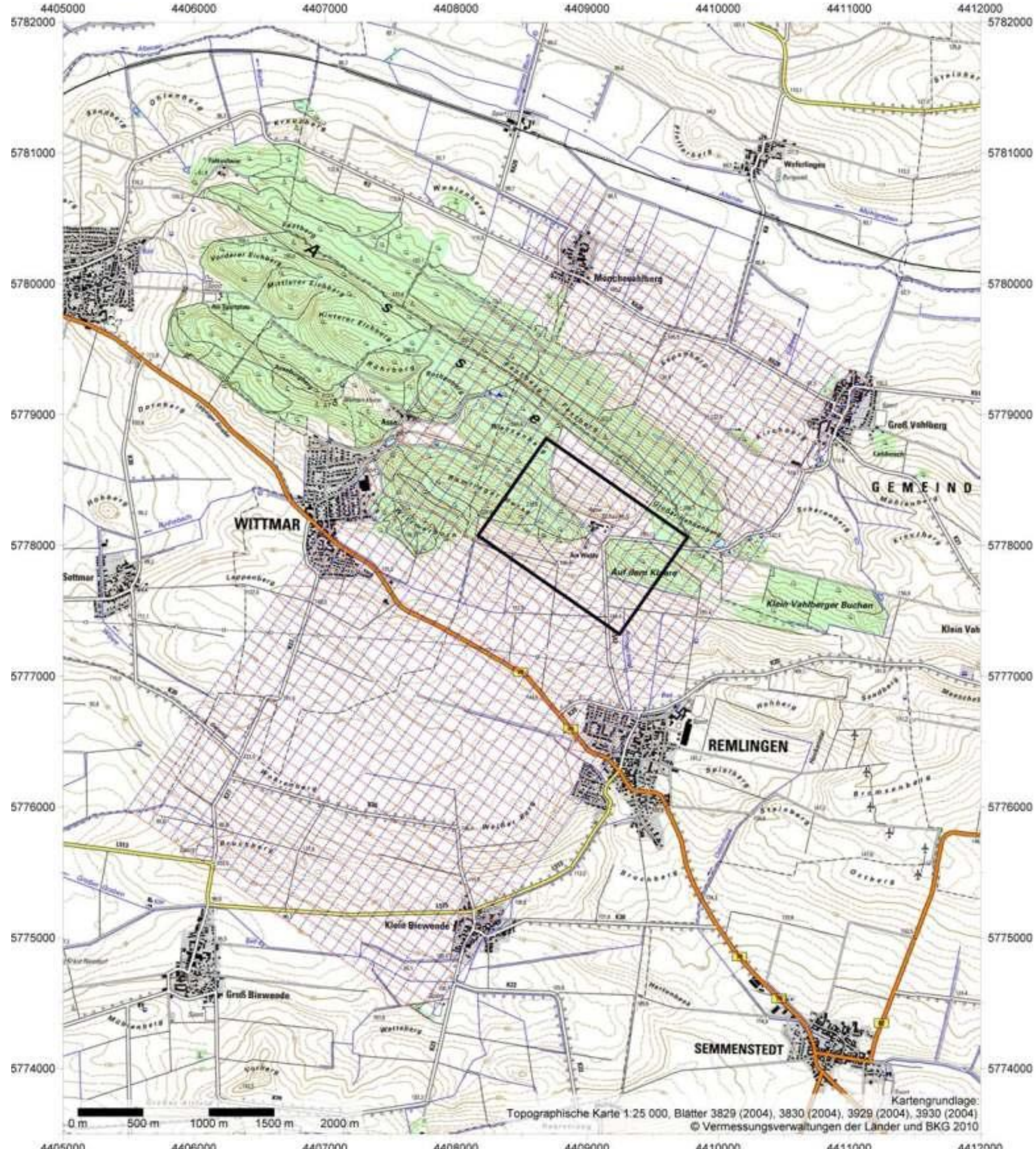

recording van
geophones
seismic source
weathering layer
reflection horizon 1
reflection horizon 2
reflection horizon 3


Consulting


2
14


10


HYATT


4405000
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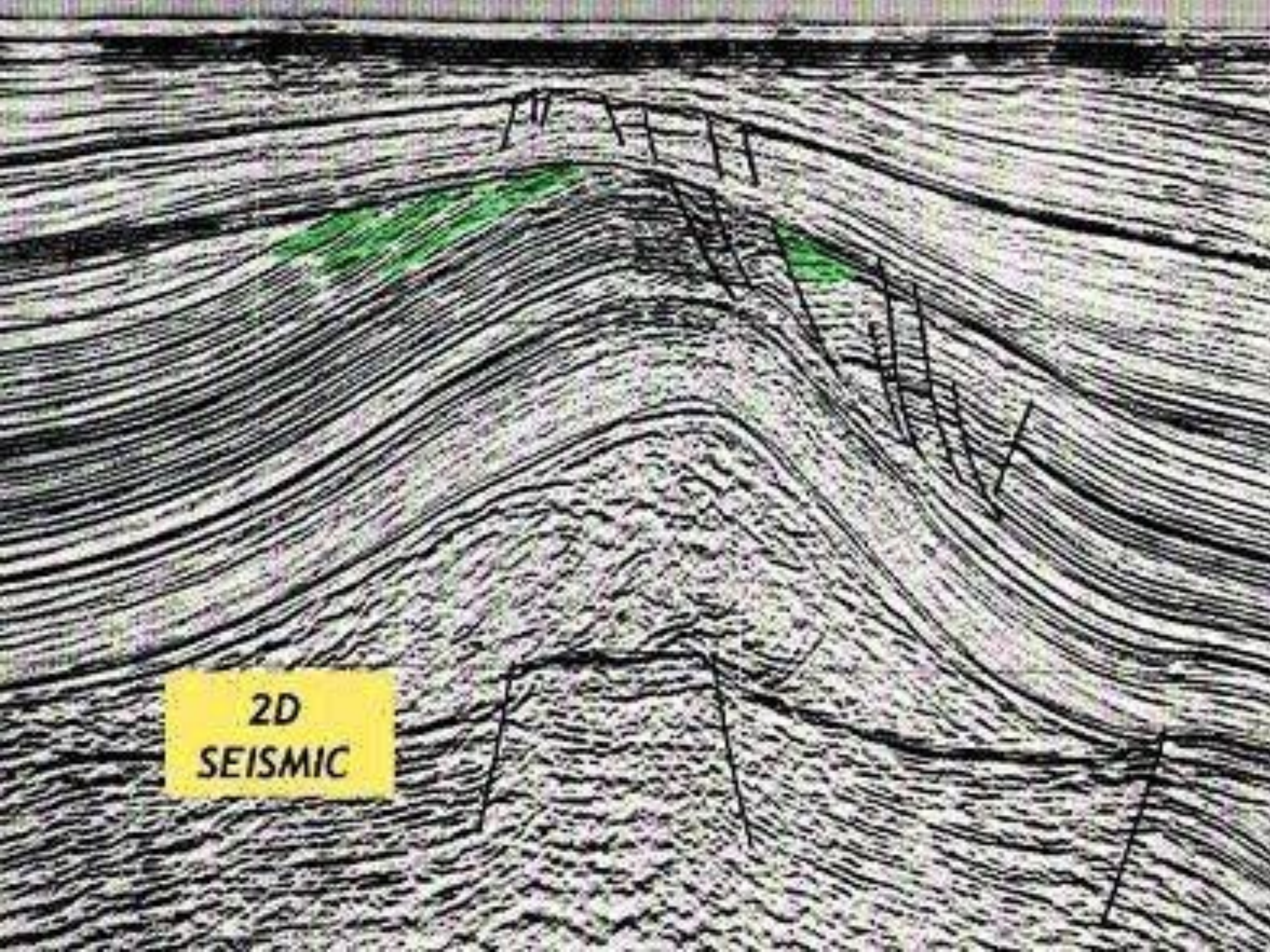
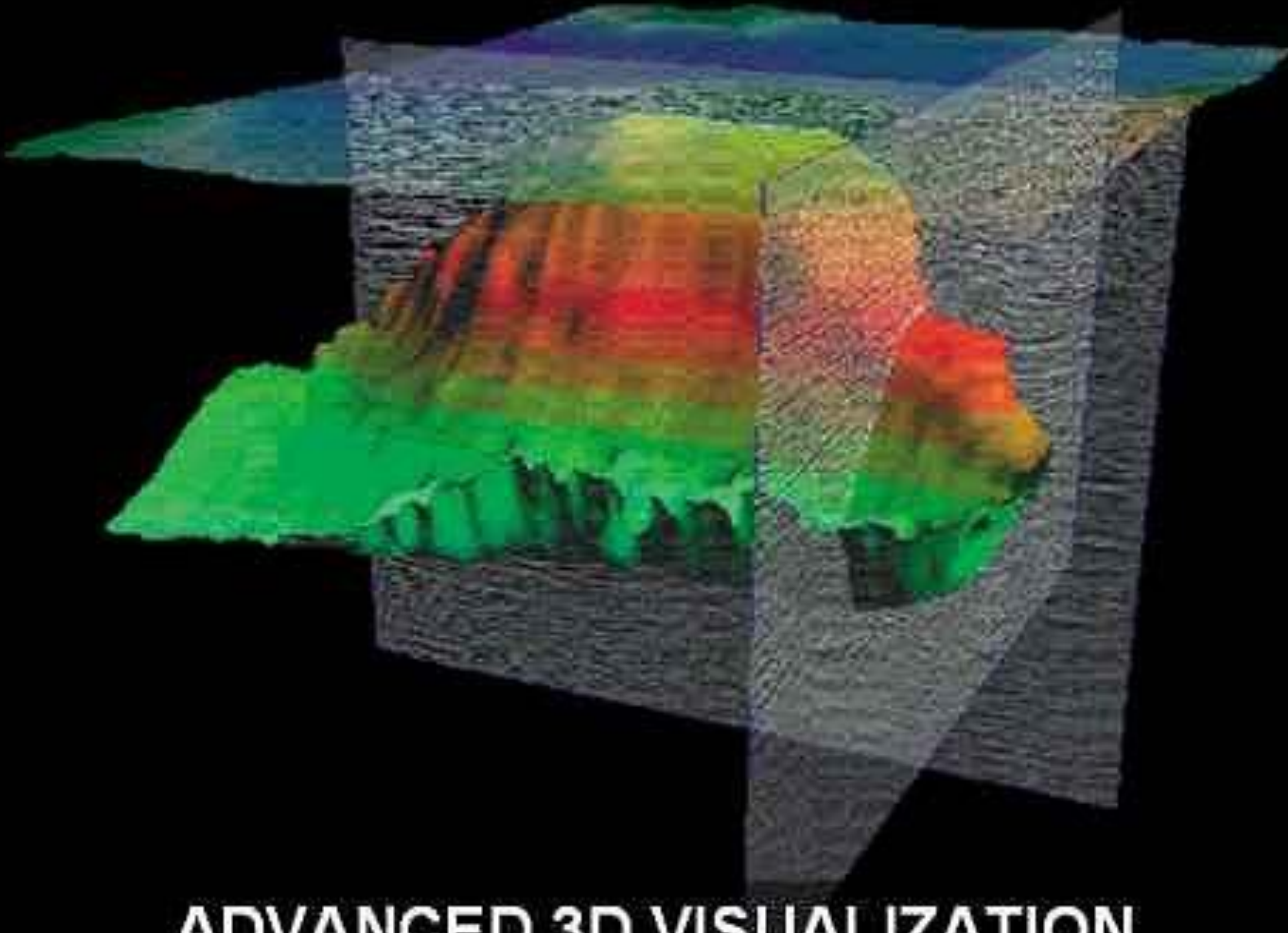
4410000
4411000
4412000
5782000
5781000
5780000
5779000
5778000
5777000
5776000
5775000
5774000
WITTMAR
REMLINGEN
SEMMENSTEDT
G E M E I N D
Groß Vahlberg
Klein Vahlberger Buchen
Klein Biewende
Groß Biewende
Sottmar
0 m
500 m
1000 m
1500 m
2000 m
Kartengrundlage:
Topographische Karte 1:25 000, Blätter 3829 (2004), 3830 (2004), 3929 (2004), 3930 (2004)
© Vermessungsverwaltungen der Länder und BKG 2010


2D
SEISMIC



ADVANCED 3D VISUALIZATION

Exploratory wells

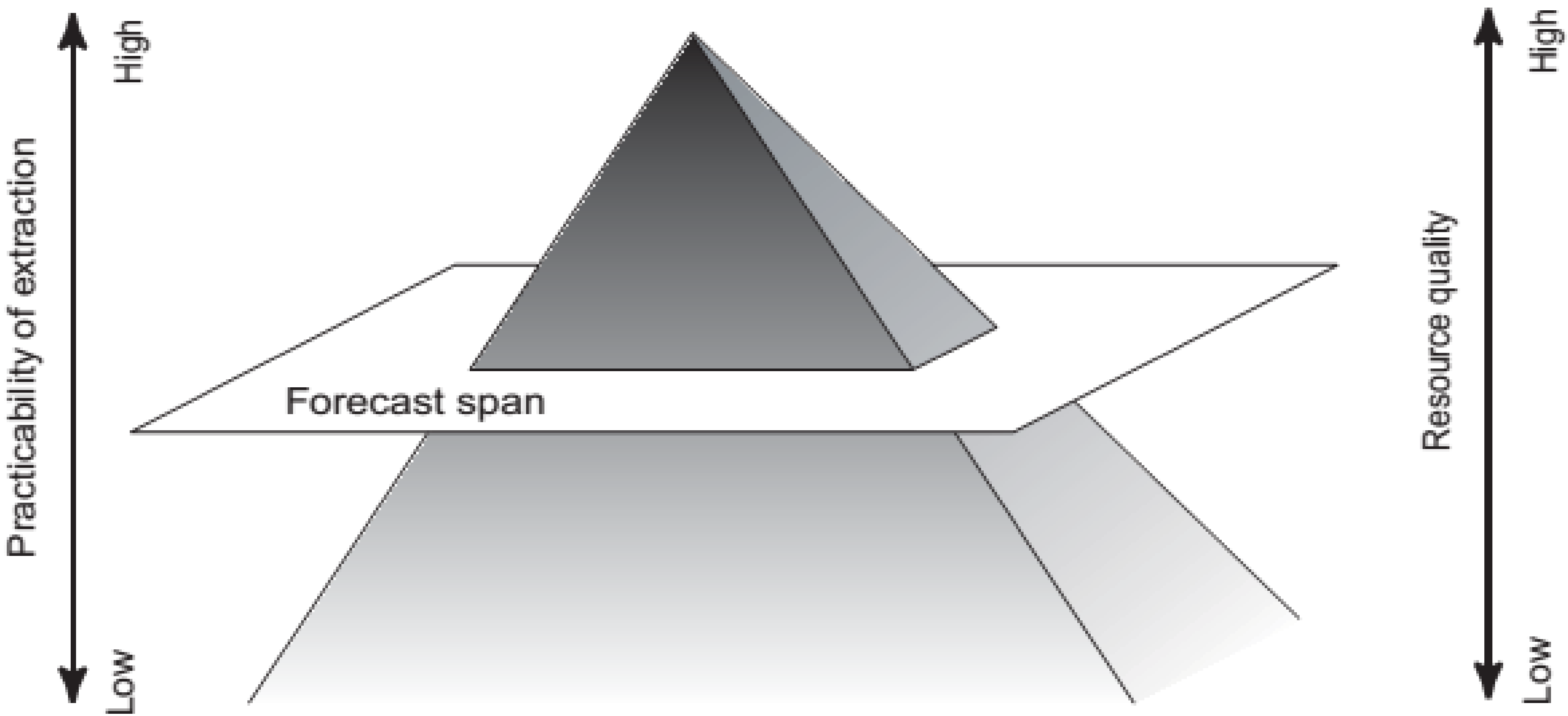
- Final stage of exploration
- Hypothesis testing only
- Same process as with production wells

- Success rates:
  - 1970s, 1980s (USA): 25%
  - 2005 (USA): 50%
  - Deepwater (Gulf of Mexico, 2006): 10%

  => Gulf of Mexico 1996-2000: just 8% out of 3,000 leases drilled

Result: reserves (3P)

- Proven – 90% probability of being technically and commercially producible.
- Probable – 50%
- Possible – 10%



Evaluation

Exploration efficiency

- Costs per unit of recoverable reserves
- Estimation of recoverability vs. actual recoverability
- Average costs per unit found

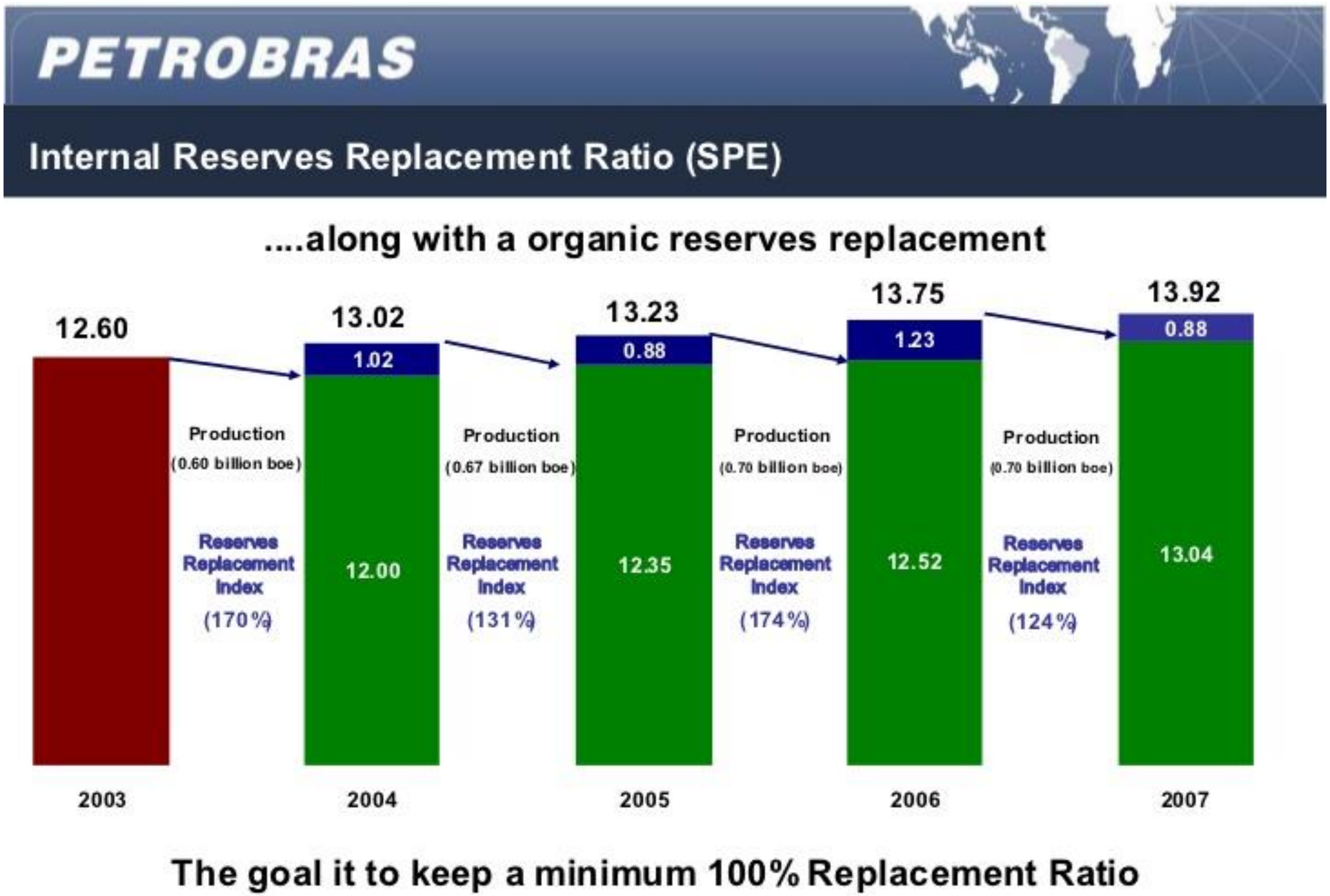
Both overestimation and underestimation are very common

Company	Market Capitalization ($Billion)	Total Production (thousand barrels of oil equivalent per day)
ExxonMobil	$430.3	4,018
Chevron	$236.1	2,585
PetroChina (NYSE: PTR)	$227.8	3,807
Royal Dutch Shell (NYSE: RDS-A)	$225.1	3,262
BP (NYSE: BP)	$147.7	2,259
Total (NYSE: TOT)	$136.7	2,299
Petrobras (NYSE: PBR)	$90.0	2,314
Eni (NYSE: E)	$85.8	1,653
Statoil (NYSE: STO)	$75.7	1,852
Occidental Petroleum (NYSE: OXY)	$75.1	767

Company	% of net income from exploration and production activities
ExxonMobil	85.2
Chevron	95
PetroChina	106
Royal Dutch Shell	77
BP	89
Total	78
Petrobras	172
Eni	124
Statoil	74
Occidental	90

Reserves replacement ratio

The amount added to its reserves divided by the amount extracted

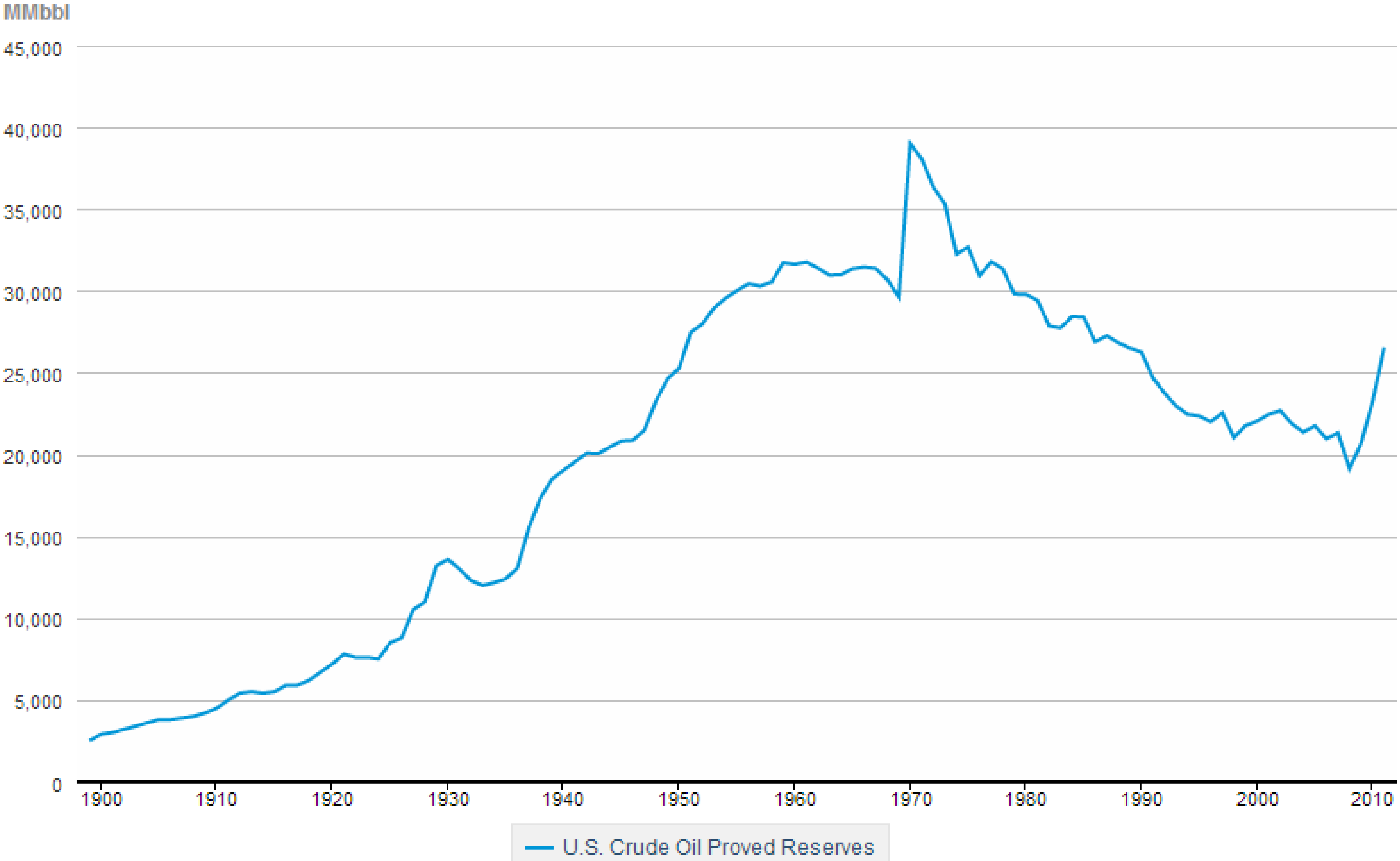


Exploration portfolio

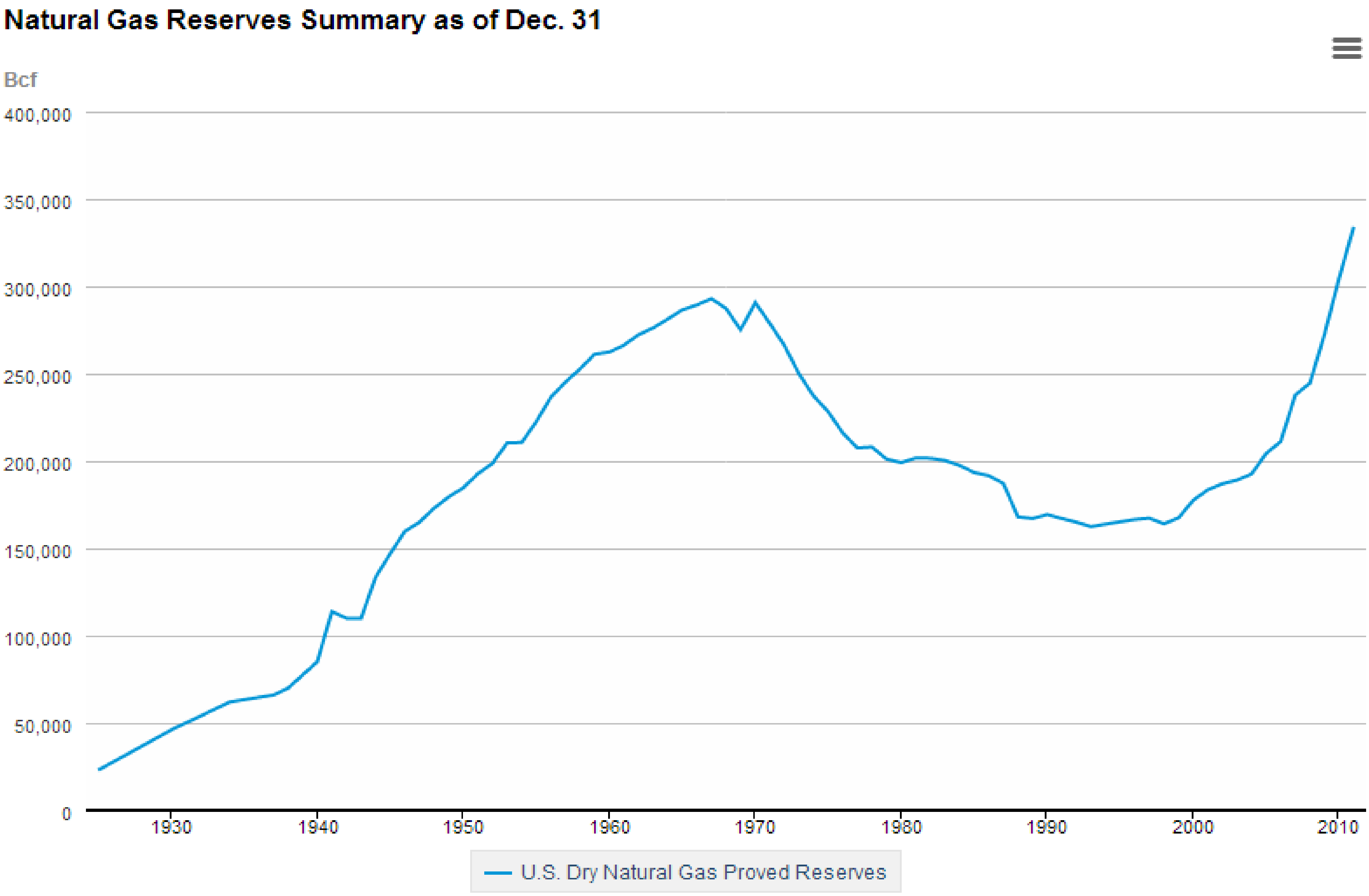
- Vast majority of exploration ventures fails and ends with financial loss
- Each step of exploration work refines the likelihood of success, but makes the whole process more expensive
- Individual ventures show different levels of risk
  - Geological
  - Economic
  - Political

Company success <= RRR <= good exploration portfolio

Crude Oil Proved Reserves, Reserves Changes, and Production

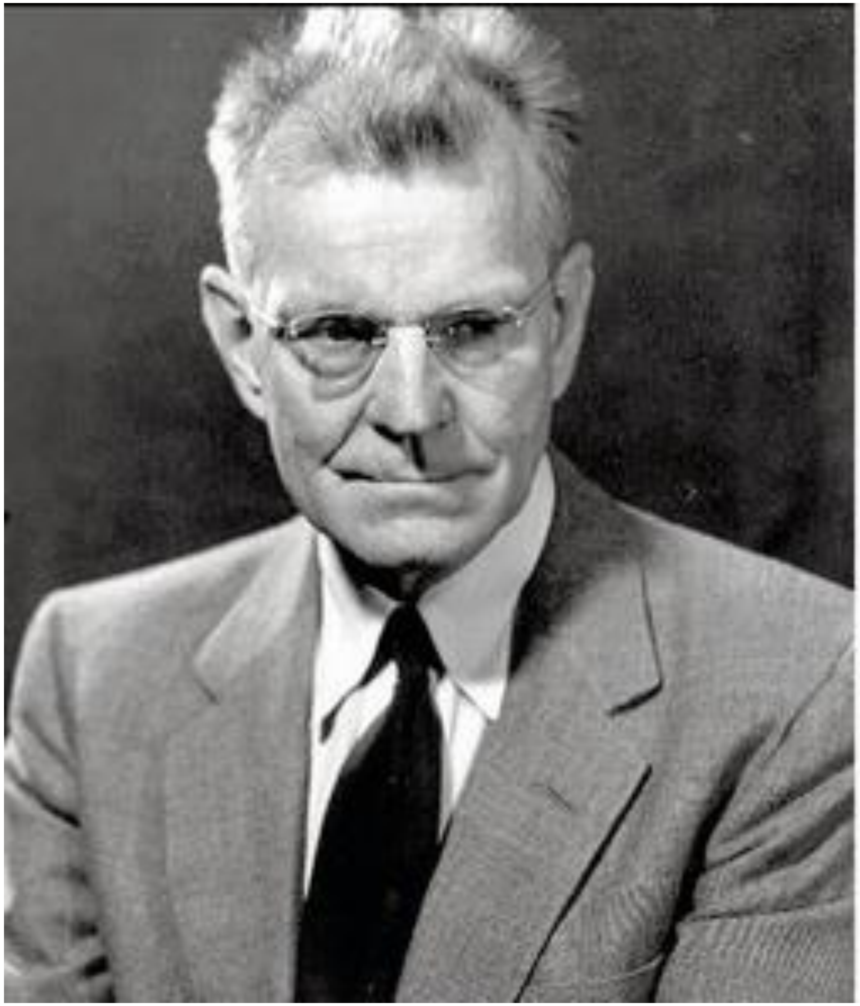


* Total amount of oil produced between 1965 and 2013 in the US: 163,000 MMbbl



* Total amount of gas produced between 1970 and 2013 in the US: 845,000 Bcf

Peak oil?



- End of oil predicted many times already
- Availability of oil is a function of demand rather that supply

Oil and Gas Production

Jan Osička

Lecture outline

- Oil and gas drilling
- Oil and gas recovery
- CS: Macondo oil spill

Phases of production

- Planning
- Drilling
- Completing
- Production
- Abandoning

Planning

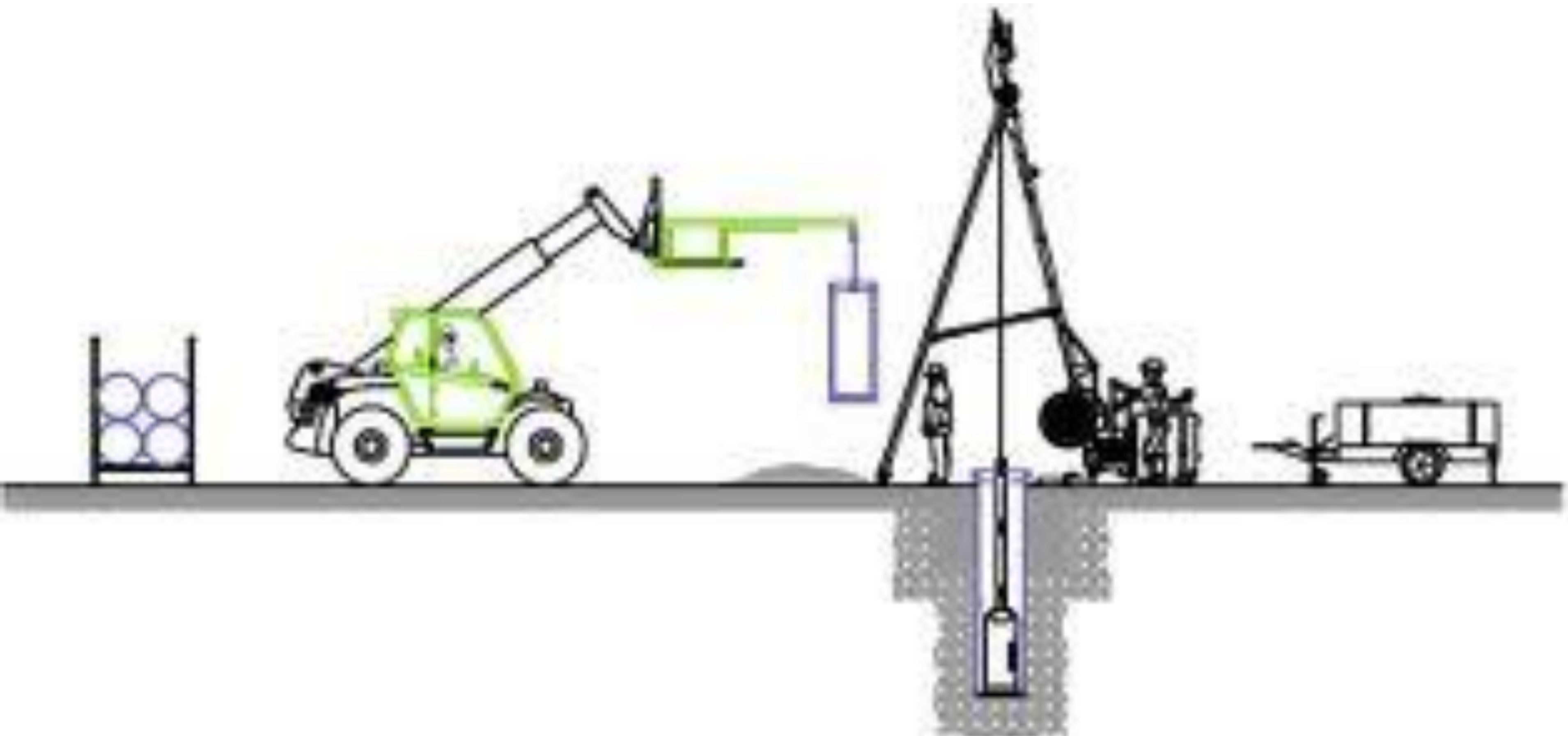
- According to the outcomes of exploration
- According to the production license

- Technology, material and tools
- Succession of activities
- Logistics
- Subcontractors
- Land access

Drilling

- Percussion
- Rotary drilling

Percussion drilling






+ Remote areas

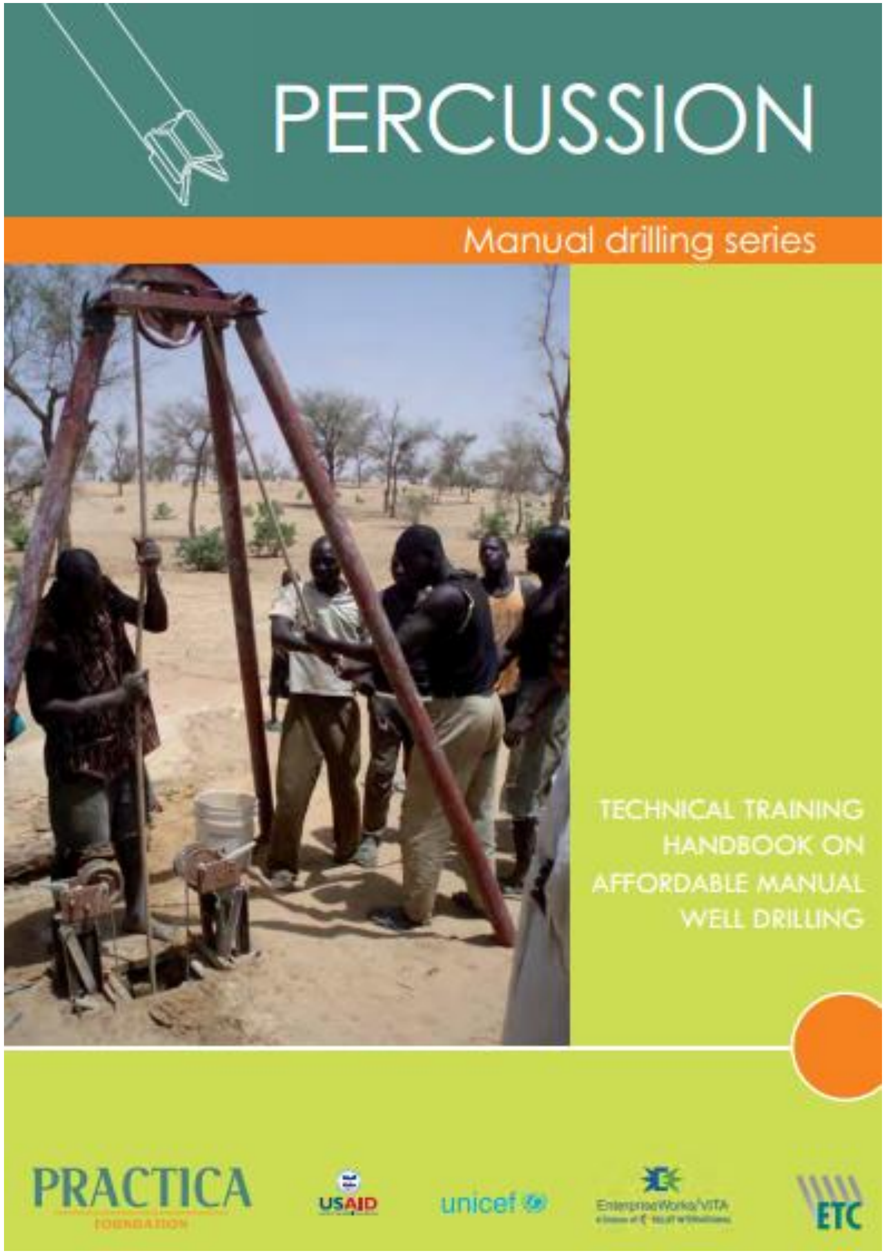
+ Low capex, cheap maintenance

+ Low water use

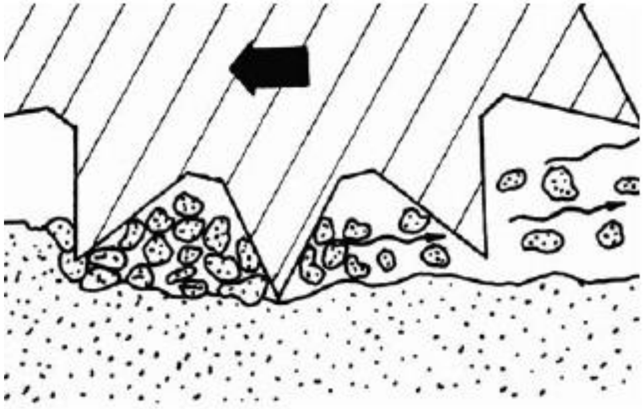
+ Efficient use of personel

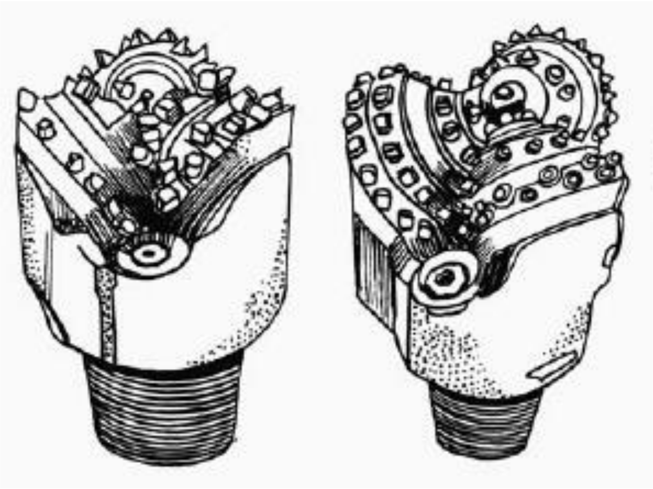
- Low productivity
- Low penetration rate in hard formations

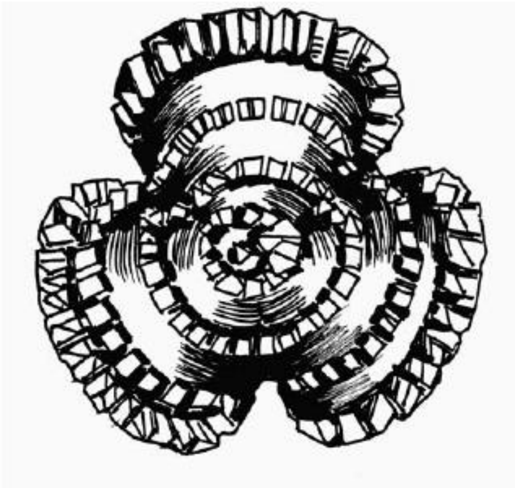
www.practica.org



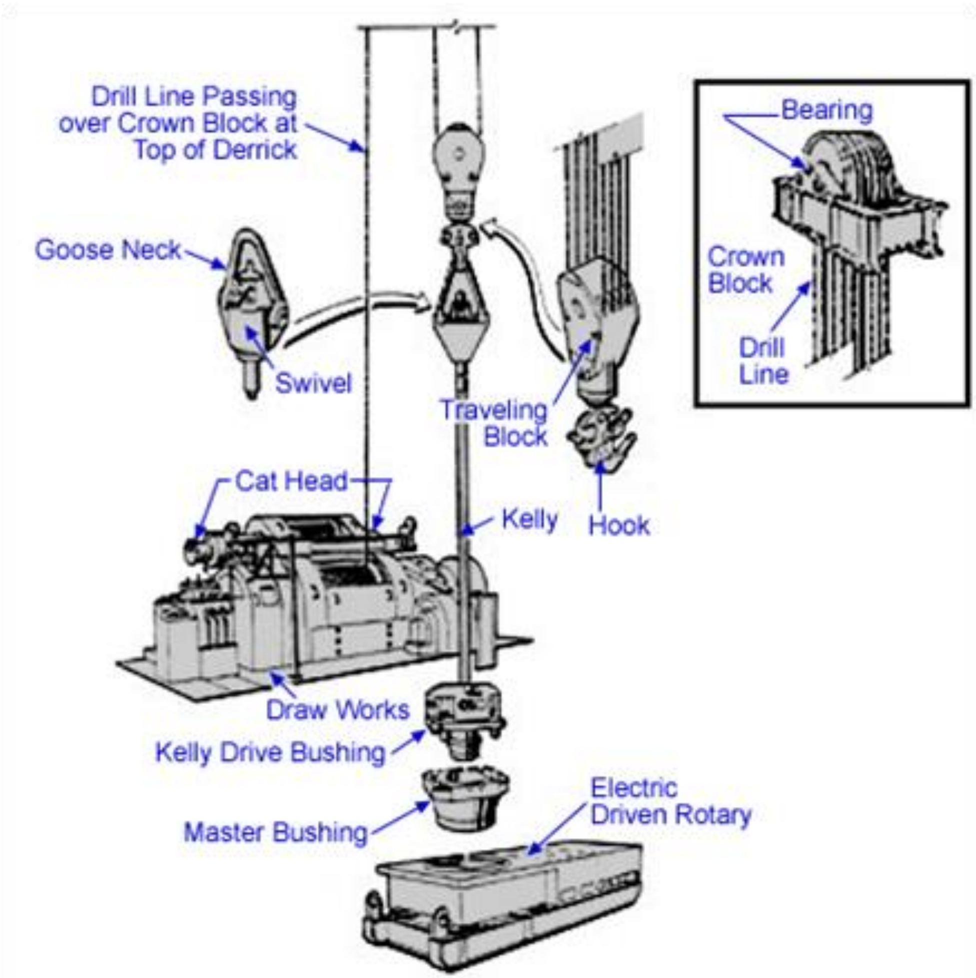
Rotary drilling

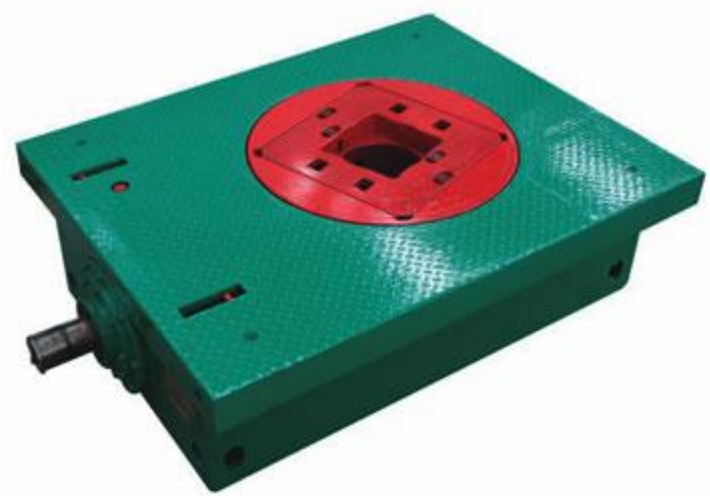




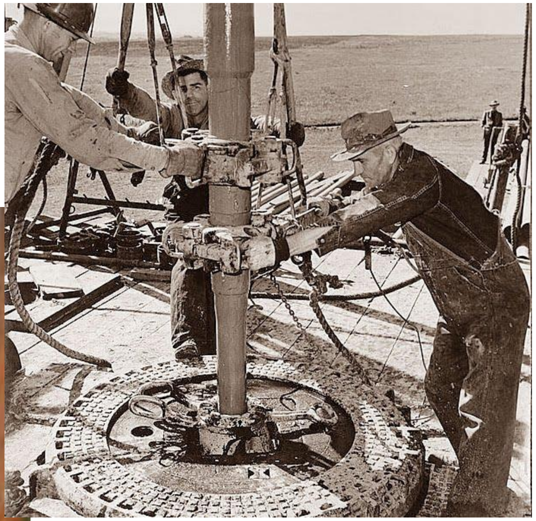


Rotary drilling



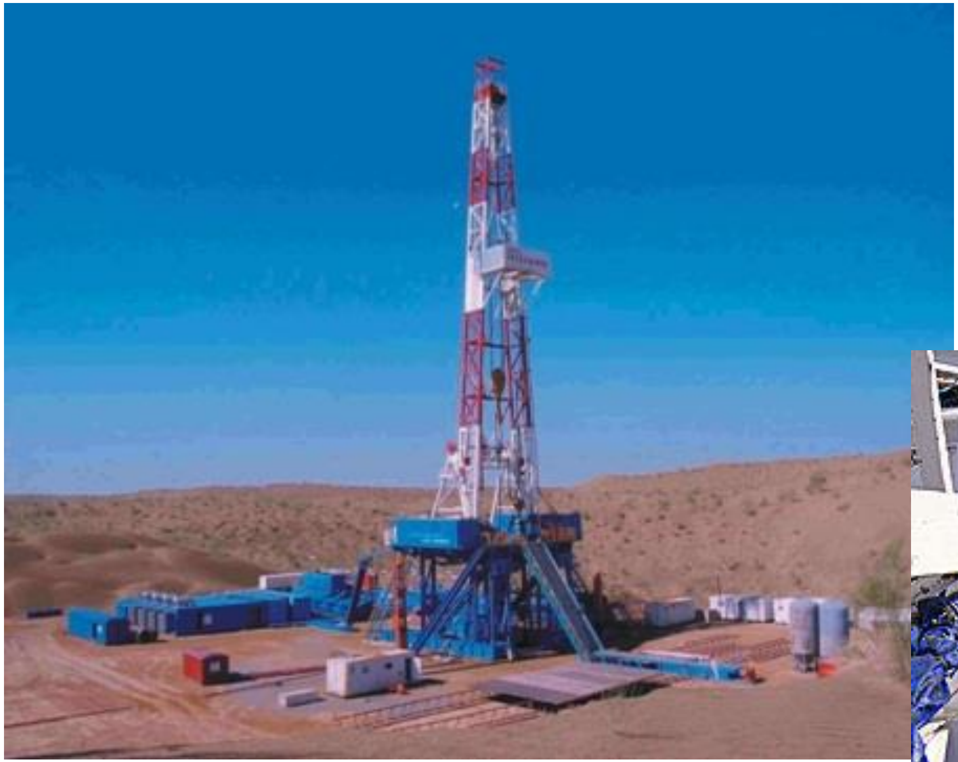


Workforce

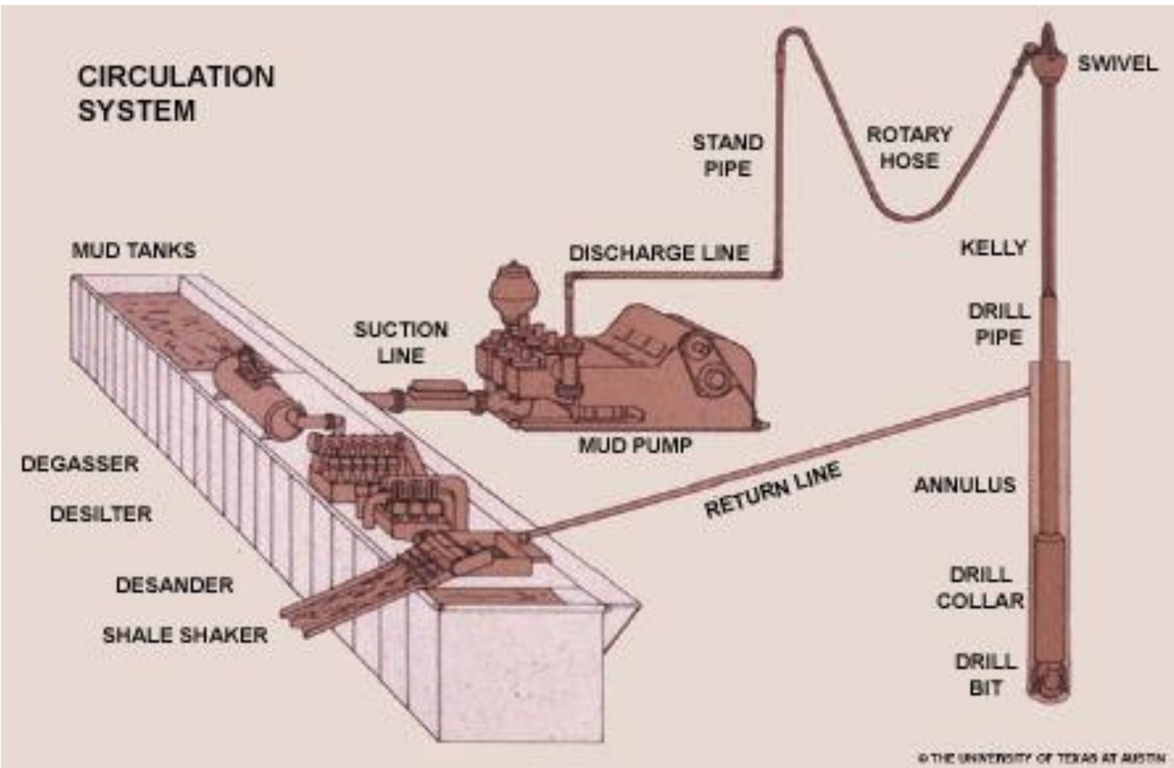


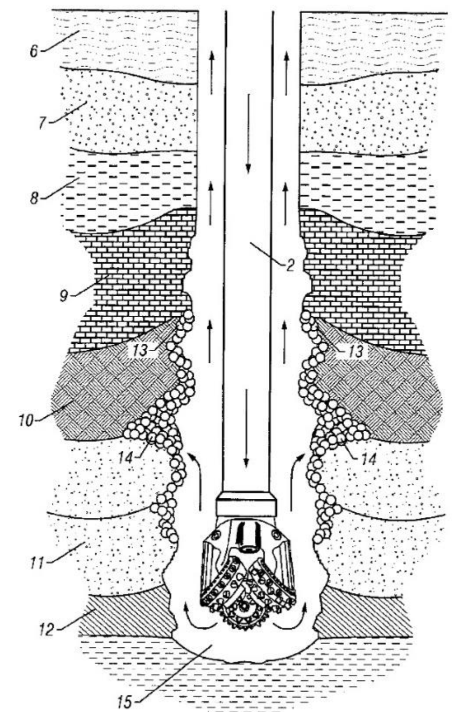
Engines

Hoisting

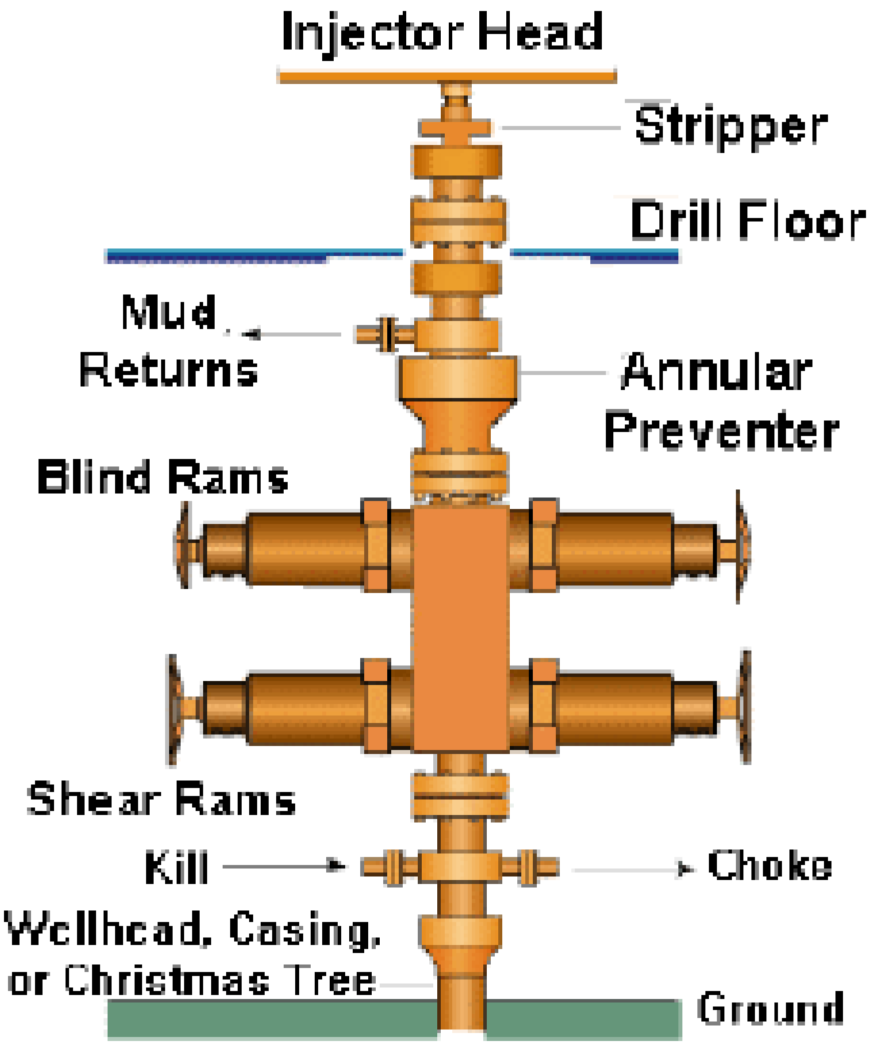


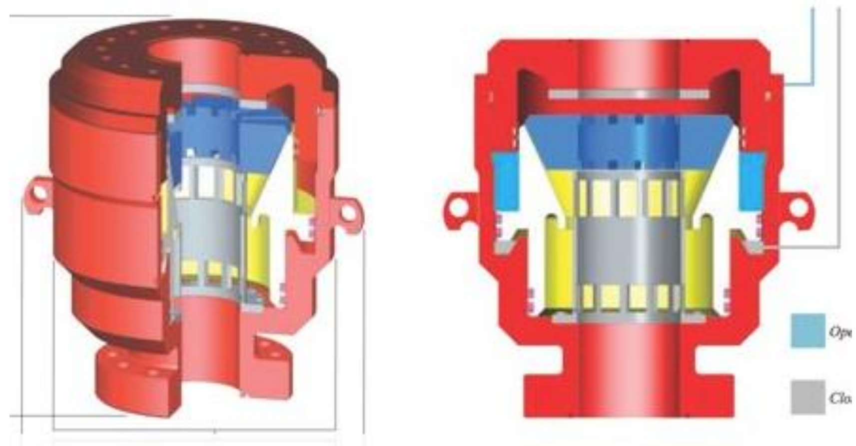
Drilling mud circulation

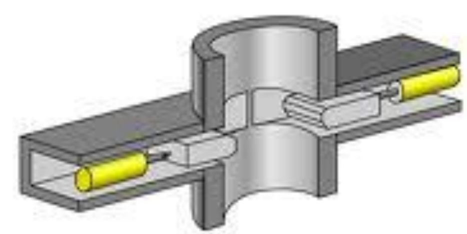


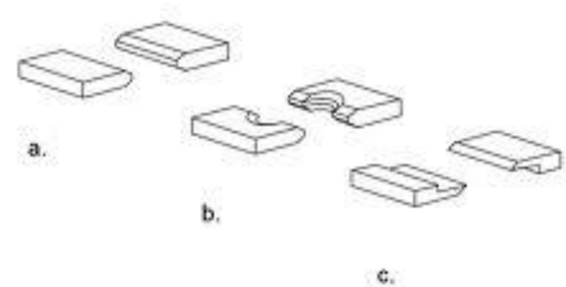


Blow-out preventer

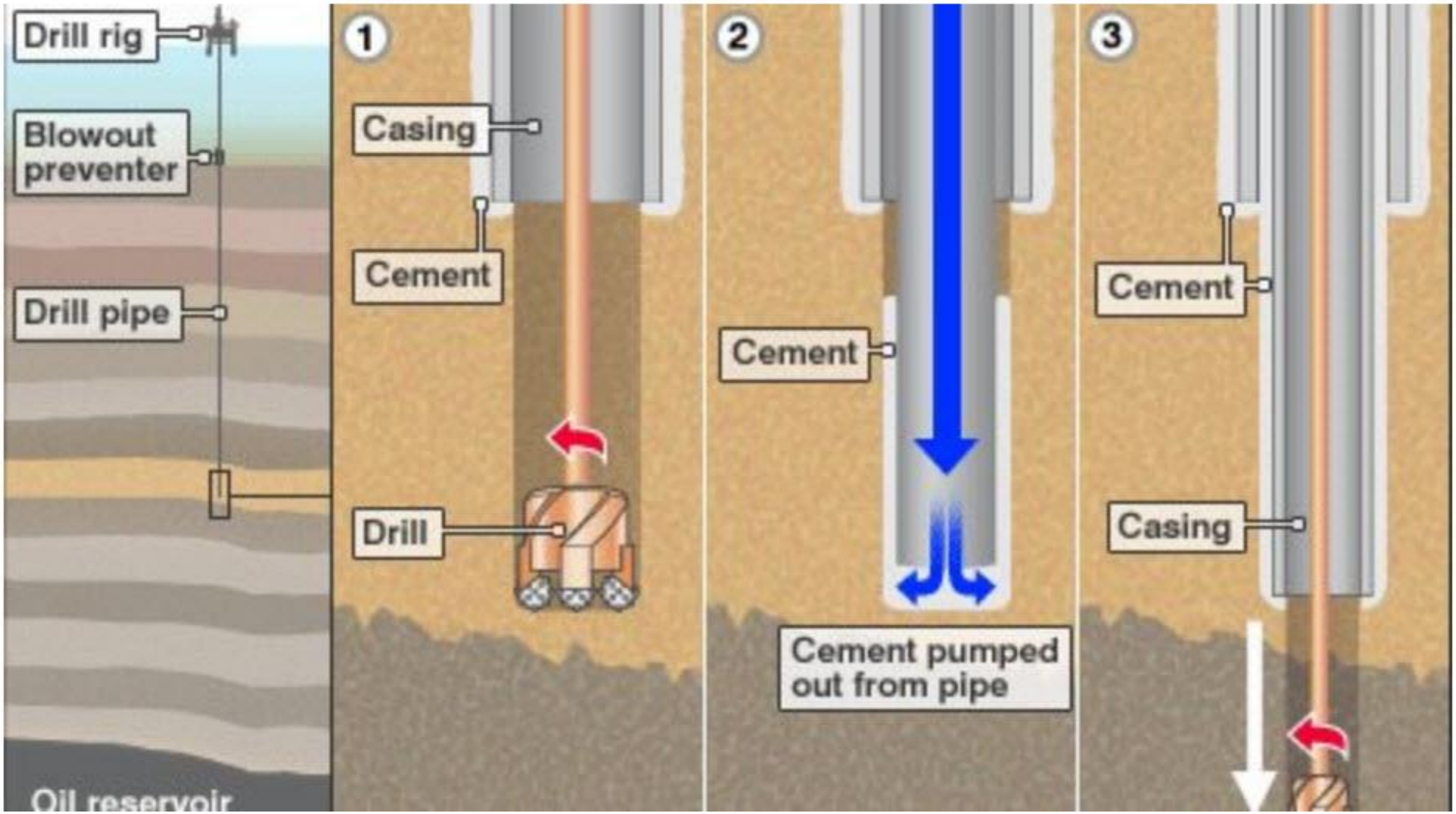




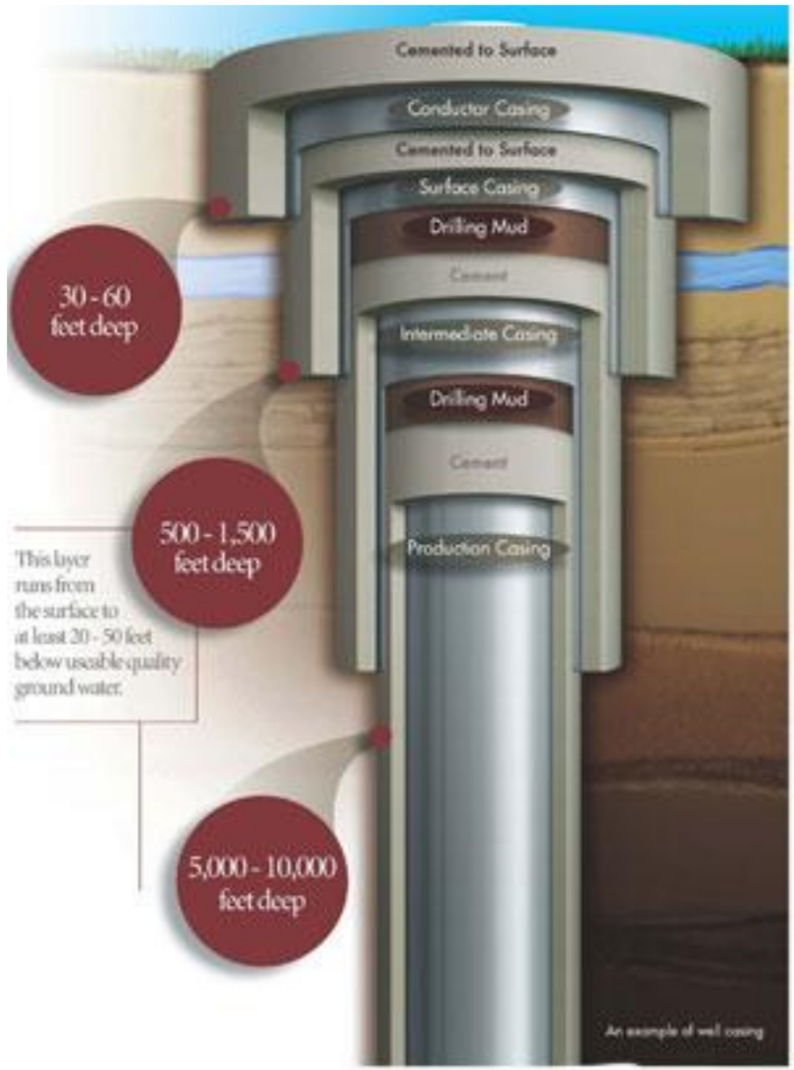




Cementing and casing

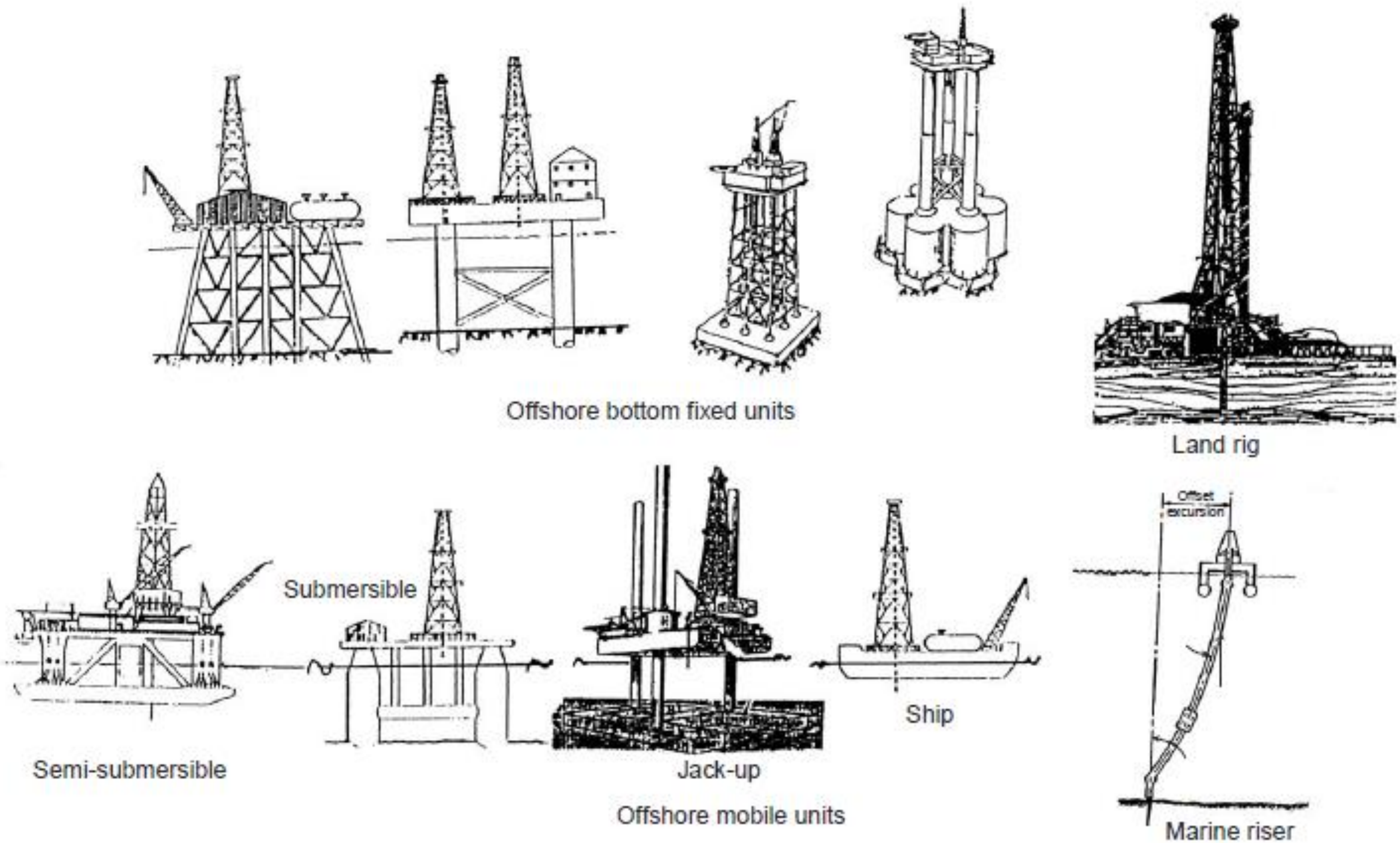


Cementing and casing

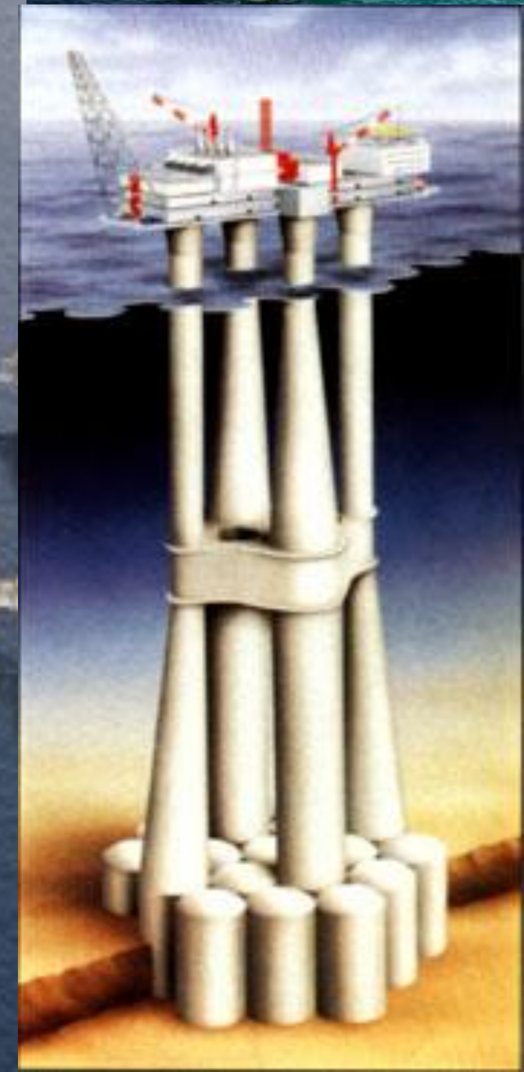


Graphic Courtesy of Texas Oil and Gas Association

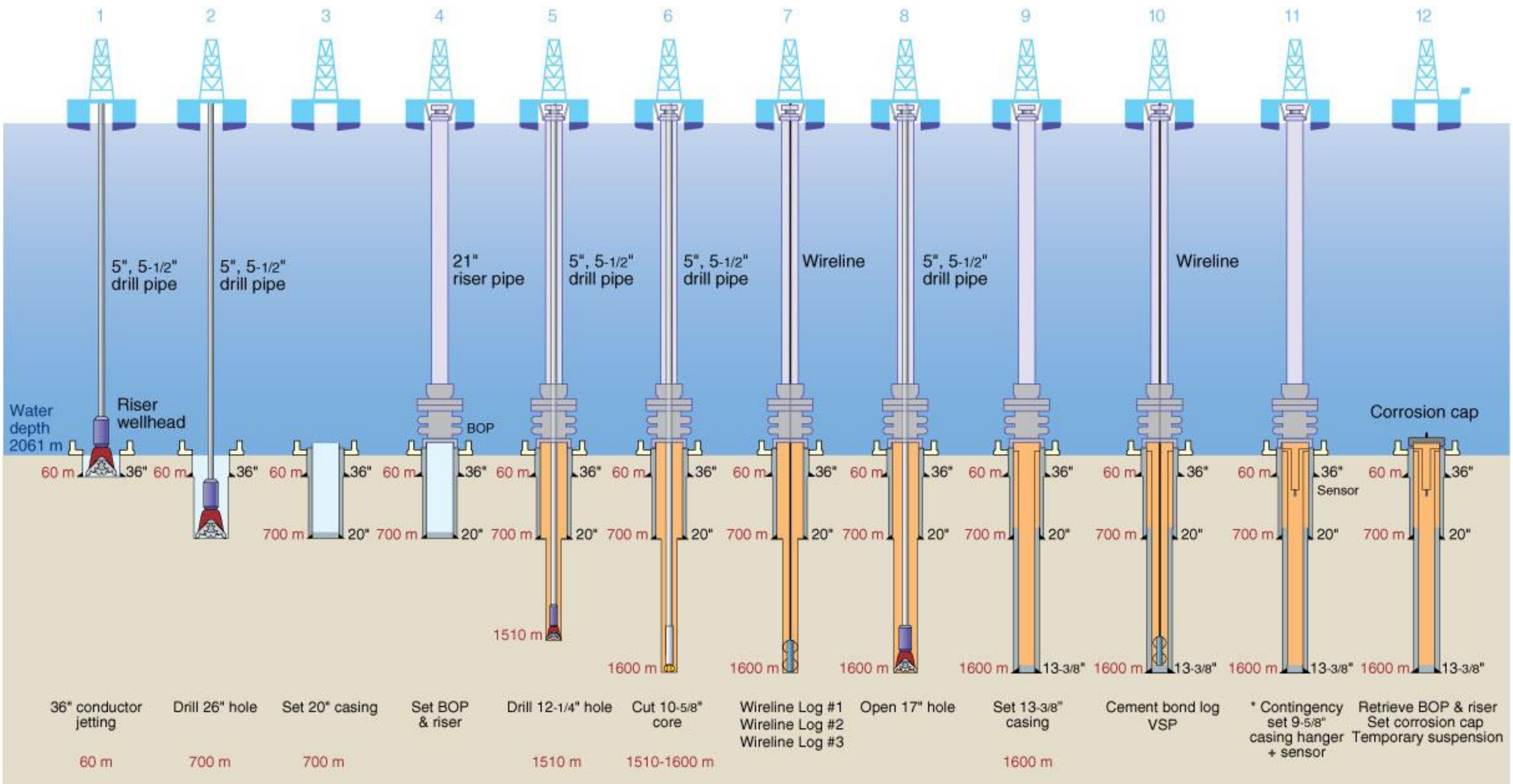
Offshore drilling





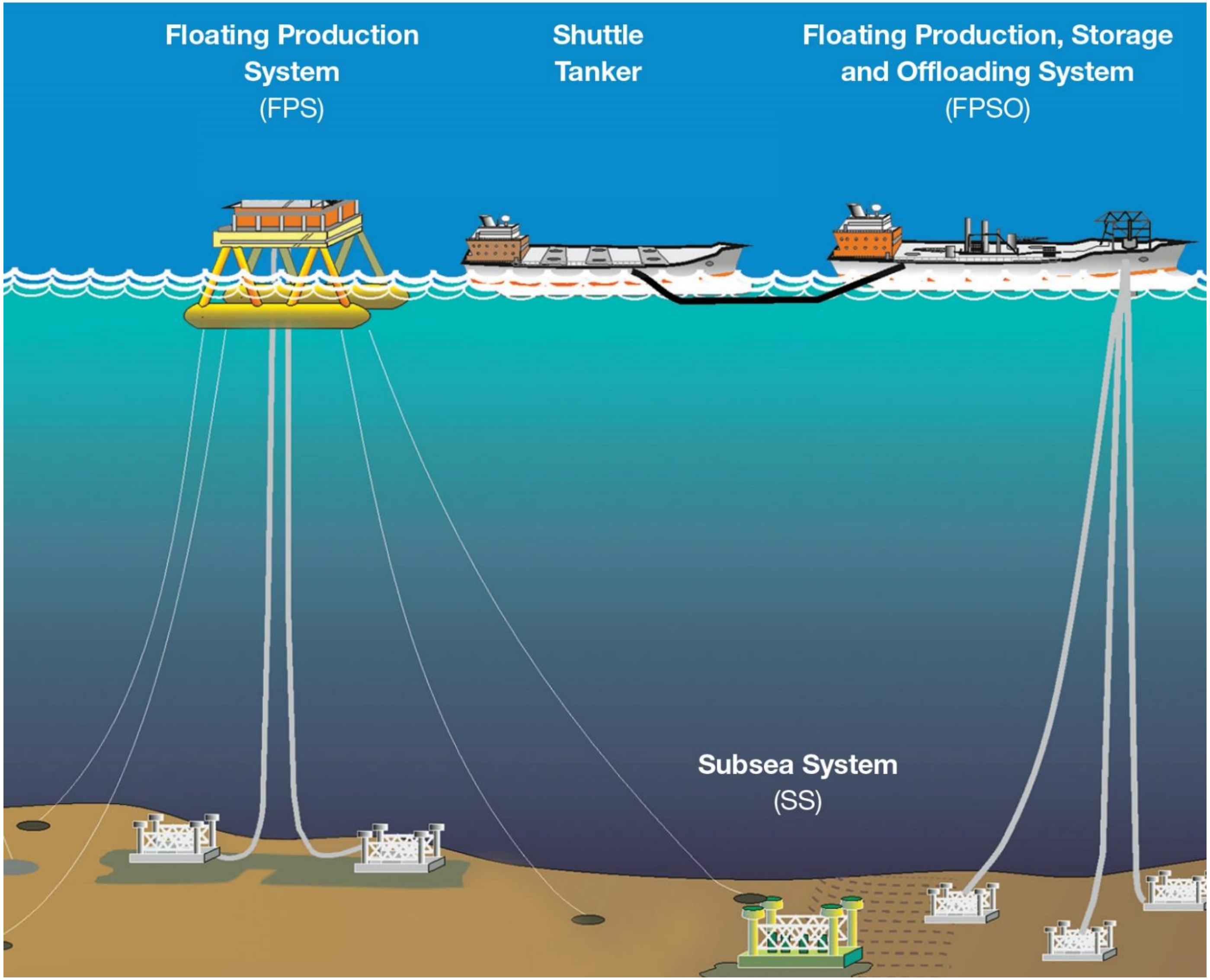


Activity log



Completing the well

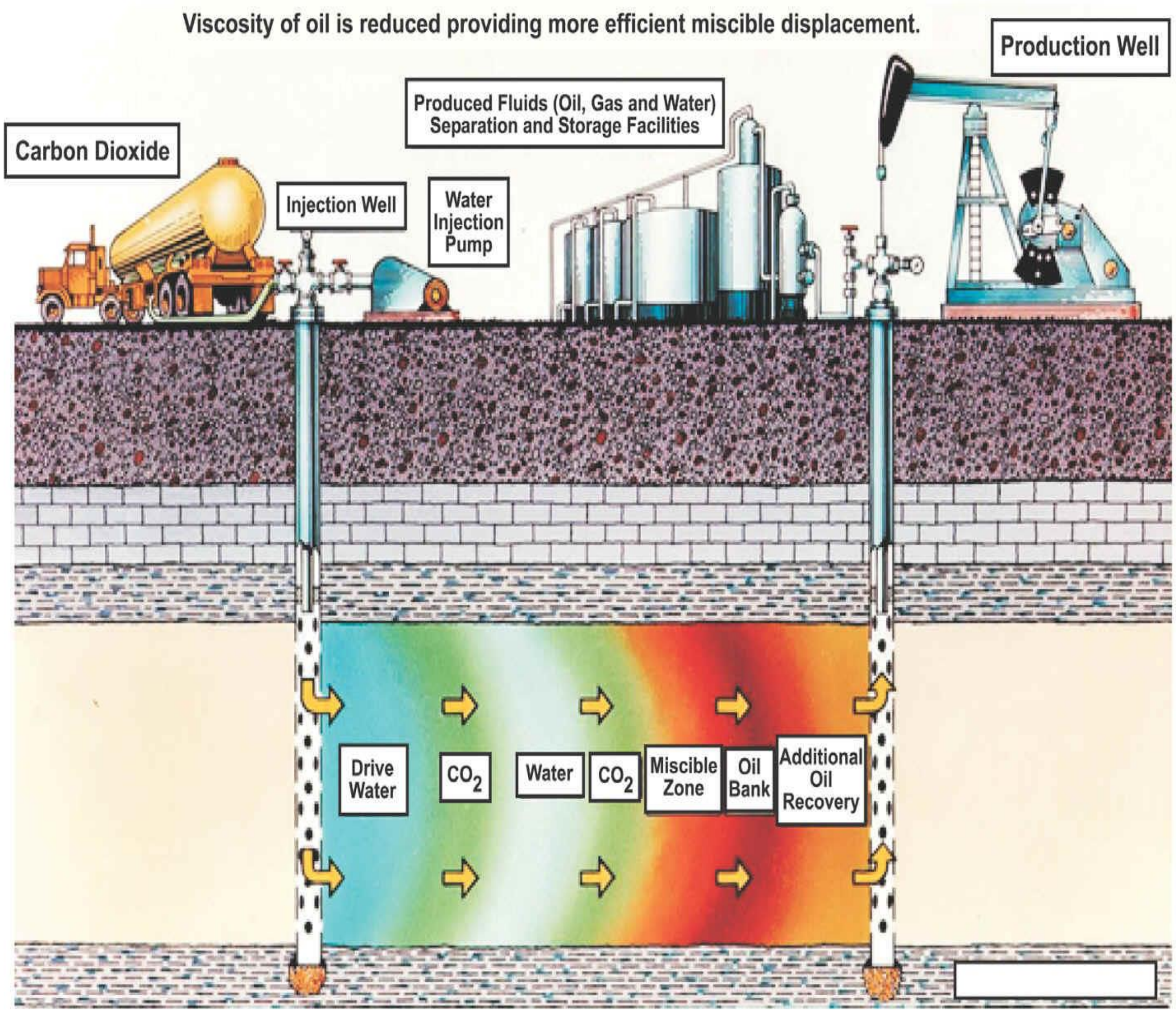
Offshore production



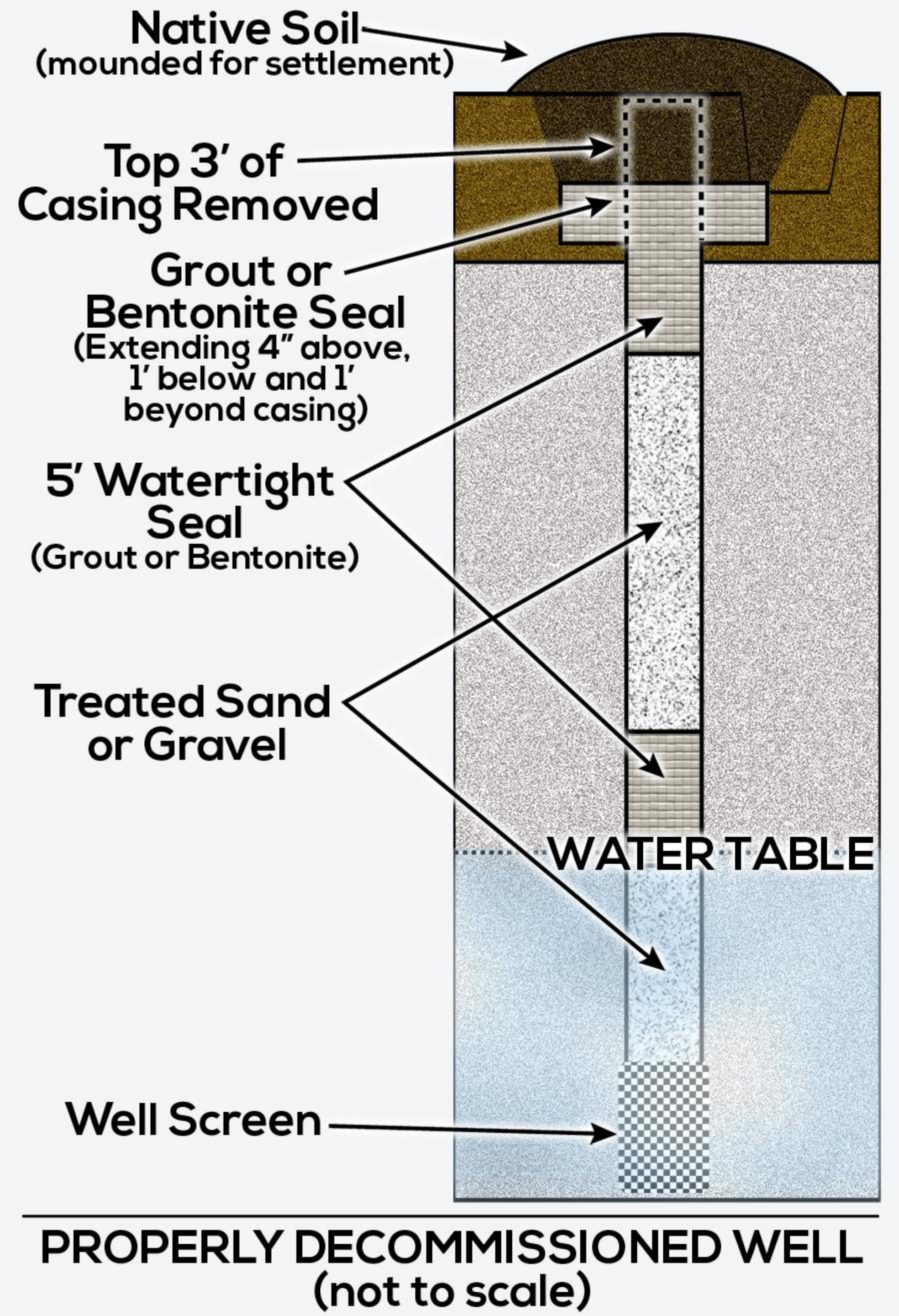
Production/recovery

- Primary
  - Natural flow
  - Gas lift
  - Pumping
- Secondary
  - Gas injection
- Tertiary
  - Water injection
  - Steam injection
  - Setting the deposit on fire
  - Increasing the permeability of the oil-bearing horizon

Enhanced recovery



Abandonment

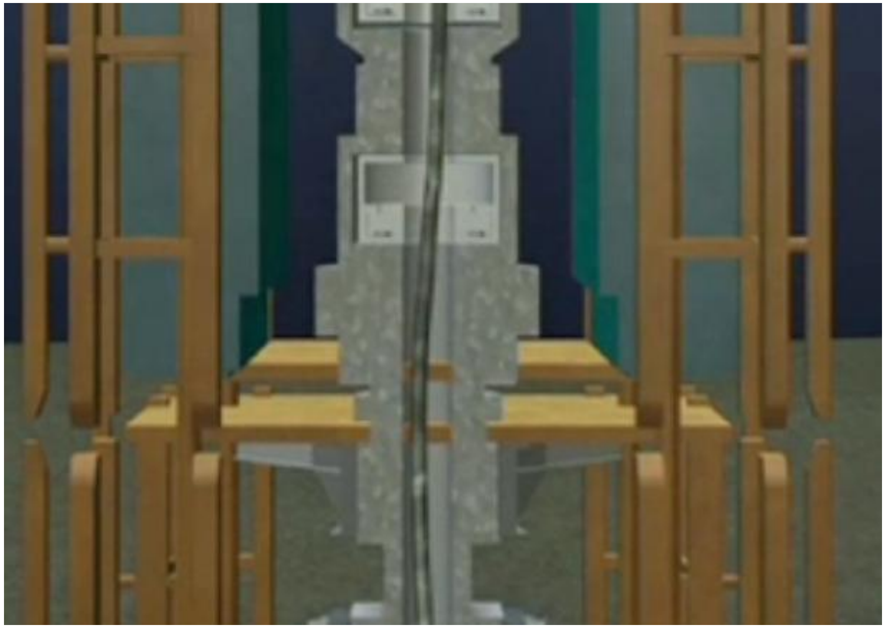


Macondo well spill 2010

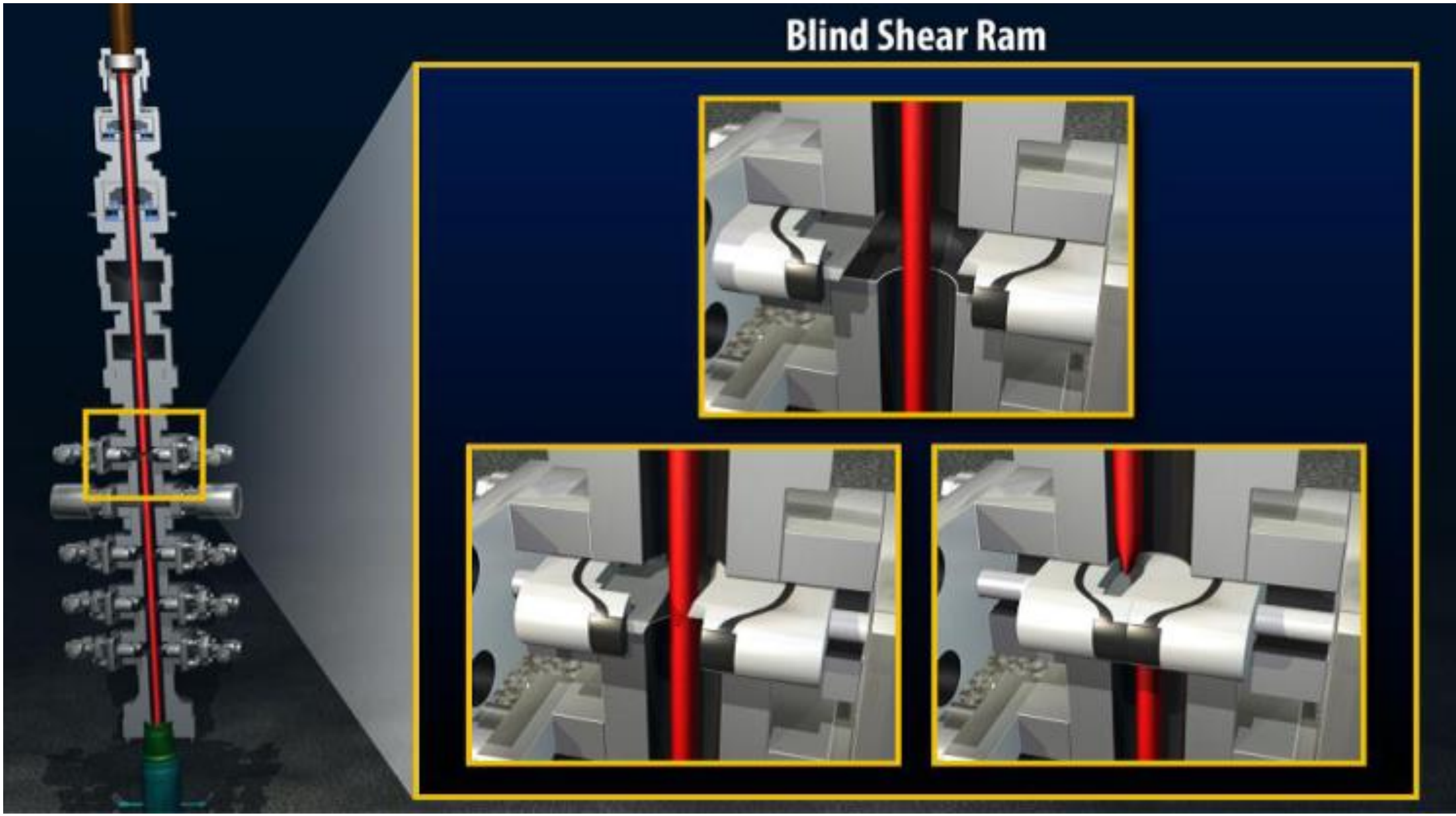
History

- High pressure well
- Gas eruption causes overpressure
- Drilling string buckles and moves off-center within the BOP

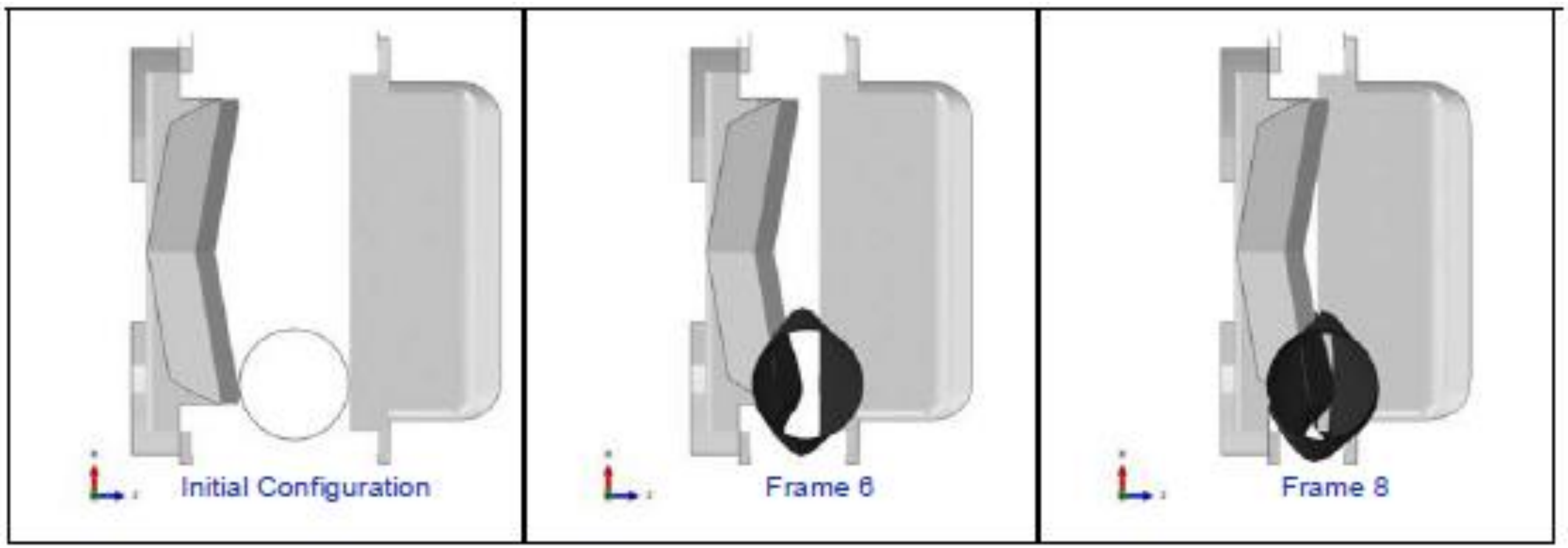
- 87 days of leaking oil
- 4.9 million barrels

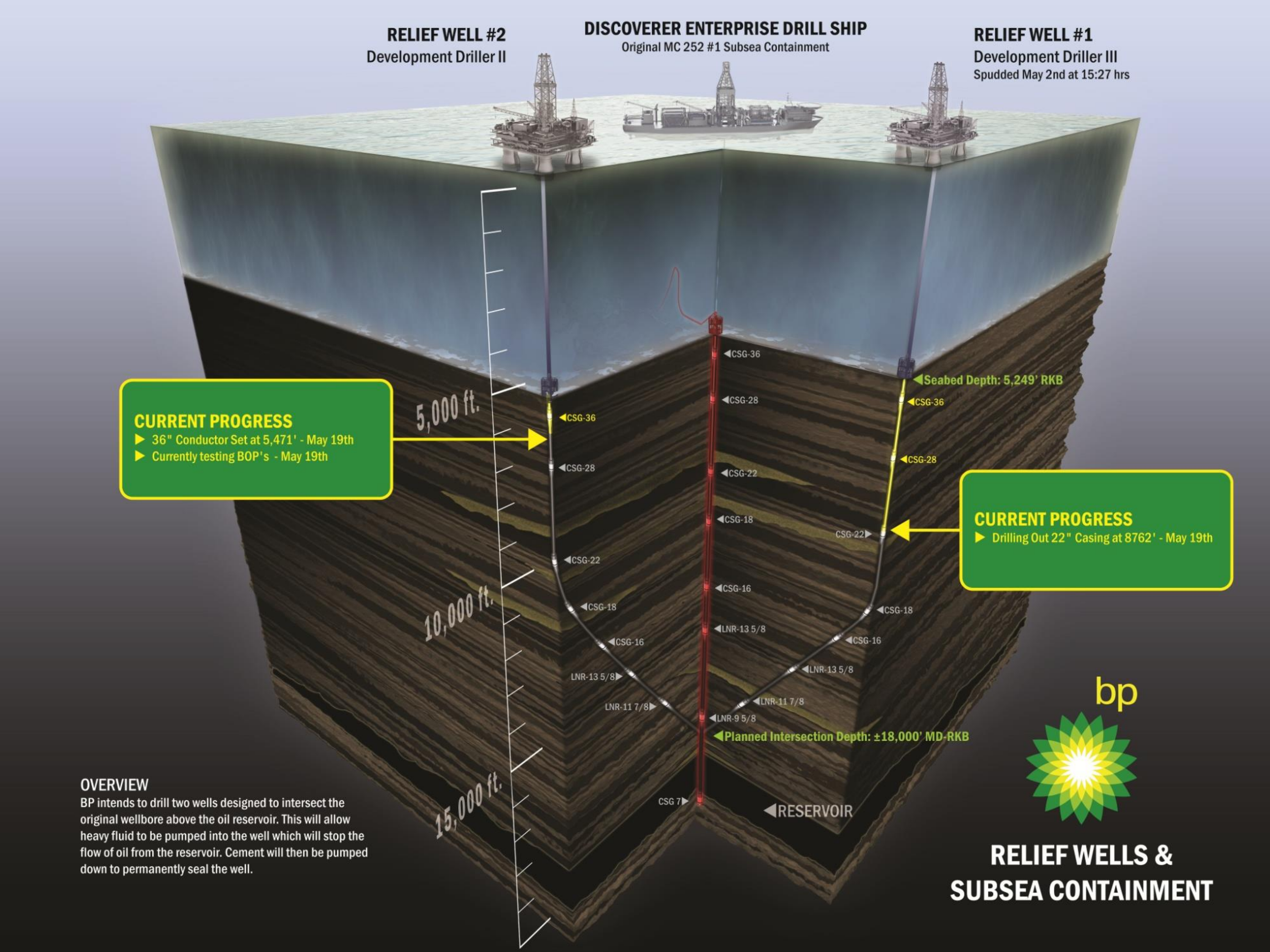


Blind shear ram failure



Blind shear ram failure




RELIEF WELL #2
Development Driller II
DISCOVERER ENTERPRISE DRILL SHIP
Original MC 252 #1 Subsea Containment
RELIEF WELL #1
Development Driller III
Spudded May 2nd at 15:27 hrs
CURRENT PROGRESS
▶ 36" Conductor Set at 5,471' - May 19th
▶ Currently testing BOP's - May 19th
5,000 ft.
10,000 ft.
15,000 ft.
CSG-36
CSG-28
CSG-22
CSG-18
CSG-16
LNR-13 5/8
LNR-11 7/8
LNR-9 5/8
CSG 7
Seabed Depth: 5,249' RKB
CURRENT PROGRESS
▶ Drilling Out 22" Casing at 8762' - May 19th
Planned Intersection Depth: ±18,000' MD-RKB
RESERVOIR
bp
OVERVIEW
BP intends to drill two wells designed to intersect the original wellbore above the oil reservoir. This will allow heavy fluid to be pumped into the well which will stop the flow of oil from the reservoir. Cement will then be pumped down to permanently seal the well.
RELIEF WELLS &
SUBSEA CONTAINMENT

Causes and liabilities

BP

- No risk assessment of operational decisions (well design only)
- Operational decisions aimed on cost-reduction

BP Decisions

BP Decision	Less Cost to BP	Less Rig Time	Greater Risk
6 versus 21 Centralizers	Yes	Yes	Yes
Cement Bond Log	Yes	Yes	Yes
Full Bottoms Up on 4/19	Yes	Yes	Yes
Long String versus Liner	Yes	Yes	--
Timing of Lock Down Sleeve Installation After the Negative Test	Yes	Yes	Yes
Pumping mud to boat while displacing	Yes	Yes	Yes
Lost circulation material ("LCM") pills combined for Spacer	Yes	Yes	Unknown

SOURCE: THE BUREAU OF OCEAN ENERGY MANAGEMENT, REGULATION AND ENFORCEMENT (2011): REPORT REGARDING THE CAUSES OF THE APRIL 20, 2010 MACONDO WELL BLOWOUT.

Causes and liabilities

Federal court decision 2014

- BP found grossly negligent
- Transocean and Halliburton found negligent

BP (61.6 bn USD, as of July 2016)

Transocean (1.4 bn USD)

- Inproperly maintained, powered and connected BOP
- Lack of training of the crew (with regards to the BOP)
- The crew fails to test the cement slurry properly

Halliburton (1.1 bn USD)

- Cement slurry did not meet the API standards

Causes and liabilities

Mineral Management Service

- 2004 Report:
  - Existing BOPs do not work properly even in controlled conditions
  - recommends to use two blind shear rams at each BOP

=> Not translated to legal requirements

Unconventional gas and oil

Jan Osička

Lecture outline

- What is uncoventional gas and what makes it distinct from conventional gas
- Hydraulic fracturing controversies
- Uncoventional oil recovery

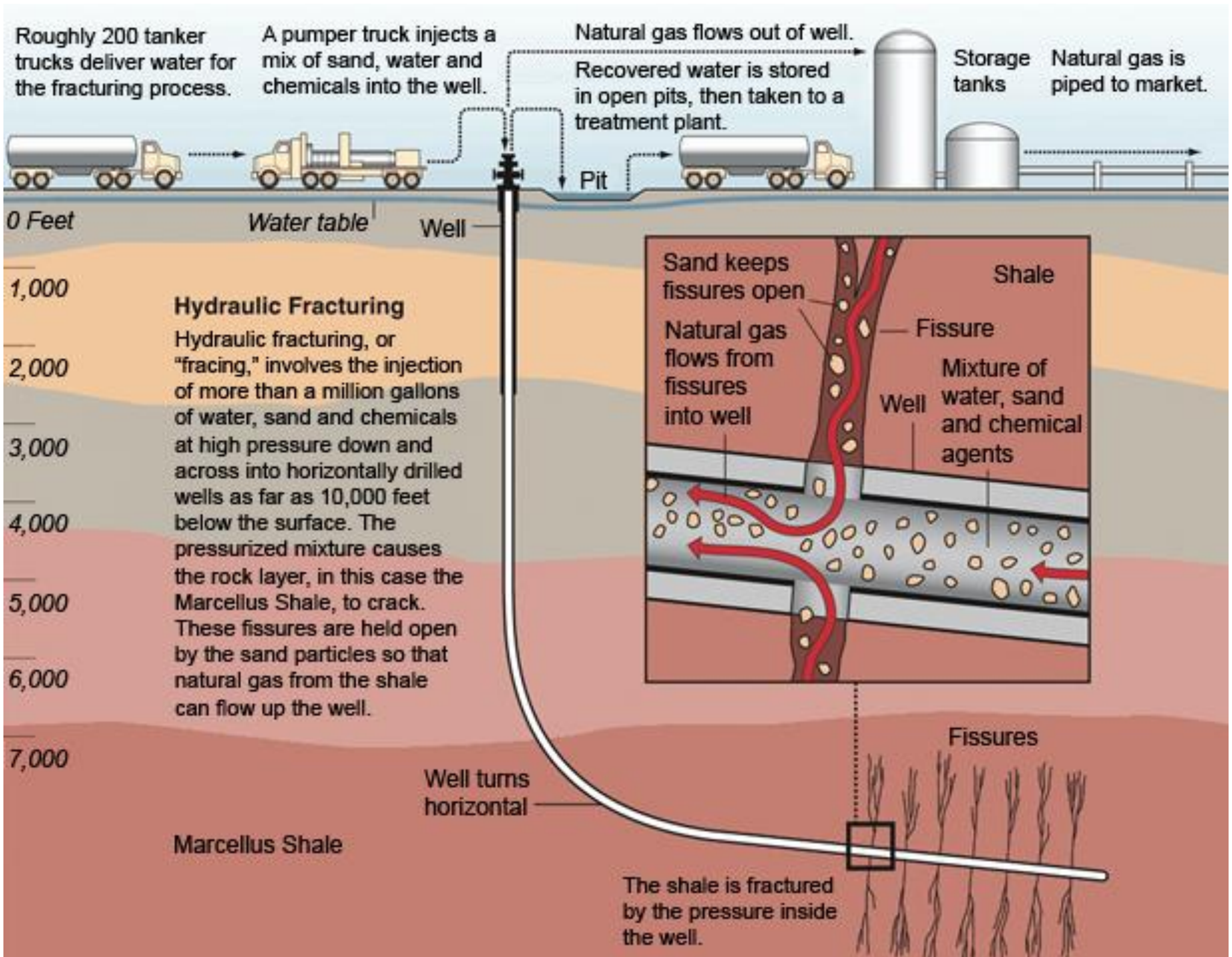
Shale gas

- Conventional gas found in unconventional reservoirs
- Unconventional reservoir needs stimulation to release gas.

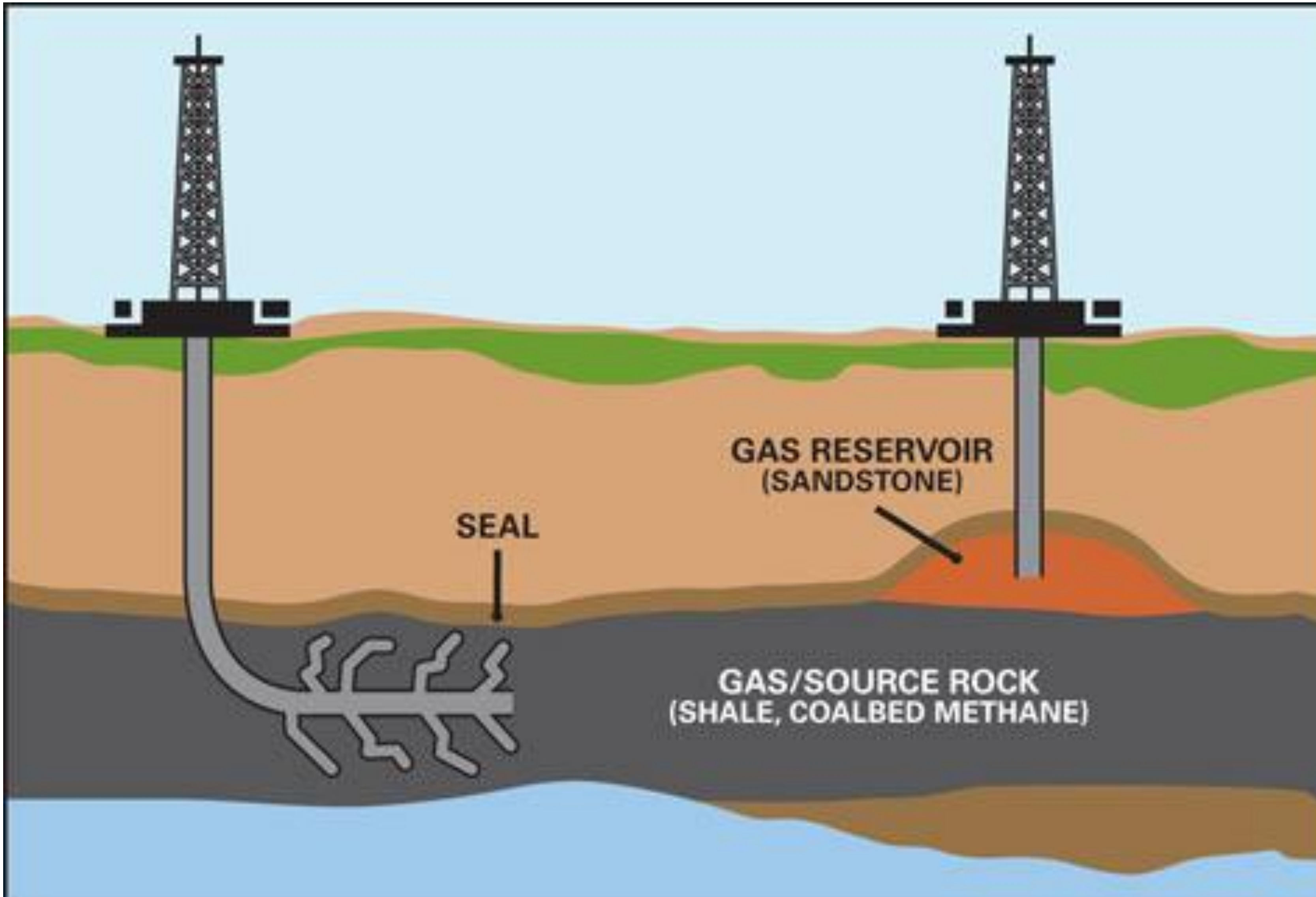
Field development

Field development

Field development

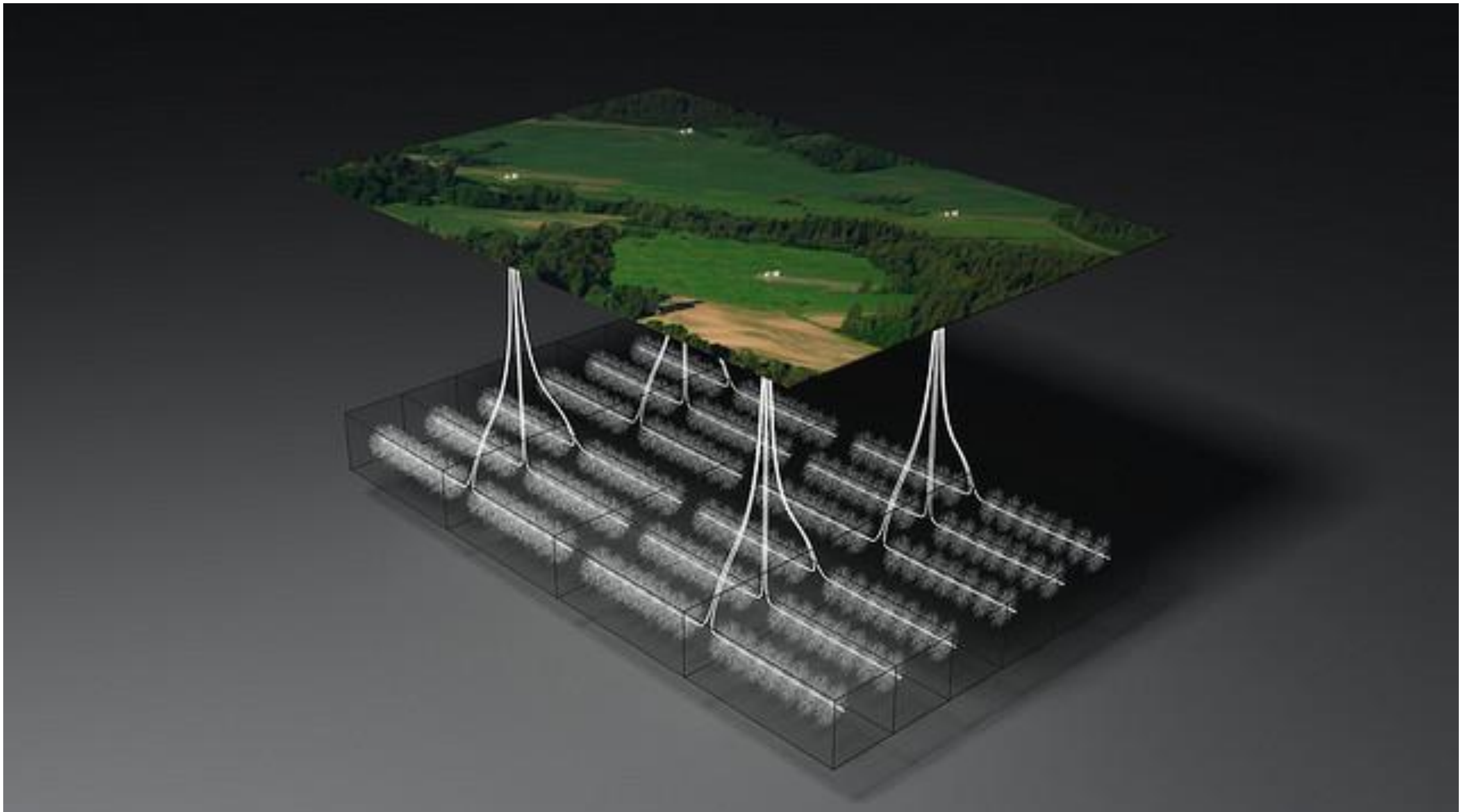


Field development



Field development

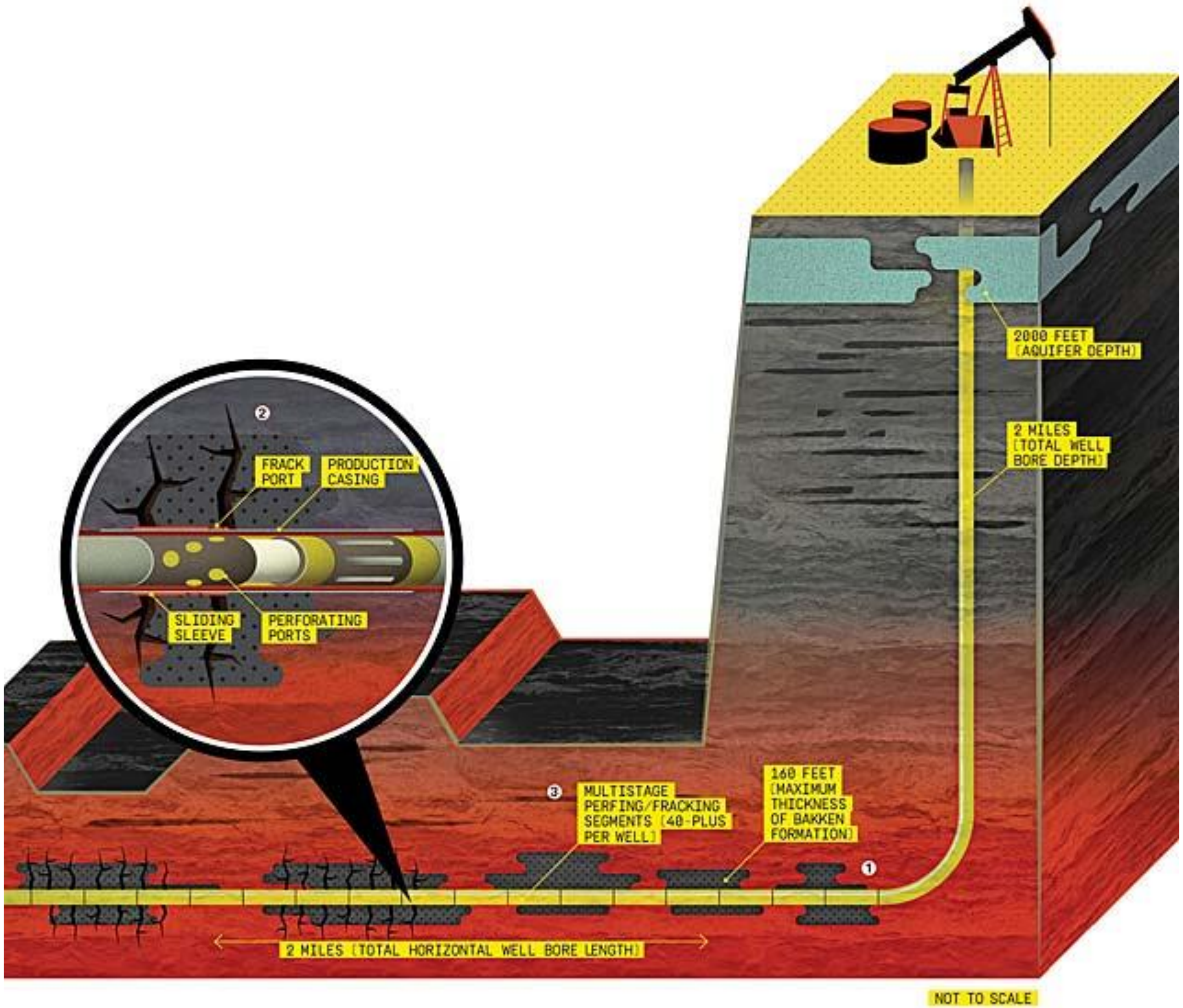
Shale play development



Unconventional oil

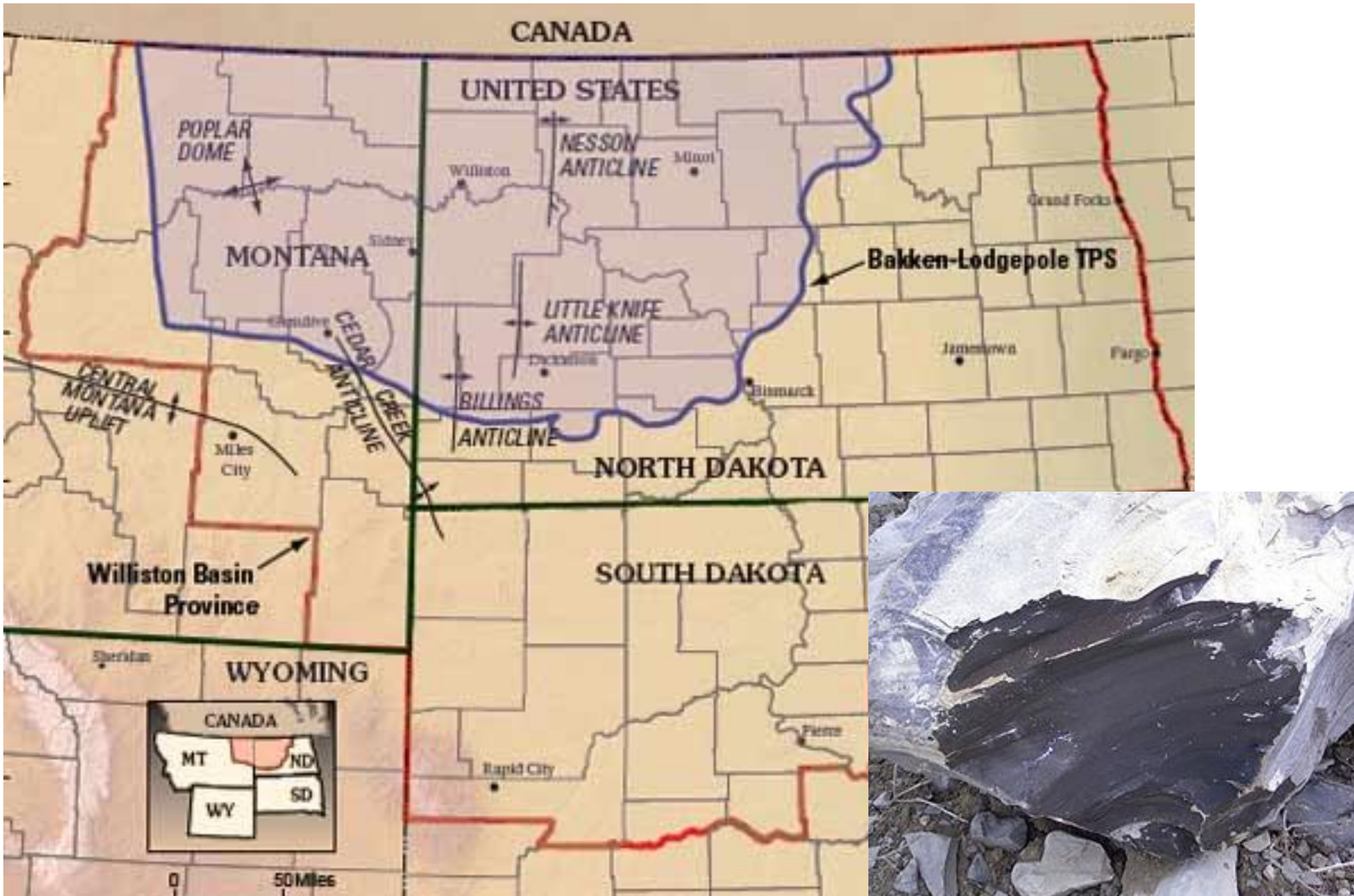
	Low-Permeability Reservoir	High-Permeability Reservoir
Medium to light oil	**Tight Oil** Horizontal Drilling Stimulation	**Conventional Oil** Vertical Drilling
Heavy Oil	**Immature Oil** **“Oil Shale”** Mining	**Heavy Oil** **Bitumen - Oil Sands** SAGD/Mining

Shale oil



2000 FEET (AQUIFER DEPTH)
2 MILES (TOTAL WELL BORE DEPTH)
FRACK PORT
PRODUCTION CASING
SLIDING SLEEVE
PERFORATING PORTS
MULTISTAGE PERFING/FRACKING SEGMENTS (40-PLUS PER WELL)
160 FEET (MAXIMUM THICKNESS OF BAKKEN FORMATION)
2 MILES (TOTAL HORIZONTAL WELL BORE LENGTH)
NOT TO SCALE

Bakken, North Dakota



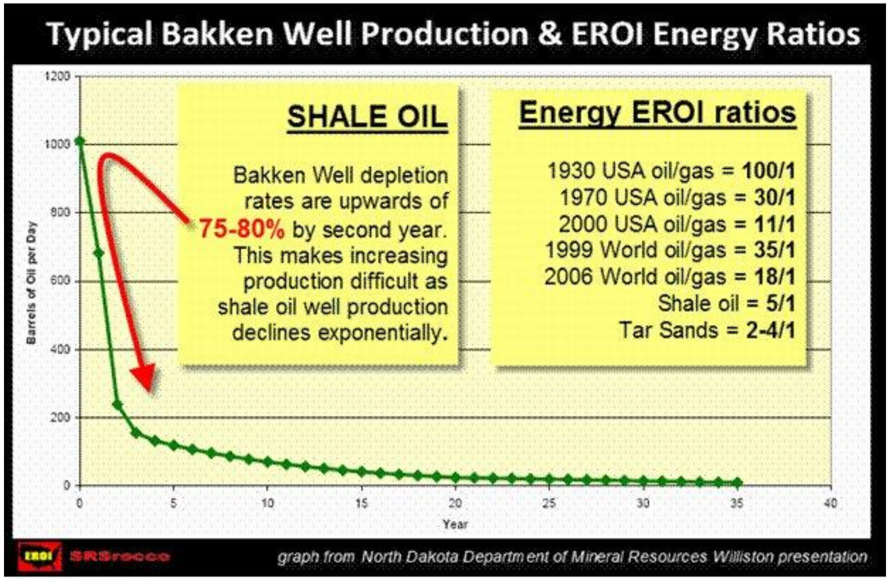
Shale oil flow rates

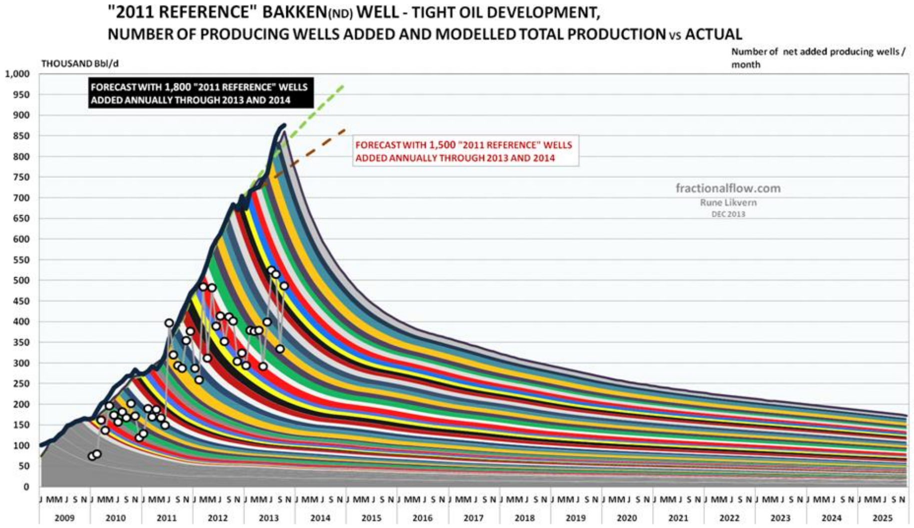
TIGHT OIL PLAY WELL RATES[1]

Table 4

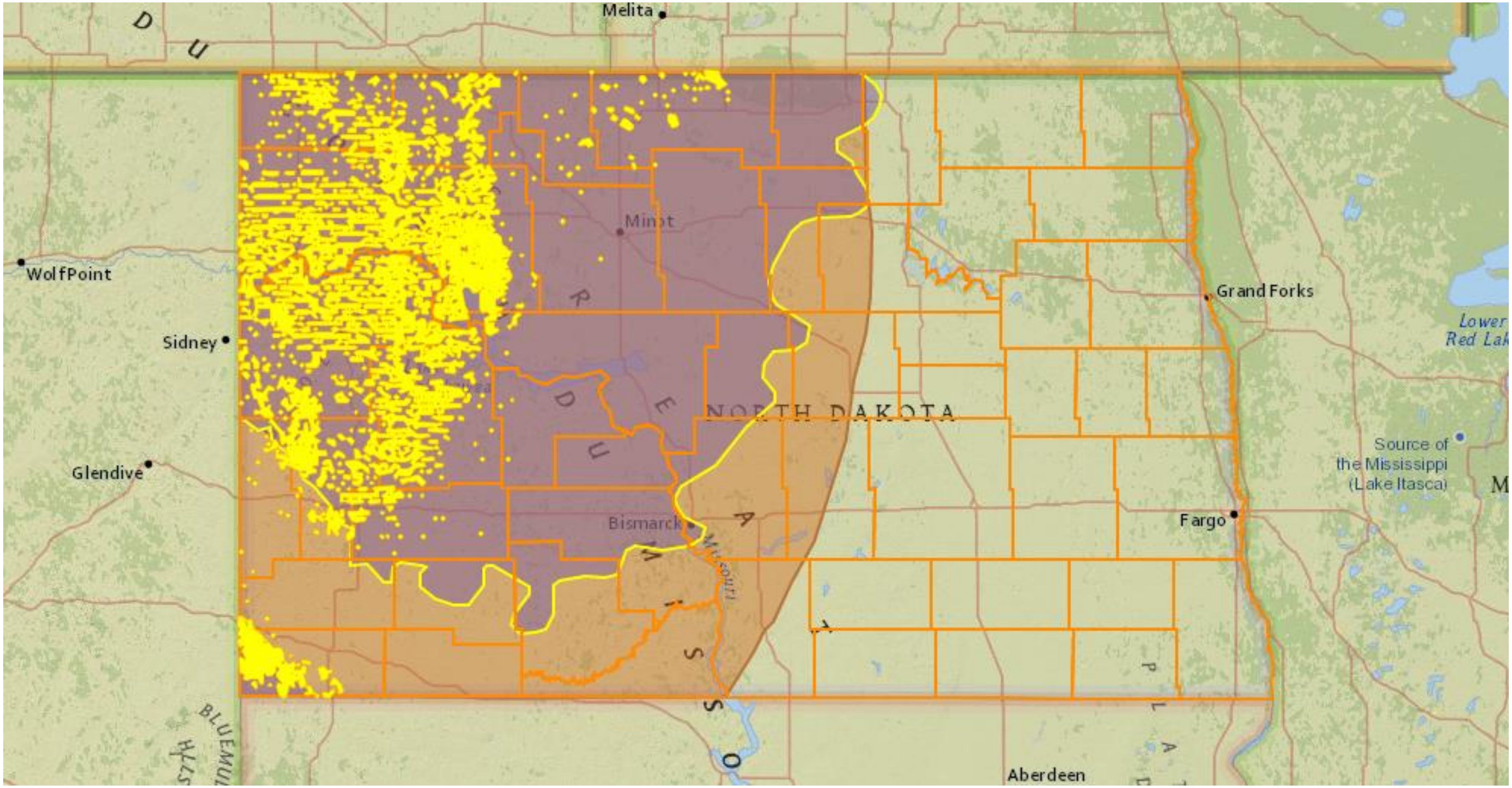
	Initial well rates, b/d	Early well decline rates, %
Barnett	2.0	70
Elm Coulee (Bakken)	[2]425	65
Bakken	2,000	65-80
Eagle Ford	1,340-2,000	70-80
Niobrara	400-700	80-90
Monterey	623	80
Avalon and Bone Spring	534	60

[1]Initial well rates and first-year well decline rates.
[2]IP rates are for multilateral wells; decline rates for vertical wells are more than 80%.
Sources: EPRINC2012, Producers, seekingalpha, and several others

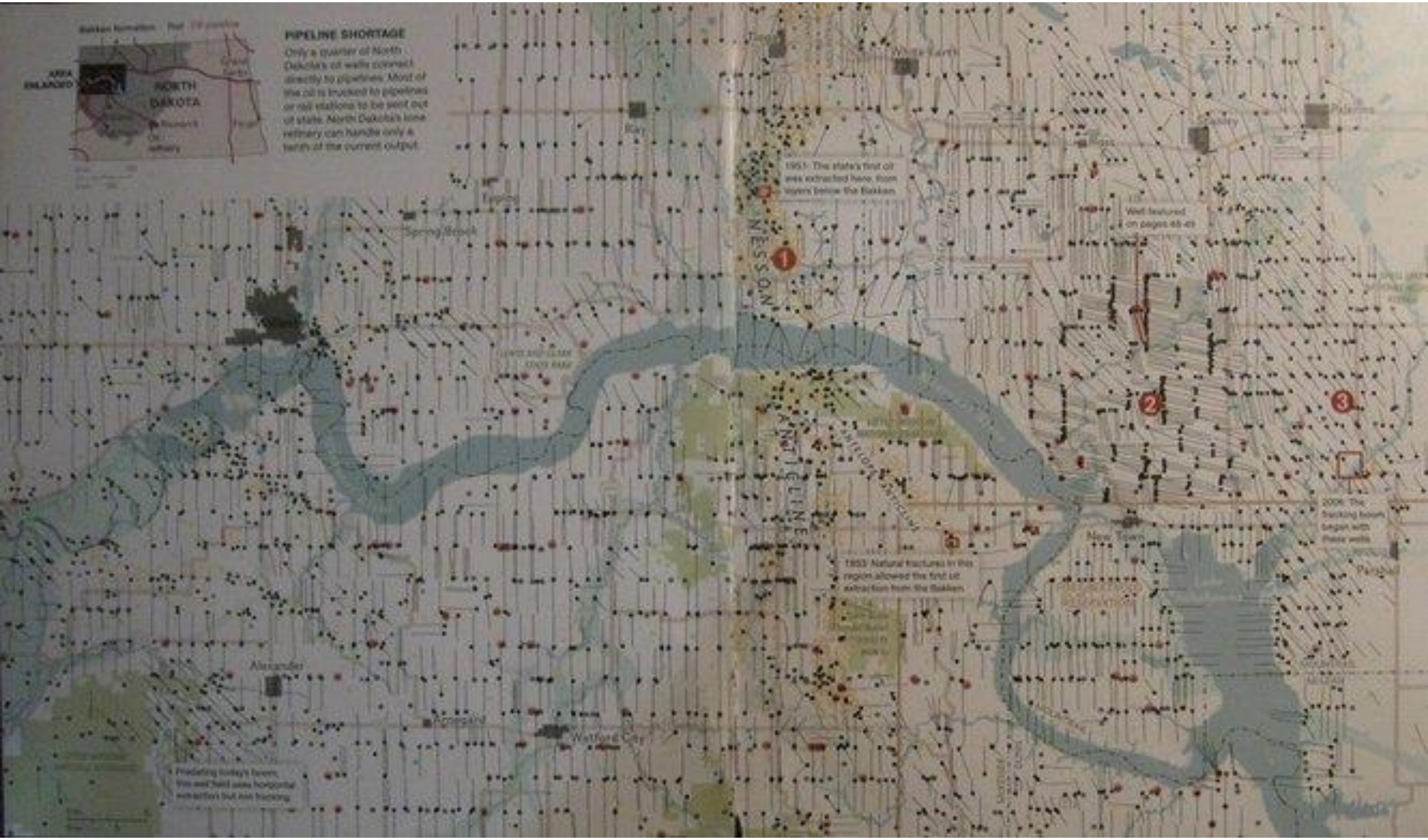




Well frequency

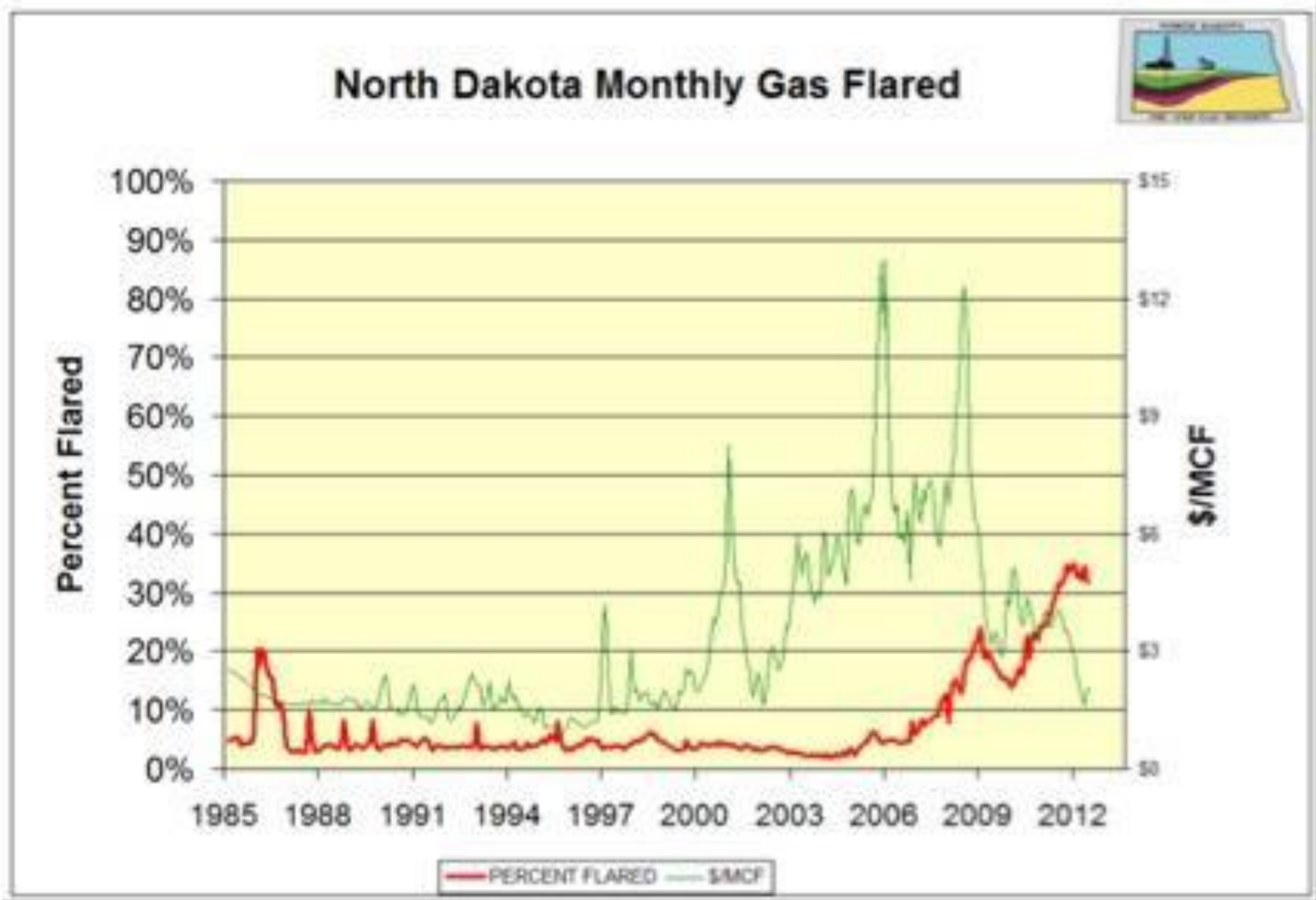


Well frequency



Gas flaring

Gas flaring



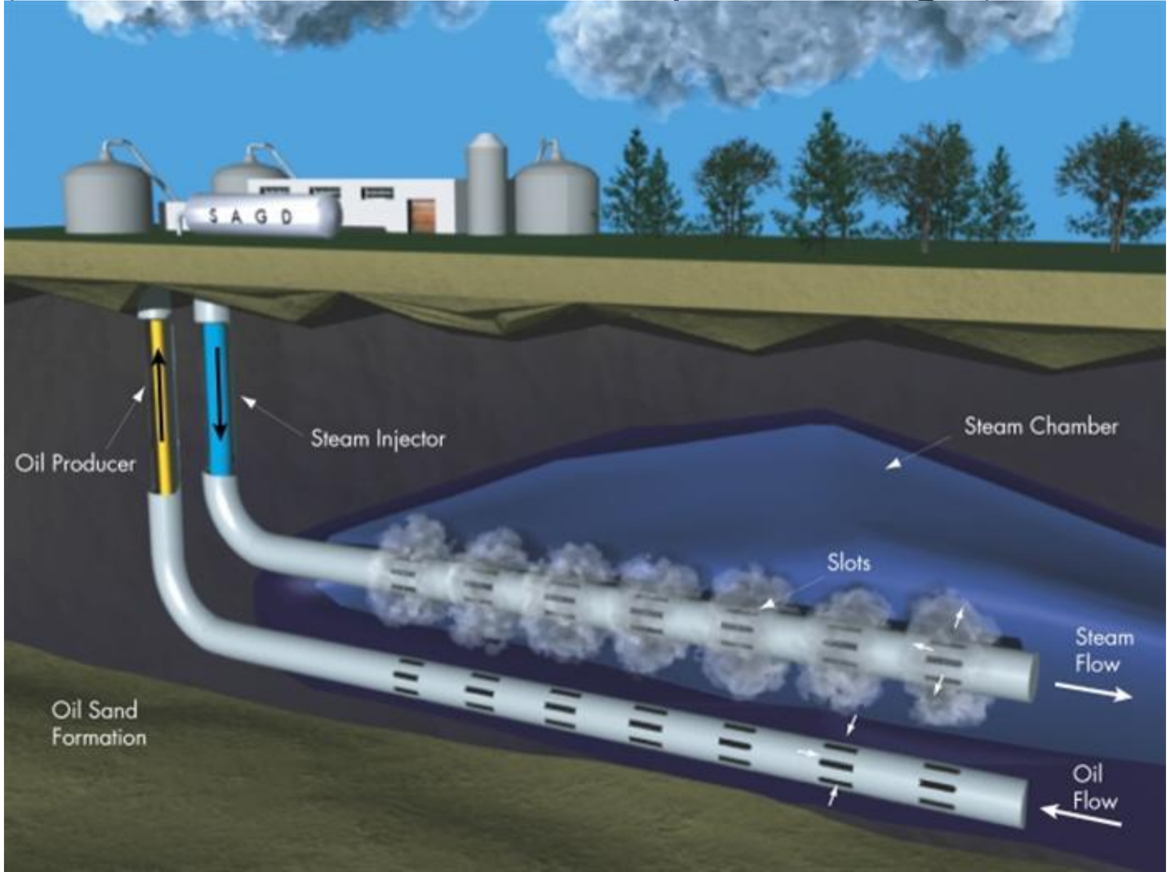
North Dakota Monthly Gas Flared
Percent Flared
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
$/MCF
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
PERCENT FLARED
$/MCF

Oil sands

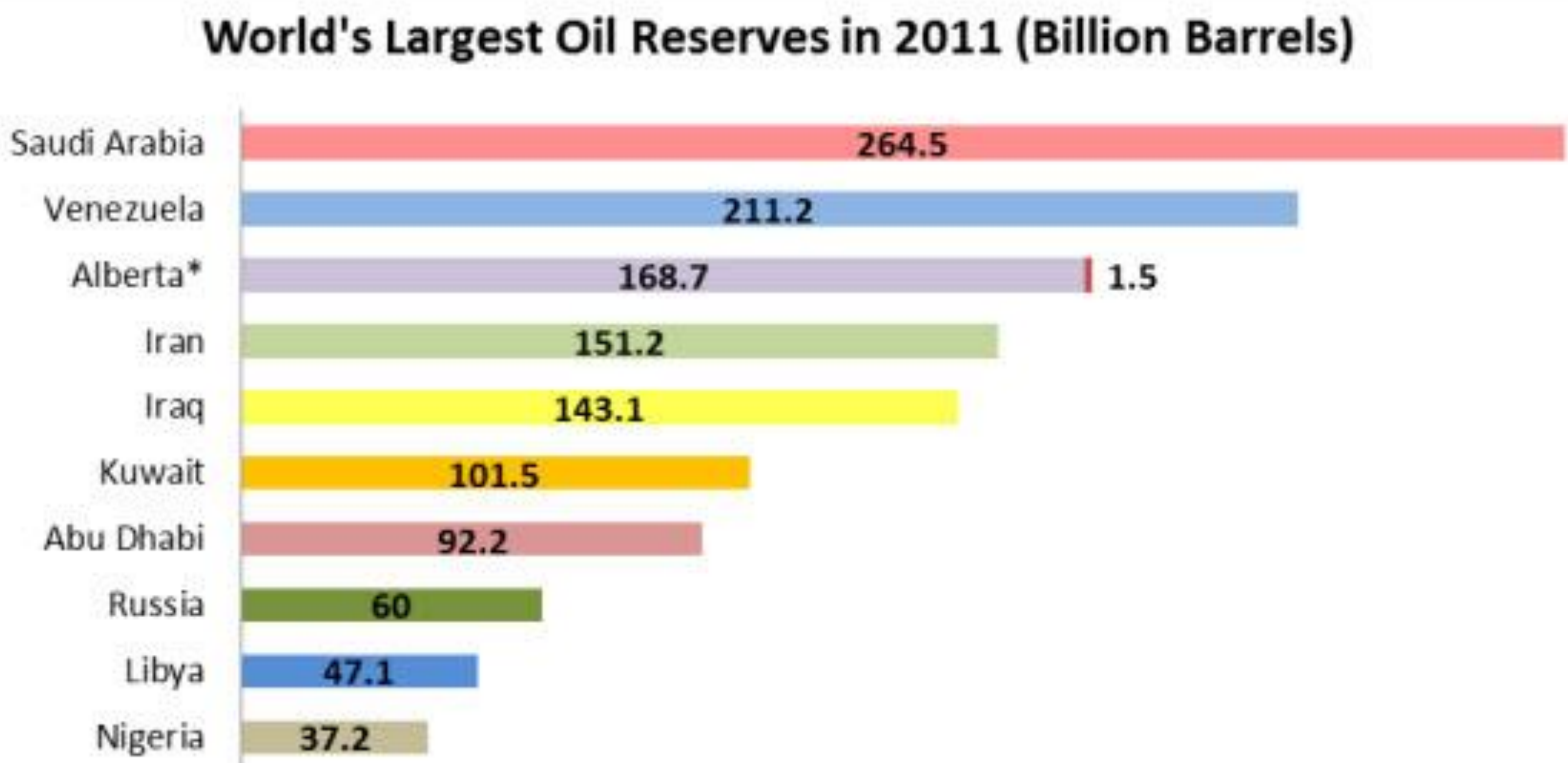
- Alberta, Kanada
- Bitumen (1-20%) –soaked sand
- Extraction:
  - Surface mining (20%)
  - *In situ* methods

In situ methods

- CSS (Cycle Steam Stimulation)
- SAGD (Steam Assisted Gravity Drainage)



Proven reserves



*Alberta's total oil reserves were 170.2 billion barrels, of which crude bitumen reserves accounted for 168.7 billion barrels and conventional crude oil reserves for 1.5 billion barrels.

Sources: ERCB 2012 ST-98 Report "Alberta's Energy Reserves 2011 and Supply/Demand Outlook 2012 - 2021" and Oil & Gas Journal "Worldwide Look at Reserves and Production. Special Report",

Oil shale

Surface layers that contain kerabitumen („early“ oil)

Extraction

- In situ
  - Drilling
  - Heating towards 350-450 °C throughout several months
  - Kerabitumen dissolution => collecting condensed oil vapors
- Surface
  - Excavation => crushing => burning in conventional plants

Oil shale

Table 4.6 • Oil shale resources by country (billion barrels)

	Oil originally in place	Technically recoverable
United States	≥ 3 000	≥ 1 000
Russia	290	n.a.
Dem. Rep. of Congo	100	n.a.
Brazil	85	3
Italy	75	n.a.
Morocco	55	n.a.
Jordan	35	30
Australia	30	12
China	20*	4
Canada	15	n.a.
Estonia	15	4
Other (30 countries)	60	20
World	**≥ 3 500**	**n.a.**

Environmental controversies

Environmental controversies

- Fresh water contamination
- Countryside degradation
- Water consumption
- Earthquakes
- Greenhouse gases emissions
- Increased heavy traffic

Fresh water contamination

The Oposition:

- HF fluid contains toxic chemicals.
- Nearby wells, exogenous substances were found; fresh water contained gas

The Industry:

- Gas-rich formations are separated from fresh water by several hundreds of meters of impermeable rock
- The chemicals are present at very low concetrations
- In some areas, gas siphons are natural phenomenon
- Connection between gas presence in water and drilling has never been proved despite long history of the technique

Fresh water contamination

The Federal Government:

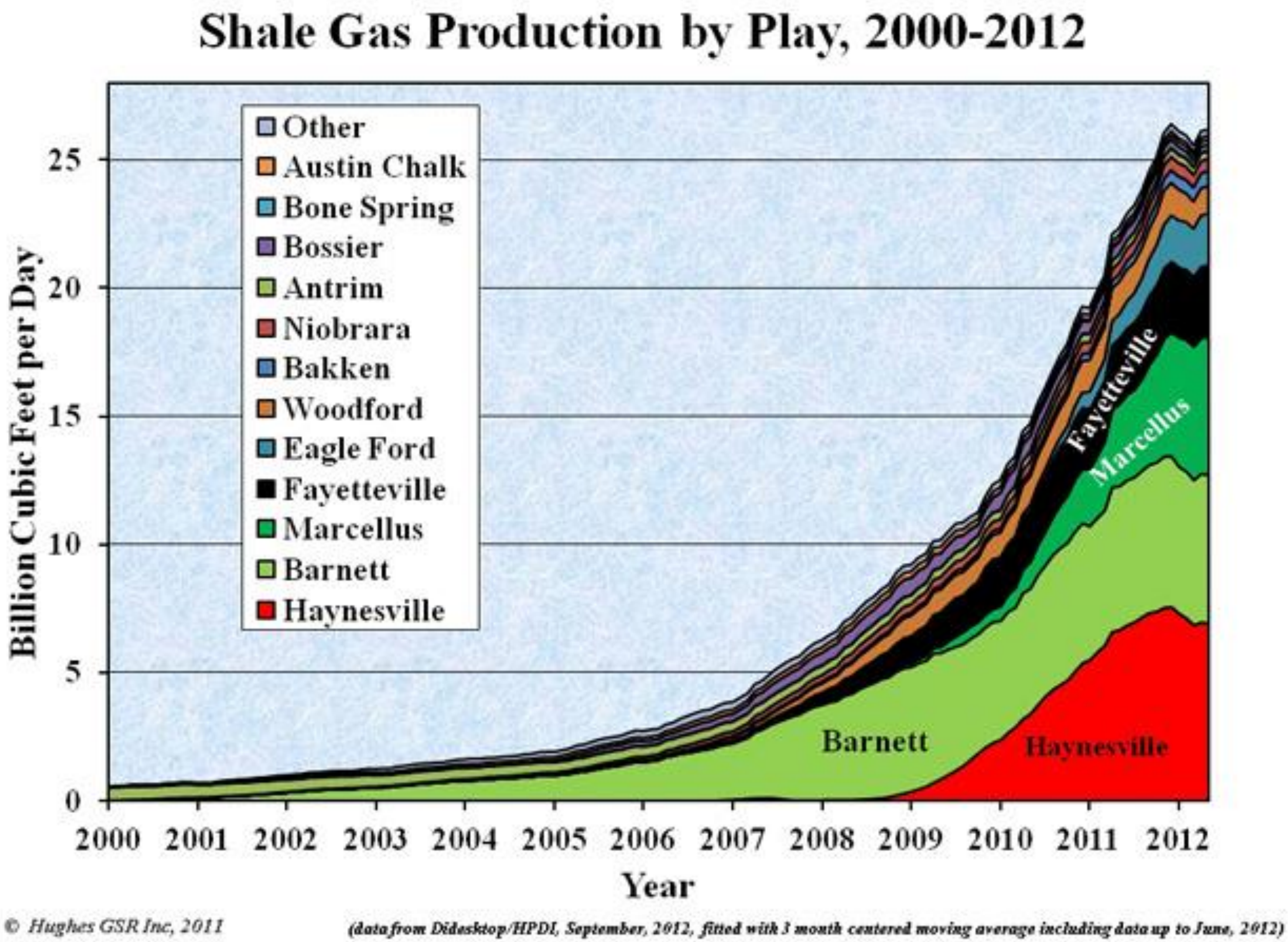
- Energy is regulated at the state level
- Federal laws to govern HF:
  Clean Water Act (CWA); Clean Air Act (CAA); Resources Conservation and Recovery Act (RCRA); Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); Emergency Planning and Community Right-to-Know Act (EPCRA); Toxic Substances Control Act (TSCA); and Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)

Fresh water contamination

Is HF exempted from the „Safe Drinking Water Act (SDWA)“

- 1940s: HF employed at conventional wells
- 1974: SDWA: does not concern neither composition nor usage of the fluid
- 1997: U.S. Court of Appeals for the 11th Circuit (Atlanta) rules that HF of coal seams (CBM) qualifies as „underground injection“ and subsumes it under the scope of SDWA => EPA is authorized to examine the impact of HF CBM on underground fresh water reservoirs
- 2004: EPA claims that the risk is low and federal regulation unnecessary (unless naphta injection is taking place).
- 2005: Energy Policy Act (EPAct) exempts „fluid and propant injection for HF purposes“ from the SDWA‘s „underground injection“ definition

Fresh water contamination



Fresh water contamination

- 2010: The Congress orders EPA to reinvestigate HF‘s environmental impact
- 2012: EPA Progress Report
- 2014: Draft for peer review
- 2019: Final Report

=> regulation

„Connection between gas presence in water and HF has never been proved“

Cabot Oil & Gas Company: 14 wells at Dimock, Susquehanna County, Pennsylvania;

- 2009: the EPA finds manganese, barium, arsenic, natural gas in a water well after another one blew out during nearby fracking operation
- 2010: Consent Order and Agreement between DEP and Cabot
  - pay the impacted families settlements worth twice their property values ($ 4 M)
  - install a “gas mitigation device” (a water filter) at each residence
- 2014: Ohio State University study: leaky well to be blamed, not HF

⇒ HF as such does not cause contamination.

⇒ Other related activities do.

Fresh water contamination

Marcellus shale play, Pennsylvania

Marcellus Shale Wells Drilled (2010): 1,454
Marcellus Shale Violations (2010): 1,227
Marcellus Shale Violations (2009): 656
Marcellus Shale Violations (2008): 206
% of Wells with Violations in 2010: 18%
Total # of Marcellus Shale Wells Drilled (2005-10): 2,498
Total # of Violations at Marcellus Shale sites (2008-10): 2,089

Fresh water contamination

Violation Type	Number
Administrative	176
General Violations (Clean Streams Law, Oil and Gas Act, permit conditions)	262
Frac Pit and storage violations (leaks, improper construction, etc.)	303
Spill & illegal disposal & discharge of industrial waste (frac fluid, wastewater, etc.)	209
Stormwater runoff violations (includes erosion and sedimentation)	119
Improper cementing/casing of wells	84
Hazardous well venting	4
Other	70

source: PA Department of Environmental Protection (DEP)

Countryside degradation

The oposition

- In the desserts of the US the drilling does not bother anybody, in countries like CZ this is not possible

The industry

- In the US, the drilling takes place everywhere, including city centers or an uni campus (Arlington, TX).
- Population density above the Barnett Shale is 5x larger that average population density of the CZ

Jonah tight gas wells, Wyoming

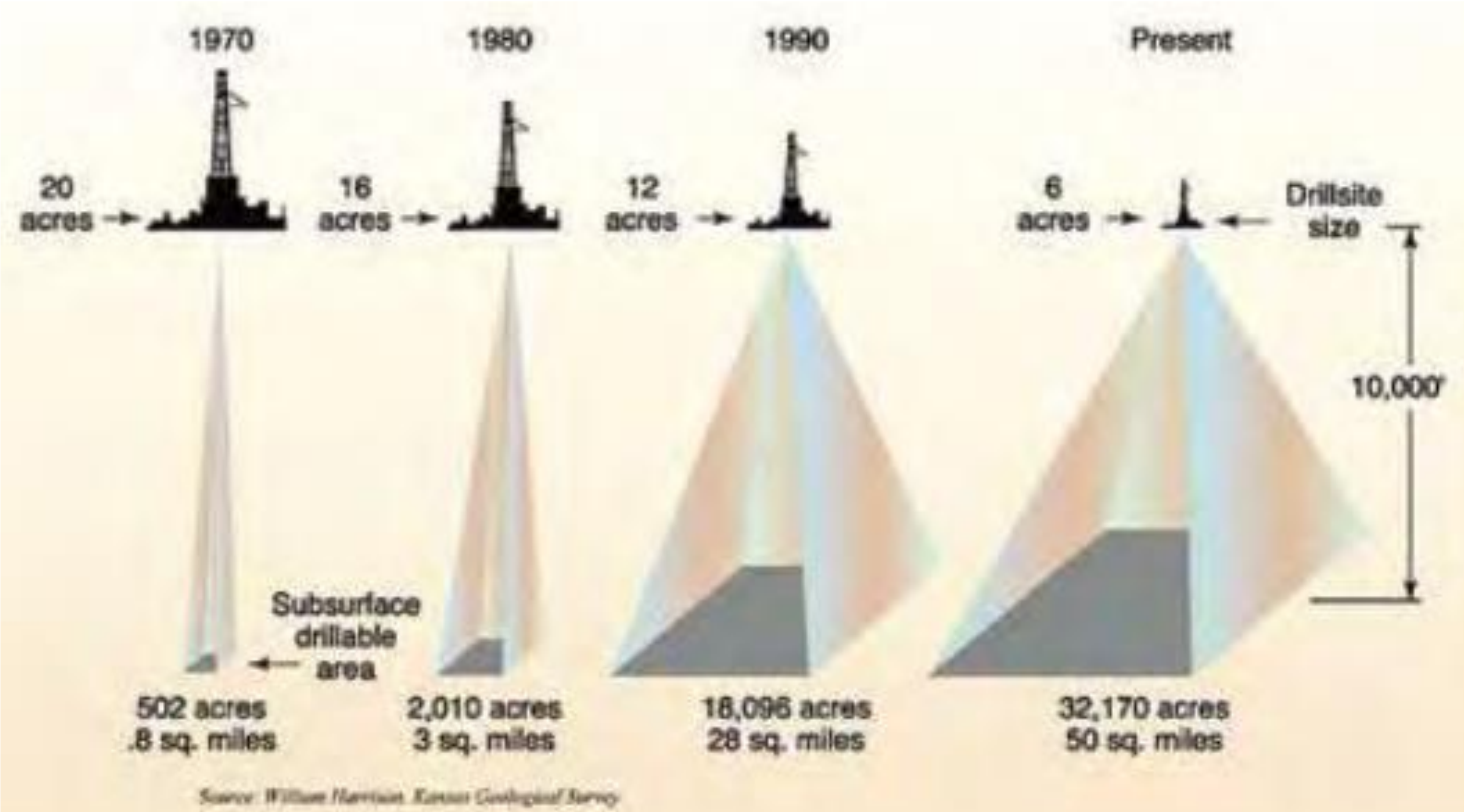
Horní Věstonice, 50 km south of Brno

Countryside degradation

Electricity Source	Land Intensity (Incl. Fuel Production)
Gas	100
Biomass	205
Coal	190
Nuclear	177
Wind	1538
PVE	2154

Countryside degradation

Trend: fewer drilling pads, longer laterals



Water consumption

The oposition

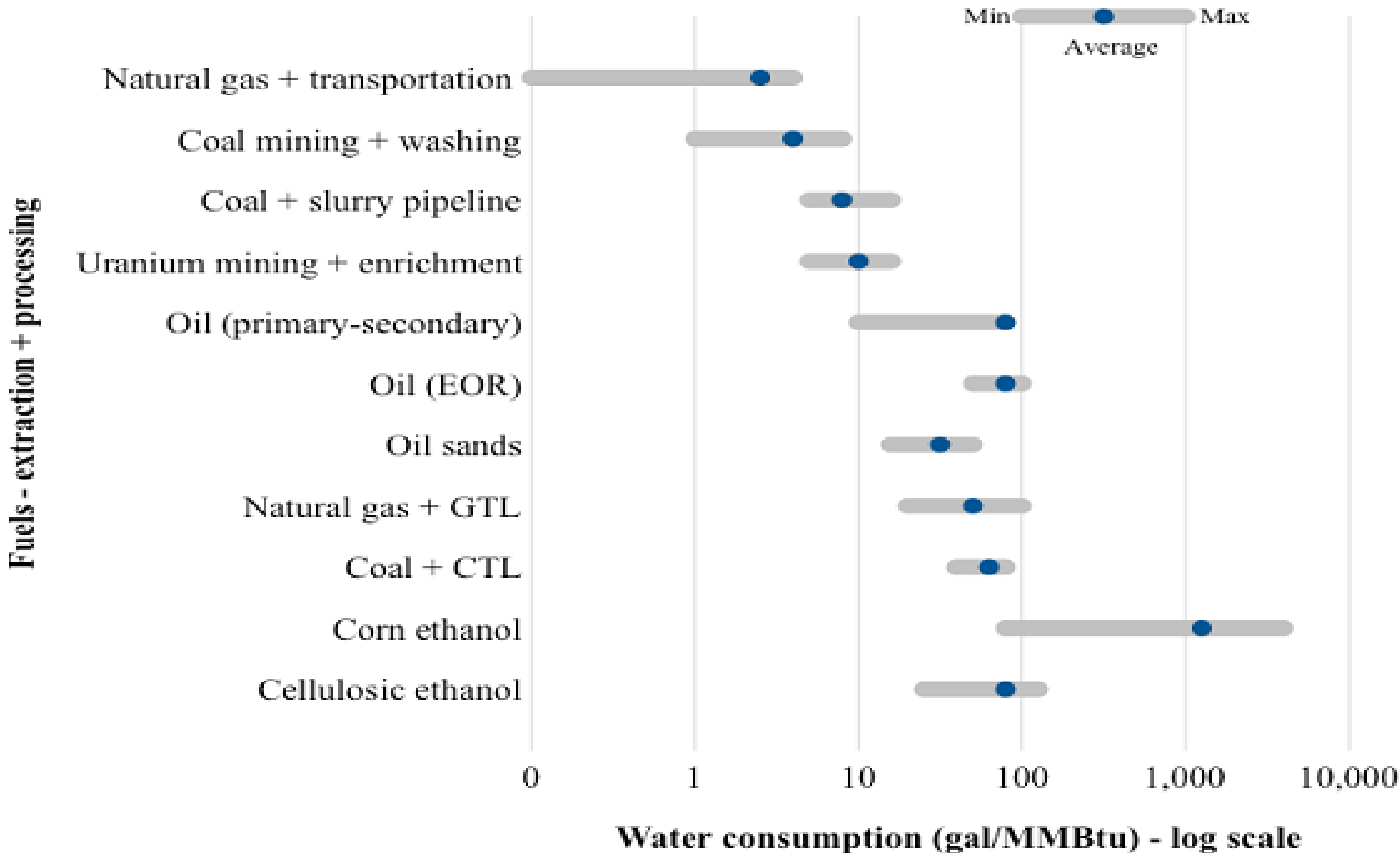
- Fracking of one well requires tens of millions of liters of water

The industry

- In a typical production area, the extraction activities account for approx. 0.1 – 5 % of the regional water consumption.
- Other sectors such as agriculture, residential, or coal mining consume significantly more water.

Water consumption

Chart ES-1: Water consumption of extraction and processing of fuels



Earthquakes

- HF induces local earthquakes that may be dangerous at the surface (Blackpool, UK)

- Earthquakes occur only in contact with already strained stratas of rock
- Current technology can measure secondary vibrations and adjust the pump pressures accordingly

Greenhouse effect

- Flow back contains large amounts of methane, more wells and gathering pipes lead to more leakages.
- Methane is 28x stronger greenhouse gas than carbon dioxide.

- No one knows how much methane is actually released.

The Cornell study

- Howarth and Ingraffea (Cornell Uni) proved, that if the whole cycle is considered, shale gas is worse than coal in terms of climate effect.

- No one knows. Neither do Howarth and Ingraffea know. They only point out the importance of overseeing the whole cycle.

The Cornell study

"We reiterate that all methane emission estimates, including ours, are highly uncertain. As we concluded in Howarth et al. (2011), "the uncertainty in the magnitude of fugitive emissions is large. Given the importance of methane in global warming, these emissions deserve far greater study than has occurred in the past. We urge both more direct measurements and refined accounting to better quantify lost and unaccounted for gas." The new GHG reporting requirements by EPA will provide better information, but much more is needed.„

(http://www.eeb.cornell.edu/howarth/Howarthetal2012_Final.pdf, str. 10)

Air pollution by fuel

Pollutant	Gas	Oil	Coal
Carbon Dioxide	100	140	178
Carbon Monoxide	100	83	520
Nitrogen Oxides	100	487	497
Sulfur Dioxide	100	1,112,200	259,100
Particulates	100	1,200	39,200

Traffic

- A typical 1,5-4 km deep well requires 700 to 2000 truck trips
- In the hot phase, the daily traffic can be as high as 250 truck trips
- It requires 3.5 to 5 years to complete 25-36 wells drilled from one pad.

- A well is a matter of just a few months, after that only the „christmass tree“ is left.

Shale gas environmental impact

- Shale gas affects the environment negatively
- The notion that HF and water contamination are totaly unrelated does not hold.

- However, other energy sources affect the environment too.

Oil and Gas Transportation

Outline

- Marine transportation: oil and LNG tankers
- Pipeline transportation: building, financing, operating pipelines

History

- 1877: Zoroaster – 250 DWT
- 1940s: 12 500 DWT
- 1950s: 20 000 DWT
- 1956 and 1967: Suez crises
- 1960s: 80 000 DWT (1966: VLCC Idemitsu Maru 206 000)
- 1970s: ULCC (350 000)
- 1981: Sea Wise Giant/Happy Giant/Jahre Viking/Knock Nevis/Mont (564 650)

AFRA tanker classification

• Product Tanker	10–60,000 DWT
• Panamax	60–80,000
• Aframax	80–120,000
• Suezmax	120–200,000
• VLCC	200–320,000
• ULCC	320–550,000

Daily consumption (2018):

• USA	2,200,000 tons
• China	1,560,000
• Germany	279,000
• Australia	128,000
• Egypt	114,000
• Portugal	25,000
• Armenia, Estonia Eritrea, Malta	500

Tanker ownership structure

Owner	**No.**	**Share**	**Age**
Independent companies	4391	83%	9.6
States	490	9%	12.4
Energy companies	156	4%	11.0
State-owned energy companies	150	4%	16.9
Total	**5187**	**100%**	**11.5**

Tanker transport costs

- Operation costs (wages, insurance)
- Regular maintenance (dry dock)
- Transportation costs (fuel, fees)
- Cargo-related costs (onloading, discharge, demurrage)
- Capital costs (new ships: approx. 50%)

Renting

Tankers are usually owned and rented via indepent shipping companies

- Voyage charter (one voyage from onloading to discharge ports)
- Time charter (a set period of time, for multiple voayages)
- Bareboat charter (the charterer becomes the vessel‘s operator => is responsible for crew and maintenance)
- Contract of affreightment (a total volume of cargo to be carried in a specific time period and in specific sizes)

Shipping tariffs

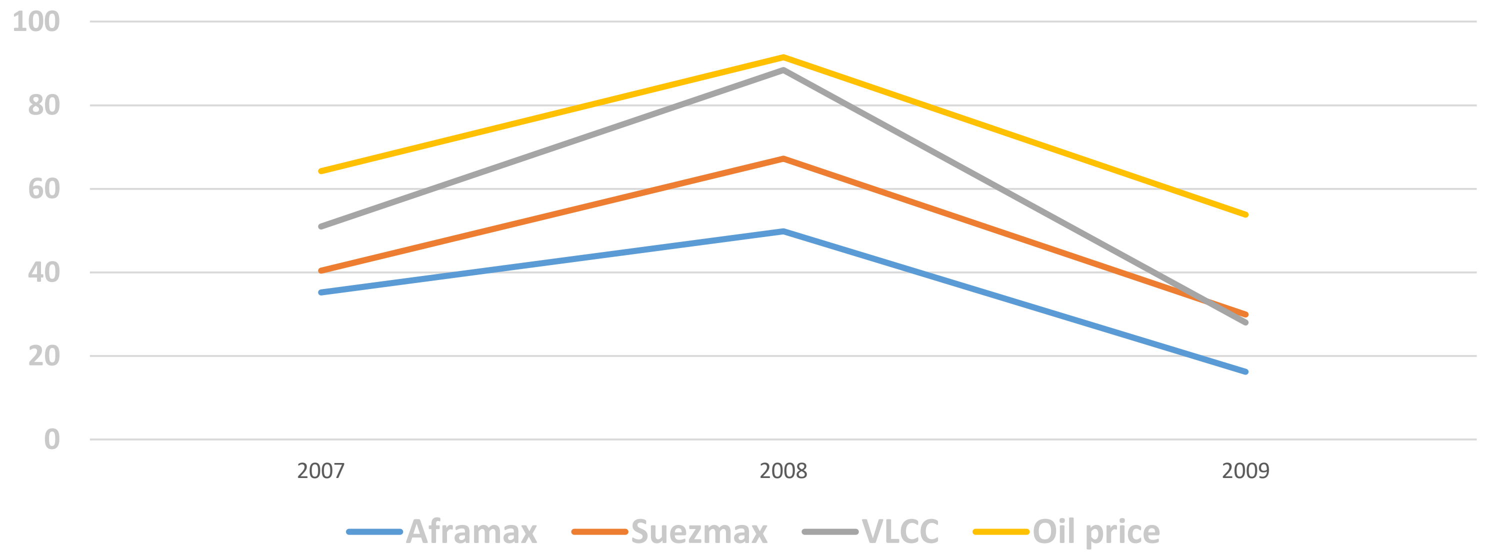
- Lump sum rate (sum for a cargo delivery, port and other voayage costs paid by the operator)
- Rate per ton (sum for a cargo delivery, port and other voayage costs paid by the charterer)
- Time charter equivalent (daily rate, port and other voayage costs paid by the charterer)
- Worldscale Flat rate + Multiplier

Worldscale

- Current tariff system established during the WW II
- Before 1939: non-standardized tariffs
- During the war tanker shipping requisitioned and controled by the UK and U.S. governments => daily hire rate compensation
- Between the end of the war and the end of gov. control (1948) tankers made available for IOCs to rent
- The rent tariffs were scaled so that, after allowing for port costs, bunker costs and canal expenses, the net daily revenue was the same for all voyages
  - Bunker costs: fuel costs
  - Canal expenses: canal (Suez, Panama) tolls
  - Port costs: tariffs for onloading/offloading (demurrage costs not included)

Daily shipping rates (kUSD)

Class	2007	2008	2009
Aframax	35.2	49.8	16.2
Suezmax	40.4	67.2	29.9
VLCC	51.0	88.4	28.0
Oil price	64.2	91.5	53.8



Tanker transportation market

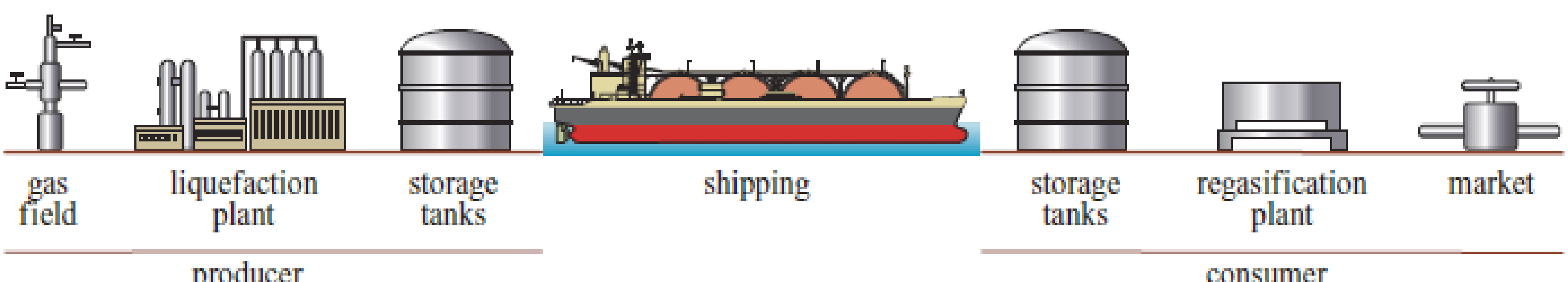
Near perfect competition

- Highly standardized product (identical service)
- Many suppliers who are unable to influence the price
- Availability of information (Baltic index)
- No regulation-related entry barriers (right of flag)
- No exit barriers (well functioning after market)

LNG chain

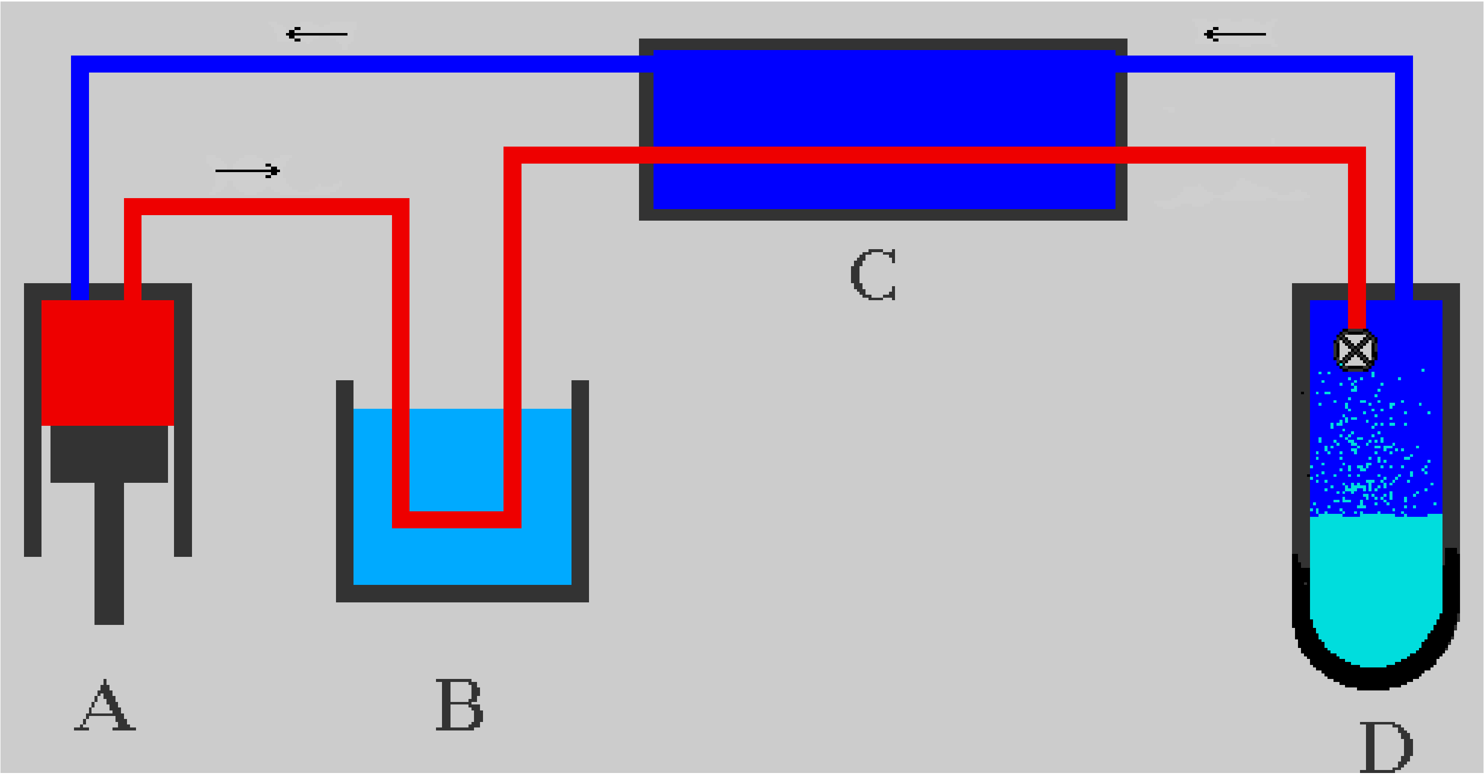
Assumptions

- Small production costs
- Price level at the target market
- More expensive, undesirable, impossible pipeline transport
- Deposits close to sea shores
- Low content of impurities



Liquefaction

Hampson-Linde cycle



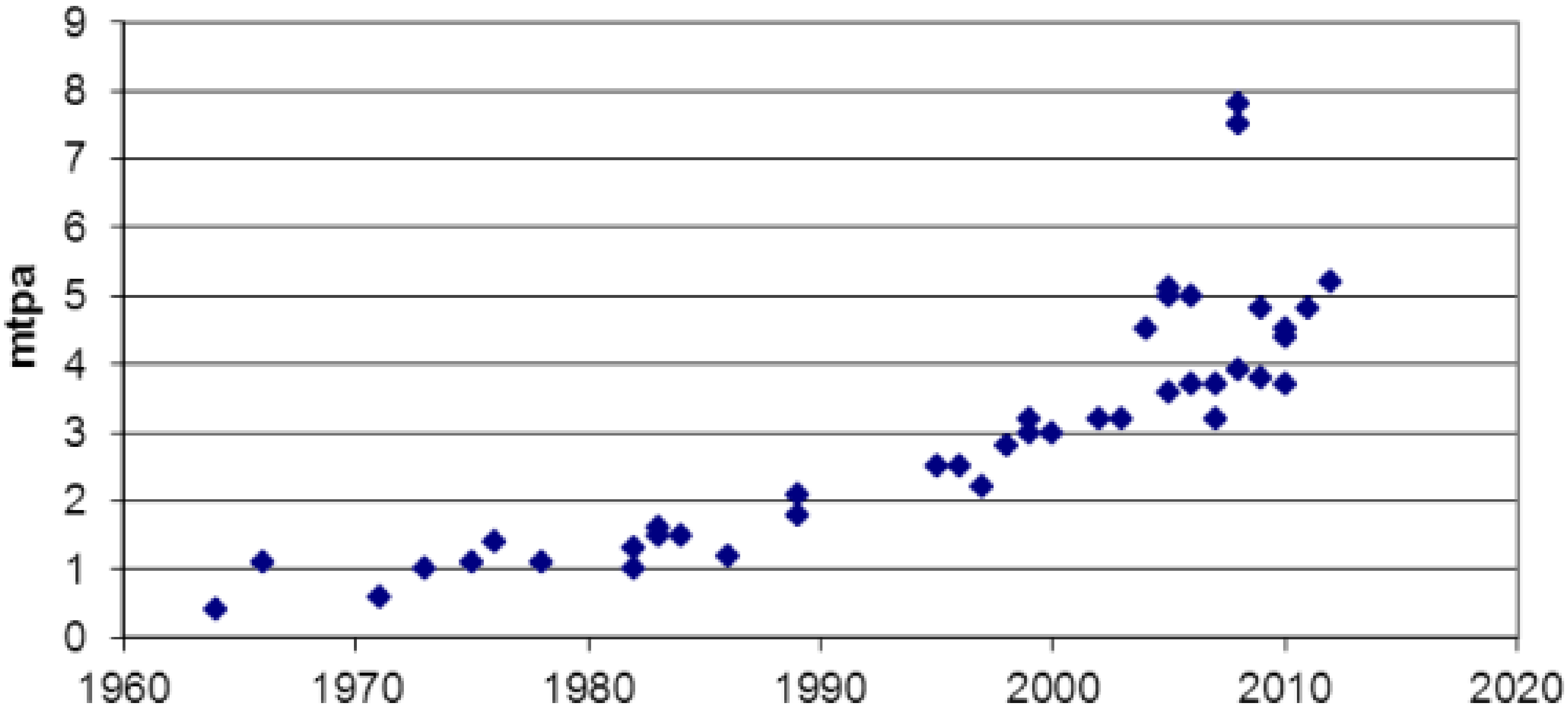
Liquefaction unit manufacturers

- JCC Corp. (Jap)
- Chiyoda Corp. (Jap)
- Kellog Brown & Root (USA)
- Bretchel (USA)
- Foster Wheeler (USA)
- Chicago Bridge & Iron (USA)
- Snamprogetti (Ita)
- Technip (Fra)

LNG train: capacity development

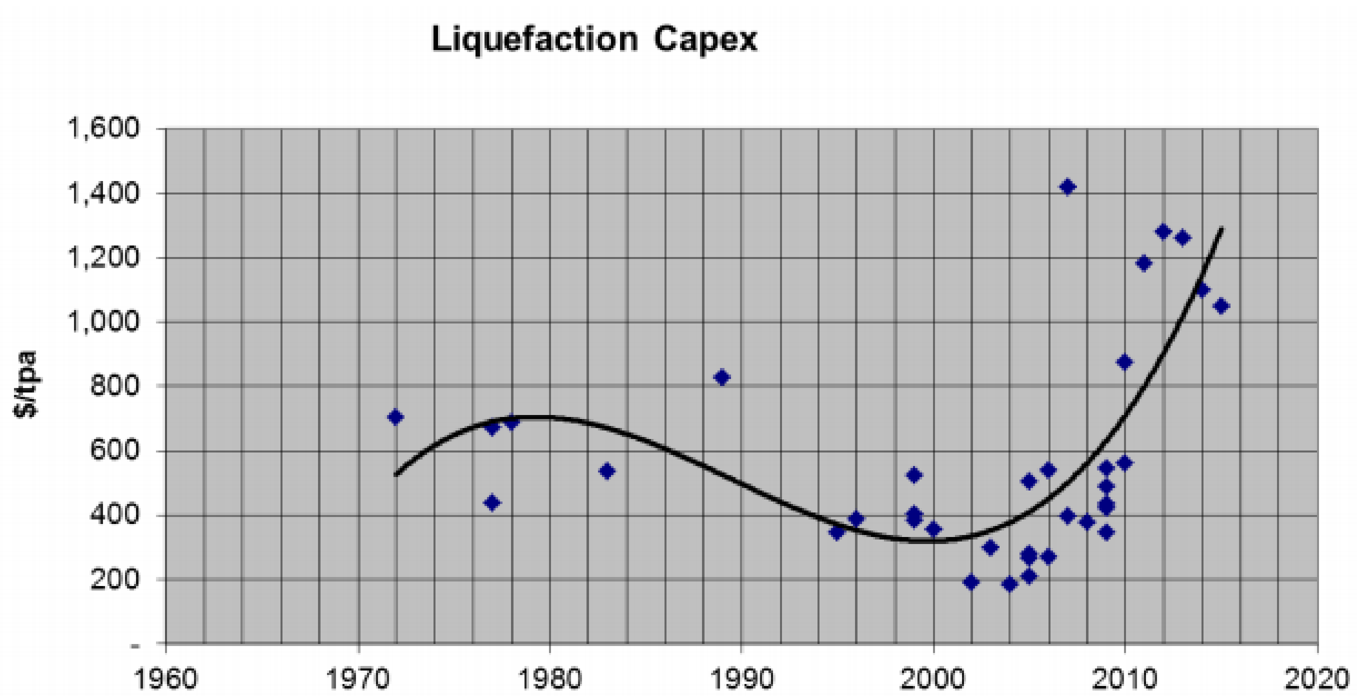
Train size

- 1990: 4 bcmy (2.3 Mtpa)
- 2005: 6.2 bcmy (4.5 Mtpa)
- 2010: 11 bcmy (8.0 Mtpa)

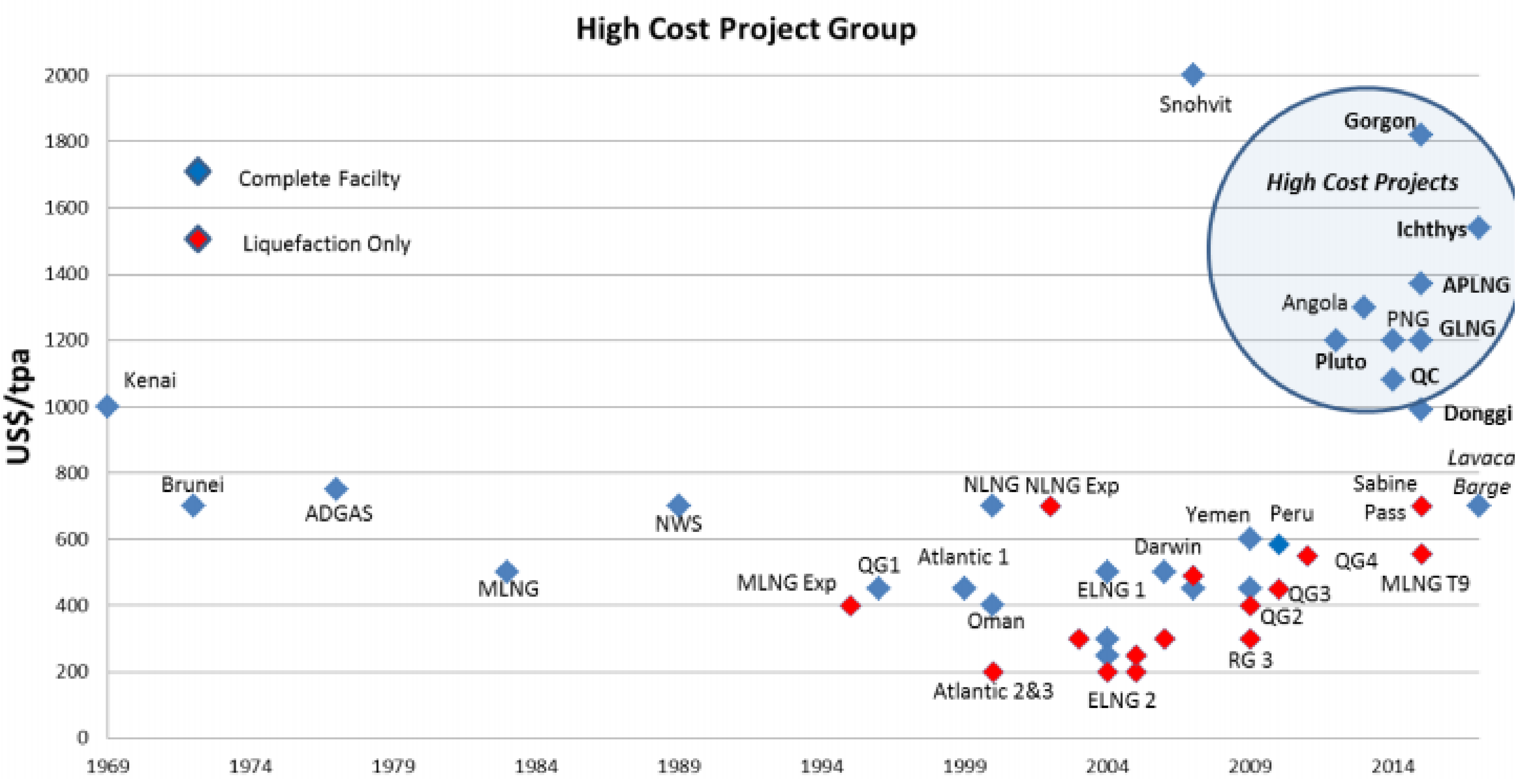


Liquefaction costs

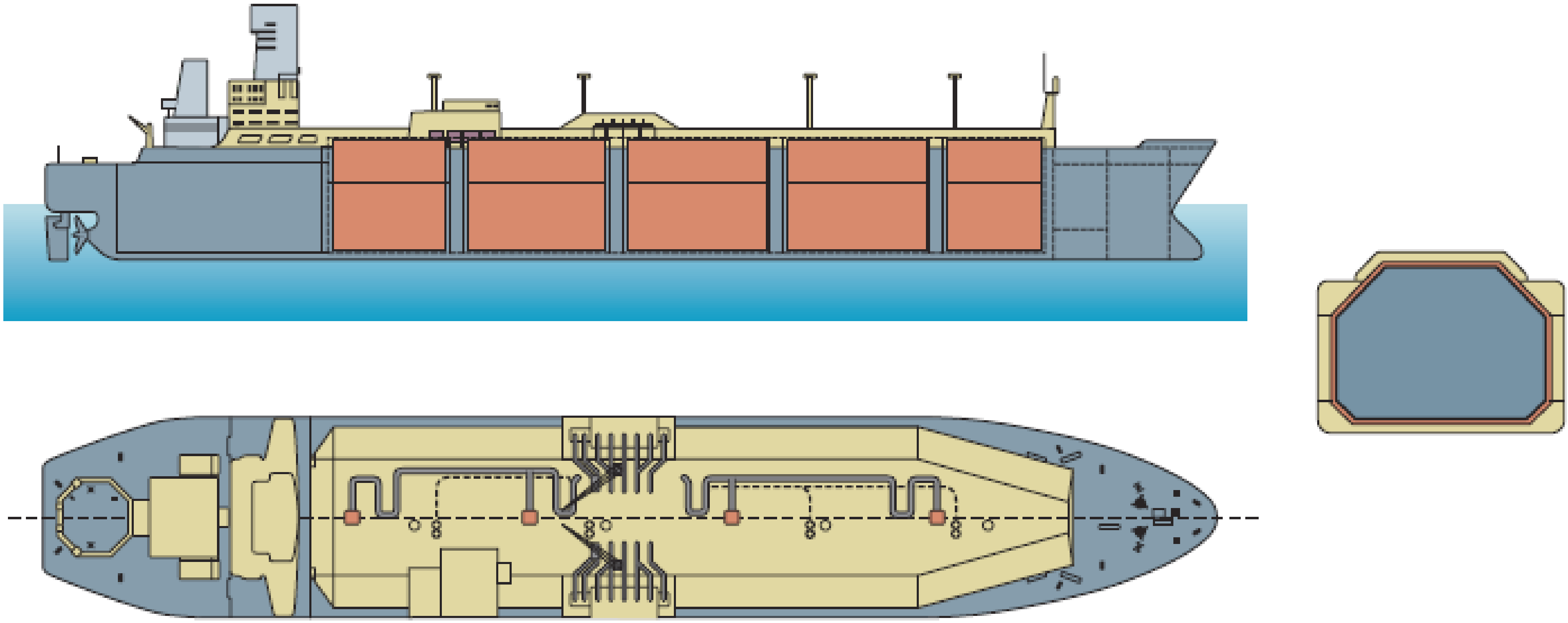
- 1970-2000: Gradual decrease in capex
  - Learning curve
  - Expansion projects (new trains within existing facilities – 50% of costs)
- After 2010: high costs projects (namely Australia)

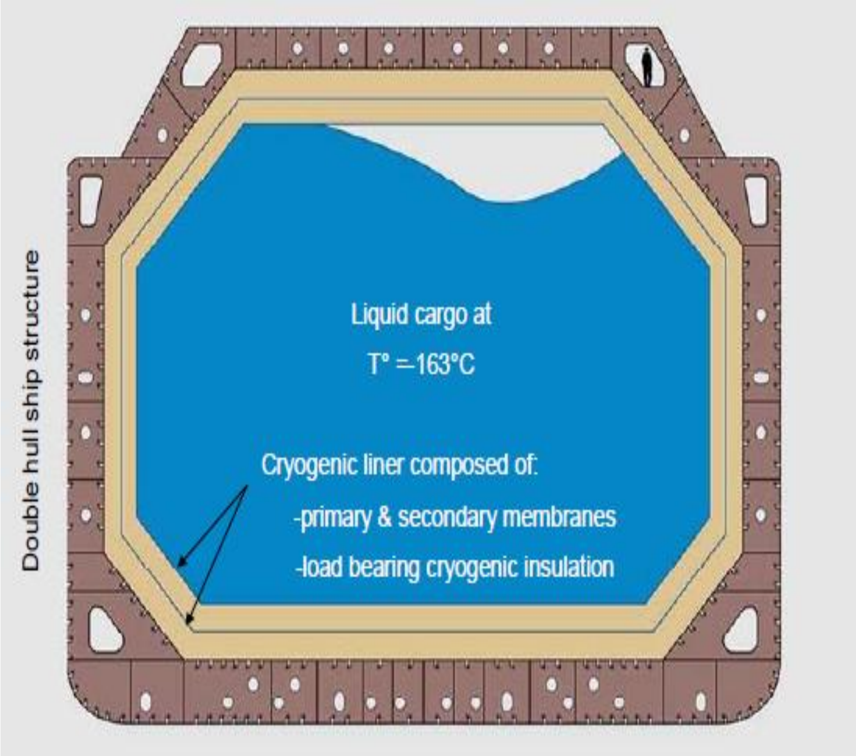


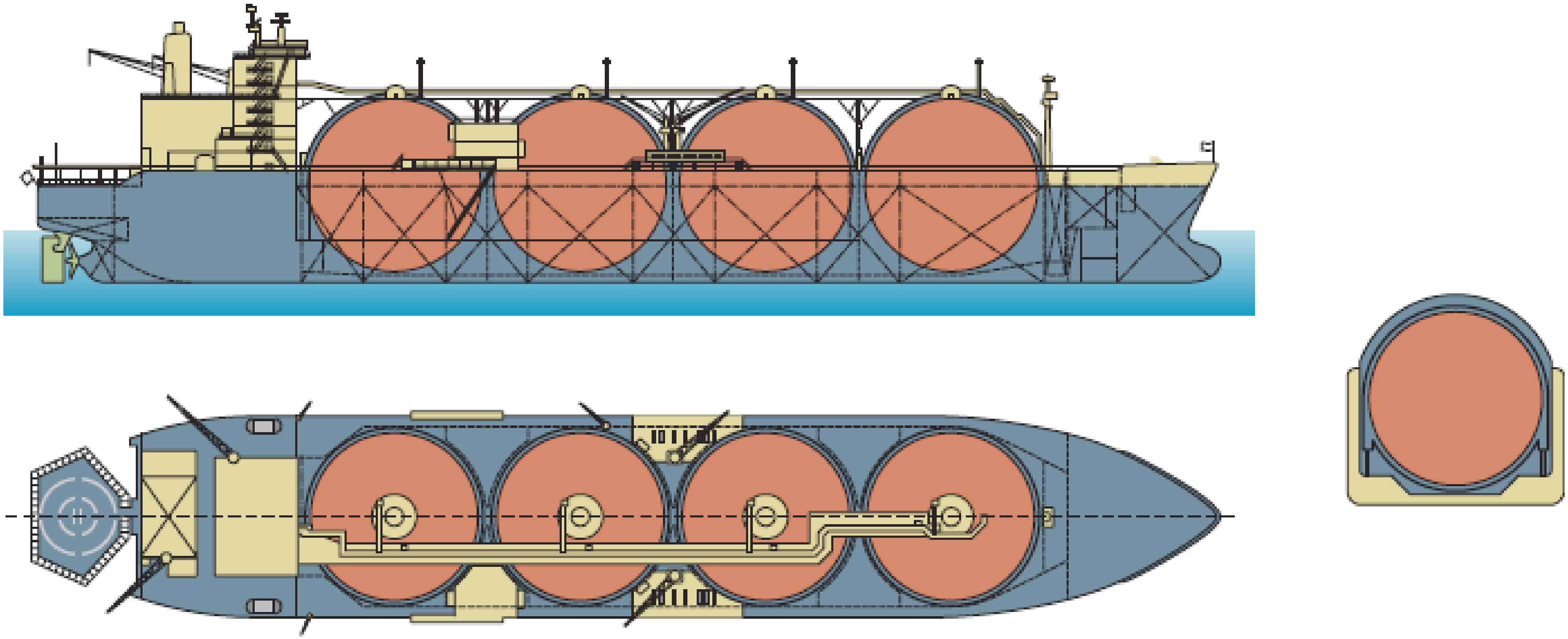
Liquefaction costs



LNG Vehicle (LNGV)




Double hull ship structure
Liquid cargo at
T° =-163°C
Cryogenic liner composed of:
-primary & secondary membranes
-load bearing cryogenic insulation



LNG Fleet

Class	Capacity (tcm)
Small	< 90
Small conventional	120-149
Large conventional	150-180
Q-flex	200-220
Q-max	> 260

LNG Fleet

- Fleet size
  - 2003: 150 LNGVs
  - 2005: 203
  - 2007: 247
  - 2008: 266
  - End of 2013: 357 LNGVs, another 108 ordered
- Average voyage length
  - 2000: 5,700 km
  - 2006: 6,300 km
  - 2007: 6,700 km
  - 2010: 8,000-8,500 km
    (Qatar-Europe: 9,660 km, Qatar-USA: 12,800 km)

Receiving terminal

- Storage tanks
- Regasification (heating, water, sea water)
- Measurement

=> Pipeline network

- Usual utilization (Europe): 50%

Pipeline transportation

BUILDING PIPELINES

Assumptions

- Available commodity (export capacity)
- Outlet (insufficiently supplied market)
- Distance

Production costs + transport < wholesale price

The Process

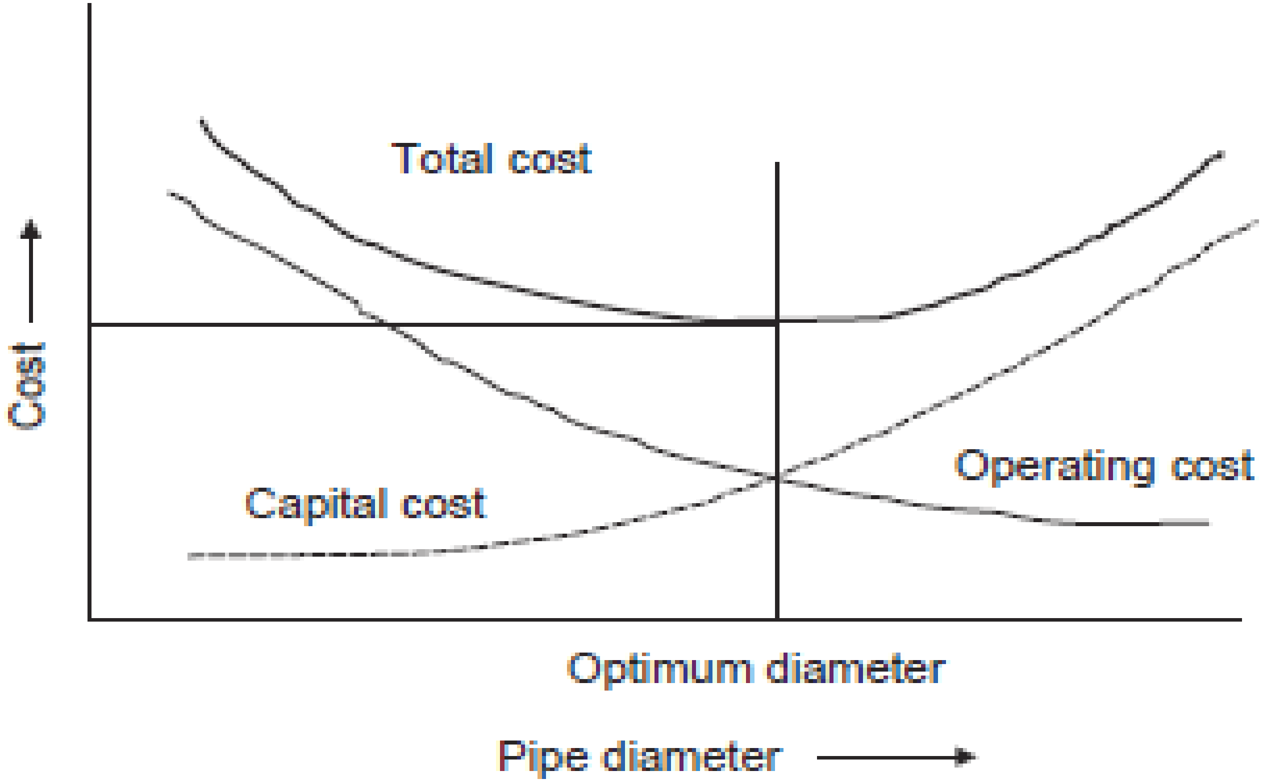
- Feasibility study (technology, costs, EIA)
- Open season (capacity auction – non/binding)
- Funding
- Regulator‘s permit
- Land access
- Logistics and materials
- Construction
- Testing
- Commissioning

FINANCING PIPELINES

Consortiums

- High capex + low opex
- Cross-border investments

  => joint ventures



Funding

- Stakeholders‘ funds
- Private loans
- EU: EBRD, EIB, political tools (TEN-E, CEF)

- Open season indicates viability of the project

OPERATING GAS PIPELINES

Shipping contracts

- Firm
  (granted transmission capacity in the pipeline)
- Interruptible
  (transmission capacity allocated if available)

- Shipping portfolio (firm/interruptible)
  - Both the pipeline and shippers

Shipping

- Nomination
- Confirming
- Scheduling
- Allocating
- Balancing

Nomination

- A notification by a shipper to the pipeline company
- Request for transportation services
  - Shipper‘s transportation contract no. (TCN)
  - Delivering party‘s TCN
  - Start date
  - Stop date
  - Shipper‘s receipt location
  - Shipper‘s receipt amount
  - Shipper‘s delivered amount
  - Receiving party‘s TCN

Scheduling

- A notification by the pipeline to its operations personnel
  - Nominated amount
  - Receipt location => Delivery location
  - Until stop date or further notice is given
- A report to all the parties that scheduling process has been completed successfully

= *What the pipeline expects to happen*

Allocating

- The *scheduled* and *actually flowed* amount usually differ.
- Ascribing the real flows to the shippers according to the scheduled amounts
- Firm contracts > interruptible contracts

Allocating: an example

- Scheduled: 40,000 MWh
- Measured: 30,000 MWh

Shipper	**Scheduled**	**Allocated**	***note***
Firm 1	10,000	10,000	
Firm 2	10,000	10,000	
Interruptible 1	10,000	5,000	*10,000 / 20,000 * 10,000*
Interruptible 2	6,000	3,000	*6,000 / 20,000 * 10,000*
Interruptible 3	4,000	2,000	*4,000 / 20,000 * 10,000*
Total	**40,000**	**30,000**	

Balancing

- Imbalance:
  - Receipt > delivery
  - Receipt < delivery
- Tolerance (up to a few %)
- Daily imbalances above the tolerance are *cashed out* at the end of the month
  - Over-delivery (short imbalance) => market price + premium
  - Under-delivery (long imbalance) => market price – discount

=> Monthly balancing

Transit tariffs

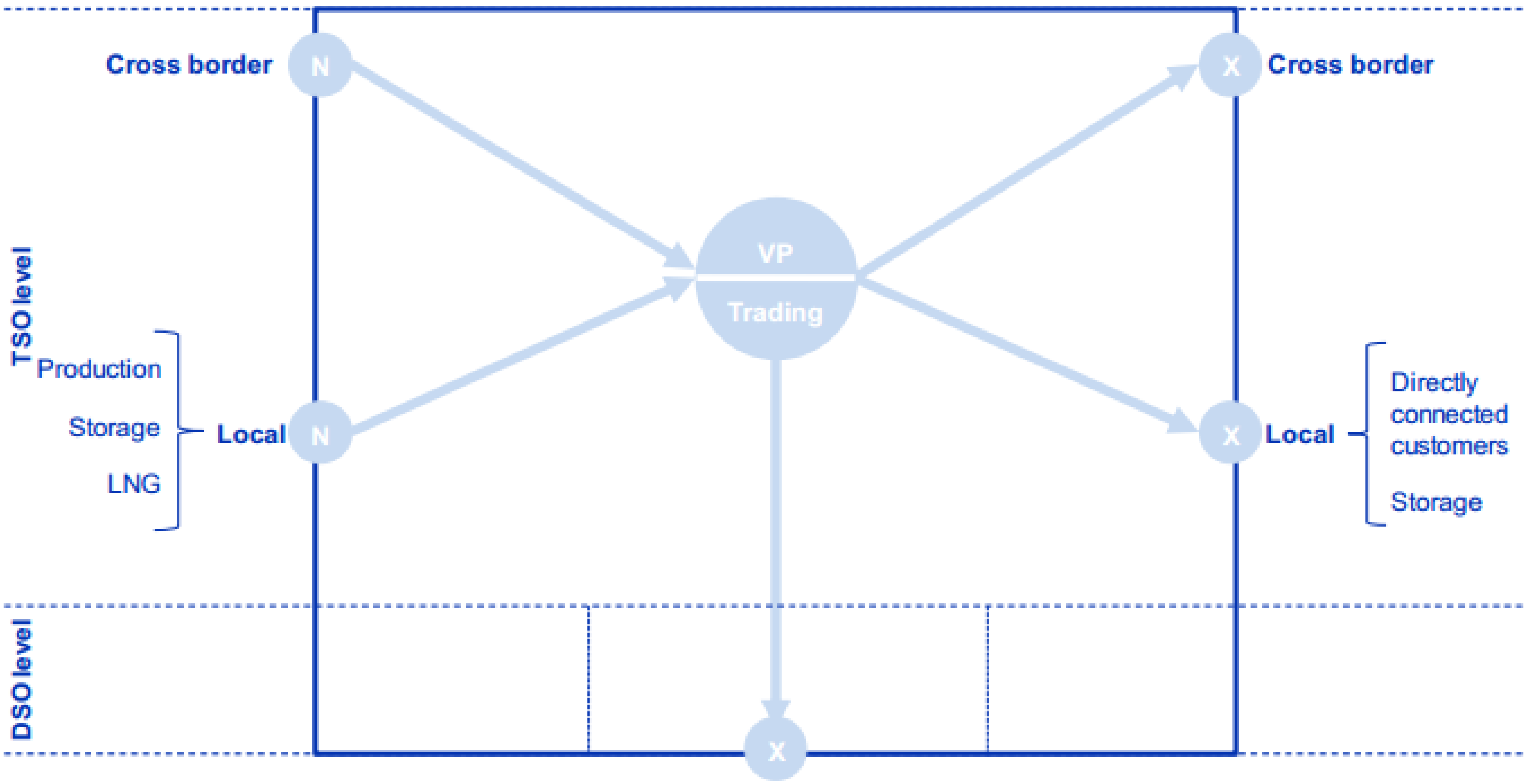
- Distance-based
- Entry-exit
- Point-to-point

Distance-based

Unit: $/1000m3/100km

Entry-exit

Units: €/MWh/d/y; €/m3/h/d/y



Entry-exit

GERMANY
NETHERLANDS
BELGIUM
LUX.
CZECH
AUSTRIA
AMSTERDAM
BERLIN
PRAGUE
Hamburg
Hannover
Kassel
Leipzig
Dortmund
Essen
Düsseldorf
Münster
Stuttgart
Karlsruhe
München
Salzburg
Linz
Basel
Zürich
Lindau
Rotterdam
Groningen
Greifswald
Szczecin
Guben
Gubin
TTF
VHP-GASPOOL
VHP NCG
ZTP-H
VOB
CEGH
Rehden
Ahlten
Steinitz
Rückersdorf
Waidhaus
Oberkappel
Wallbach
Lampertheim
Remich
Emsbüren
Oldenburg
Bunde
Julianadorp
Zevenaar
Winterswijk
Tegelen
Haanrade
Deutschneudorf
Brandov
Mallnow
Quarnstedt
Haiming 2-7F
Haidach
Überackern
Thayngen
Fallentor
Medelsheim
Obergailbach
Gernsheim
Kiefersfelden
Pfronten

Point-to-point

Units: €/MWh/d/y; €/m3/h/d/y