Oil & Gas from Shale?

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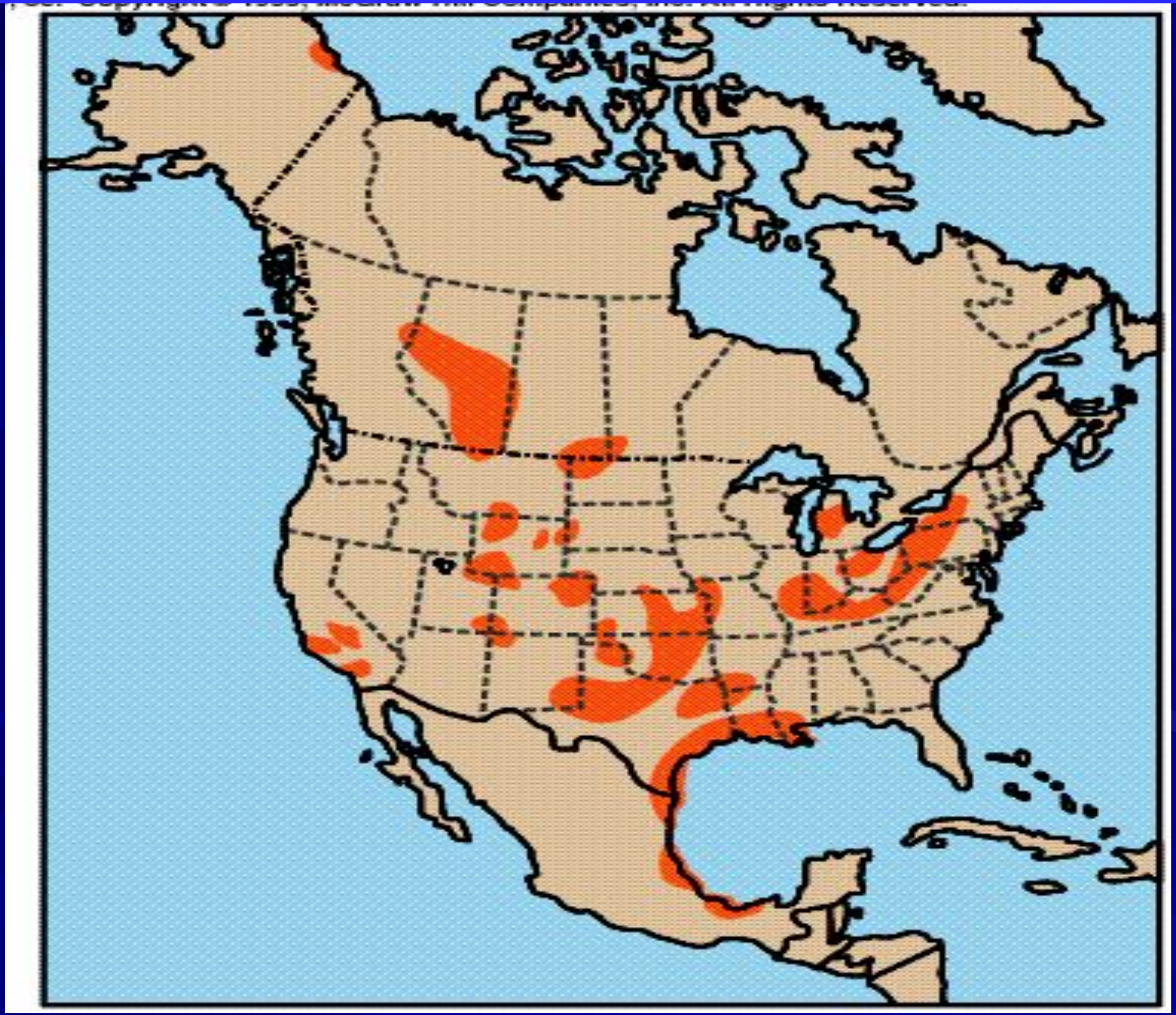
Cruces Atmospheric Sciences Forum
15 Feb 2020

Why?
How?
Risk?
Pro – Con?

Conventional Petroleum



Factors required to make a conventional petroleum deposit

- Source rock – shale rich in organic matter
- Burial & heating – maturation
- Reservoir Rock
  - Porous
  - Permeable
- Trap – Sealed closure
  - Structural trap
  - Stratigraphic trap

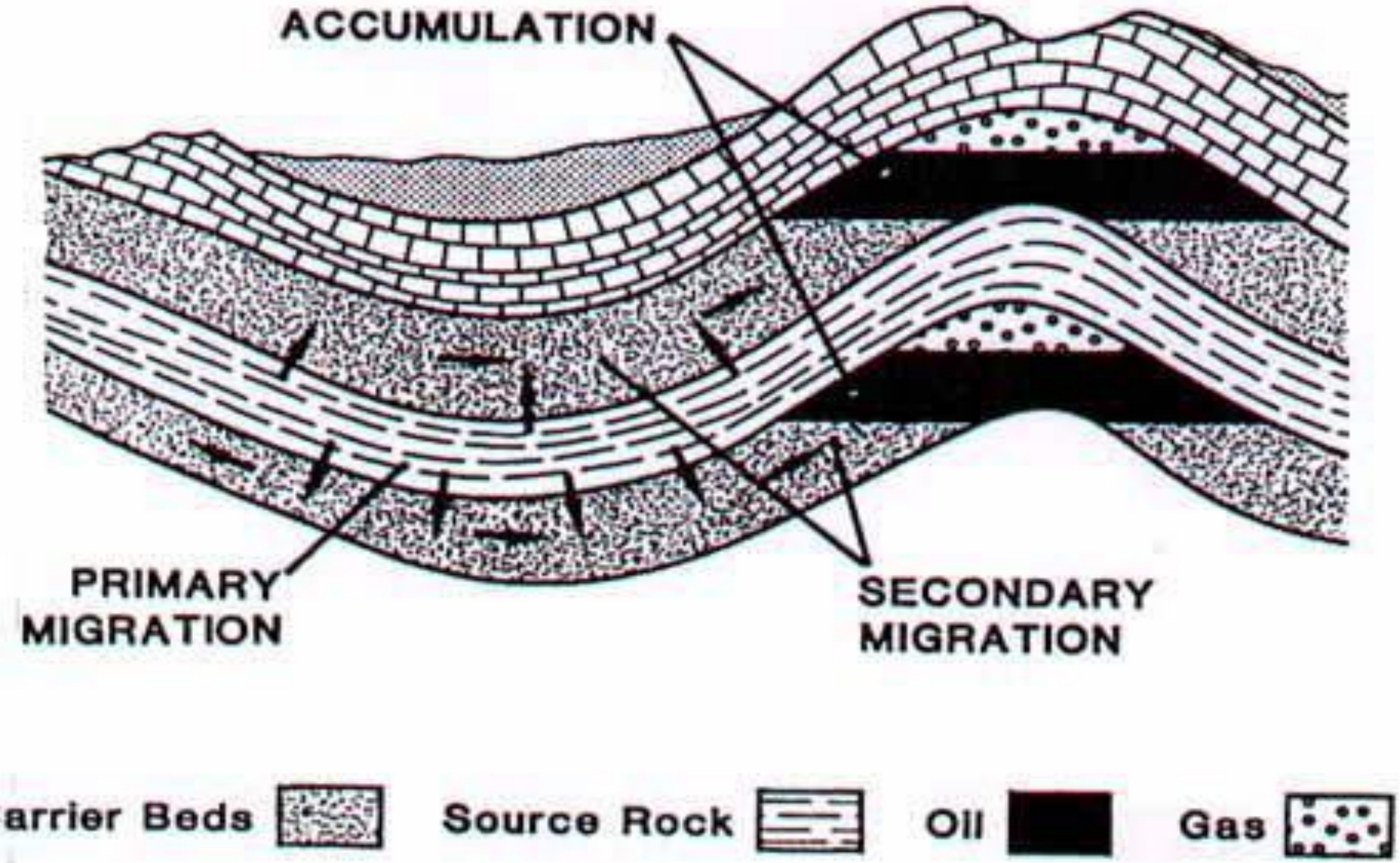
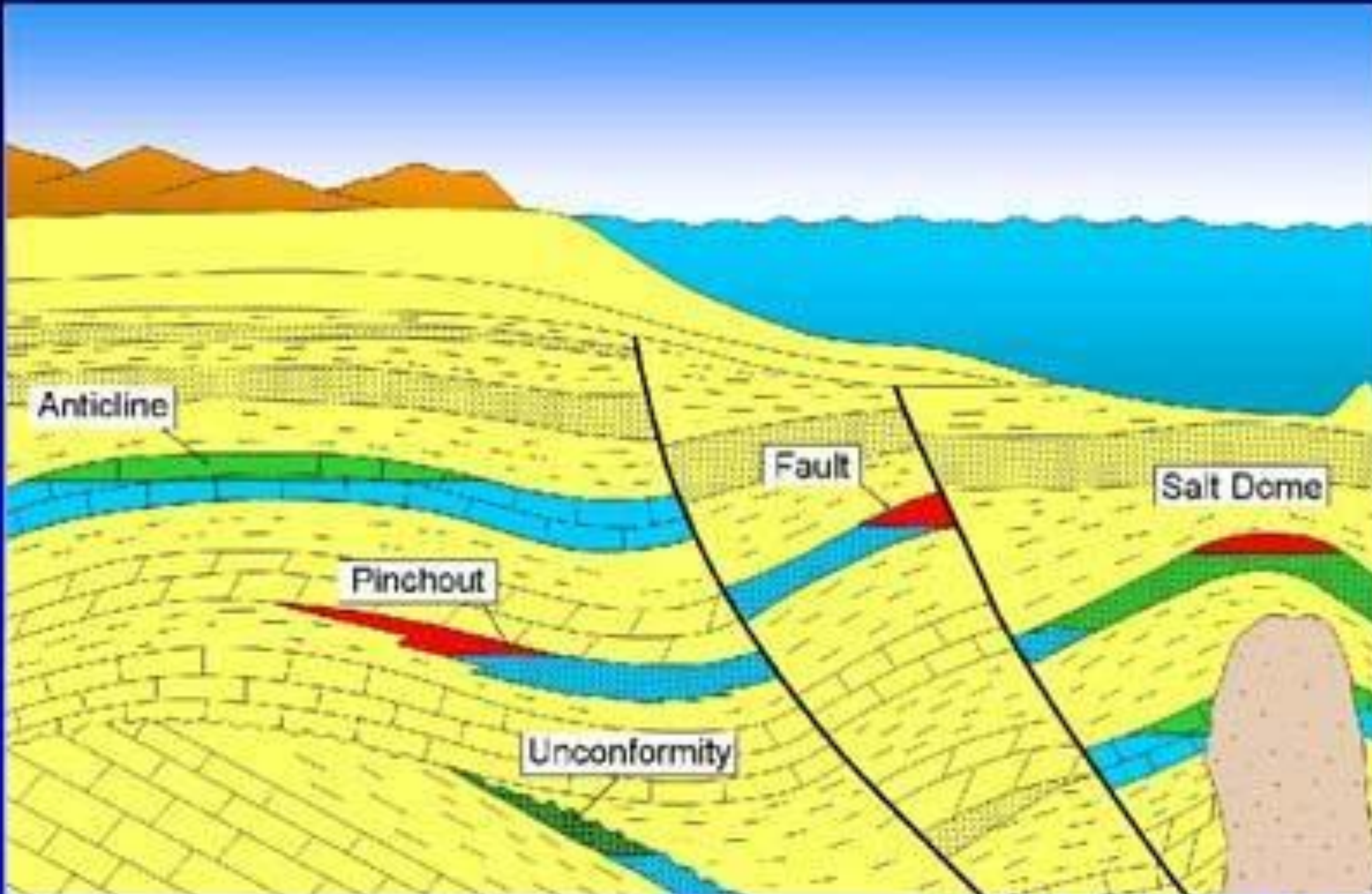


Figure 1. Definitions of primary and secondary migration. (After Tissot and Welte, 1984.)

Hydrocarbon Trap Types



JMA

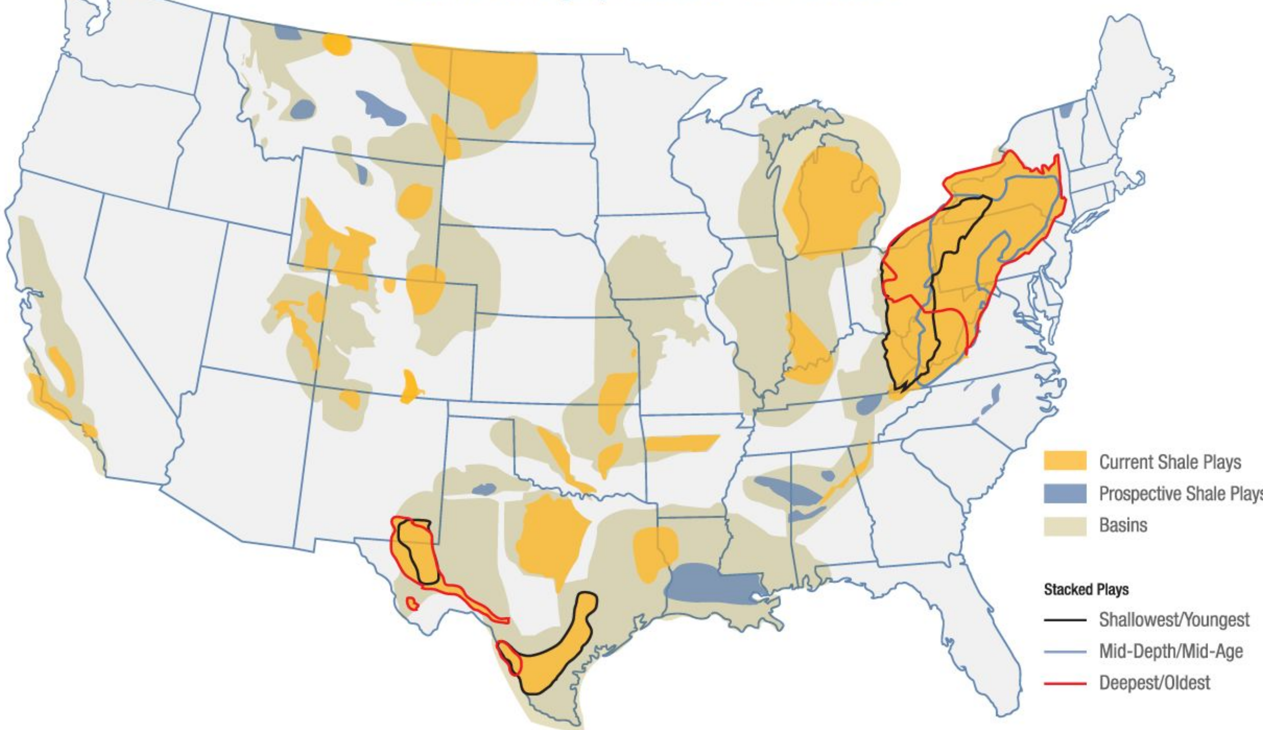
American Petroleum Institute, 1986

Petroleum from Shale

Natural gas and oil are trapped within shale formations.

Hydraulic fracturing enables the production of natural gas and oil from rock formations deep below the earth's surface.

Shale Plays, Lower 48 States



Source: EIA, based on data from various published studies. Update: May 9, 2011.

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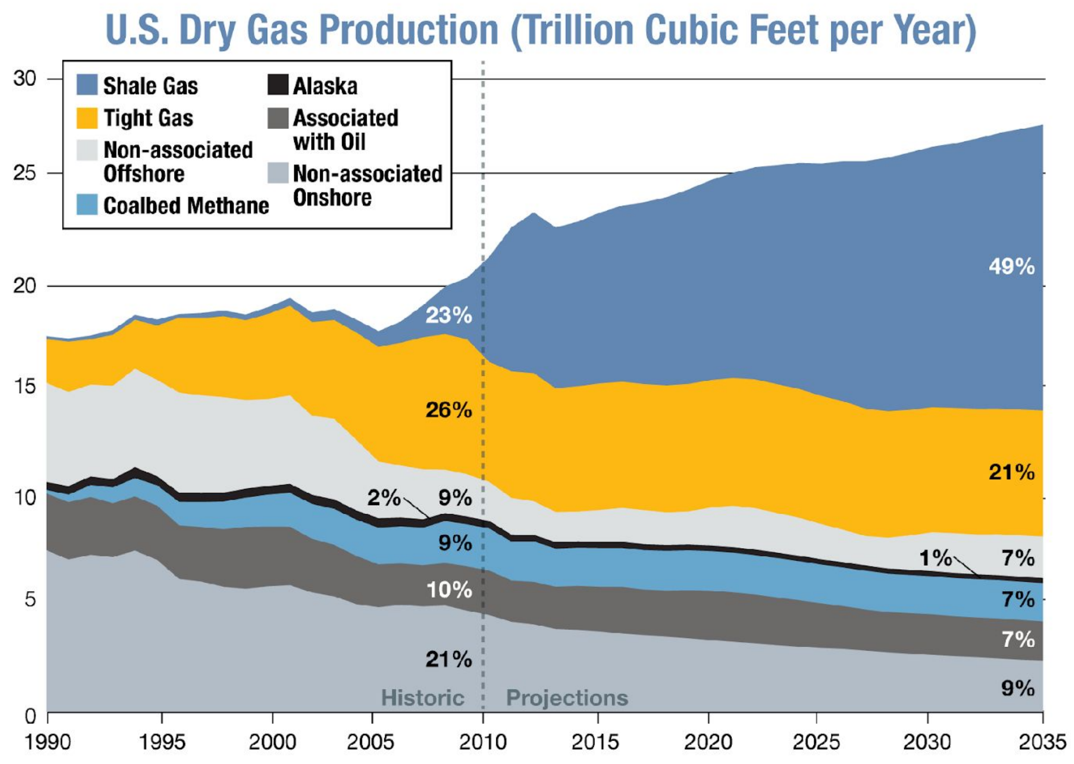


Source: EIA, *Annual Energy Outlook 2012 Early Release*

Hydraulic fracturing will account for 70 percent of natural gas development in the future.[1]

Hydraulic fracturing and horizontal drilling technology make it commercially viable to recover natural gas and oil. Without these advanced technologies, we would lose 45 percent of domestic natural gas production and 17 percent of our oil production within 5 years.[2]

[1] National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," September 15, 2011.

[2] IHS Global Insight, Measuring the Economic and Energy Impacts of Proposals to Regulate Hydraulic Fracturing, 2009.

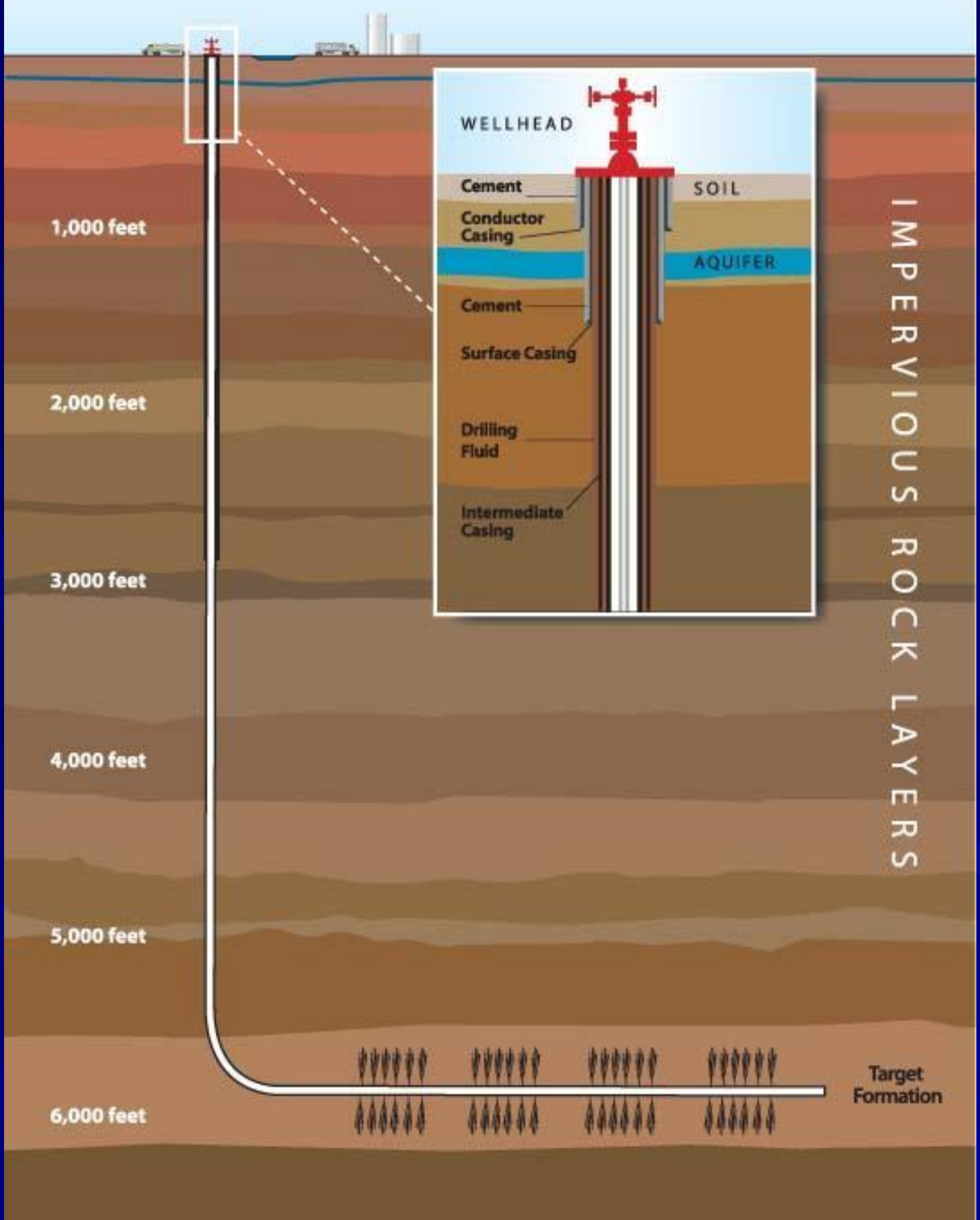
Some Shale Resource History

- 1922 Union Oil Company acquired fee minerals CO & UT
  - Researched recovery methods & built small retort plant in 1960's
  - With government subsidy built commercial mine, retort and upgrading facility at Parachute CO in 1980's

Some Fracturing History

- 1930's Service companies used nitroglycerin to stimulate well production
- 1940's and later some hydraulic fracturing was tried
- 1967 a 29 KT nuclear device was used at 4222 ft in NM to stimulate tight gas production
- 1990's Wells were drilled in coal seams and hydraulically fractured to produce coal bed methane and tight sand gas
- Late 1990's Horizontal drilling was developed and applied to shale development

Groundwater Protection through Proper Well Construction

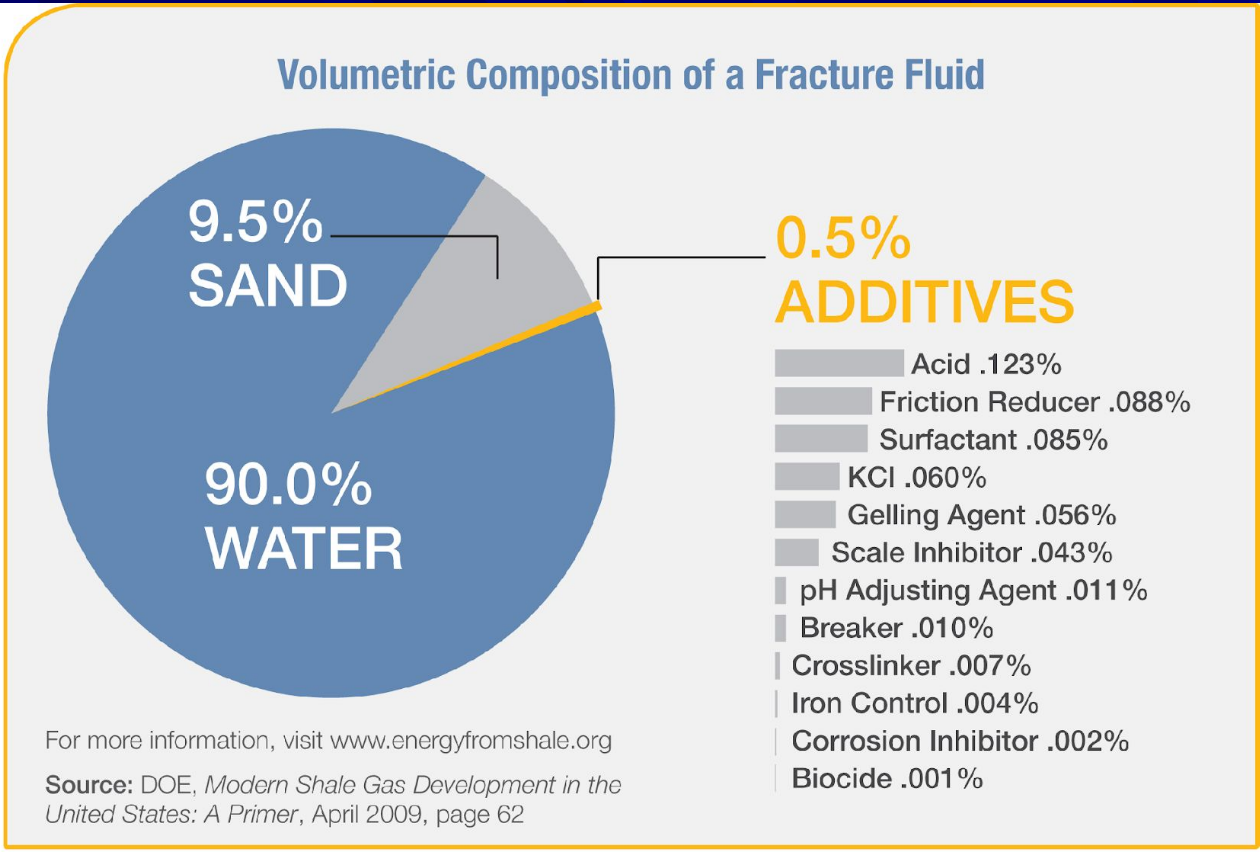


Hydraulic Fracturing Equipment

- Fluid storage tanks
- Proppant transports
- Blending equipment
- Pumping equipment
- Monitoring and control
  - Sensors
  - Data collection
  - Frac van

The contents of fracturing fluids are disclosed.

The typical fracturing fluid is 90.0 percent water and 9.5 percent sand, with the rest being additives to aid well production. Through the efforts of the natural gas and oil industry to promote transparency, companies now voluntarily disclose the contents of fluids on FracFocus.org, run by the Groundwater Protection Council.



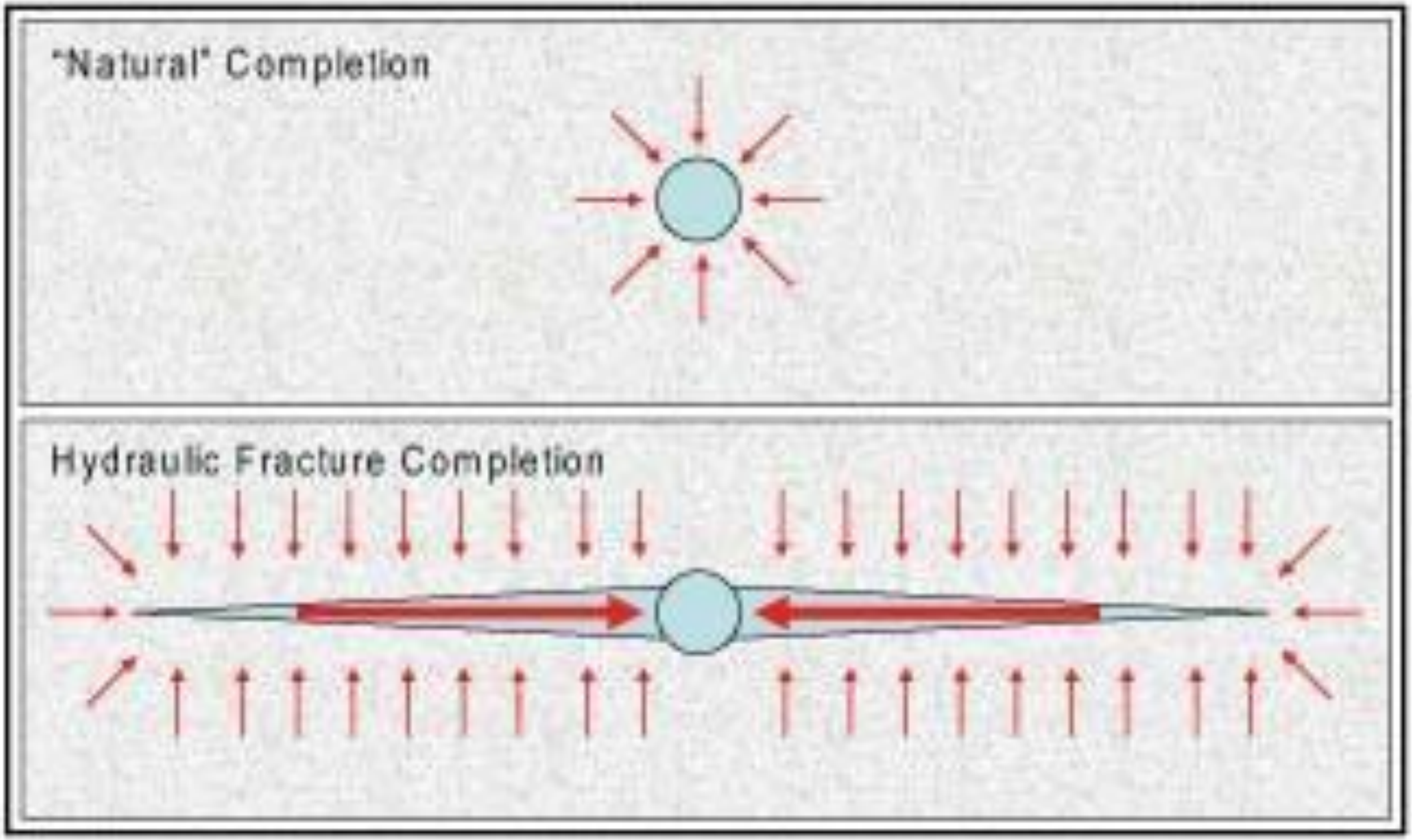
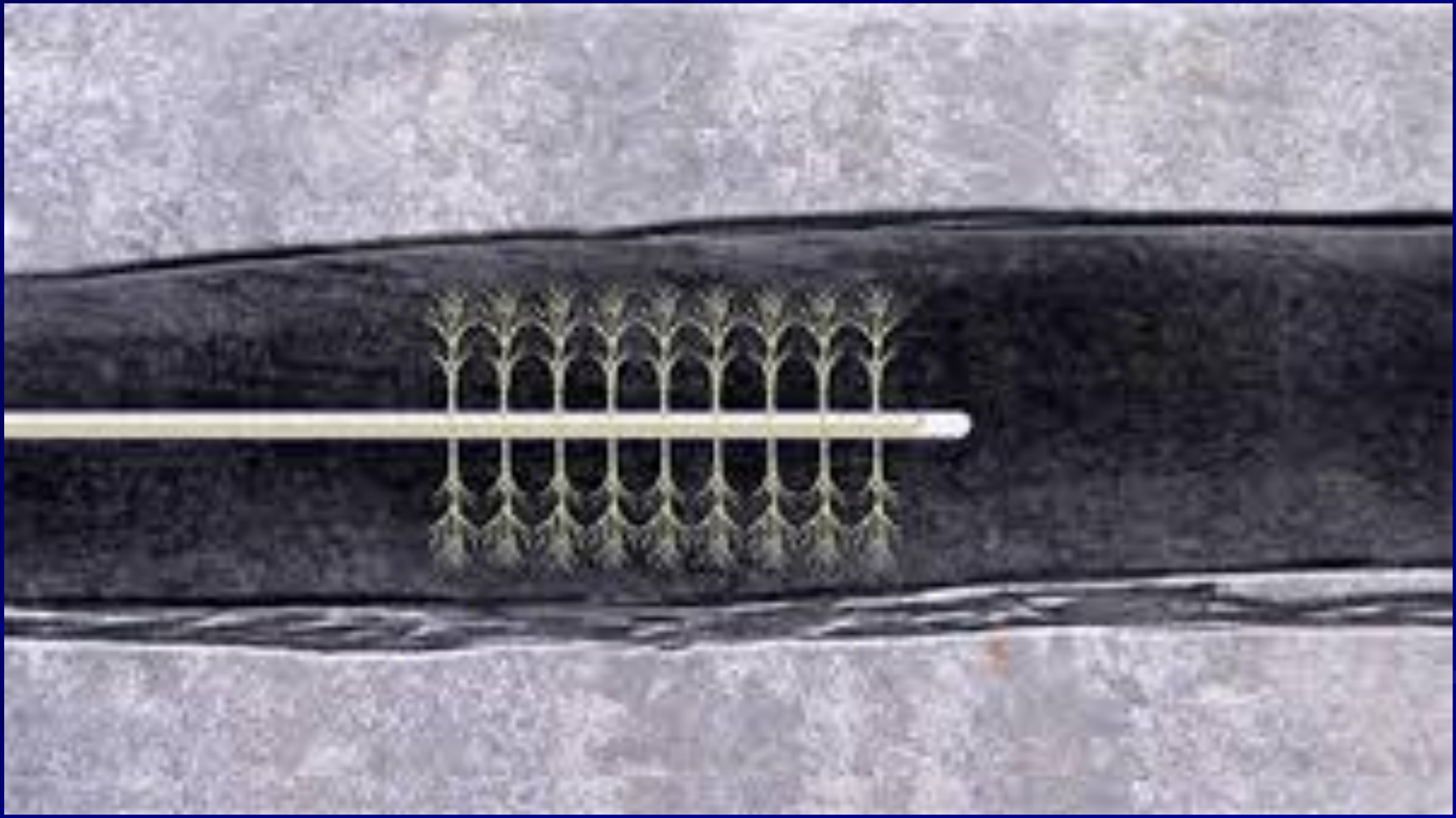
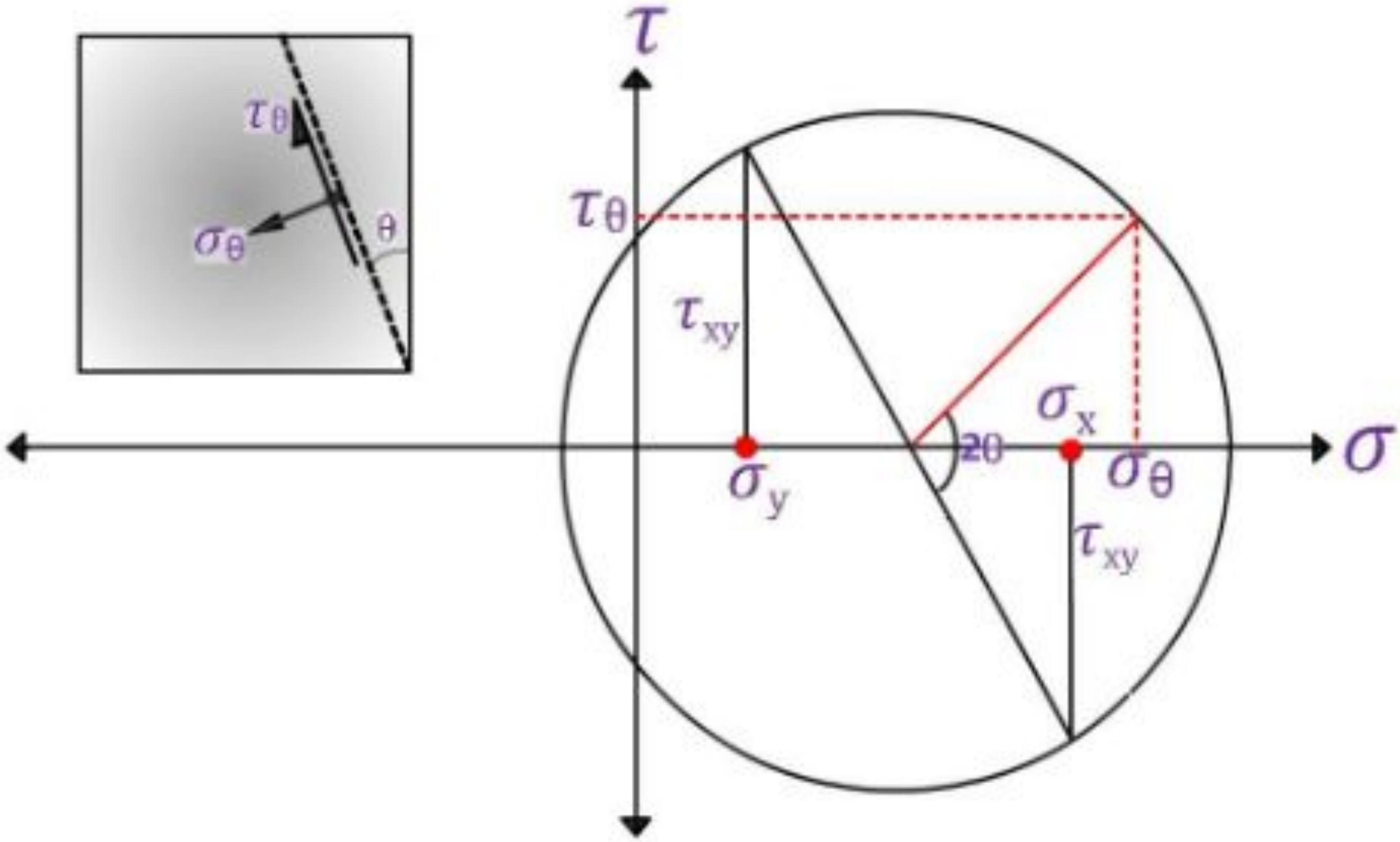


Figure 5—Illustration of a Fractured and a Nonfractured Well

Fracture Geometry ?





Mohr’s Circle

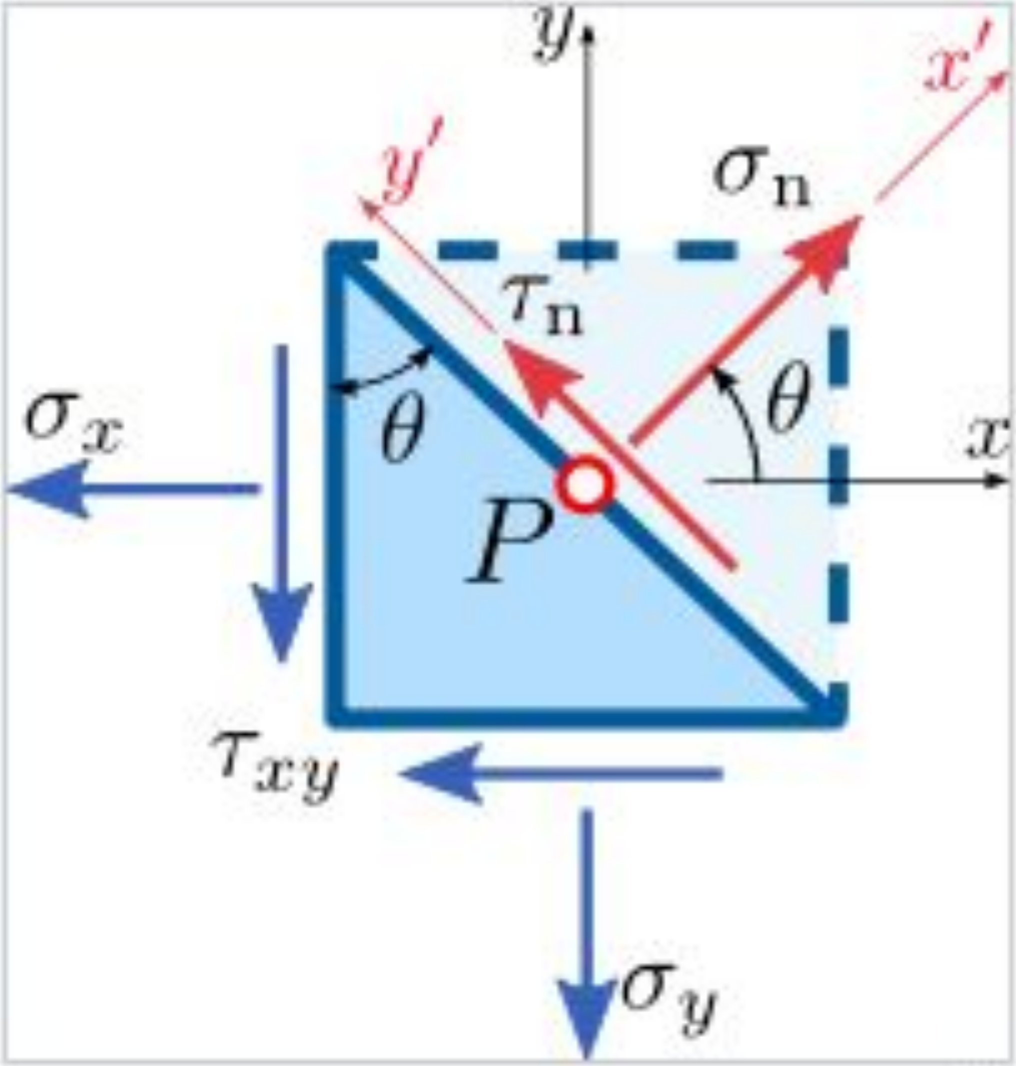


Figure 4. Stress components at a plane passing through a point in a continuum under plane stress conditions.

Mohr’s Circle

Fractures at right angle to principle stress

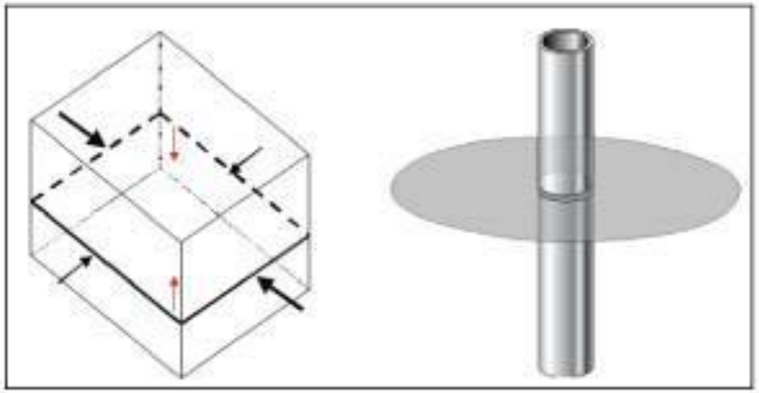
Maar eruptions

Kilbourne and Hunt Holes

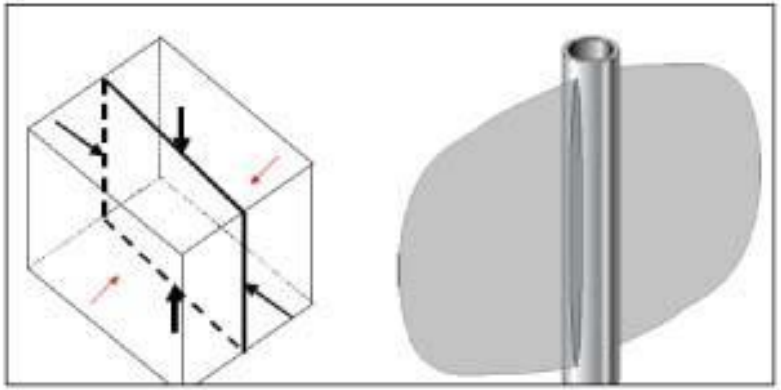
Mt. Taal

Hydraulic Fracturing

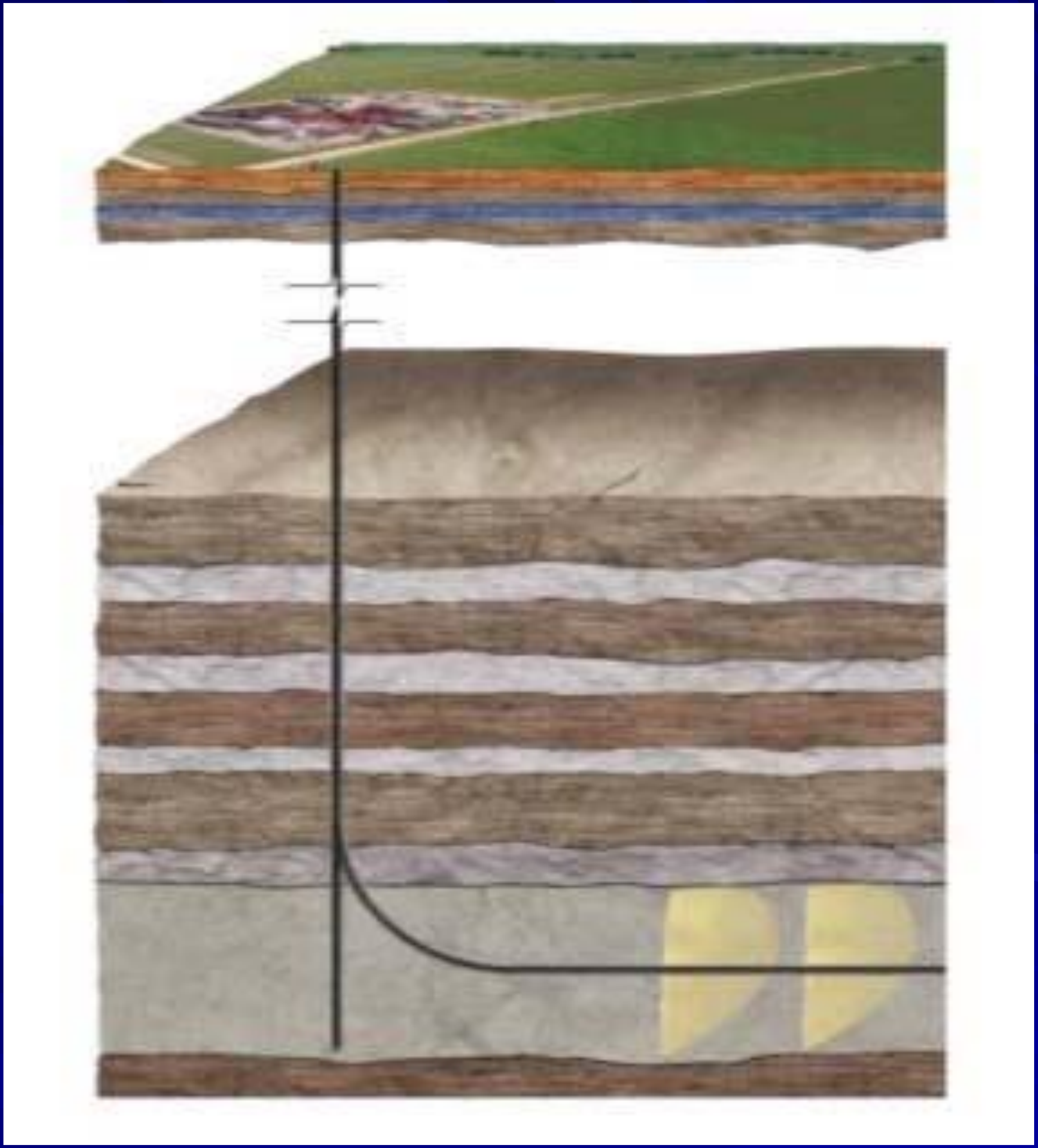
- Horizontal fractures
  - May occur at depths less than 2,000 ft
- Vertical fractures
  - Overburden stress increases with depth
  - Vertical stress becomes dominant



Least Principal Stress is in the Vertical Direction Resulting in a Horizontal Fracture



Least Principal Stress in the Horizontal Direction, Vertical Fracture

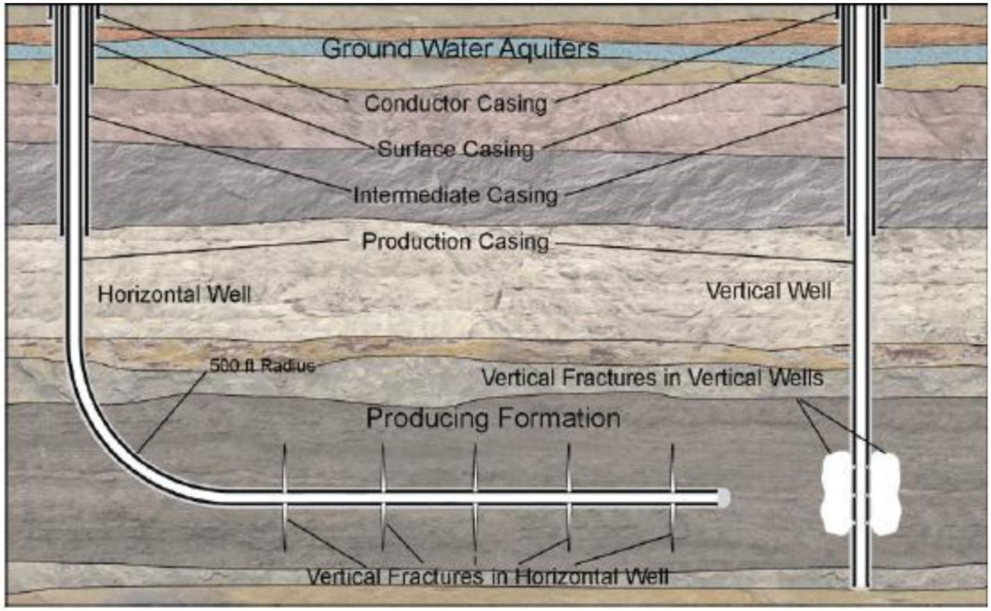


Well Construction Guidelines

Horizontal wells
- Improve performance
- Fewer wells for same resource

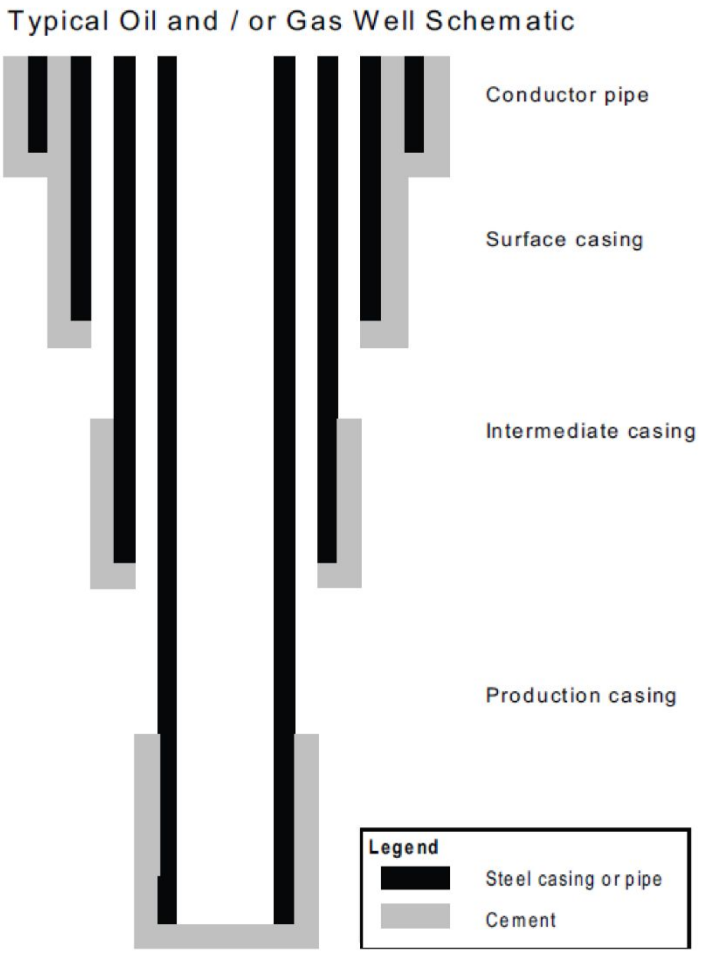
Well can still contain conductor, surface and intermediate casing strings

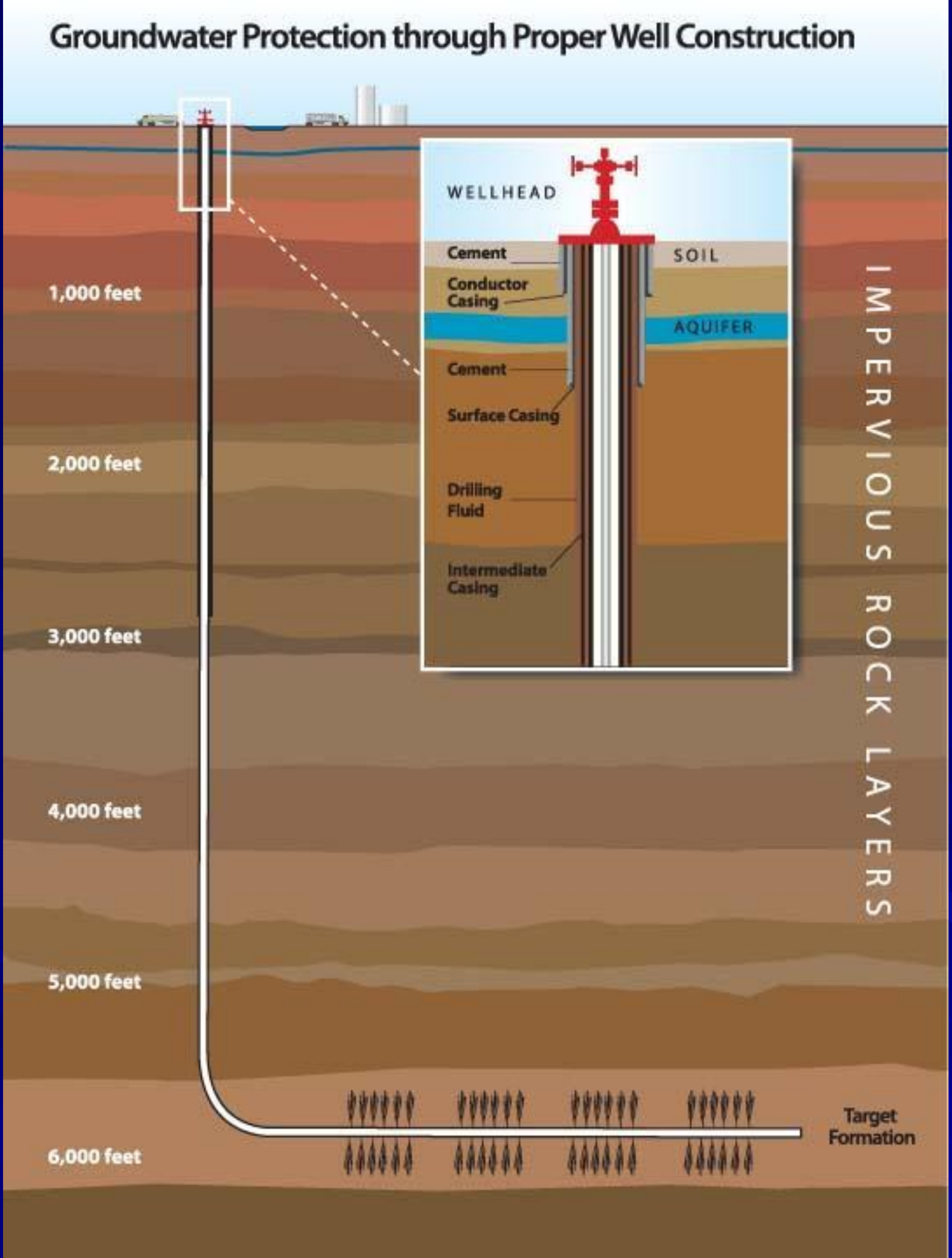
Production casing goal is the same as for a vertical well



General Principles

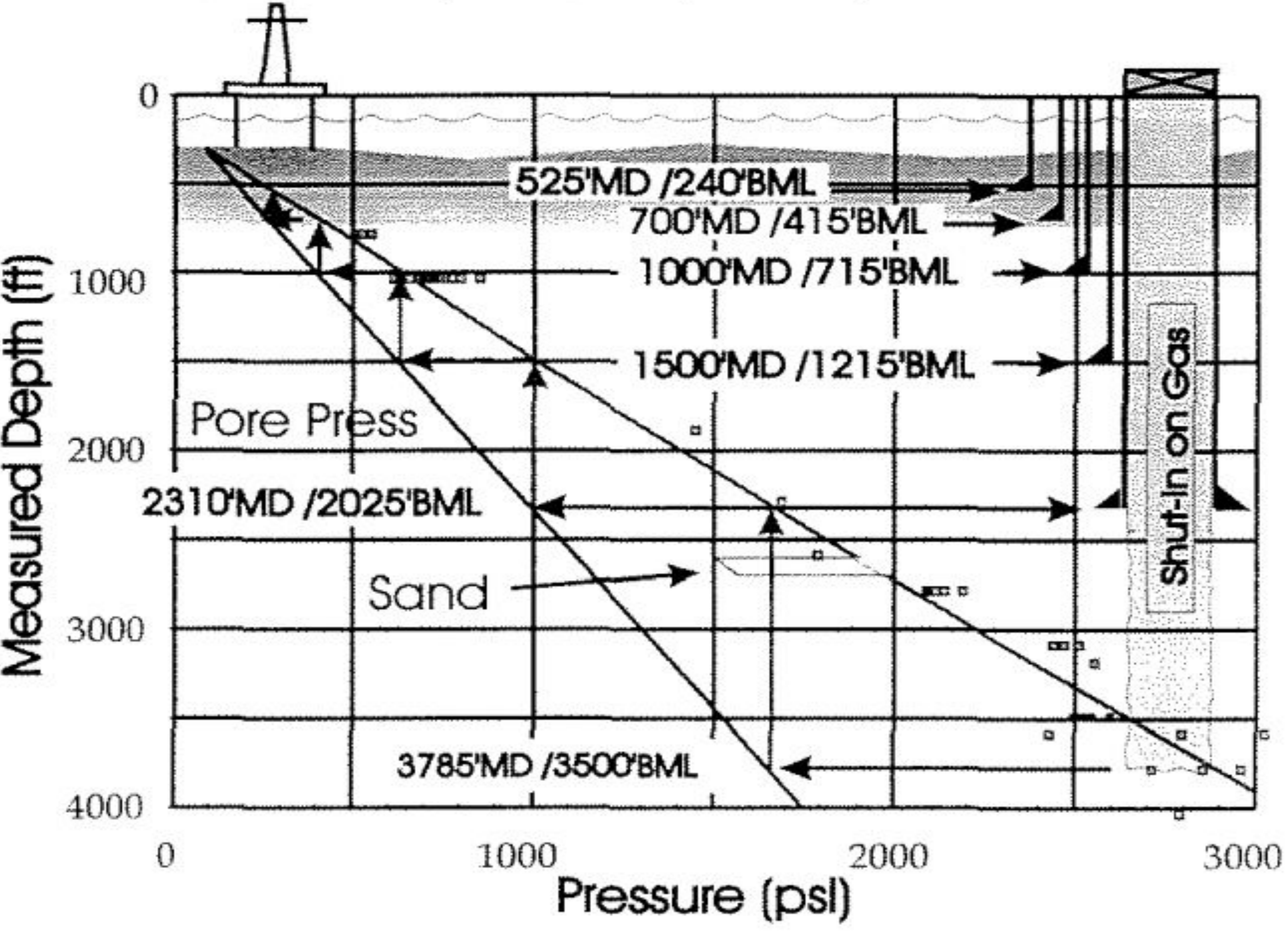
- Protect groundwater and the environment
  - Combination of steel casing and cement sheaths, mechanical isolation devices
- Well design and construction
  - Goal is to ensure environmentally sound, safe production of hydrocarbons
- Drilling and completion process
  - Cycles: drilling, running casing, cementing, perforating, fracturing, etc.





Groundwater Protection through Proper Well Construction
WELLHEAD
Cement
SOIL
Conductor Casing
AQUIFER
Cement
Surface Casing
Drilling Fluid
Intermediate Casing
IMPERVIOUS ROCK LAYERS
1,000 feet
2,000 feet
3,000 feet
4,000 feet
5,000 feet
6,000 feet
Target Formation

Figure 14 - Example design for gas filled open hole section



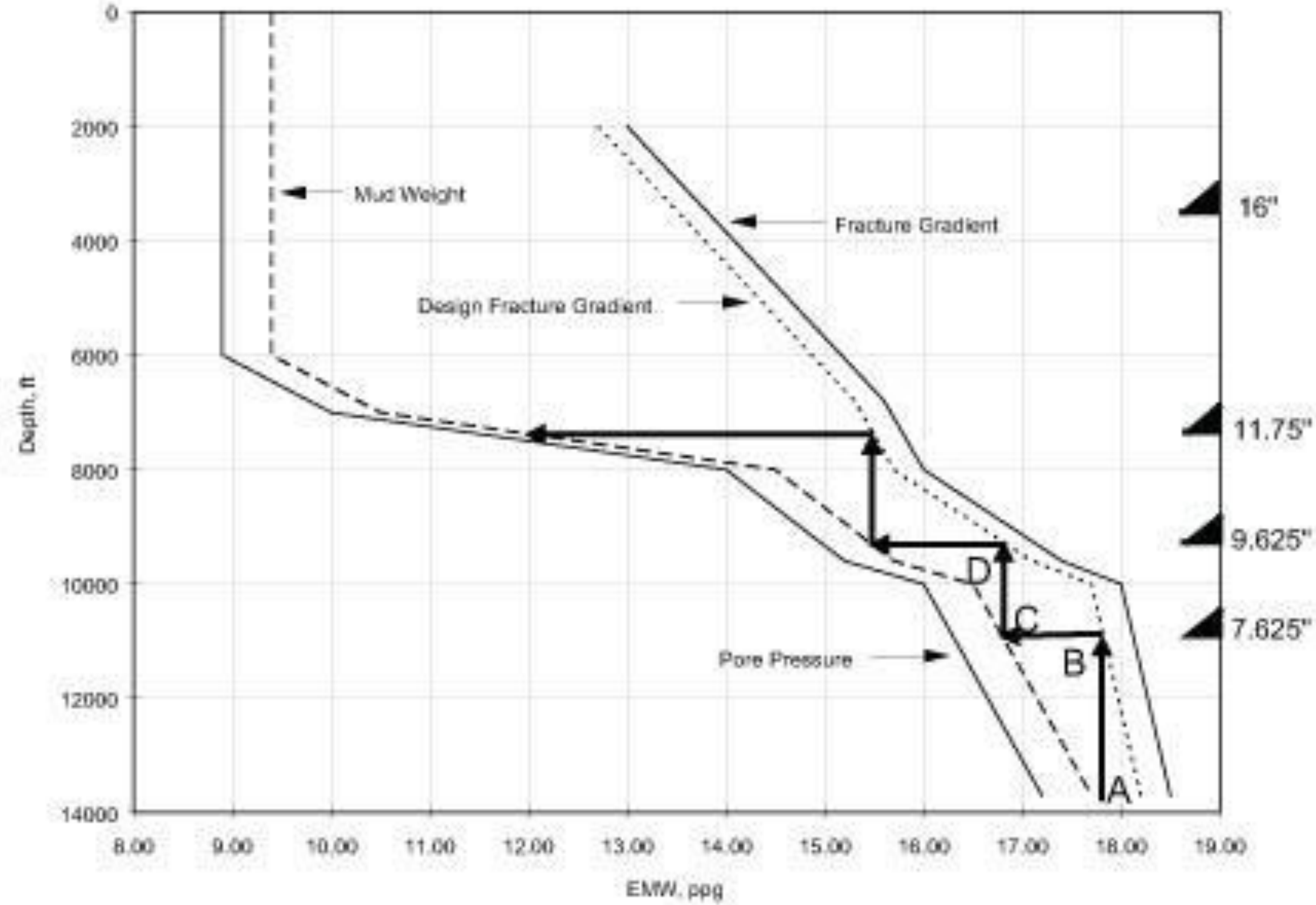


Figure B.1—Casing Shoe Depths with Pore Pressure/Fracture Gradient Graph

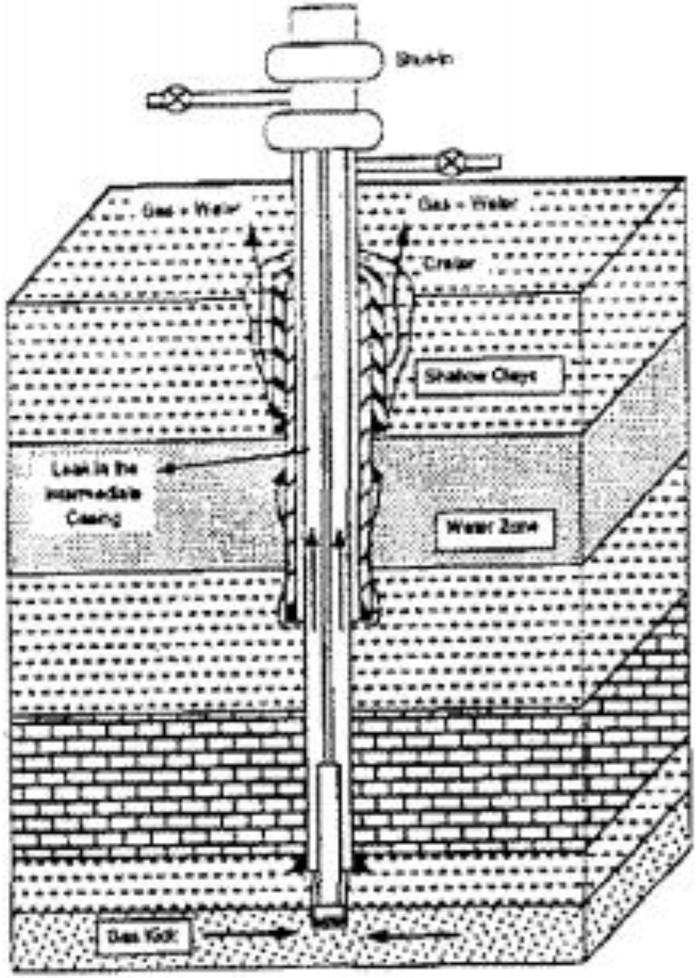


Figure 1 - Schematic of Example Well Configuration used in Borehole Erosion Simulation.

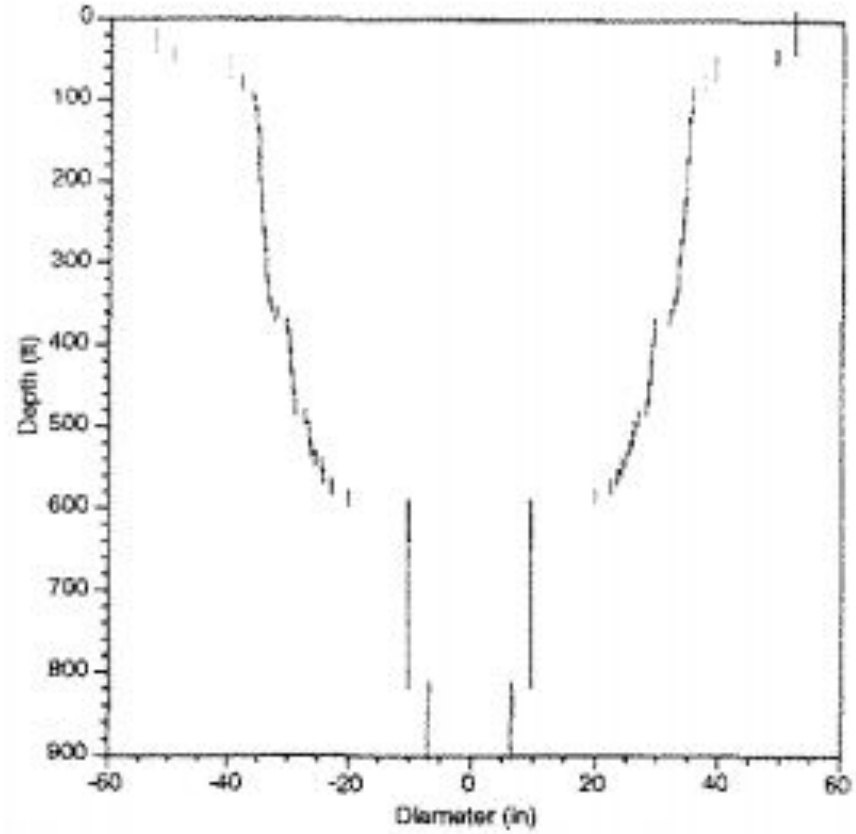


Figure 2 - Calculated Crater Profile due to Borehole Erosion after 5 days

Dod Cuadras Field

Platform A Blowout

1969

Ixtok I Blowout 1979
Bay of Campeche

Resources to Protect

- Surface property
- Environment – land / water / air / flora / fauna
- Water Conservation
- Freshwater aquifers
- Other mineral resources e.g.
  - Coal (mines & methane wells)
  - Potash / salt (mines & solution extraction)
  - Uranium / Vanadium (mines & solution extraction)

Working through API's ANSI-accredited standards program, the industry has adopted standards and practices for continuous improvement, hundreds of which are referenced in state regulations thousands of times.

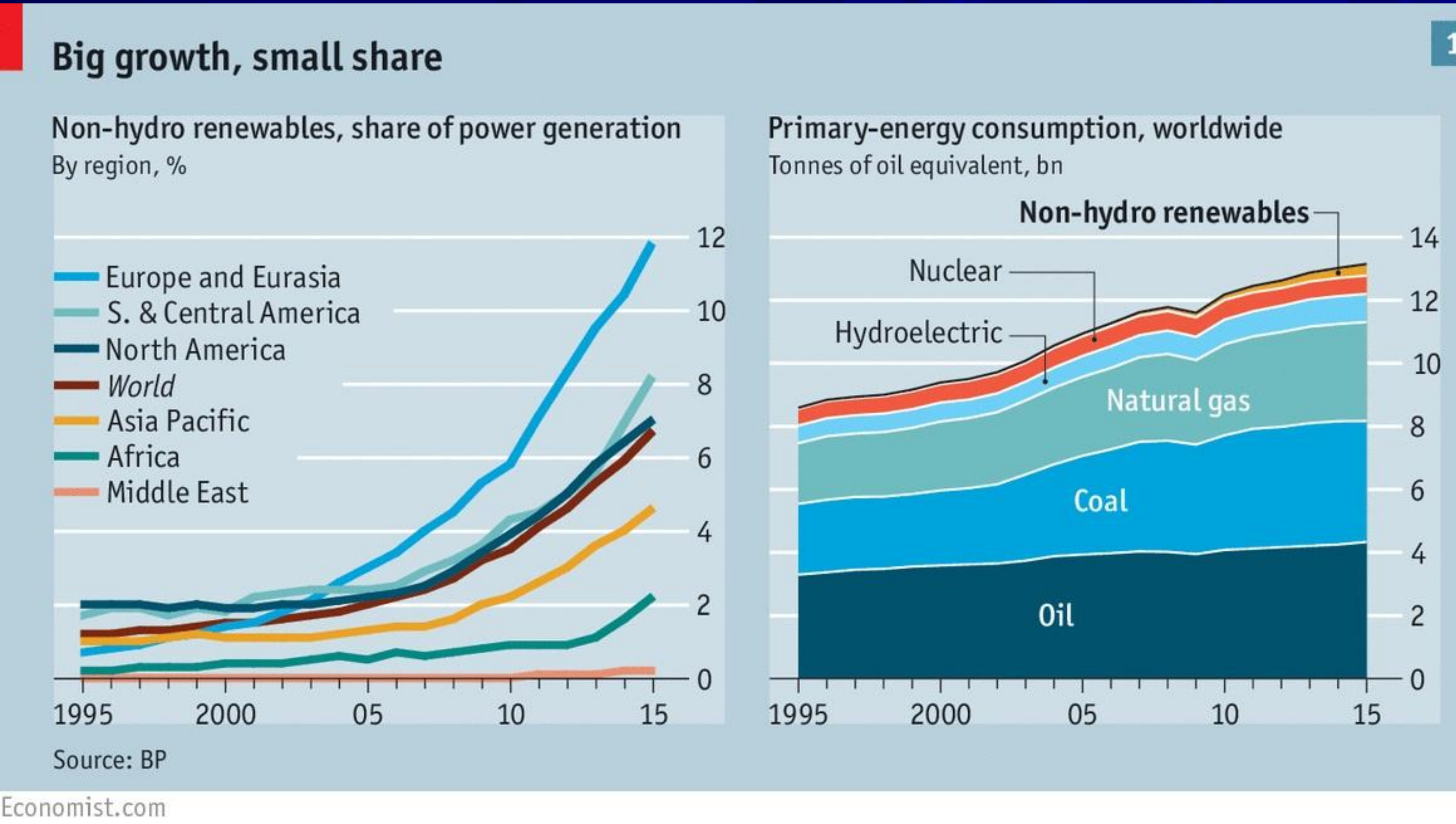
Several federal agencies, including the Environmental Protection Agency, the Bureau of Land Management, and the Occupational Safety and Health Administration, also cite API standards.

- **HF1** Well Construction and Integrity
- **HF2** Water Management
- **HF3** Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing
- **RP 51R** Environmental Protection for Onshore Oil and Gas Production Operations and Leases
- **STD 65-2** Isolating Potential Flow Zones During Well Construction

INDUSTRY PRACTICES

Pro – Con Spectrum

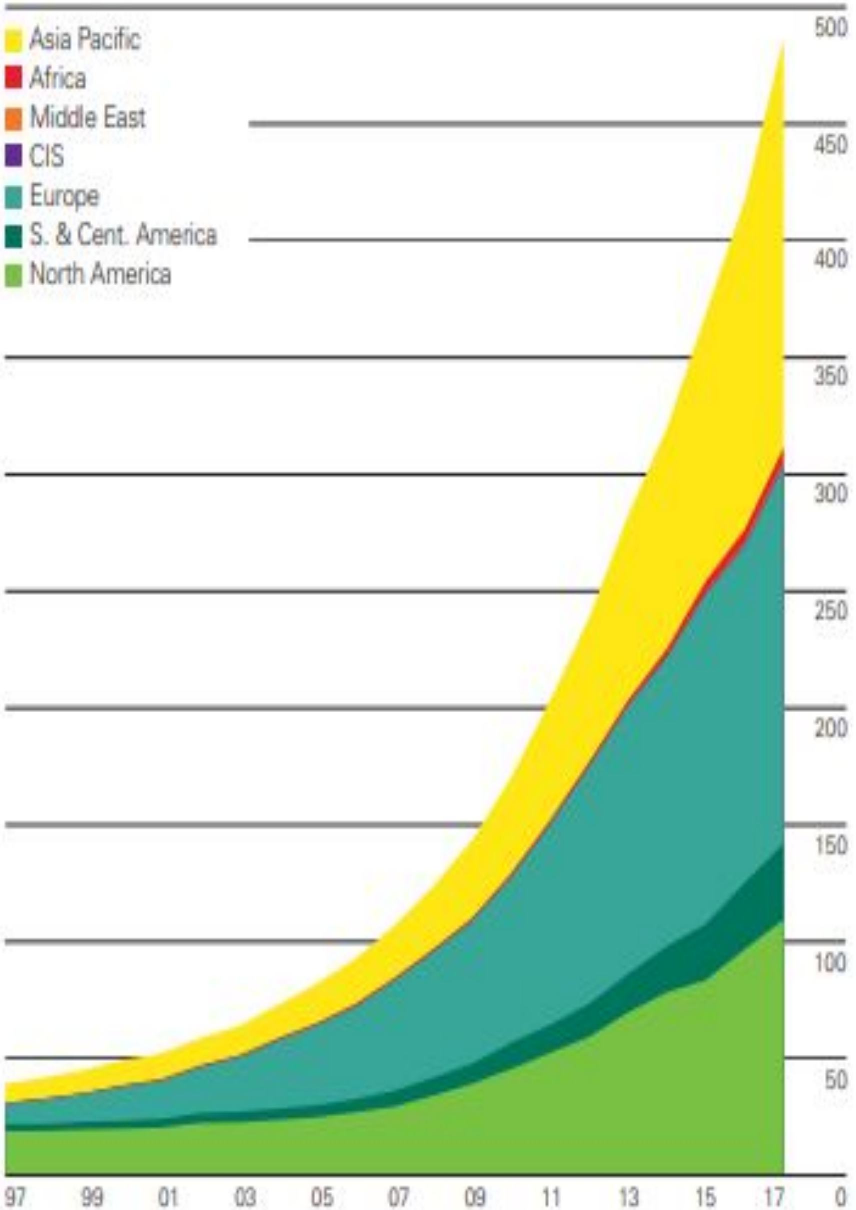
- Consumers
- Energy Exploration & Production Companies
- Fee mineral owners
  - Private
  - Public
- Service companies, e.g. Haliburton
- Community Stakeholders, e.g. Chambers of Commerce
- American Petroleum Institute / State OGA's
- Regulators (Federal, State, Local), e.g. EPA
- Environmental activist groups
- Food & Water Watch (advocates complete ban)



Big growth, small share
Non-hydro renewables, share of power generation
By region, %
Europe and Eurasia
S. & Central America
North America
World
Asia Pacific
Africa
Middle East
12
10
8
6
4
2
0
1995
2000
05
10
15
Primary-energy consumption, worldwide
Tonnes of oil equivalent, bn
Non-hydro renewables
Nuclear
Hydroelectric
Natural gas
Coal
Oil
14
12
10
8
6
4
2
0
1995
2000
05
10
15
Source: BP
Economist.com

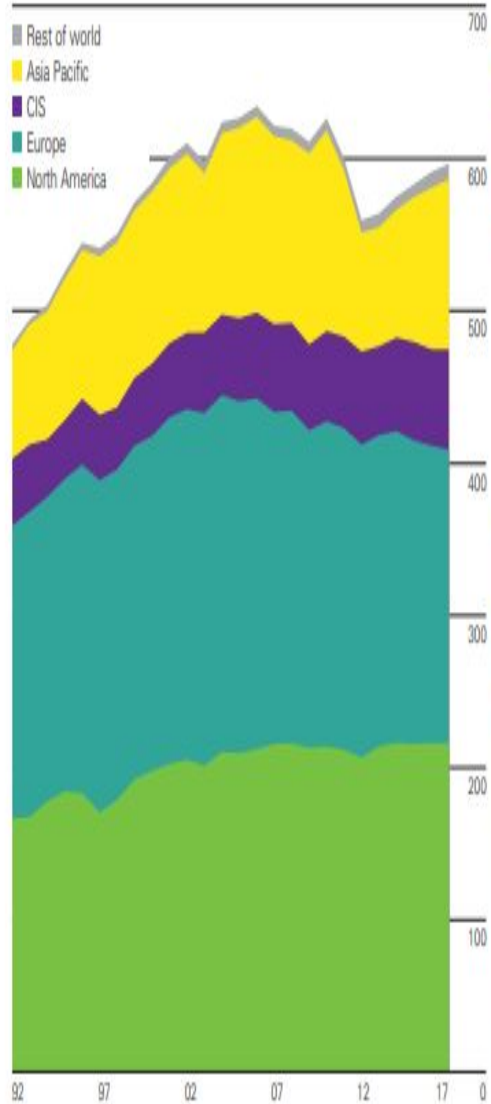
Other renewables consumption by region

Million tonnes oil equivalent



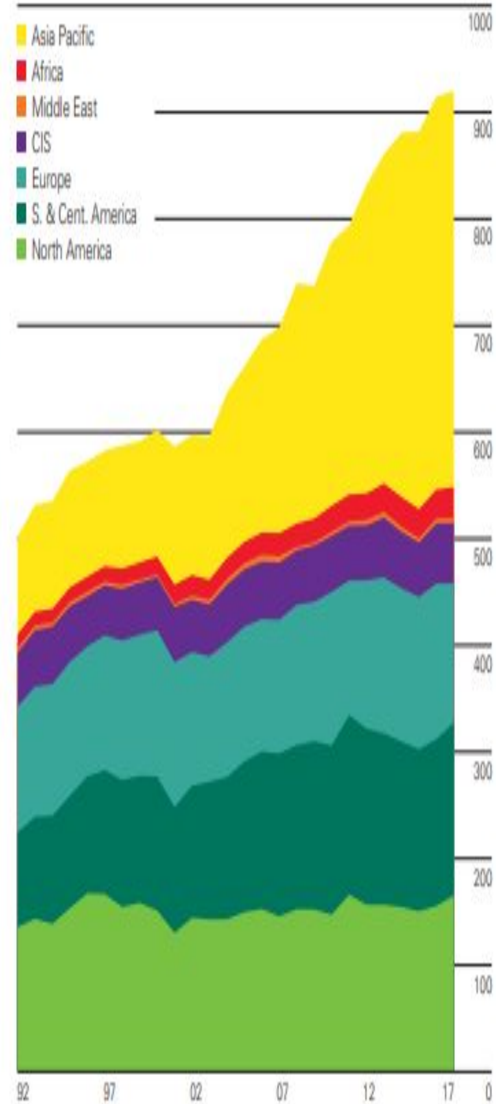
Nuclear energy consumption by region

Million tonnes oil equivalent



Hydroelectricity consumption by region

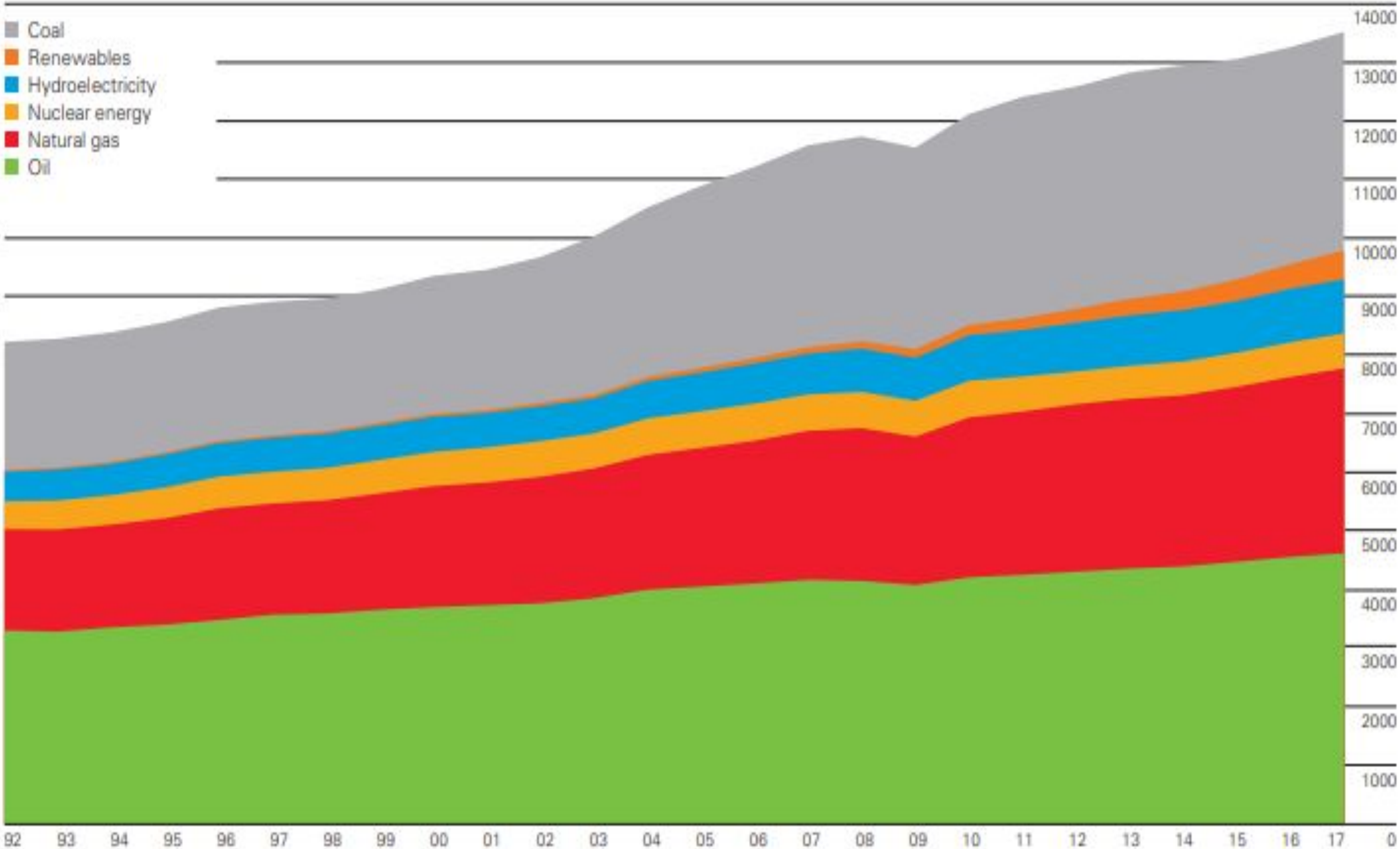
Million tonnes oil equivalent



Global nuclear generation rose by 5 million tonnes of oil equivalent (mtoe), or 1.1%, above the 10-year average growth rate of -0.7%. Growth in China (8 mtoe) and Japan (3 mtoe) was partially offset by declines in Europe (3 mtoe). World hydroelectric power generation rose by 5 mtoe, just 0.9%, compared with the 10-year average of 2.9%. The US (7 mtoe) provided the largest increment. China's growth was the slowest since 2011, while European output declined by 10.5% (-16 mtoe).

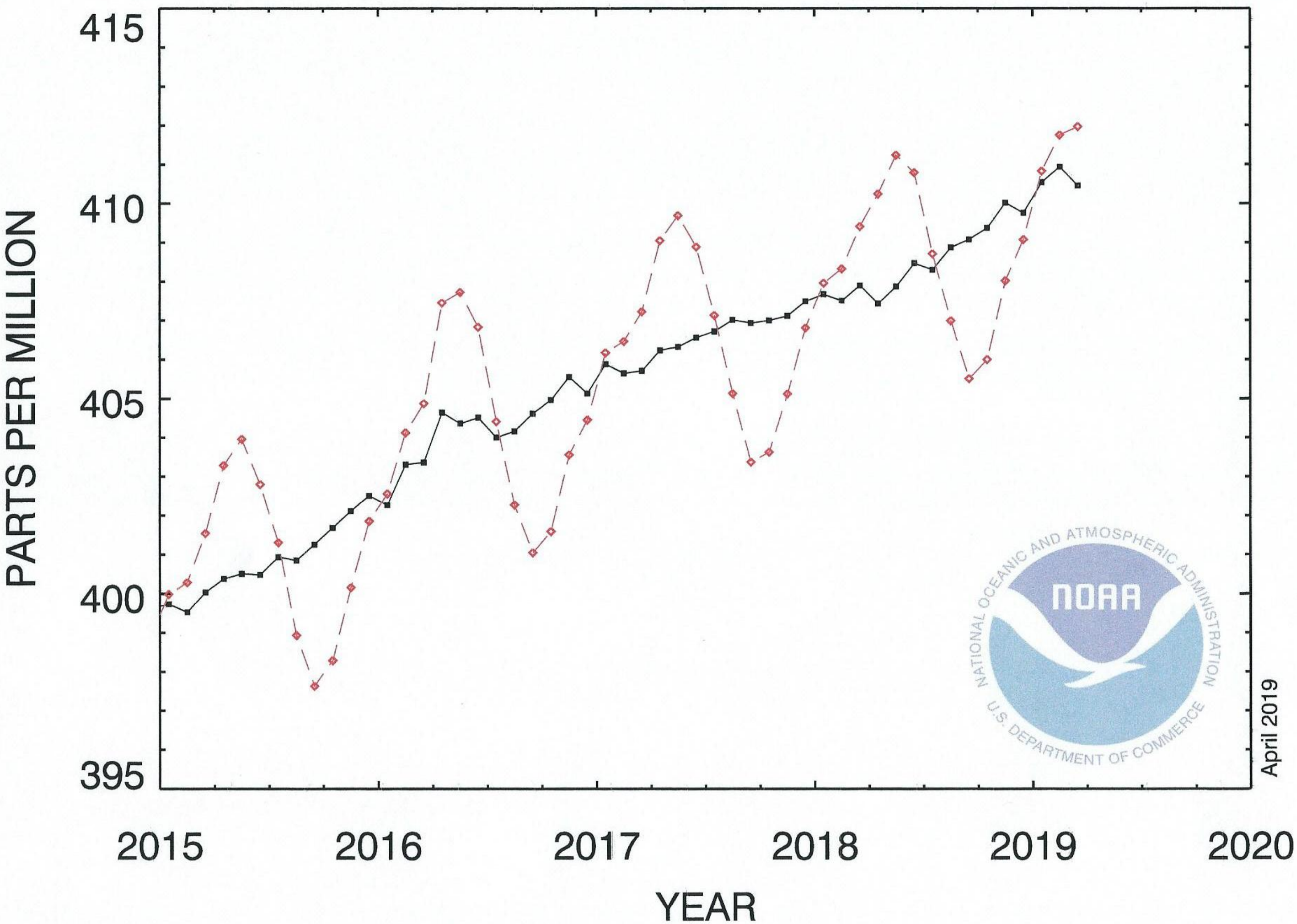
World consumption

Million tonnes oil equivalent



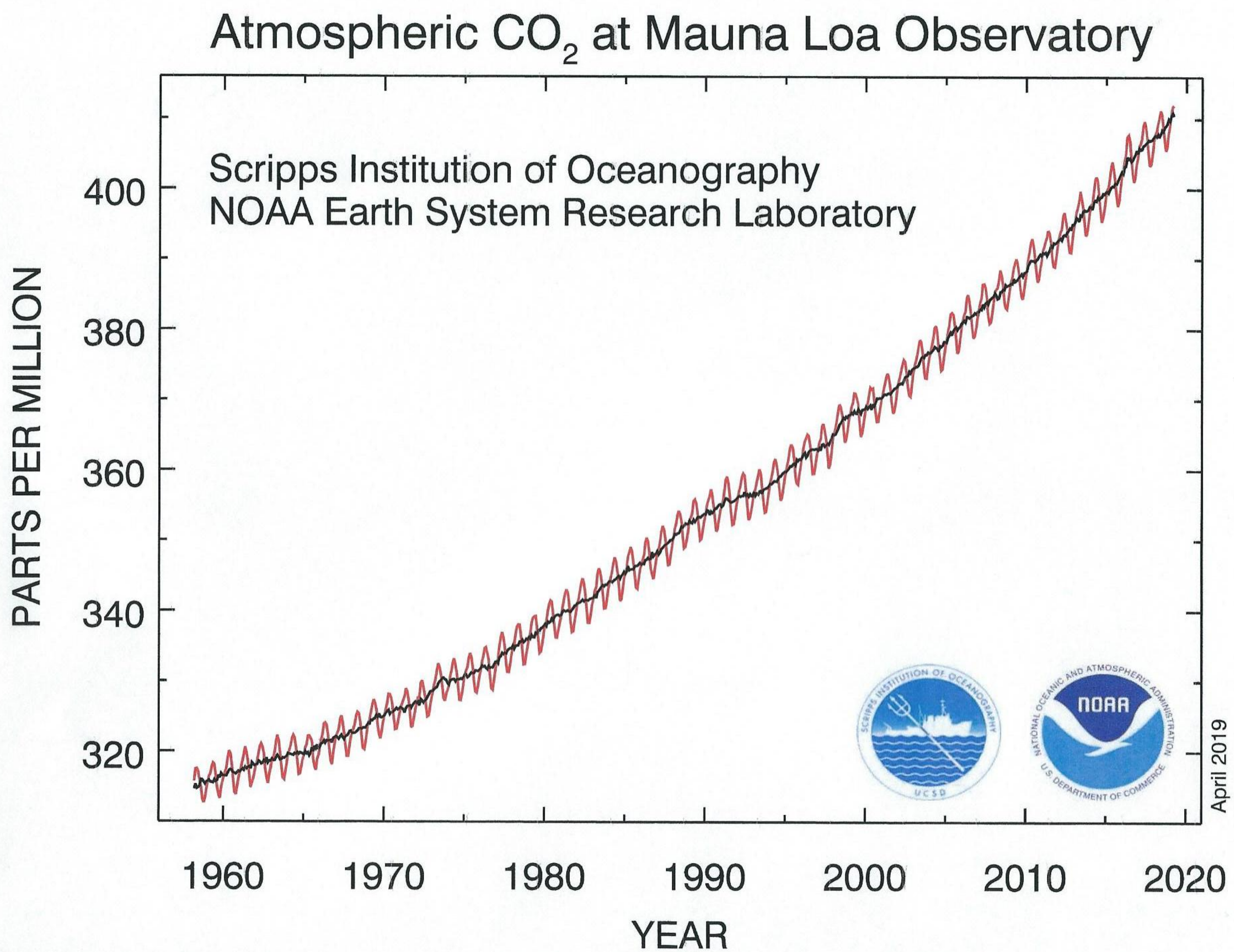
World primary energy consumption grew by 2.2% in 2017, up from 1.2% in 2016 and the highest since 2013. Growth was below average in Asia Pacific, the Middle East and S. & Cent. America but above average in other regions. All fuels except coal and hydroelectricity grew at above-average rates. Natural gas provided the largest increment to energy consumption at 83 million tonnes of oil equivalent (mtoe), followed by renewable power (69 mtoe) and oil (65 mtoe).

RECENT MONTHLY MEAN CO_2 AT MAUNA LOA



It's Alaska's summer sun that gives growers an edge, says Steve Brown, an agricultural agent at the University of Alaska Fairbanks who also serves on the fair's board of directors. Basking in as much as 20 hours of sunshine per day, Alaskan crops get a photosynthesis bonus, allowing them to produce more plant material and grow larger. Brassicas like cabbage do especially well, says Brown.

The extra sunlight also makes the produce sweeter. "People often try our carrots here, and they think we've put sugar on them," Brown says.



Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
YEAR
April 2019