The Awl Bidness

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The Oil Business

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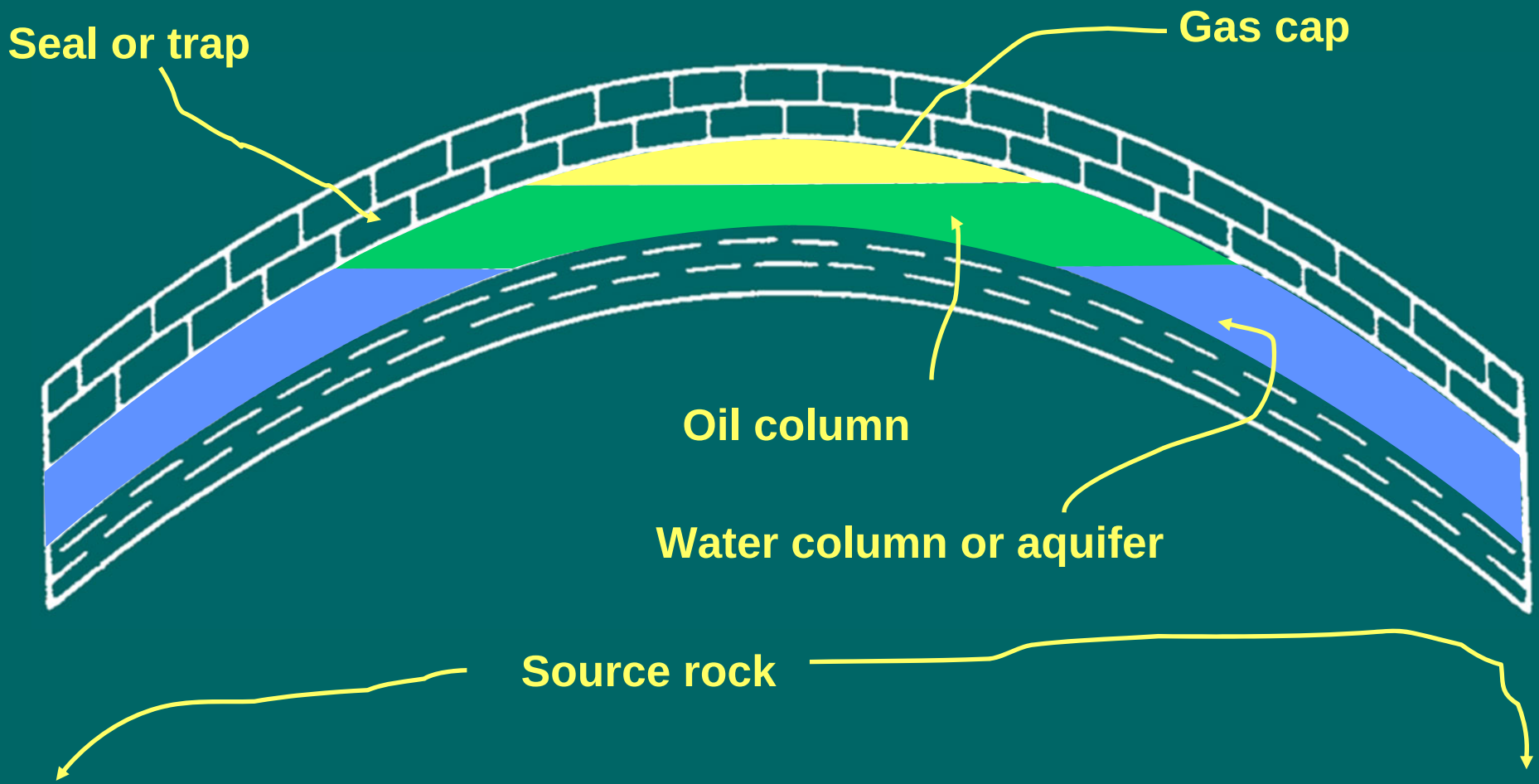
Upstream

- **Exploration**
- **Production**

Downstream

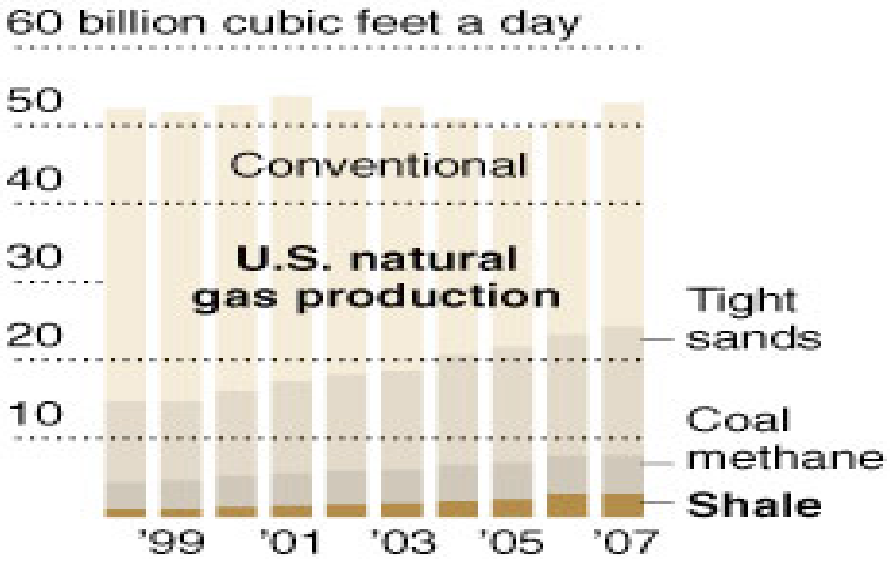
- **Refining**
- **Transportation**
- **Marketing**

Exploration…

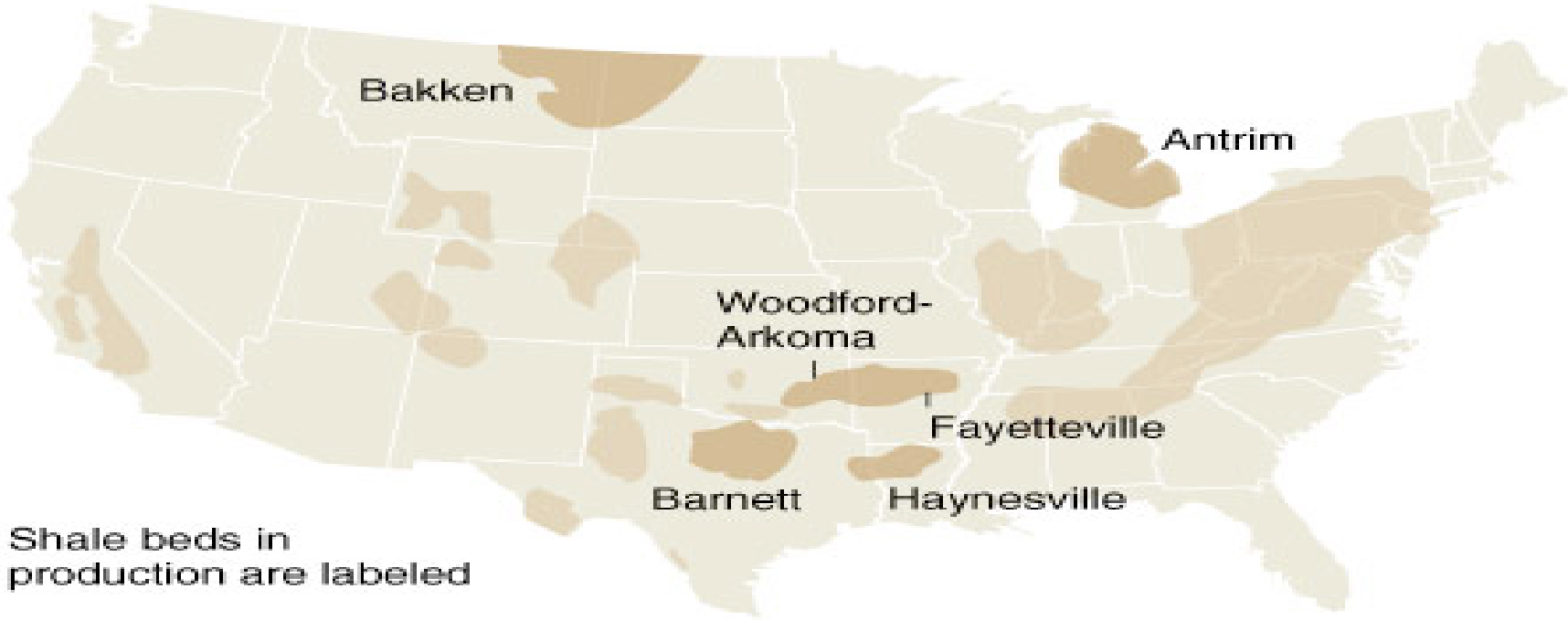


Tapping Into Shale

High prices for natural gas and new technology have allowed companies to tap shale gas, making it the fastest-rising source of new production.



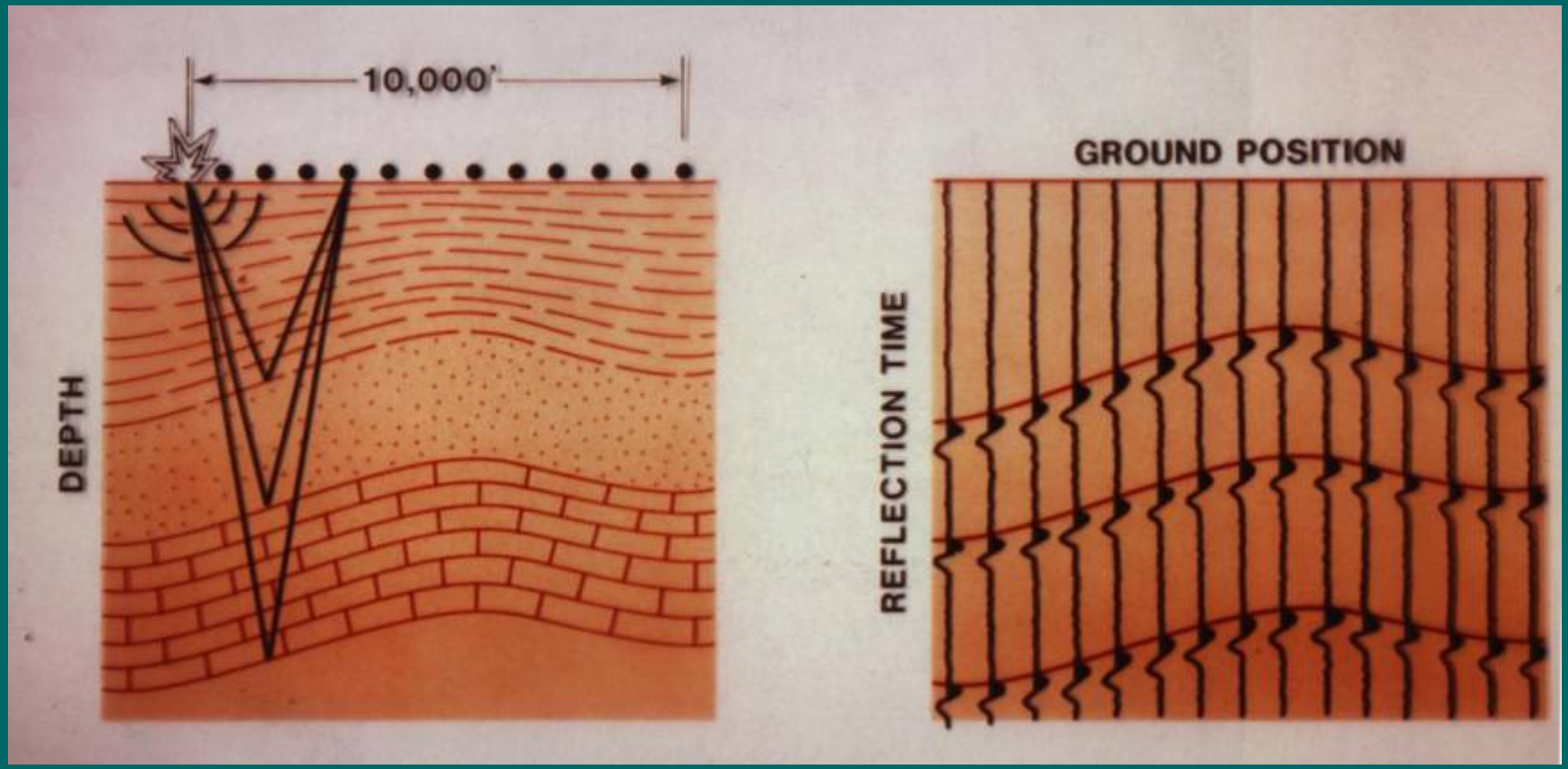
Major U.S. natural gas shale beds



Shale beds in production are labeled

Source: Navigant Consulting, via Cleanskies.org

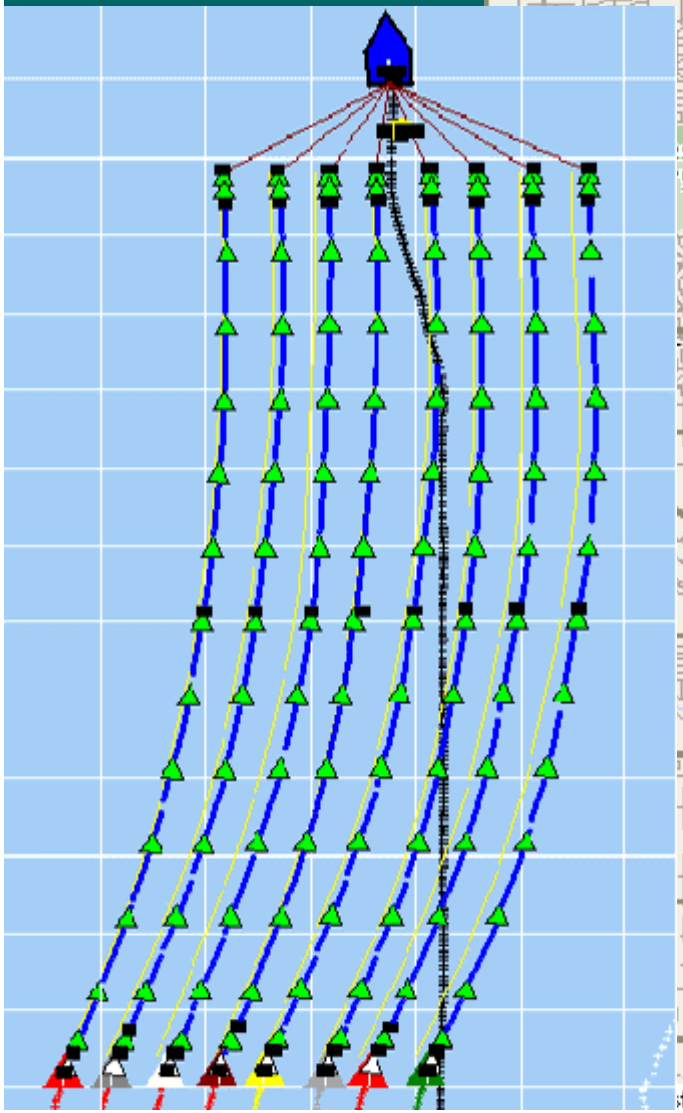
Surface Seismic….

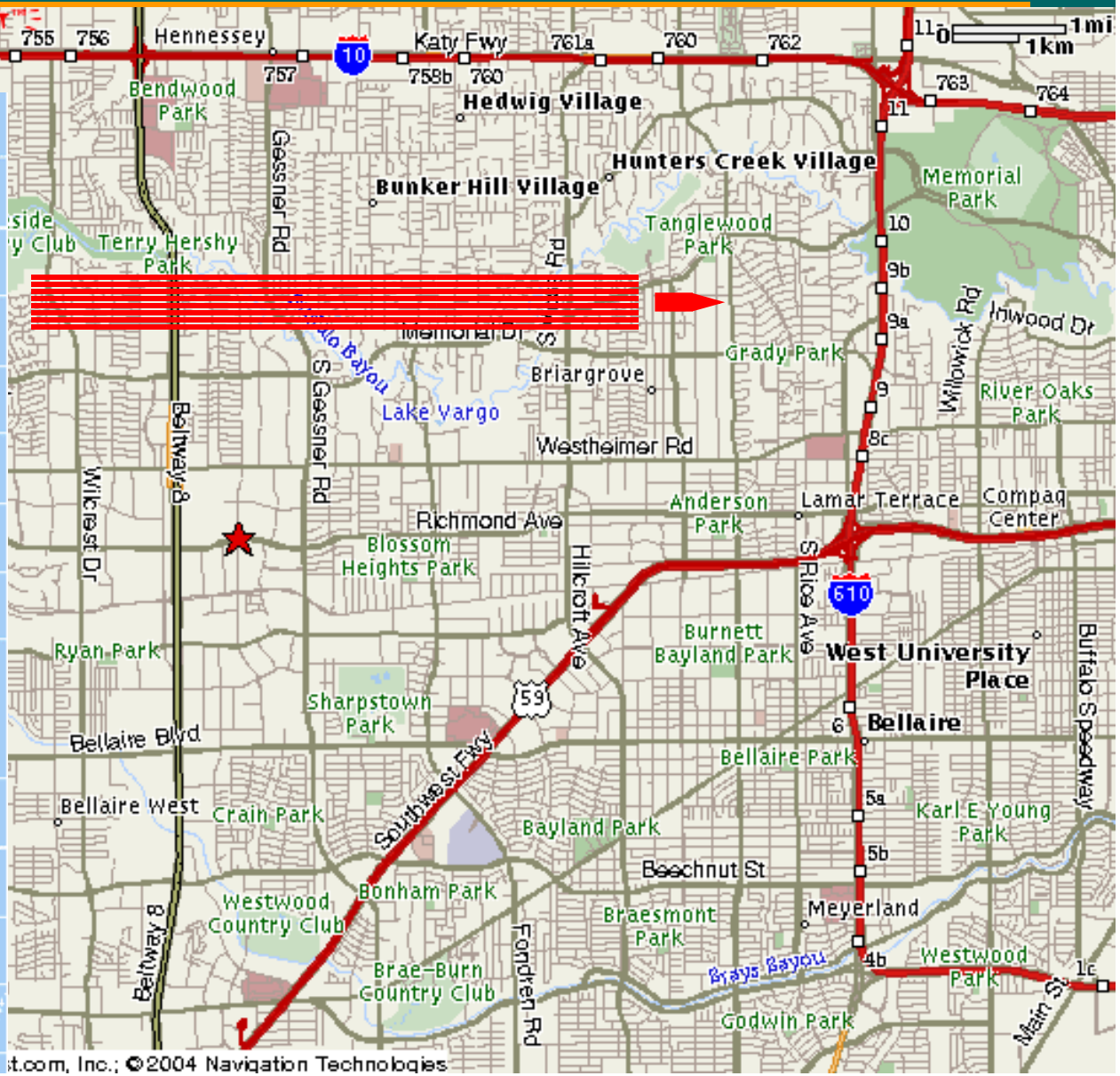


Onshore Seismic…

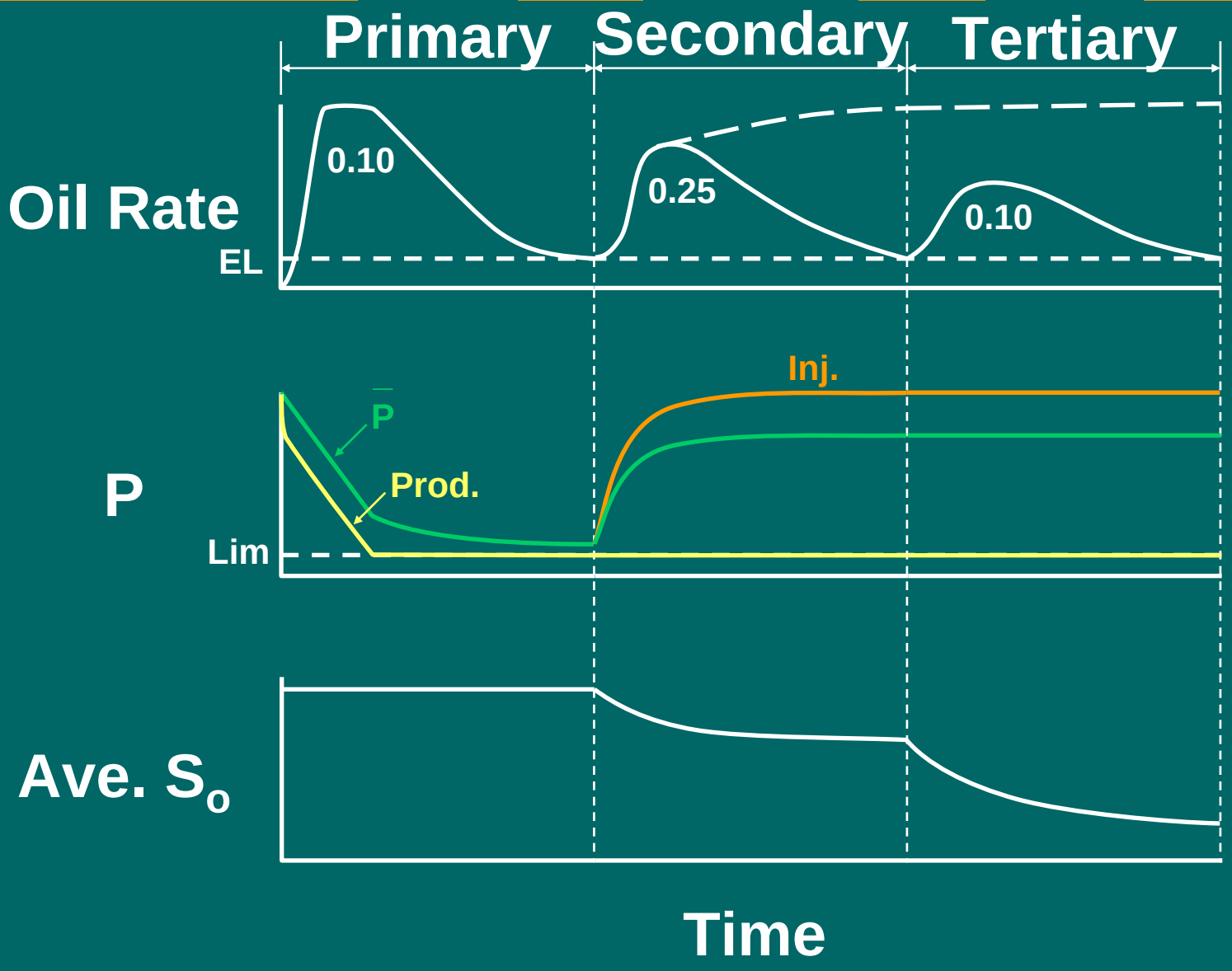
Offshore Seismic…

Offshore Receiver Spreads…





Producing Phases...



Production…

$$q_o = \frac{4\pi k h k_{ro}}{\mu_o \left[\ln\left(\frac{4A}{\gamma C_A r_w^2} \right) + 2s \right]} (\bar{P} - P_{wf})$$

Productivity Index, PI

Driving Force

Production…

$$q_o = \frac{4\pi k h k_{ro}}{\mu_o \left[\ln\left(\frac{4A}{\gamma C_A r_w^2} \right) + 2s \right]} (\bar{P} - P_{wf})$$

Oil Rate - make as large as possible

Goal of everything we do

Production…

$$q_o = \frac{4\pi khk_{ro}}{\mu_o \left[\ln\left(\frac{4A}{\gamma C_A r_w^{\,2}} \right) + 2s \right]} \left(\bar{P} - P_{wf} \right)$$

Constants - Live with them

Production…

$$q_o = \frac{4\pi k h k_{ro}}{\mu_o \left[\ln\left(\frac{4A}{\gamma C_A r_w^2} \right) + 2s \right]} (\bar{P} - P_{wf})$$

Natural logarithm - makes a large number small

For example, ln(1000) = 6.9

Production…

$$q_o = \frac{4\pi k h k_{ro}}{\mu_o \left[\ln\left(\frac{4A}{\gamma C_A r_w^2} \right) + 2s \right]} \left(\bar{P} - P_{wf} \right)$$

Permeability - basic property of rocks

- **Make large**
- **God provides or doesn't**
- **Fracturing**

Production…

$$q_o = \frac{4\pi k h k_{ro}}{\mu_o \left[\ln\left(\frac{4A}{\gamma C_A r_w^2} \right) + 2s \right]} \left(\bar{P} - P_{wf} \right)$$

Well pressure

- **Make small**
- **Lift with gas**
- **Pump (reduce fluid level)**

Production…

$$q_o = \frac{4\pi k h k_{ro}}{\mu_o \left[\ln\left(\frac{4A}{\gamma C_A r_w^2} \right) + 2s \right]} (\bar{P} - P_{wf})$$

Average reservoir pressure

- **Make large**
- **Reinject produced gas**
- **Inject water (waterflood)**

Production…

$$q_o = \frac{4\pi k h k_{ro}}{\mu_o \left[\ln\left(\frac{4A}{\gamma C_A r_w^2} \right) + 2s \right]} \left(\bar{P} - P_{wf} \right)$$

Penetrated thickness

- **Make large**
- **God provides, etc.**
- **Reperforating**
- **Horizontal wells**

Horizontal Wells….

Aggie Drilling Engineer…

From A.D. Hill

Production…

$$q_o = \frac{4\pi k h k_{ro}}{\mu_o \left[\ln\left(\frac{4A}{\gamma C_A r_w^2} \right) + 2s \right]} (\bar{P} - P_{wf})$$

Well damage (skin factor)

- **Make small**
- **Fracture well**
- **Inject acid**

Production…

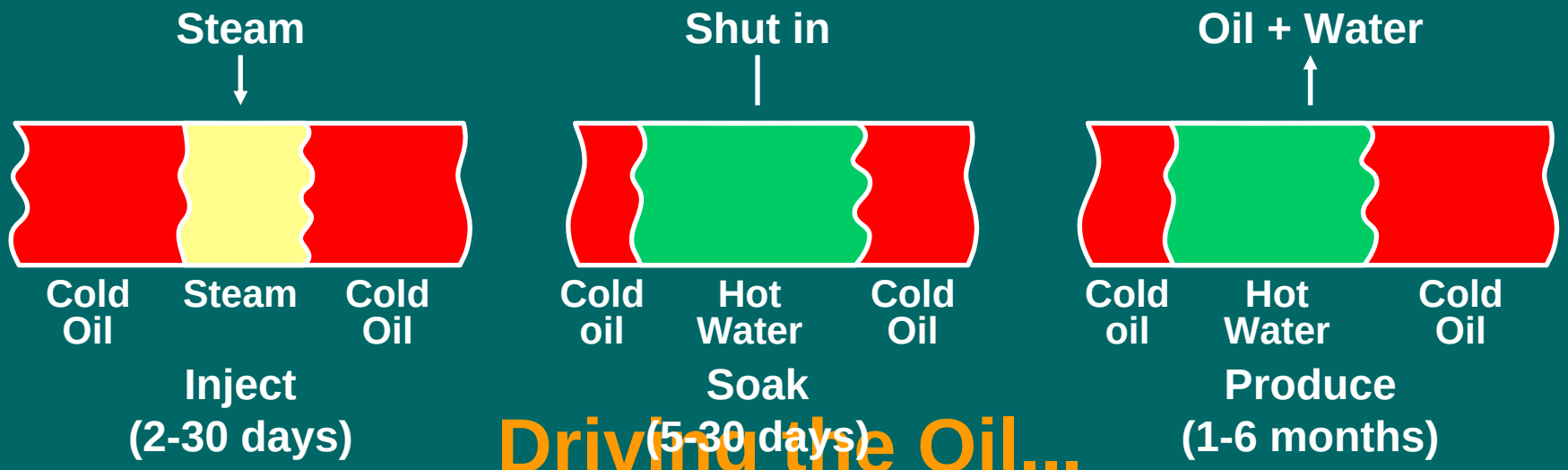
$$q_o = \frac{4\pi k h h k_{ro}}{\mu_o \left[\ln\left(\frac{4A}{\gamma C_A r_w^2} \right) + 2s \right]} (\bar{P} - P_{wf})$$

Oil viscosity

- **Make small**
- **Inject heat (steam)**
- **Burn a little oil**

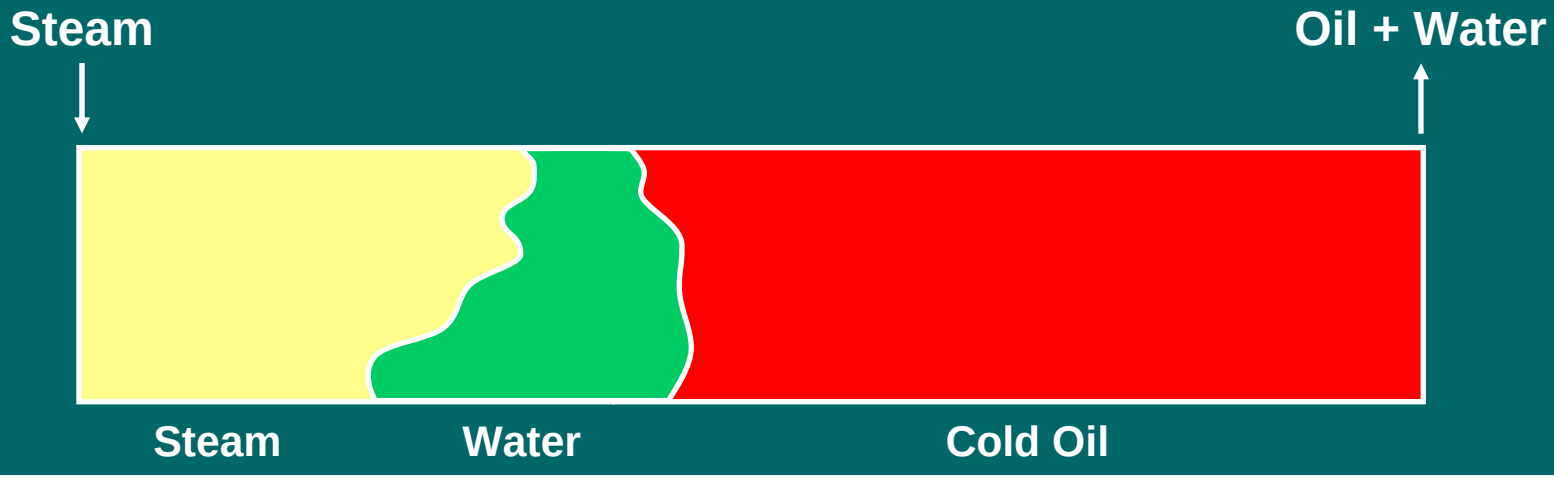
Process Variations…

Steam soak



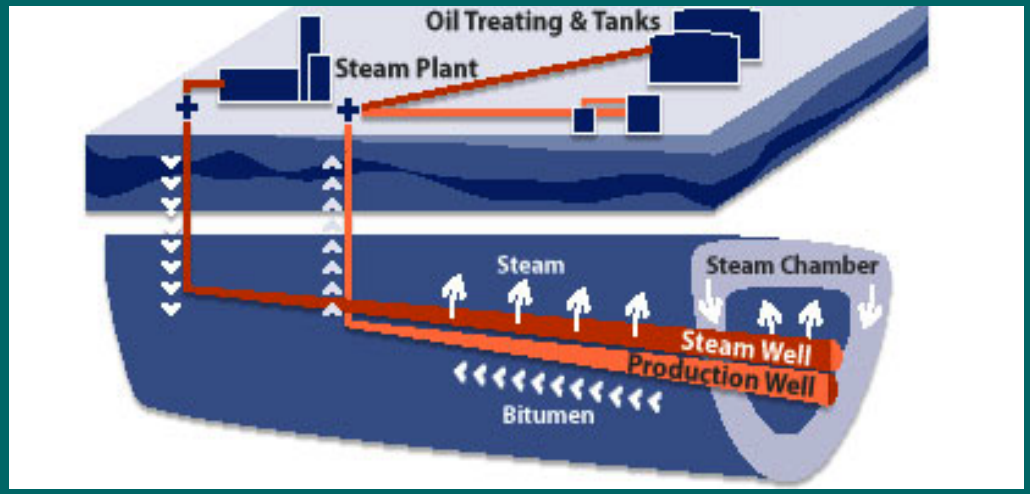
Driving the Oil...

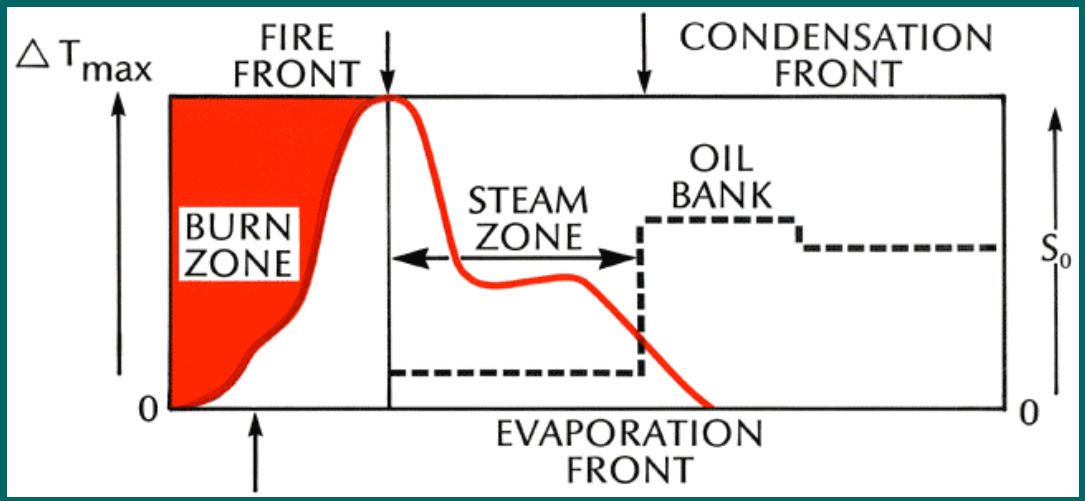
Steam Drive



More Variations...

Using horizontal wells (SAGD)





Burning the Oil

In-Situ Conversion Process (ICP)

What is it?

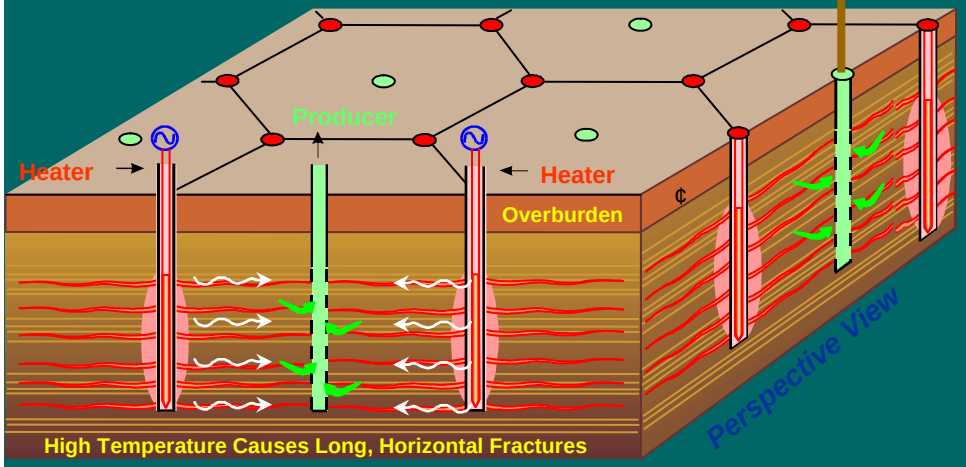
- Enhancement of natural maturation of kerogen by *slow* heating
- Results in:
  - thermal cracking
  - in-situ hydrogenation
  - high sweep vapor phase production
  - high API oil
  - N,S,O content vary with resource
- Average temperature limited to boiling point of diesel, i.e. essentially no bottoms

How is it done?

- Electric resistance or, potentially, gas heaters
- Underground conductive heat transport

Current target resources:

- Oil Shale
- Heavy Oil / Tar Sands
- Coal



High Value Products

Light Processing

- Naphtha
- Jet
- Diesel
- Nat. Gas
- Hydrogen
- Chem. Feed
- Heat

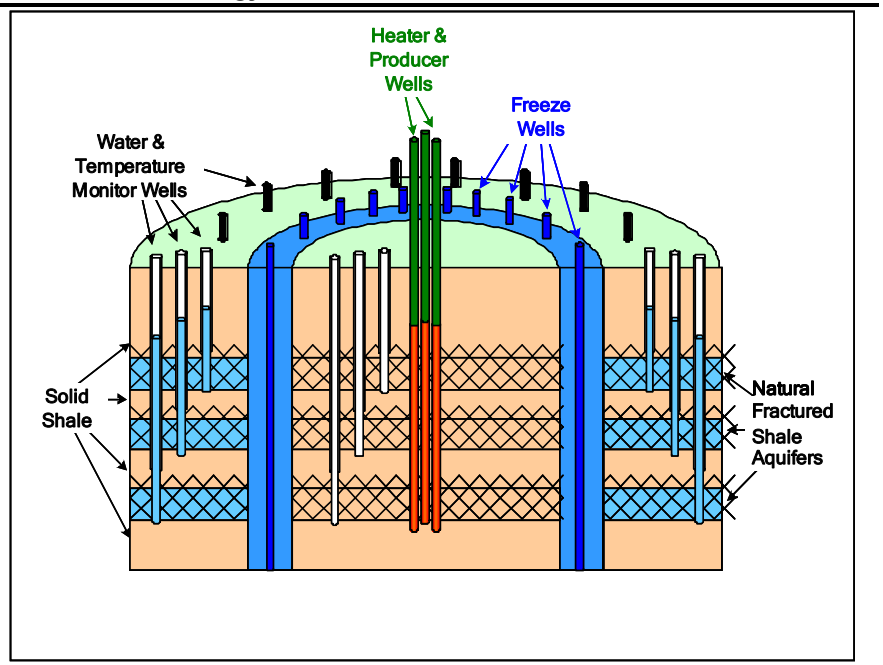
ICP Test on Surface…

Protecting the Retort Zone…

Freezewall Test

- **Football field sized test on 10 acr near existing research**
- **Test robustness of freezewall bar**
- **Active construction/production fr late ’05 – early ’07**
- **Reclamation 2010**

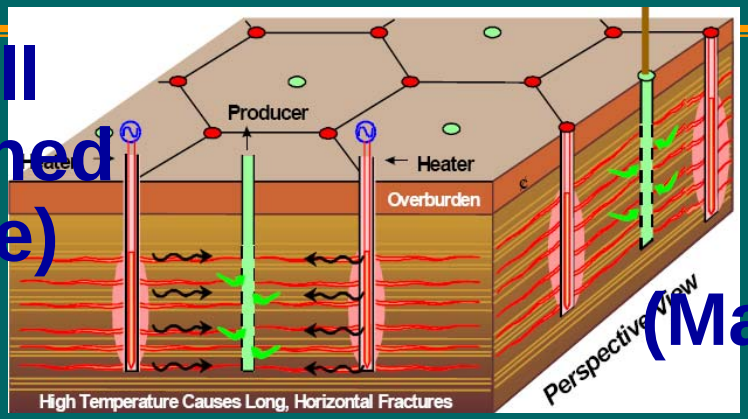
Freezewall Technology For Groundwater Isolation



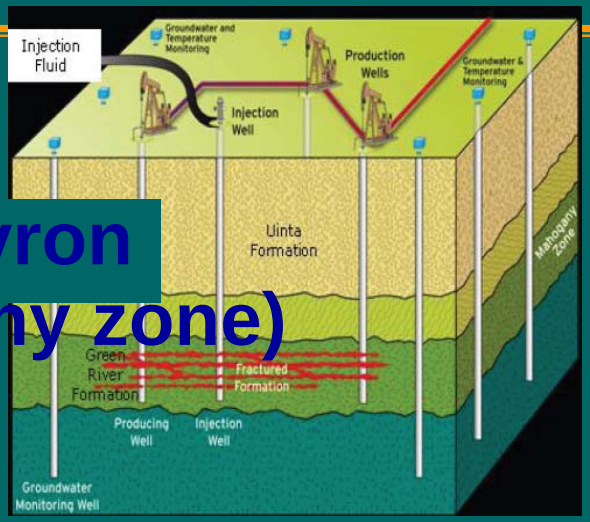
Ice Wall on Surface…

Insitu Processing Variations….

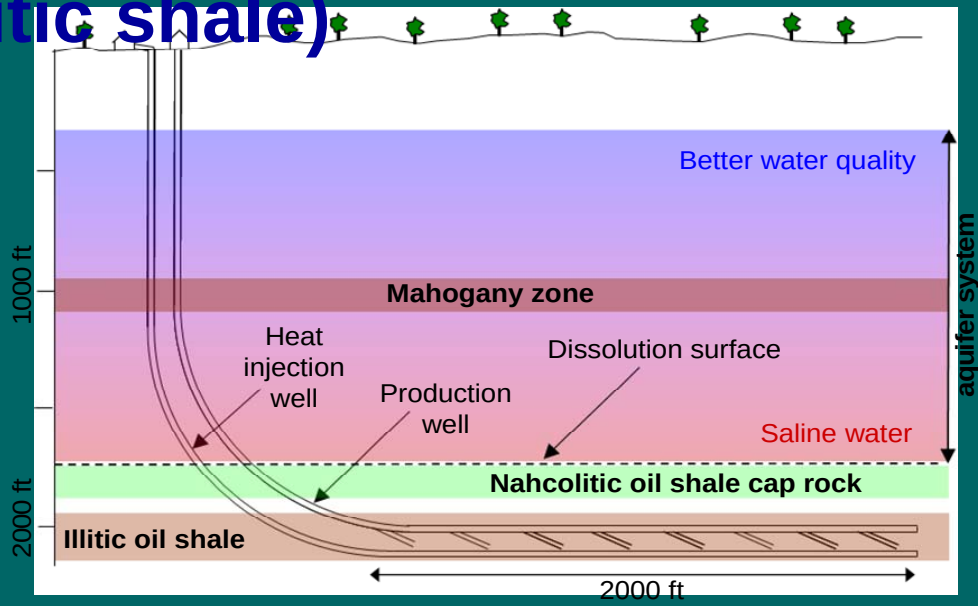
Shell (Leached zone)



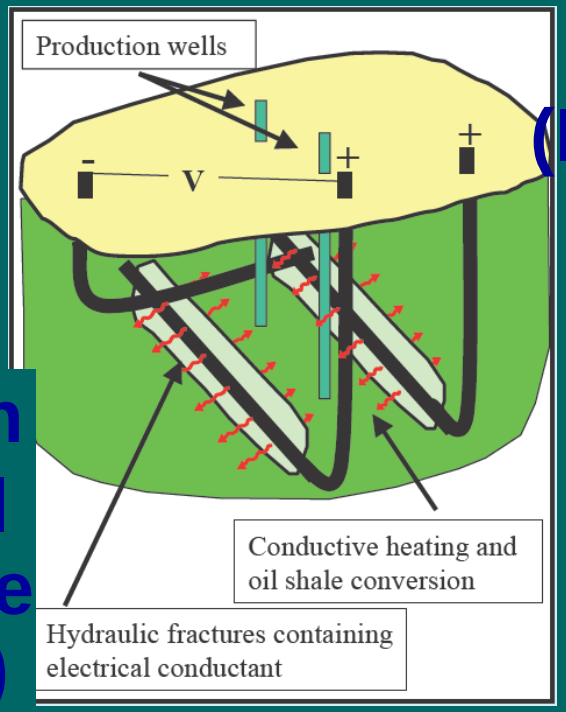
Chevron (Mahogany zone)



AMSO (Illitic shale)



Exxon Mobil (Saline zone)



Athabasca Oil Sands Mining…

Production…

$$q_o = \frac{4\pi k h k_{ro}}{\mu_o \left[\ln\left(\frac{4A}{\gamma C_A r_w^2} \right) + 2s \right]} (\bar{P} - P_{wf})$$

Oil relative permeability

- **Make large**
- **Large oil content**
- **Inject chemicals, CO_2**

Typical Micellar-Polymer Flood...

Gradual change to water

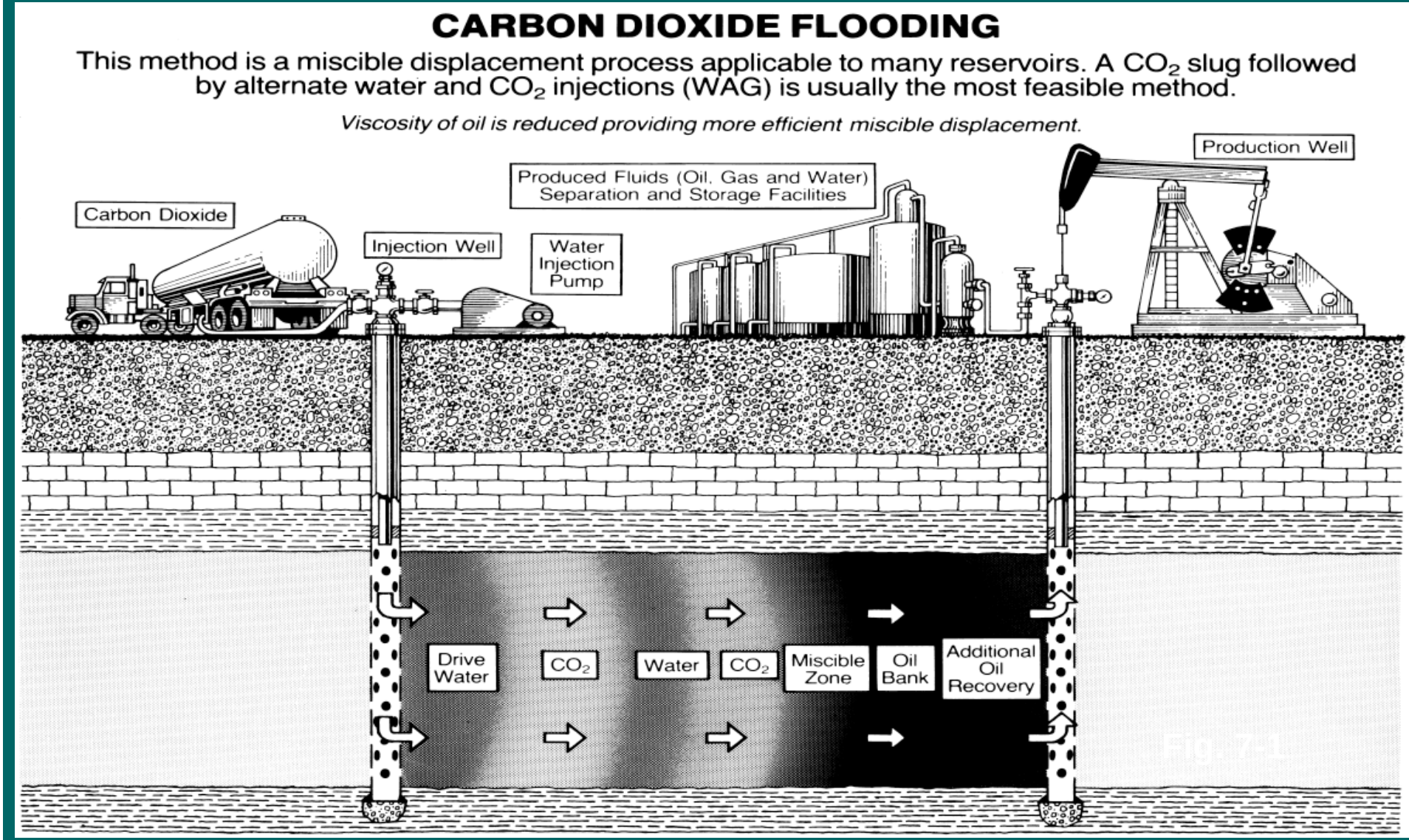
Polymer Additives

Surfactant
Co-surfactant
Co-solvent
Polymer
Oil (sometimes)
Usually 0.1 PV

Low salinity
Low calcium
Usually 0.5 PV

Fig. 9-1

Schematic of a Solvent Flood…



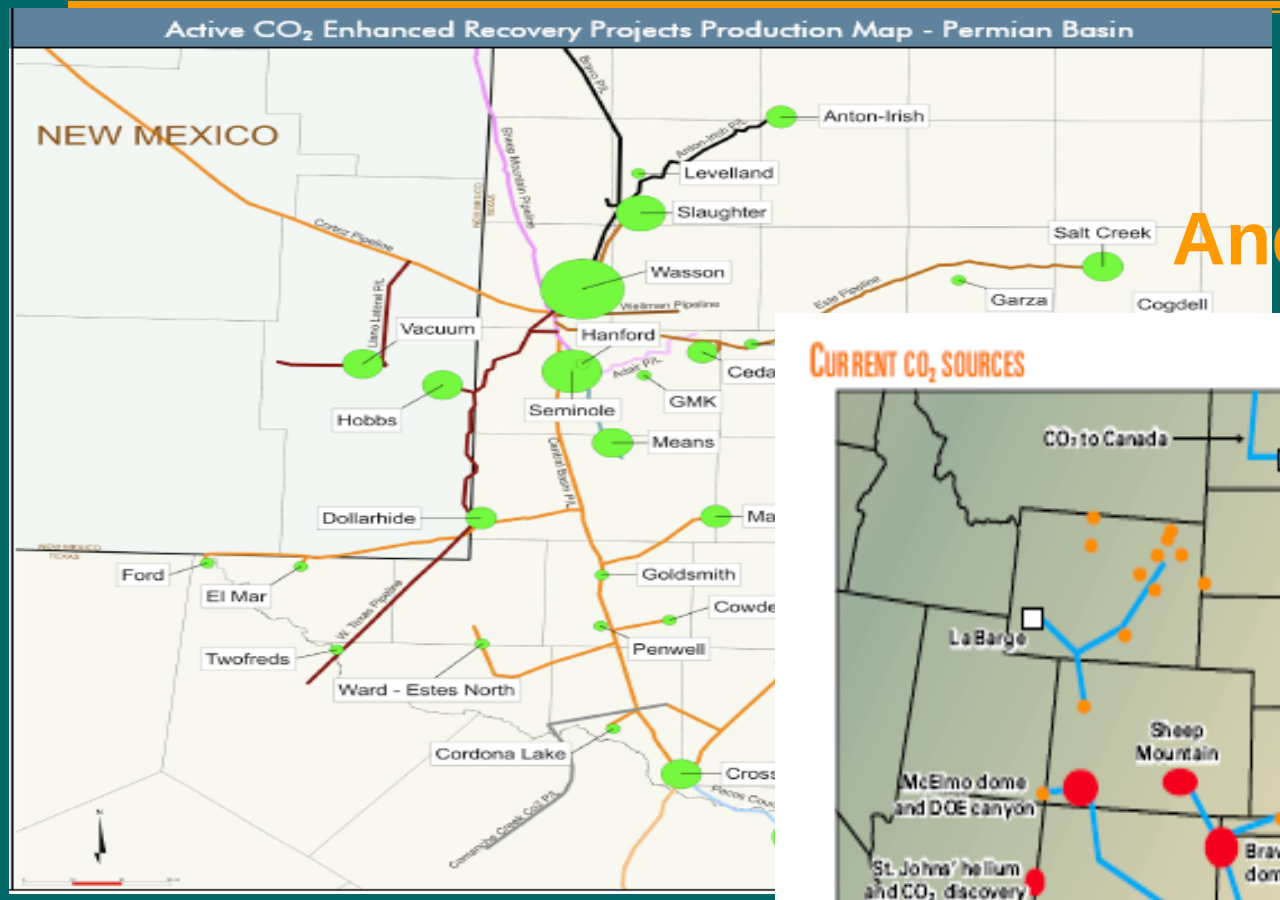
Drawing by Joe Lindley, U.S. Department of Energy, Bartlesville, OK

Several Injectants…

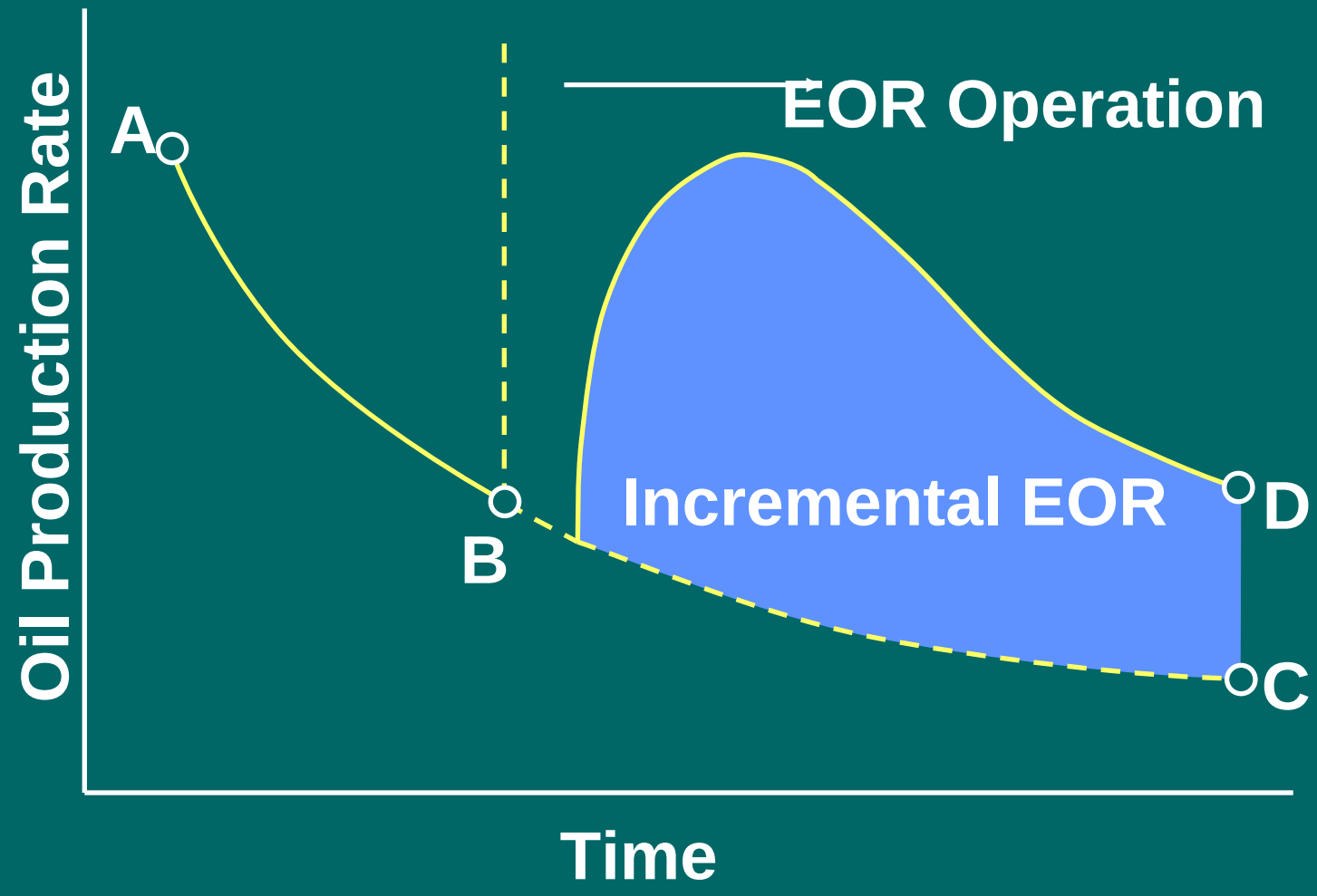
- Alcohols
- Nitrogen
- Air
- Flue gas
- Various petroleum gasses (C_3)
- Methane
- Carbon dioxide

Major West Texas CO_2 Projects…

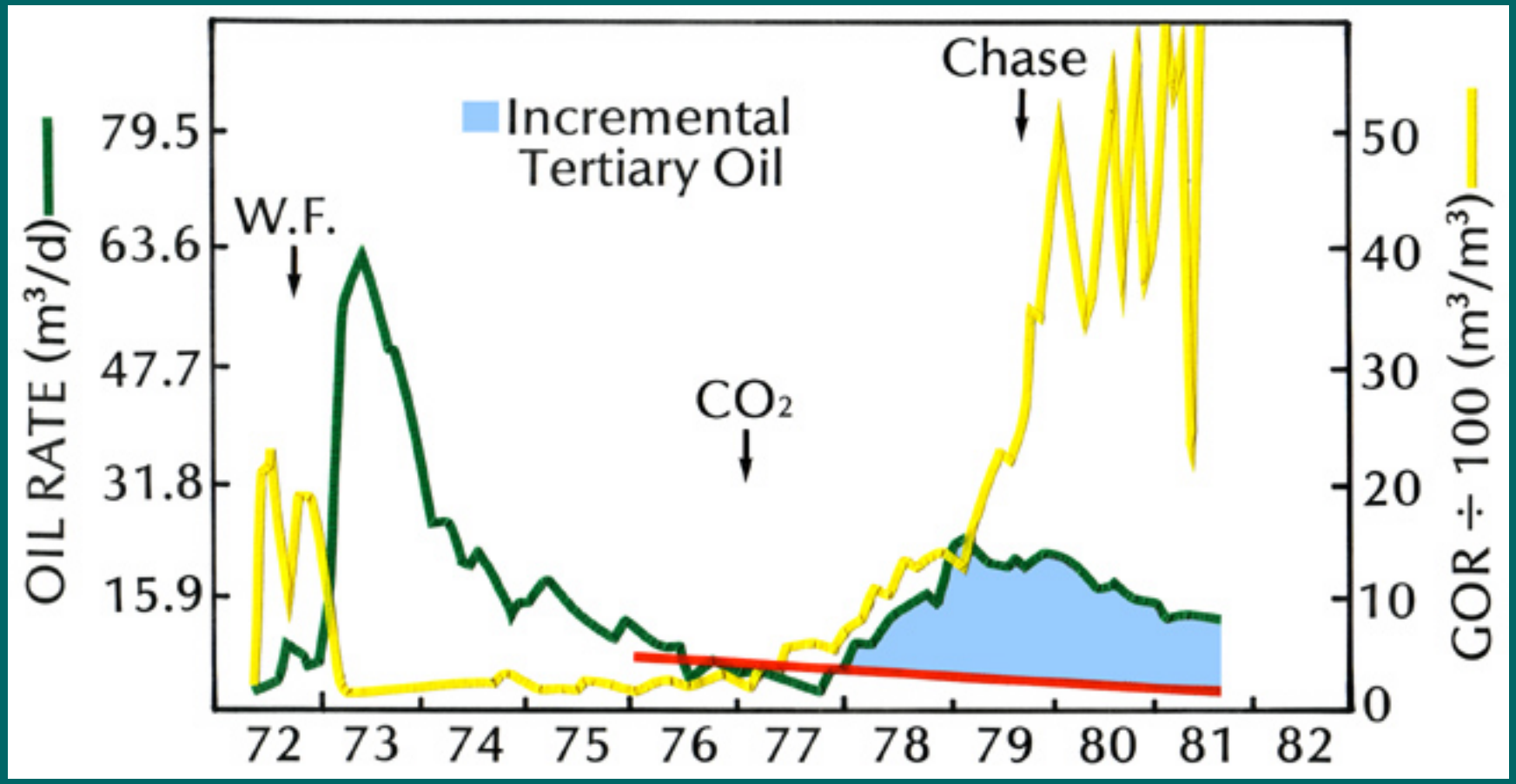
And Their Sources



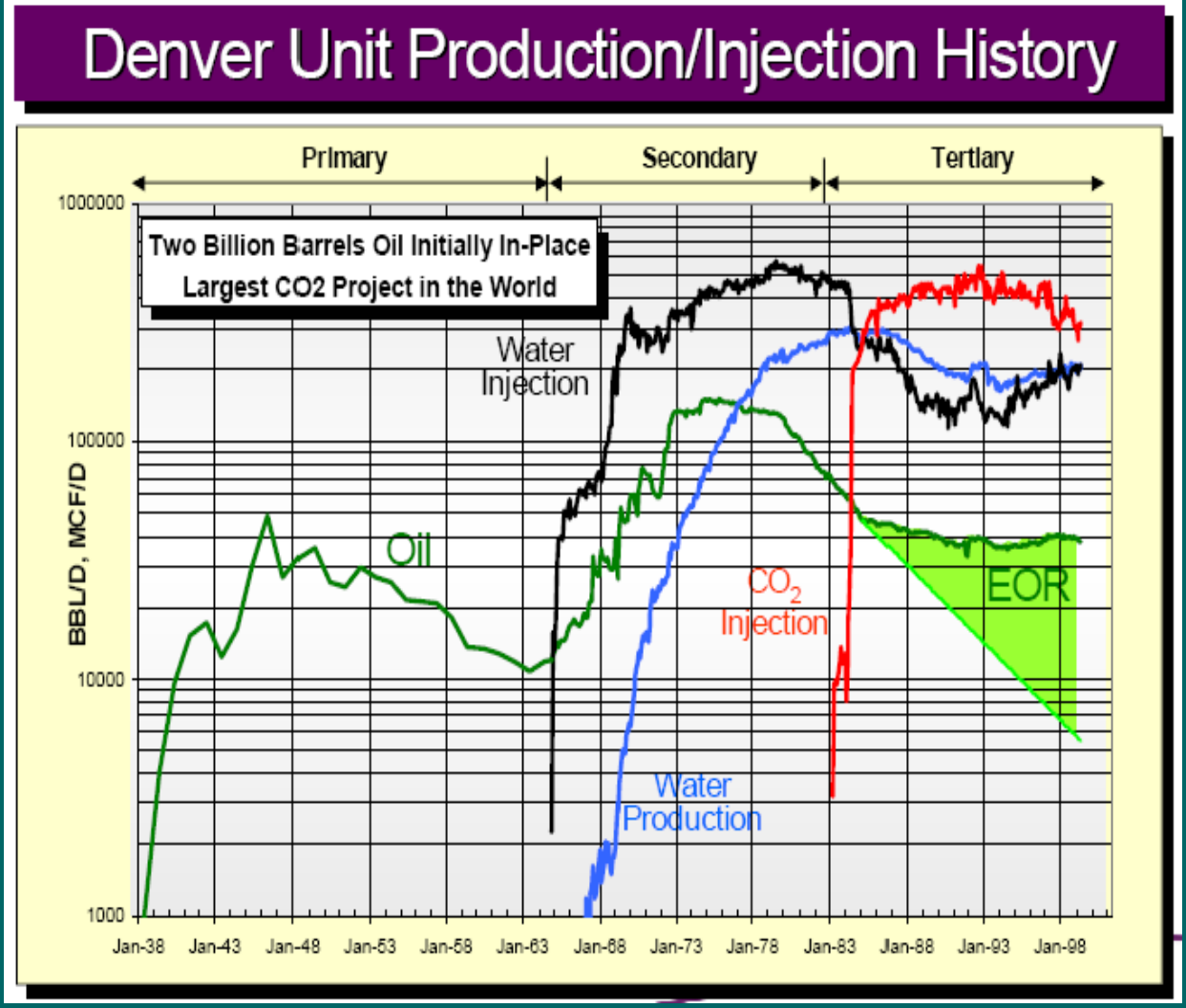
Incremental Oil Recovery...



Slaughter Estate Unit...

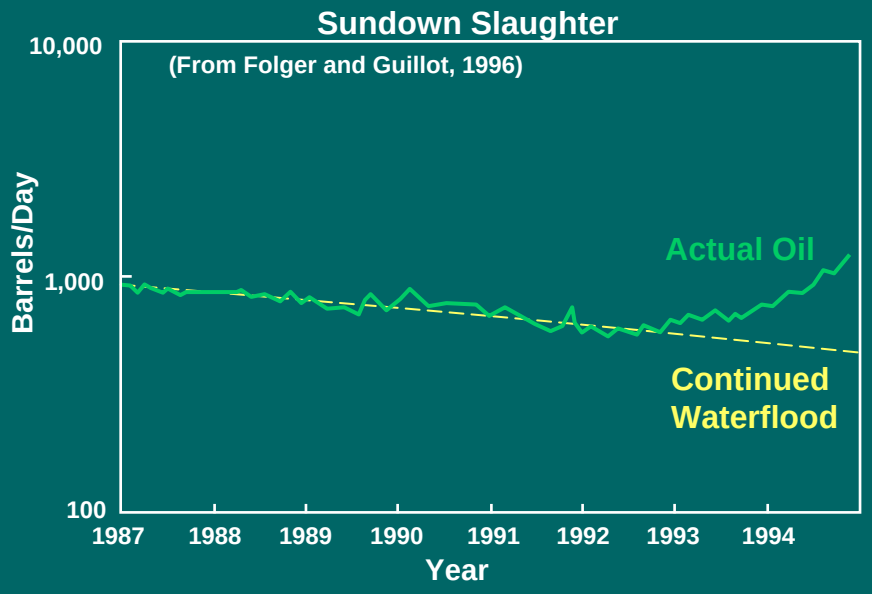


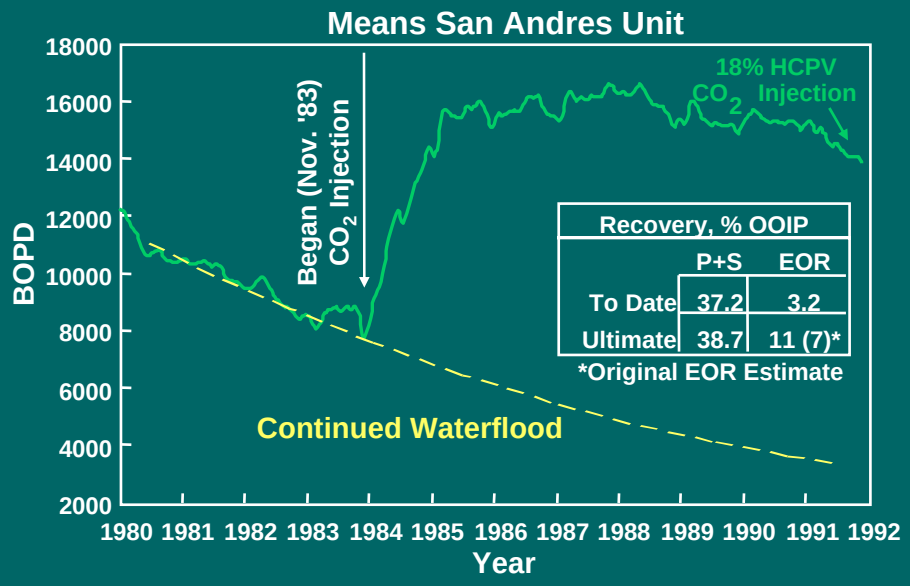
Wasson Field...

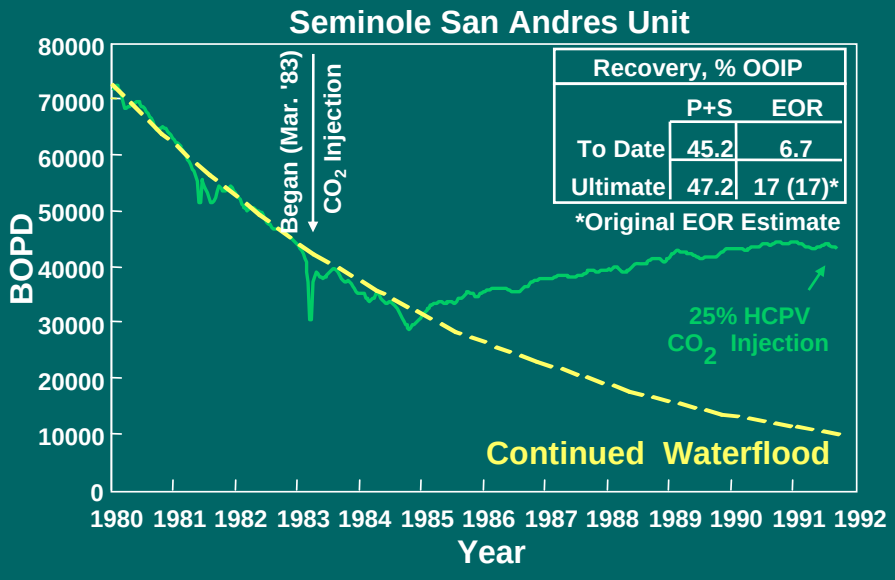


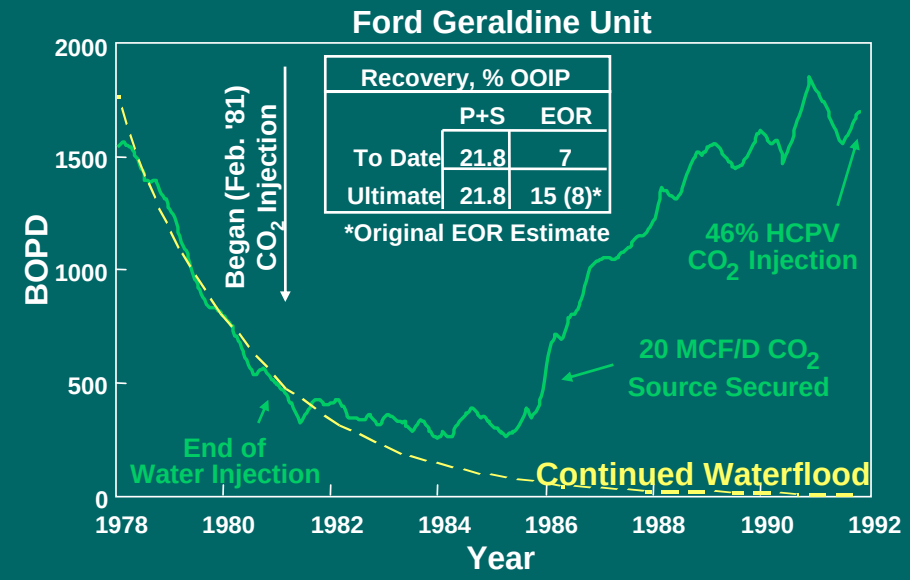
Process type:	**CO_2 miscible**
Location:	**Yoakum and Gaines Co., TX, USA**
Operator:	**Shell**
Lithology:	**Carbonate**
Subsurface depth:	**1586 m**
Oil viscosity:	**1.24 mPa-s**
Pressure:	**15 MPa**
Sq. km/producer:	**0.1**
Water salinity:	**10,000**
Est. % IOR:	**16.6**

Other CO_2 Floods...

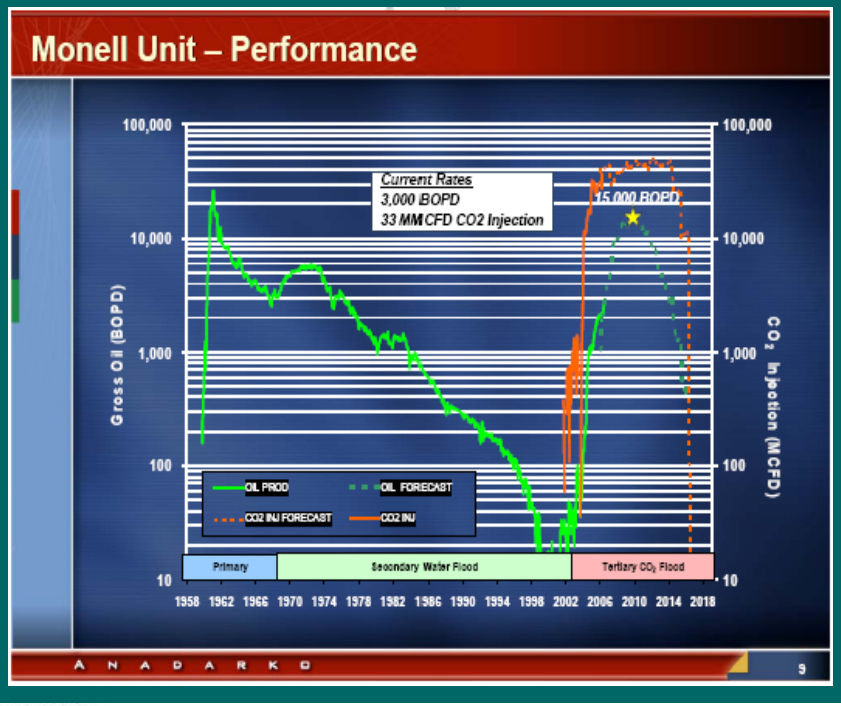


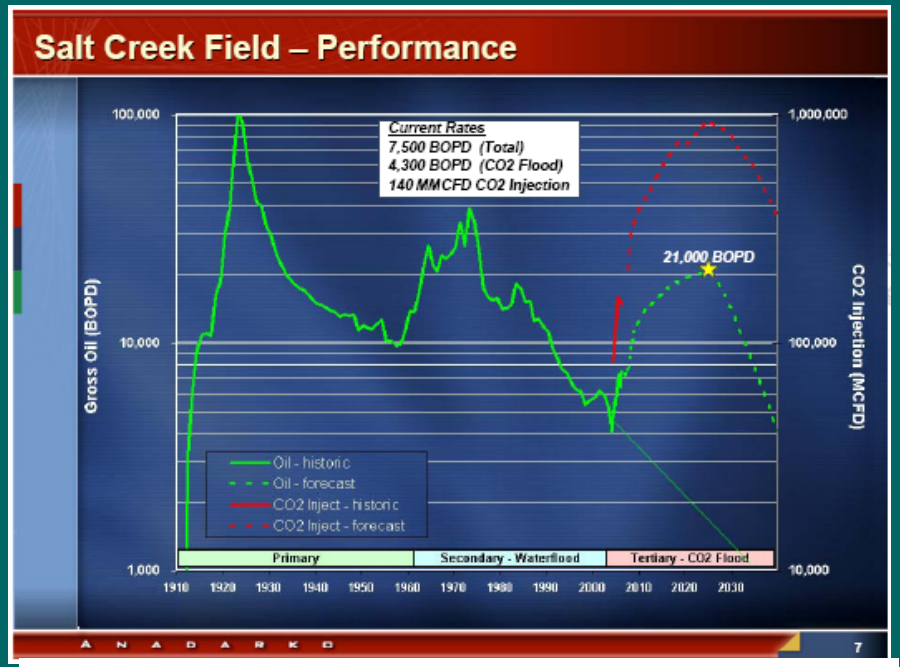


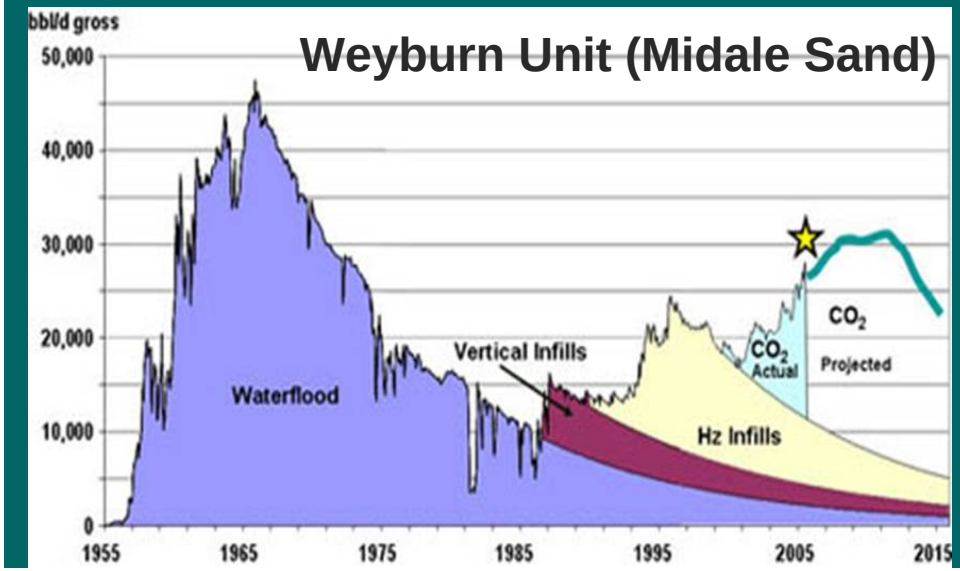


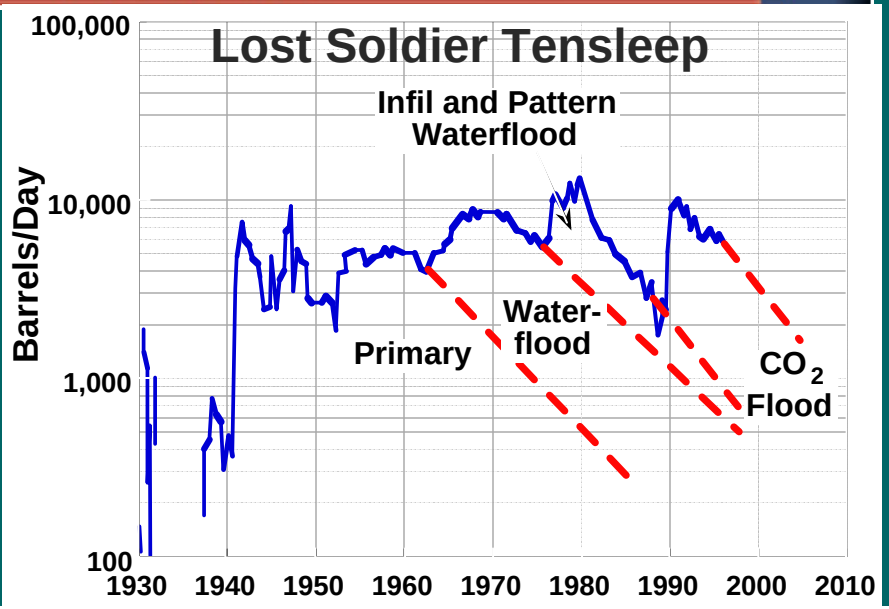


More CO_2 Floods...

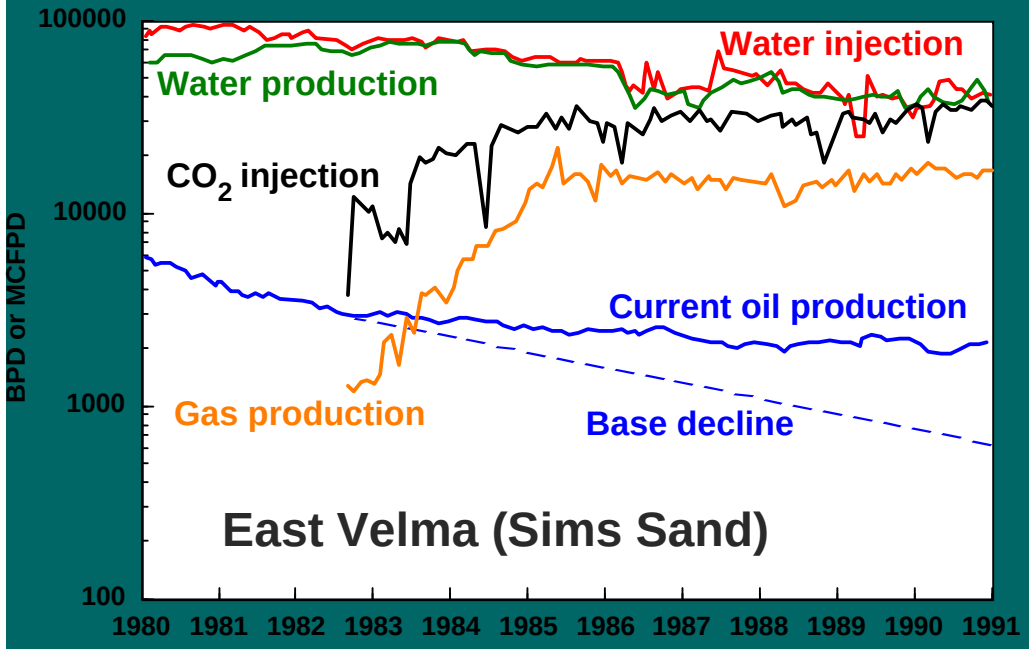


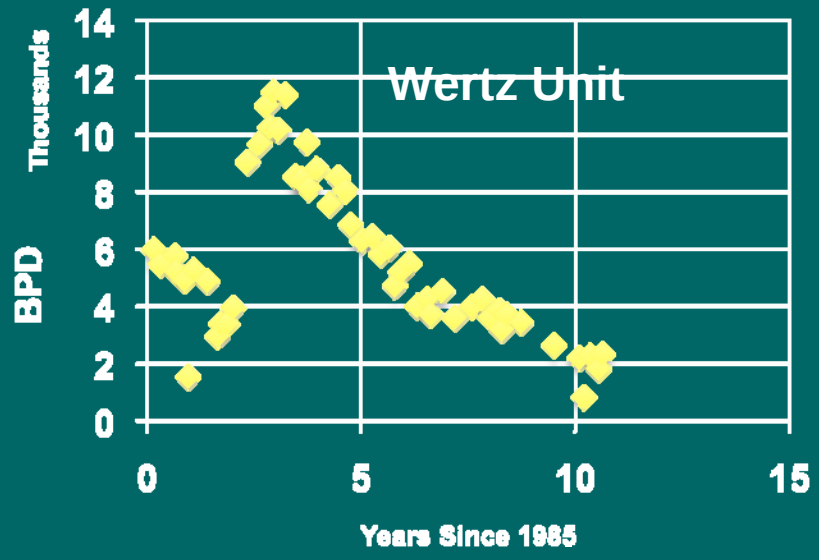


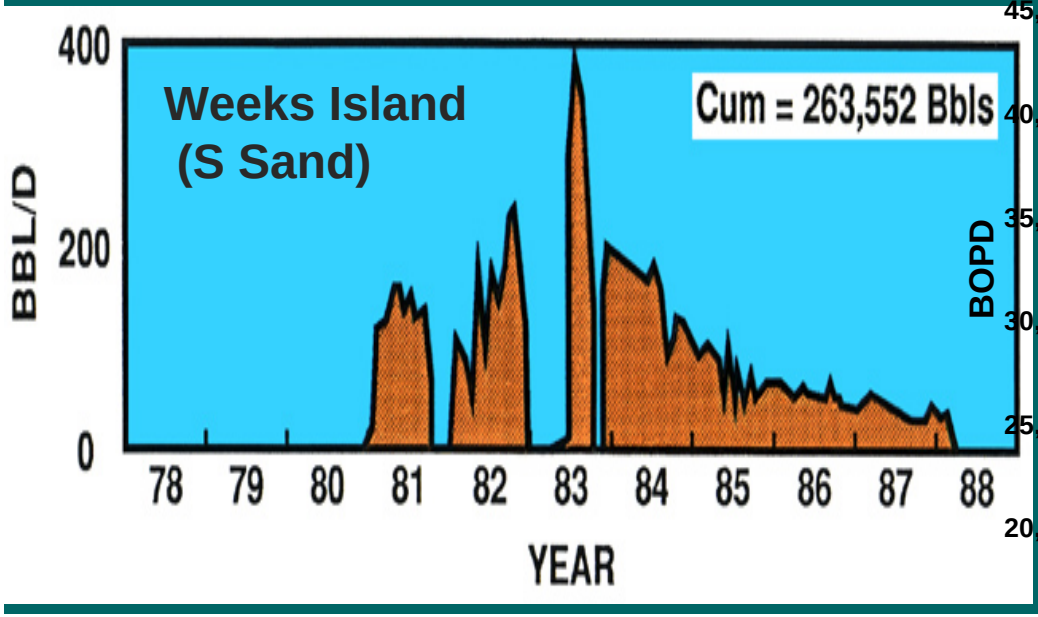


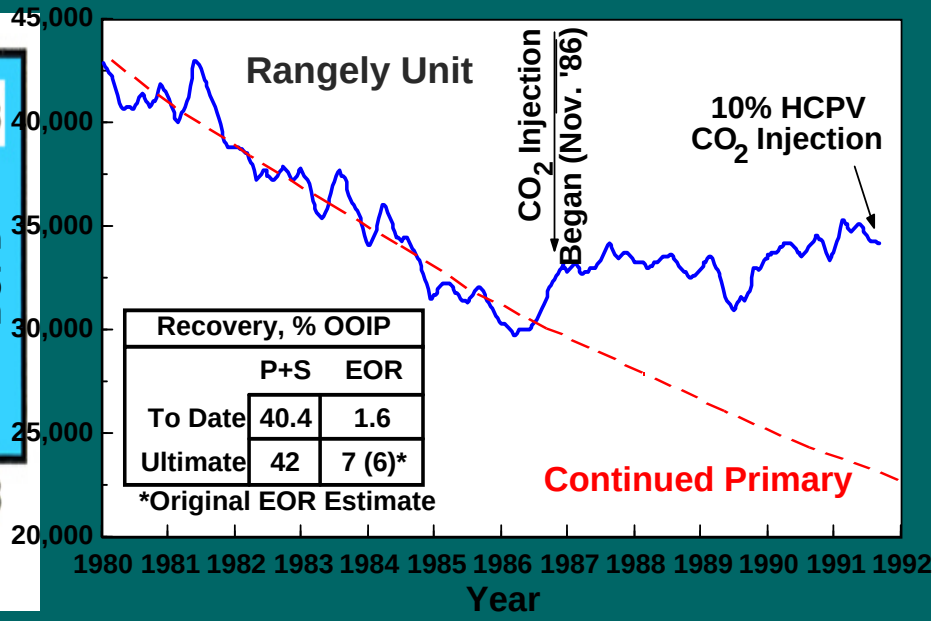


Even More CO_2 Floods...









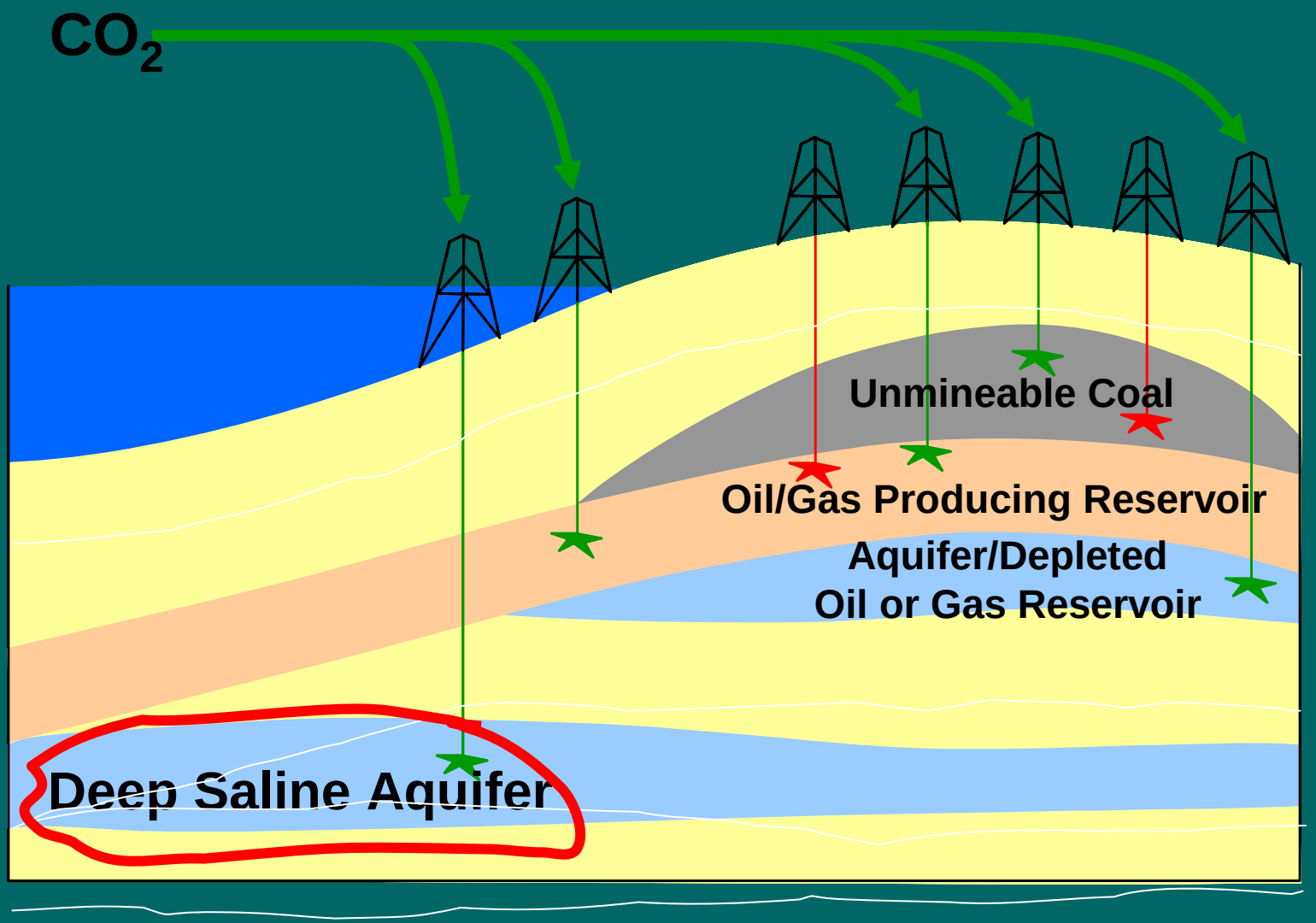
Summing Up…

- EOR been around for 50 years
- Many process variations
- CO_2 projects…
  - About 20 reported (130 ongoing)
  - Most injected CO_2 is naturally occurring
  - Average recovery 12% OOIP (like primary)
  - Utilization 10 MCF/incremental bbl
  - Huge variability
  - About one-half is recycled
  - 2-4 lb C stored/lb C produced

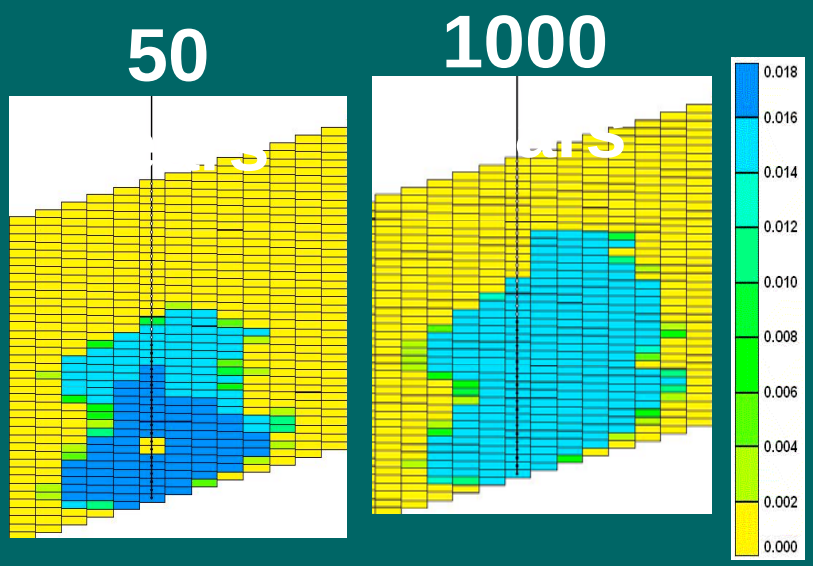
The University of Texas at Austin

- Founded in 1883
- 50,000 students enrolled from more than 100 countries (11,000 in grad school)
- Annual budget: $1.3B
- Research funding: $300M
- 3,000 faculty, 18,000 staff
- 7 museums, 17 libraries
- 450,000 alumni
- http://www.utexas.edu/

Storage in Aquifers…



Trapping CO_2…



CO_2 mole fraction in aqueous phase