



Overview - Hydraulic Fracturing Process

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South Coast Air Quality Management District
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The Dawn of Tapping Unconventional Reservoirs

Unconventional Hydrocarbon Resources



U S Experience

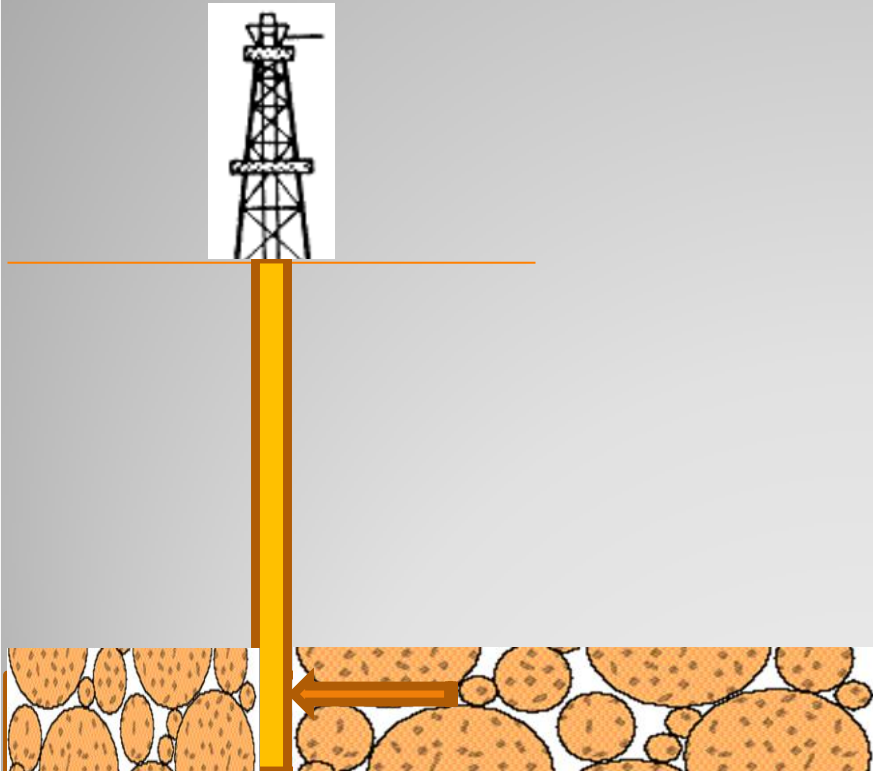
| Barnet | Marcellus | Woodford | Fayetteville | Haynsville | Eagle Ford |
|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Discovery 1998 | Discovery 2002 | Discovery 2003 | Discovery 2003 | Discovery 2005 | Discovery 2009 |
| Development 2003 | Development 2006 | Development 2007 | Development 2007 | Development 2008 | Development 2012 |



Shale Gas and Oil
Resources

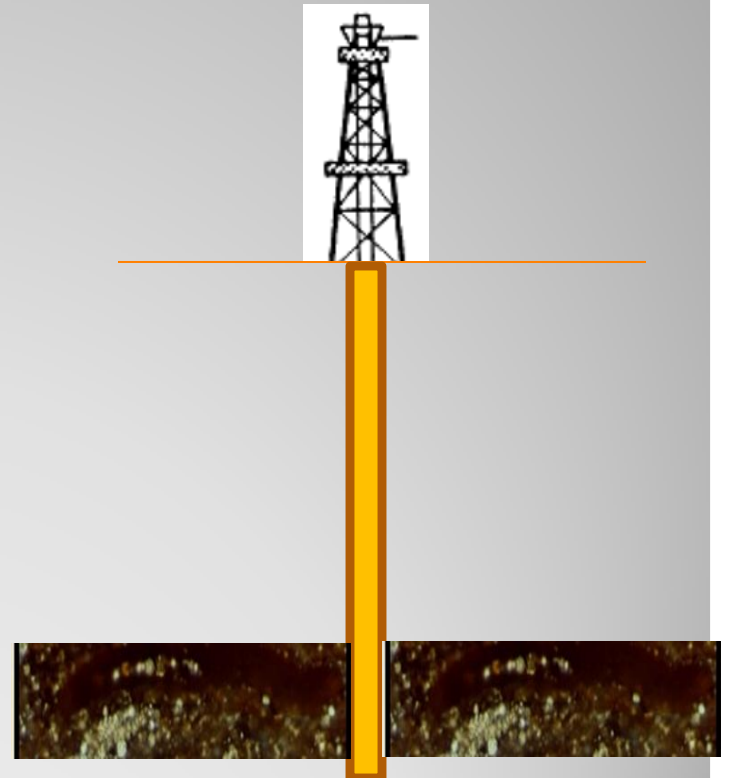
- What is Hydraulic Fracturing?
- Why do we fracture rocks?
- Where are the fracturing operations?
- What are the targets in California?

Questions



Permeability allowing the fluid to move.

Conventional
Rocks

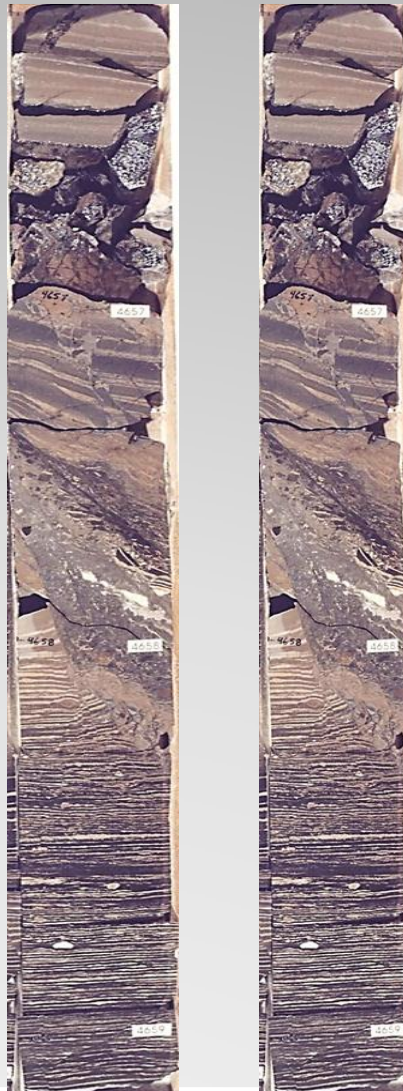


Unconventional
Rocks

Shale Rocks

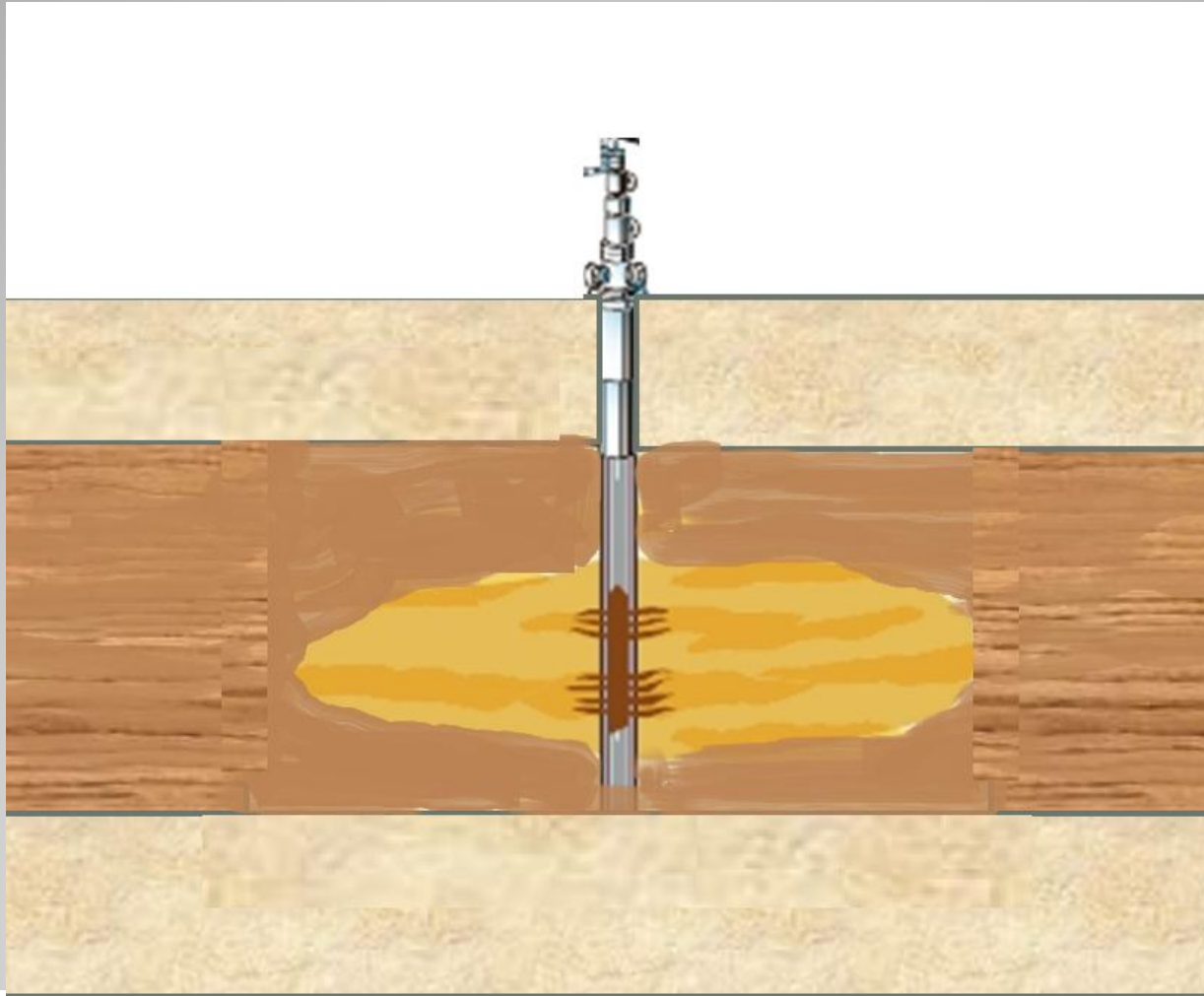


Core images

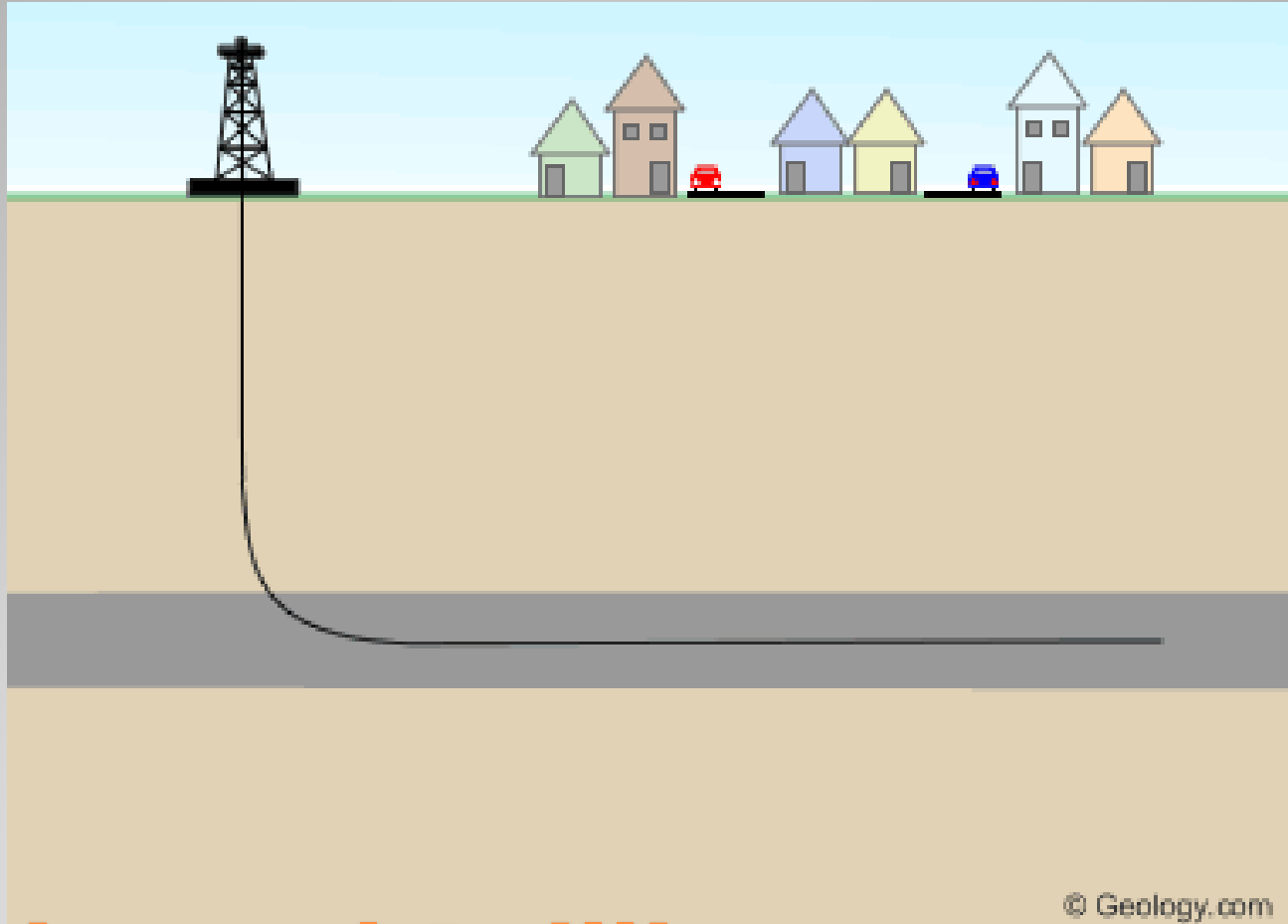


Nearly Solid Chert

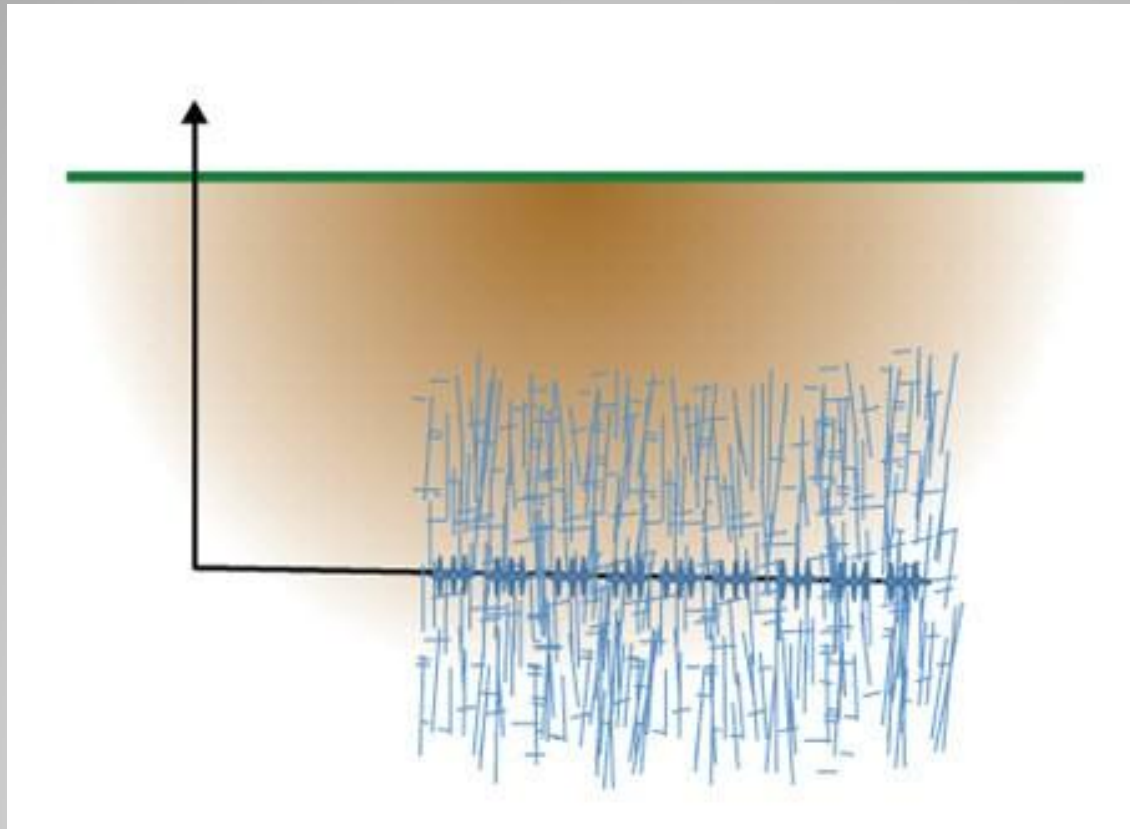
| | | | | | | | |
|-------------|--------|---------|---------|-------|-----|----------|----------|
| 7/20/2004 | HV | HFW | WD | Mag | Det | Pressure | —50.0μm— |
| 11:31:50 PM | 3.0 kV | 0.26 mm | 13.3 mm | 1000x | ETD | --- | |



Hydraulic Fracturing



Horizontal Drilling



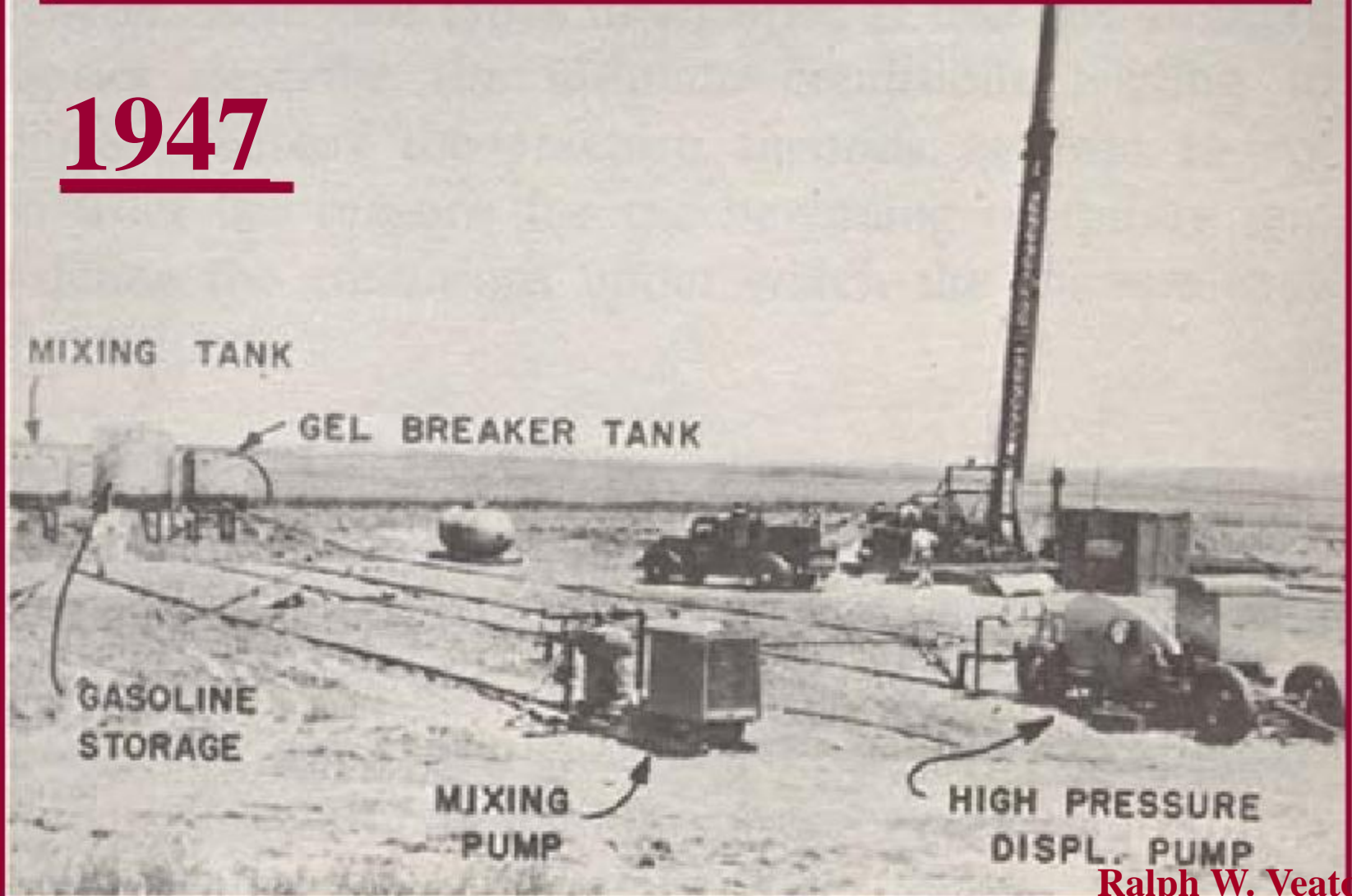
Dickinson CVB

Horizontal Drilling and Fracturing

Is it a New Concept?

Klepper Gas Unit No. 1, Hugoton field, Kans.
The first well to be hydraulically fractured to
increase well productivity. (SPE Monograph Vol. 2)

1947



Ralph W. Veatch

The Great Race

**First Commercial Fracturing Treatment – 1949 (Pictured)
Stephens County, OK - Dwight K. Smith – Halliburton Engr.**



**Second Commercial Fracturing Treatment – 1949 – 2 Hours Later
Archer County, TX - A. B. Waters – Halliburton Engr.**

Co-Inventors of Hydraulic Fracturing

Patented May 13, 1952

2,596,844

UNITED STATES PATENT OFFICE

2,596,844

TREATMENT OF WELLS

Joseph B. Clark, Tulsa, Okla., assignor to Stan-
dard Oil and Gas Company, Tulsa, Okla., a cor-
poration of Delaware

No Drawing. Application¹² December 31, 1949,
Serial No. 136,394

23 Claims. (Cl. 166—21)

1
This invention pertains to the treatment of oil and gas wells. More particularly, this invention pertains to a method of increasing the productivity of an oil or gas well by providing lateral drainage channels in selected formations adjacent a well. This application is a continuation-in-part of my application Serial Number 29,932, filed May 28, 1948.



How do we keep the fractures open?



Cross Linked Fluids – The Strange and Mysterious Globbs



J. R. Cameron, 1990

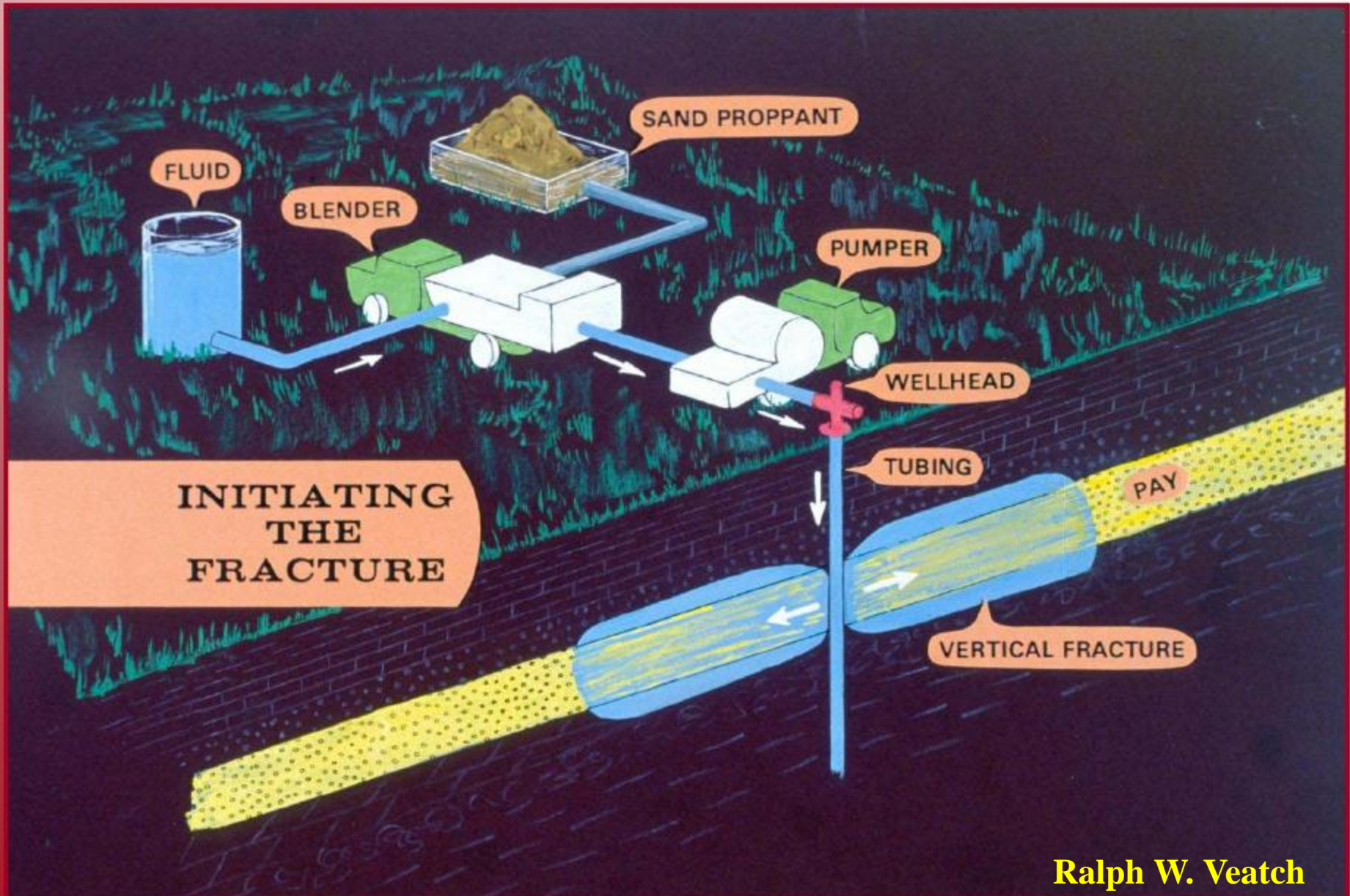
- Acid
- Anti-bacterial Agent
- Breaker
- Clay Stabilizer
- Corrosion Inhibitor
- Crosslinker
- Friction Reducer
- Gelling Agent
- Iron Control
- pH Adjusting Agent
- Scale Inhibitor
- Surfactant

2% Additives

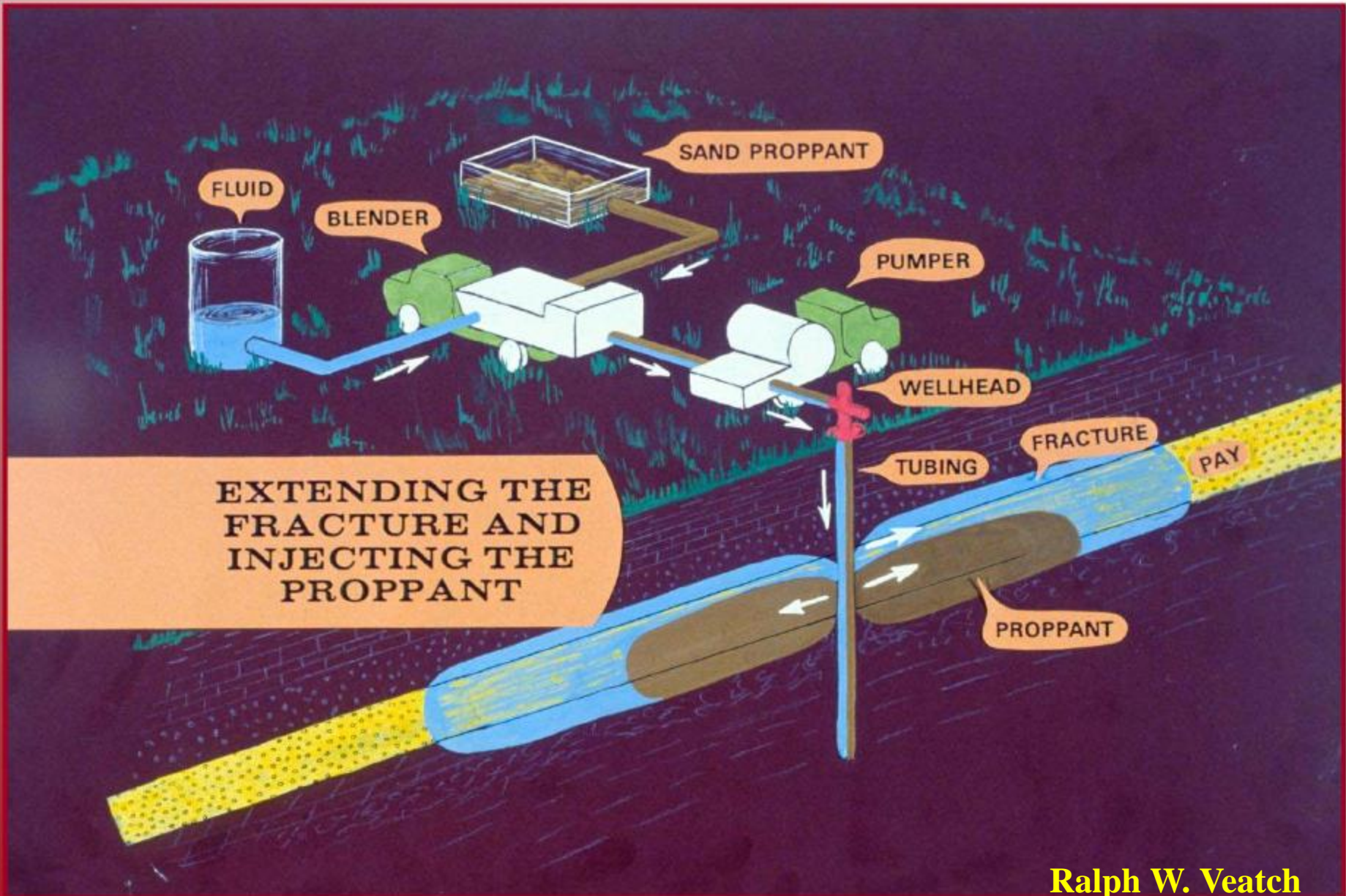
- Hydrochloric acid (HCl)
- Gelling agents, vegetable-derived guar gum,
- Oxidizers
- Biocides
- Methanol prevent polysaccharide gels degrading above temperatures of 200°F.

Process Description

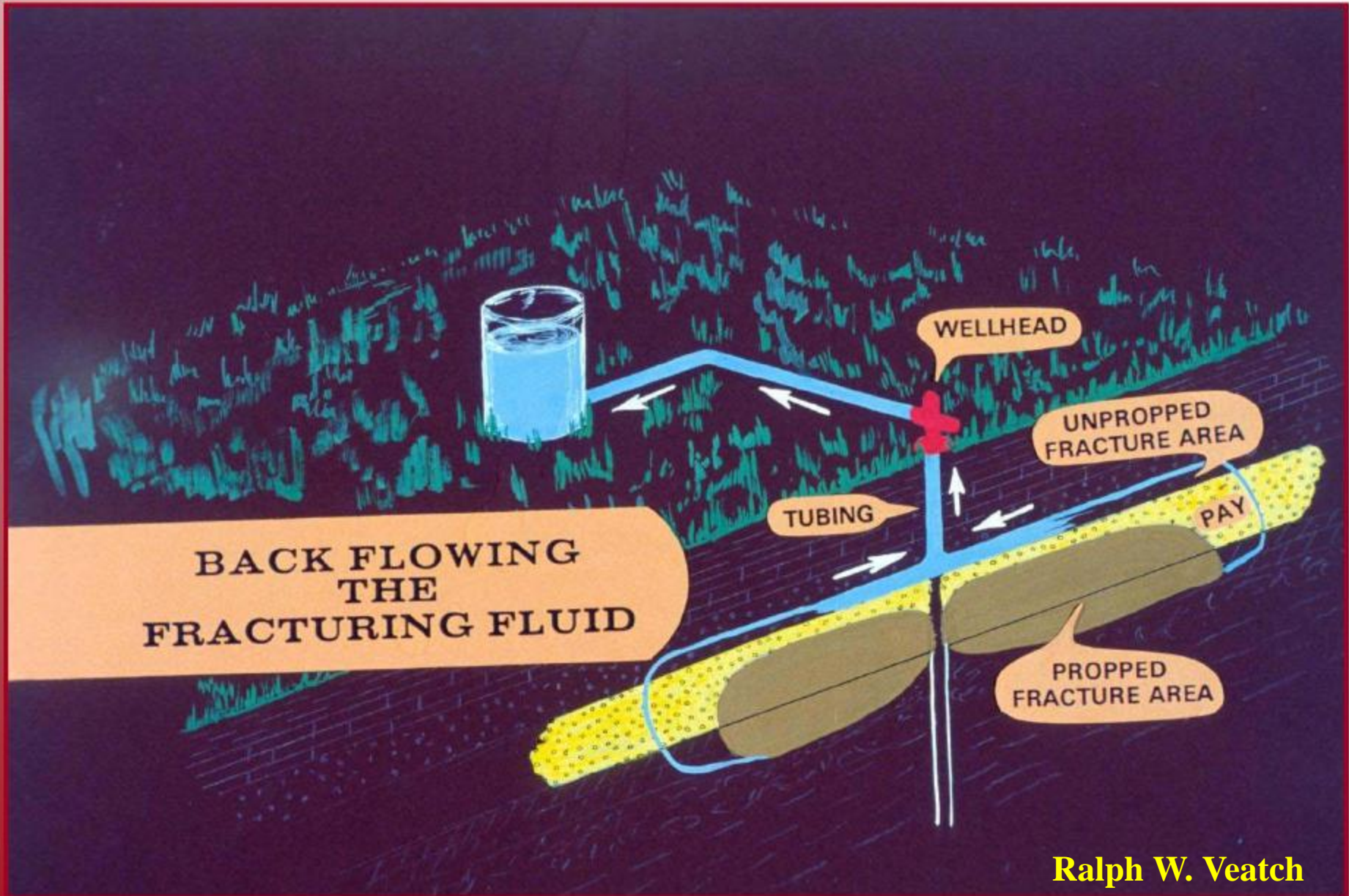
THE "TYPICAL" TREATMENT – STEP 1



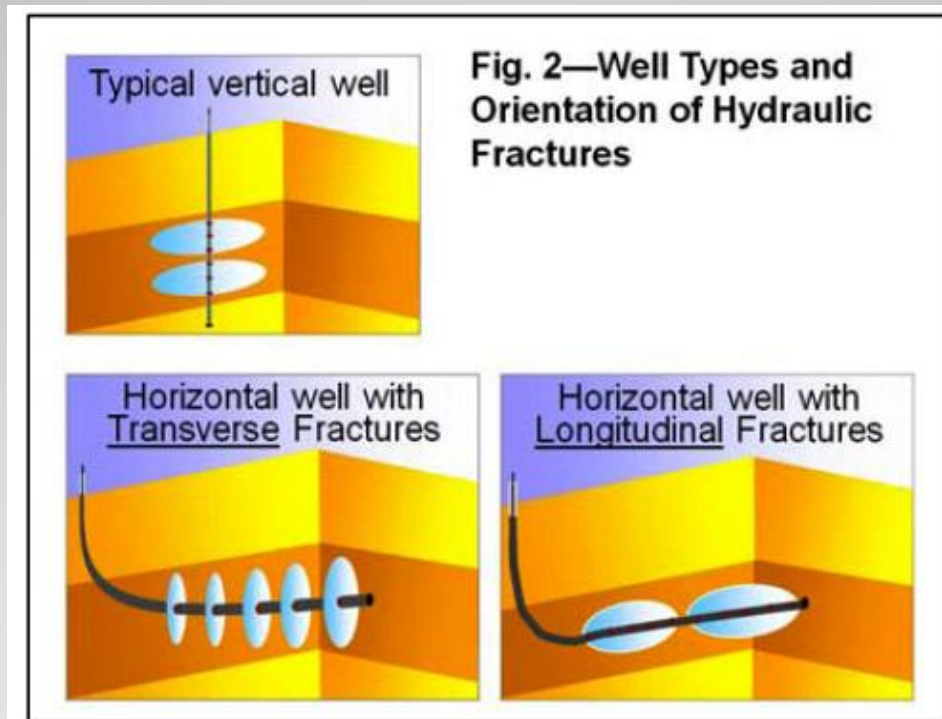
THE "TYPICAL" TREATMENT – STEP 2



THE "TYPICAL" TREATMENT – STEP 1

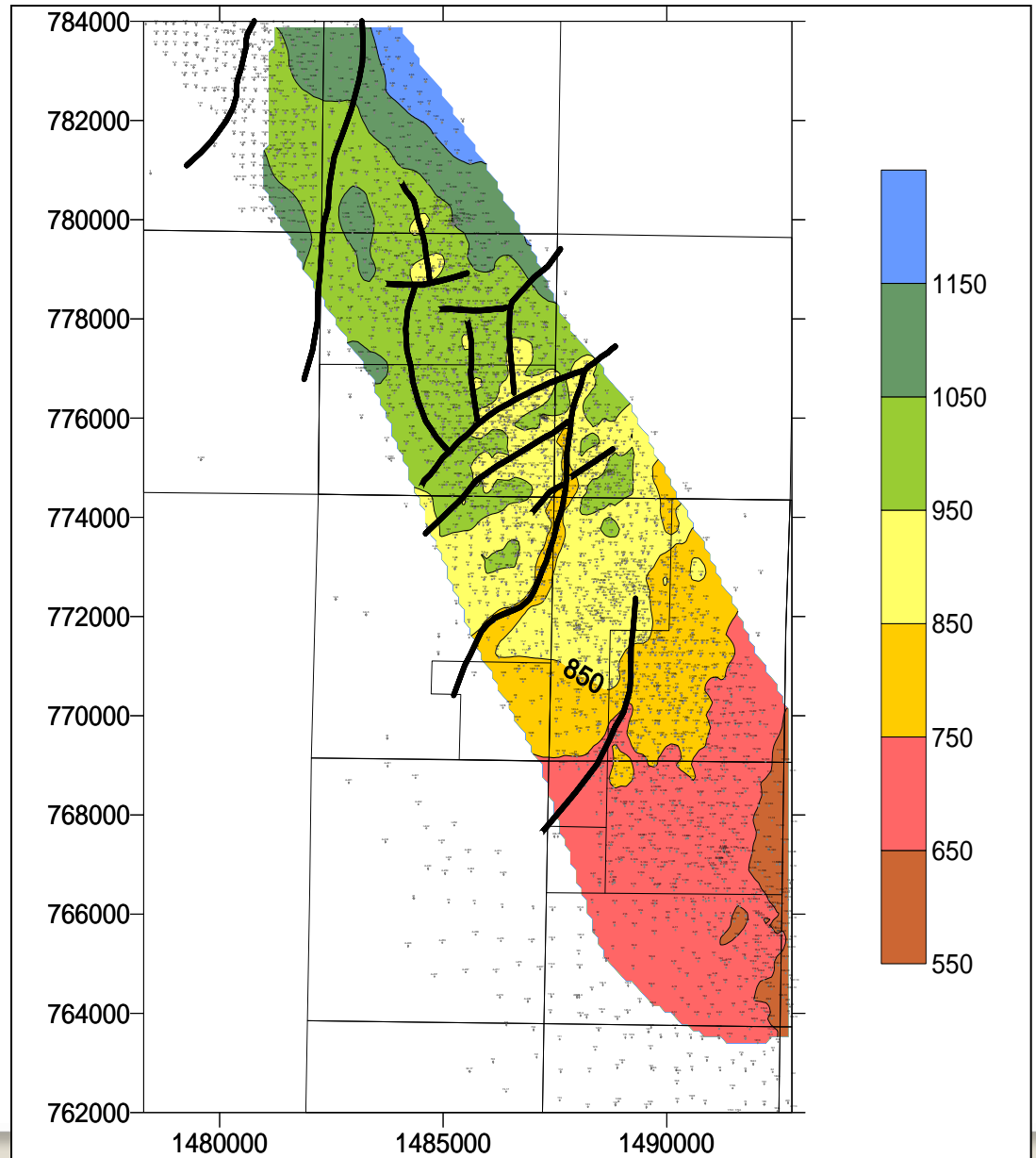


Hydraulic Fractures: Transverse vs Longitudinal



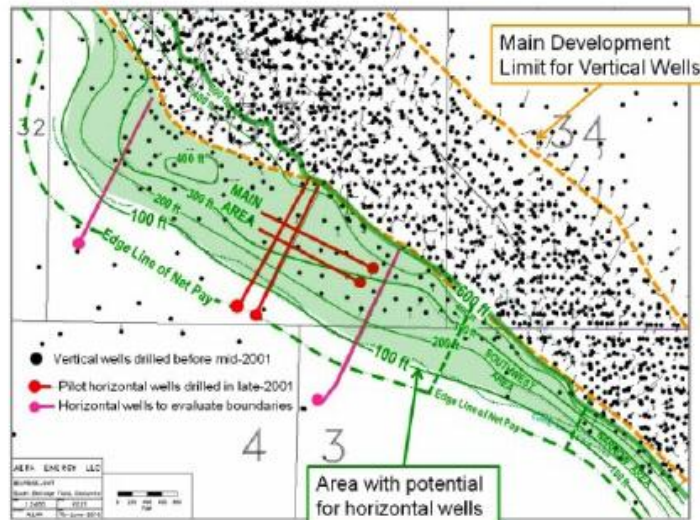
Has the technology been used in California during the last several decades?

Lost Hills



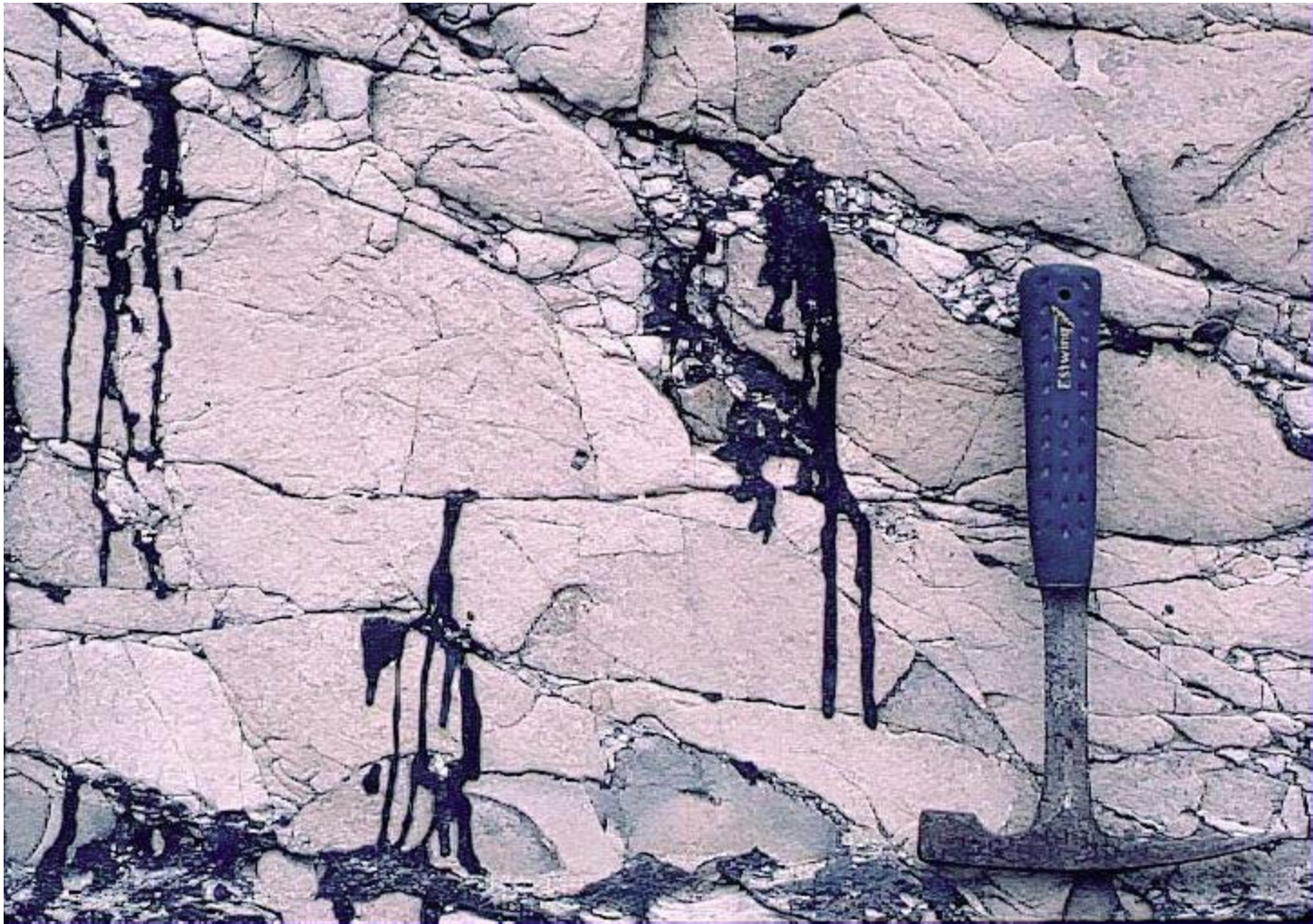
Horizontals with Longitudinal and Transverse Fractures, West Flank South Belridge

Fig. 19—Pilot Program, West Flank Project

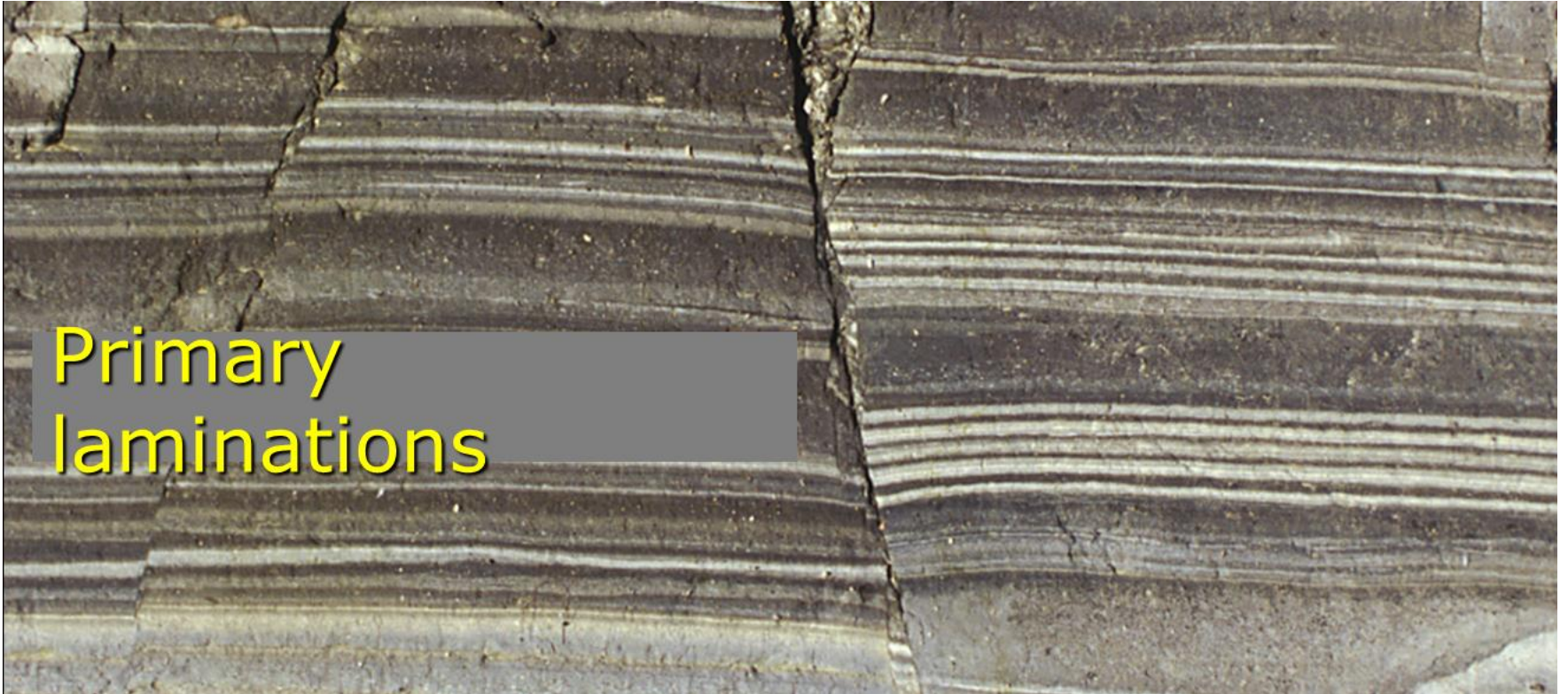


New Look at the Monterey Formation





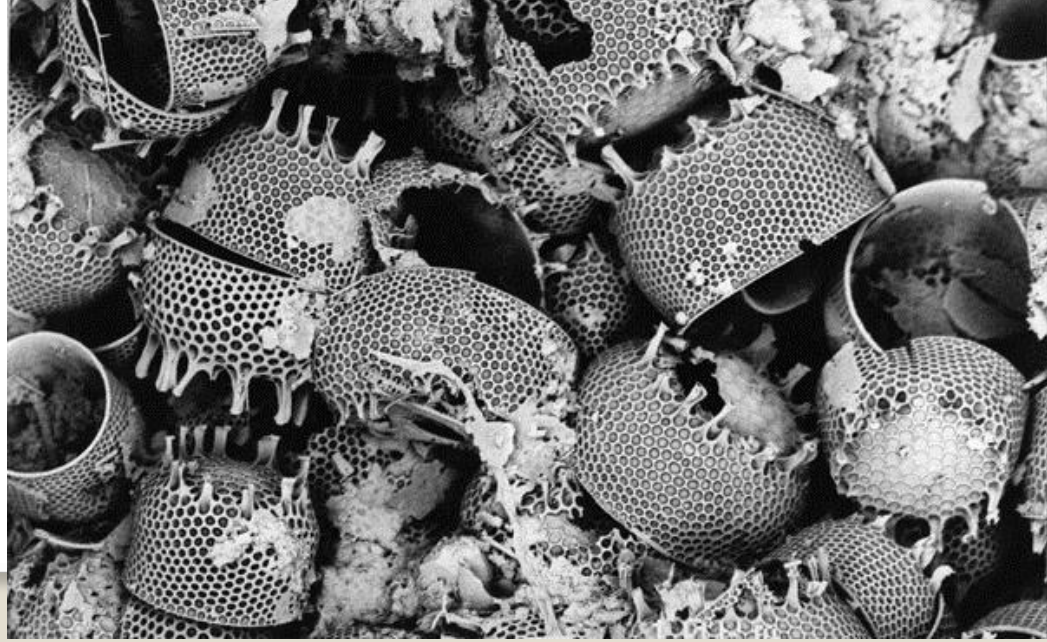
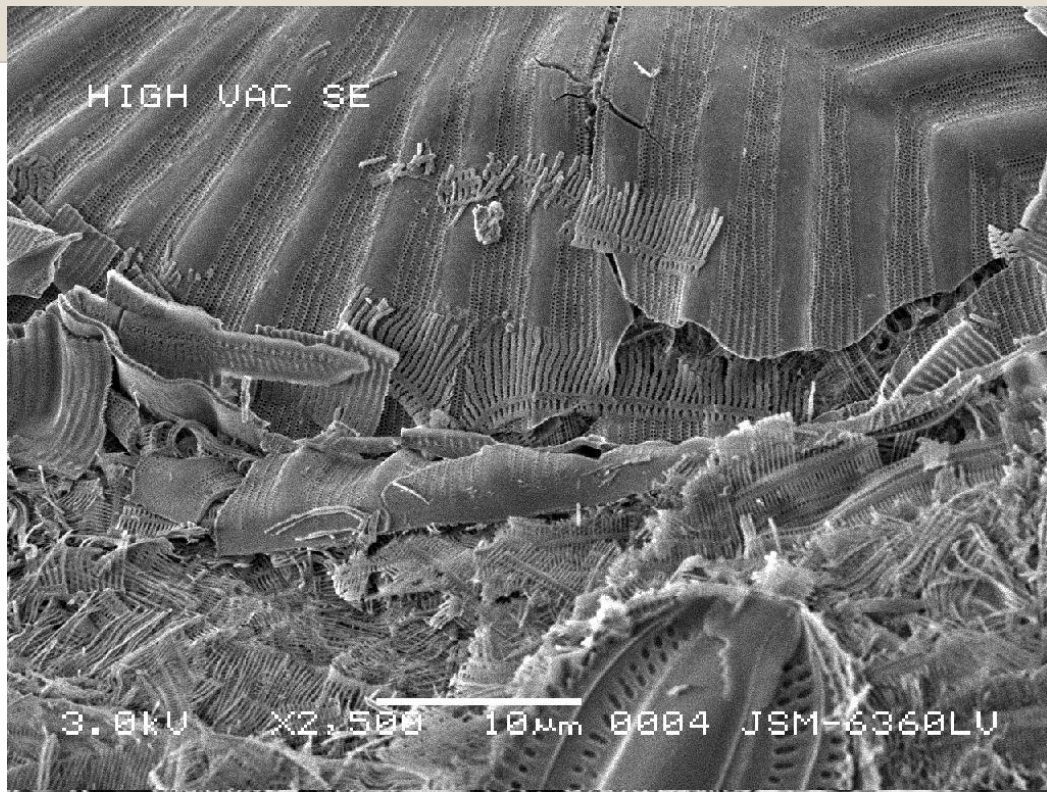
Tar Seeps Closeup at Carpinteria State Beach



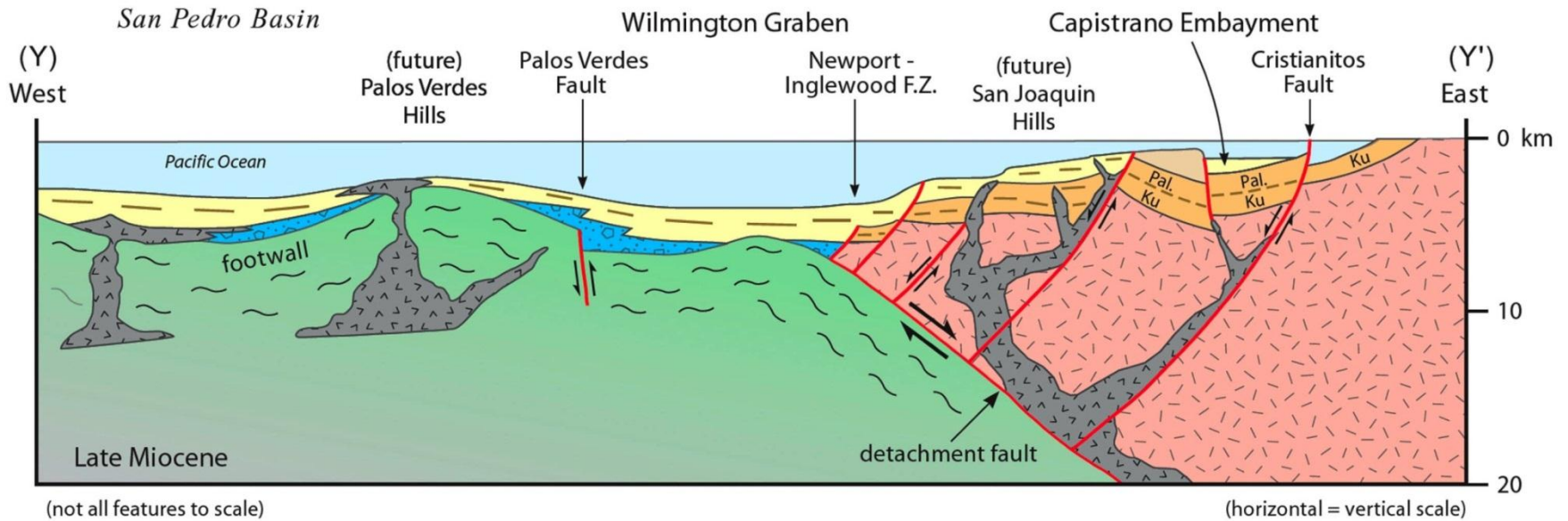
Primary
laminations

Thin beds



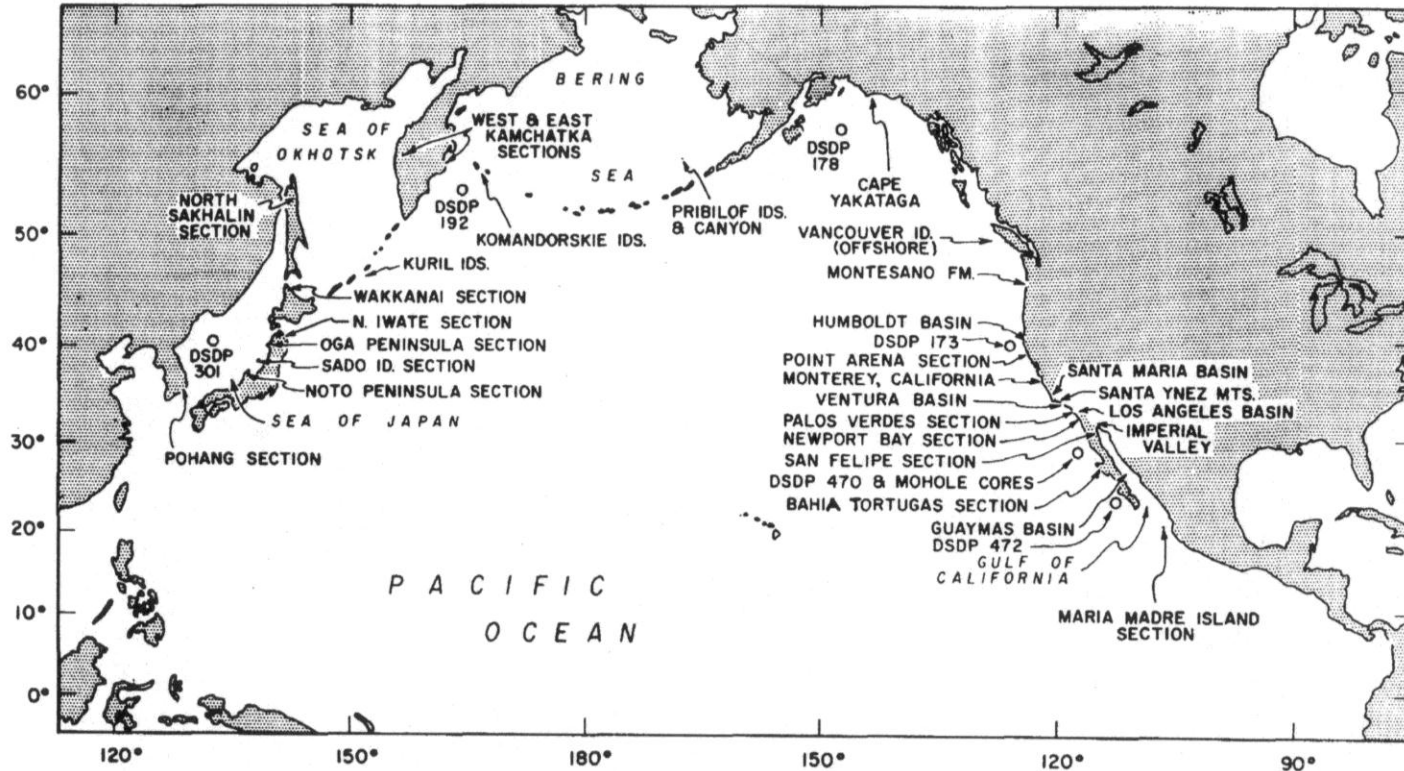


San Pedro Basin - Santa Ana Mountains



Crouch & Suppe (1993)

Figure 26
Occurrence of Monterey and Related Siliceous Rocks



After Ingle, 1981

Monterey Formation in California



- ✓ Onshore reservoirs
- ✓ Offshore Reservoirs
- ✓ Onshore source rock

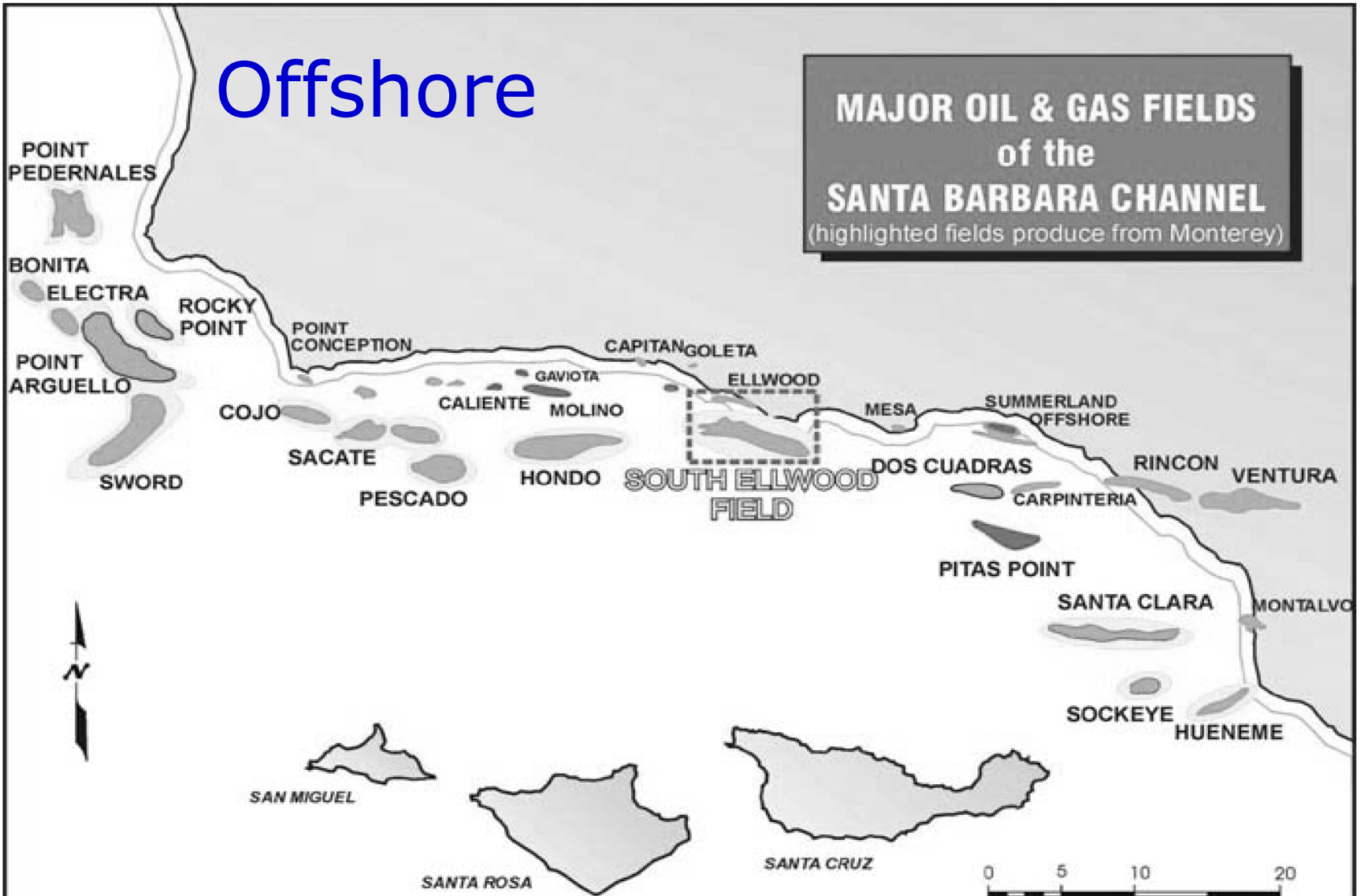
- Santa Maria Basin
- Offshore Fields-Monterey as a Reservoir Rock
- Onshore Permeability Issue (Monterey as a reservoir and source rock)

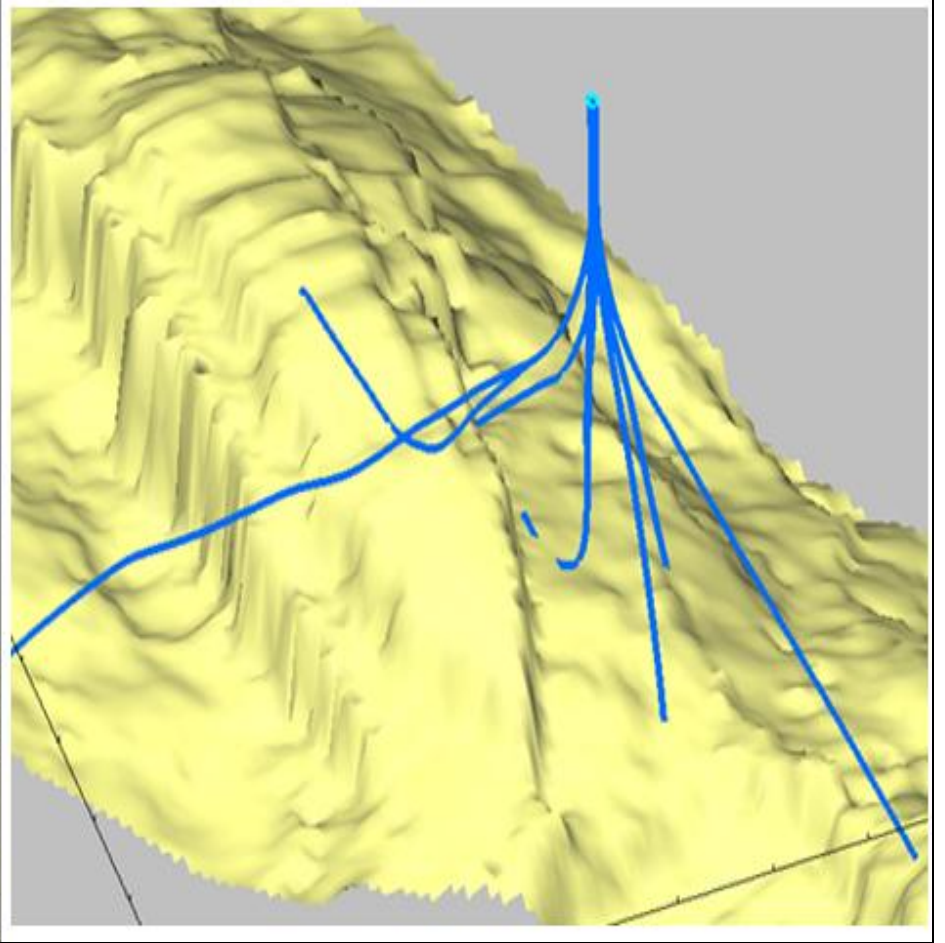
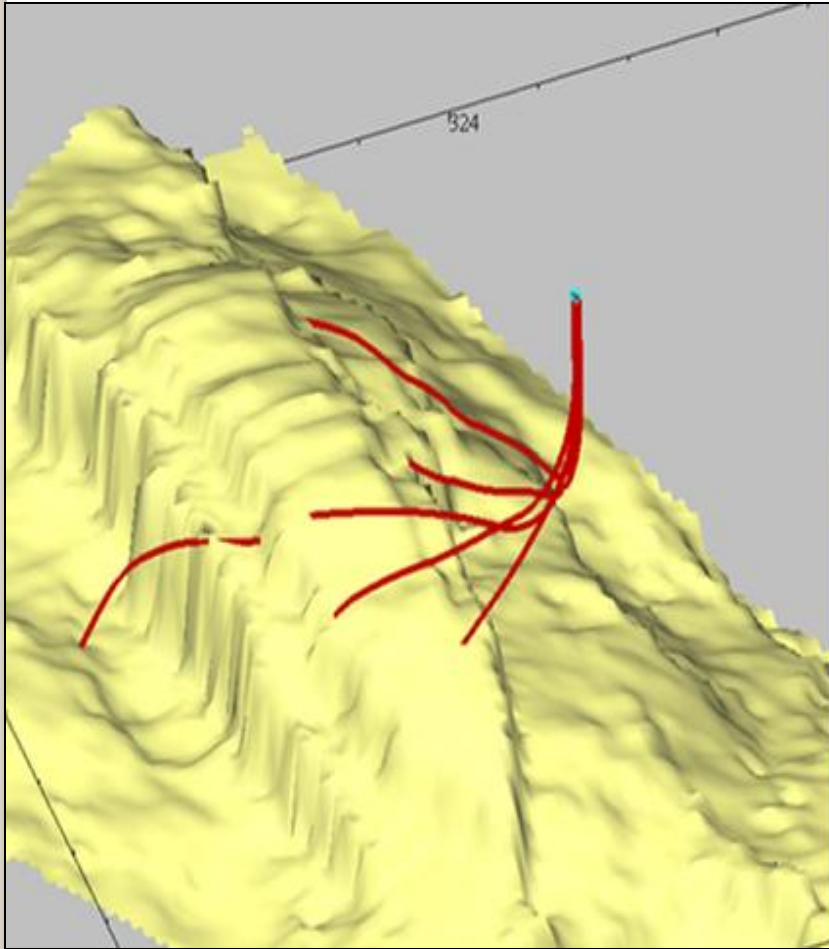
Monterey as a Reservoir Rock

Offshore

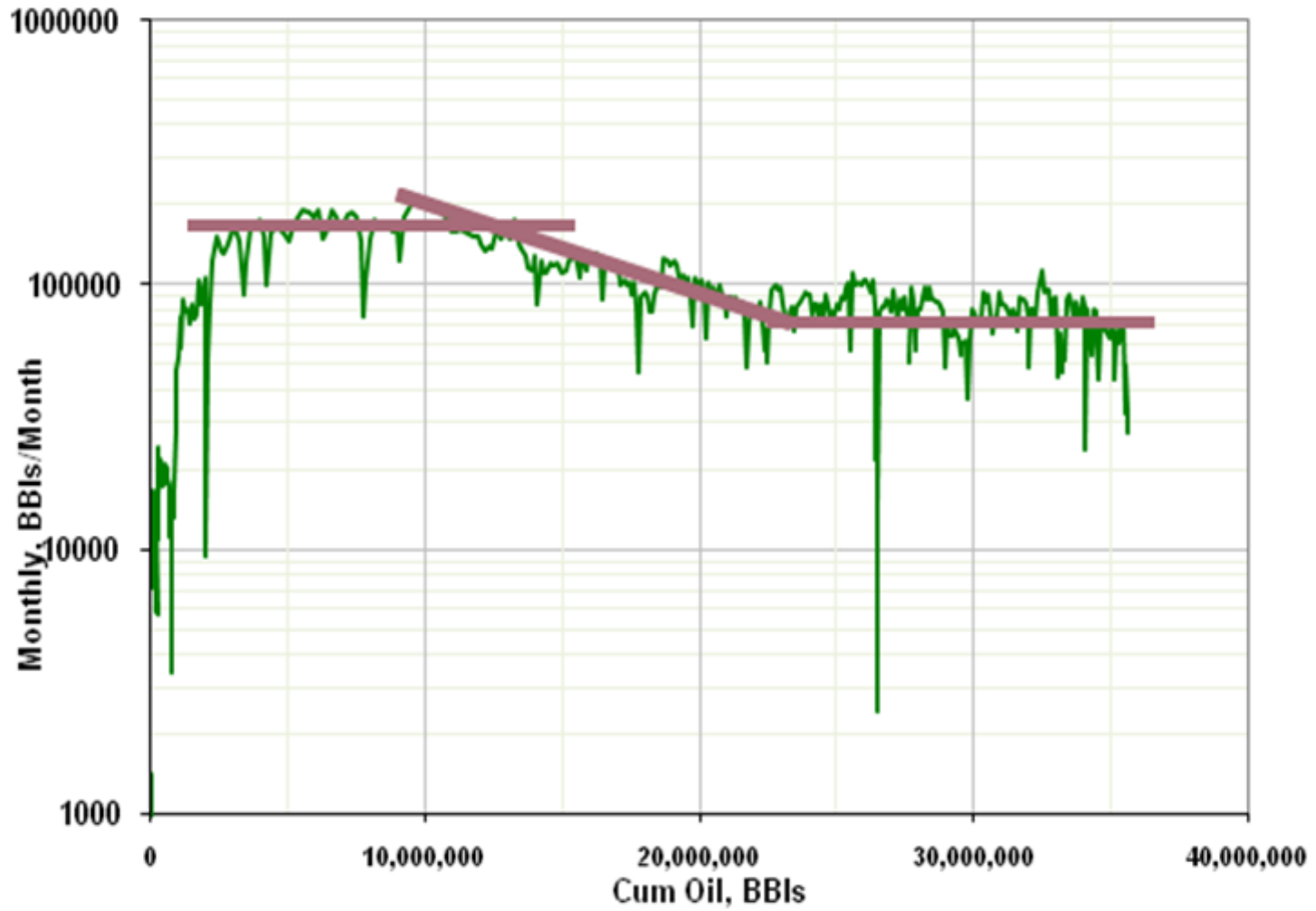
MAJOR OIL & GAS FIELDS of the SANTA BARBARA CHANNEL

(highlighted fields produce from Monterey)





Rate-Cum



| TIME (Ma) | EPOCH | FORMATION |
|-----------|-------------|-----------------------------|
| | HOLOCENE | ALLUVIUM |
| 1 | PLEISTOCENE | TULARE FM |
| 2 | | |
| | PLIOCENE | SAN JOAQUIN & ETCHEGOIN FMS |
| 5 | | |
| | MIOCENE | Reef Ridge Mbr |
| | | Belridge Diatomite |
| | | Brown Shale |
| | | Antelope Shale |
| | | McClure Mbr |
| | | McDonald Shale |
| | | Devilwater Mbr |
| | Gould Mbr | |
| 16 | | |
| | OLIGOCENE | TEMBLOR FM |
| 24 | | |
| 37 | EOCENE | KREYENHAGEN FM |

Monterey Formation

Maturity Index

| Company | Net Acreage |
|------------------------------------|--------------------|
| Berry Petroleum | 6,500 |
| National Fuel Gas Company (NFG) | 14,000 |
| Occidental Petroleum Company (Oxy) | 873,000 |
| Plains Exploration and Production | 70,000 |
| Venoco | 158,000 |

Table 57 Monterey/Santos Average EUR and Area

| | Active |
|--------------------------------|---------------|
| Area (sq. miles) | 1,752 |
| EUR (MBO/ well) | 550 |
| Well Spacing (wells/ sq. mile) | 16 |
| TRR (BBO) | 15.42 |

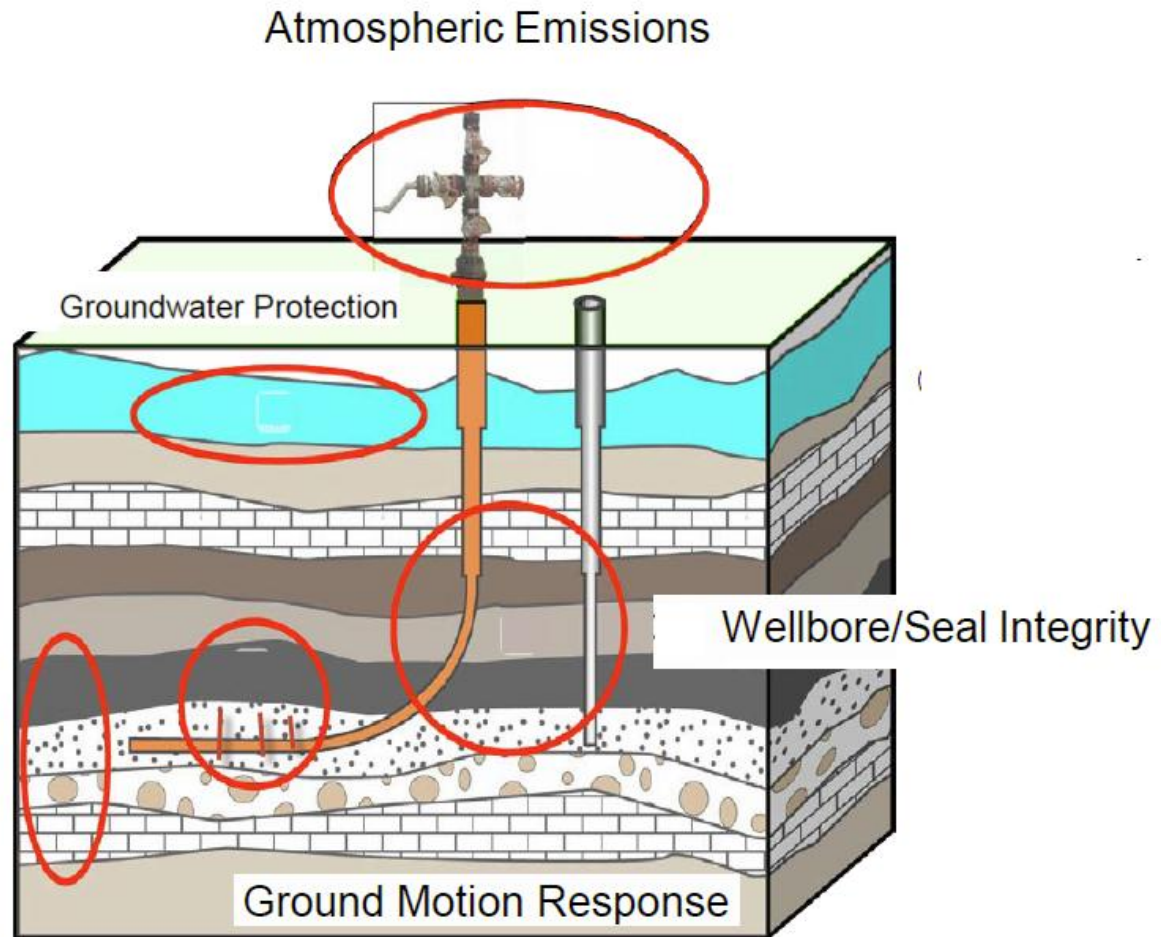
California Monterey

Table ii U.S. Technically Recoverable Shale Oil Resources Summary

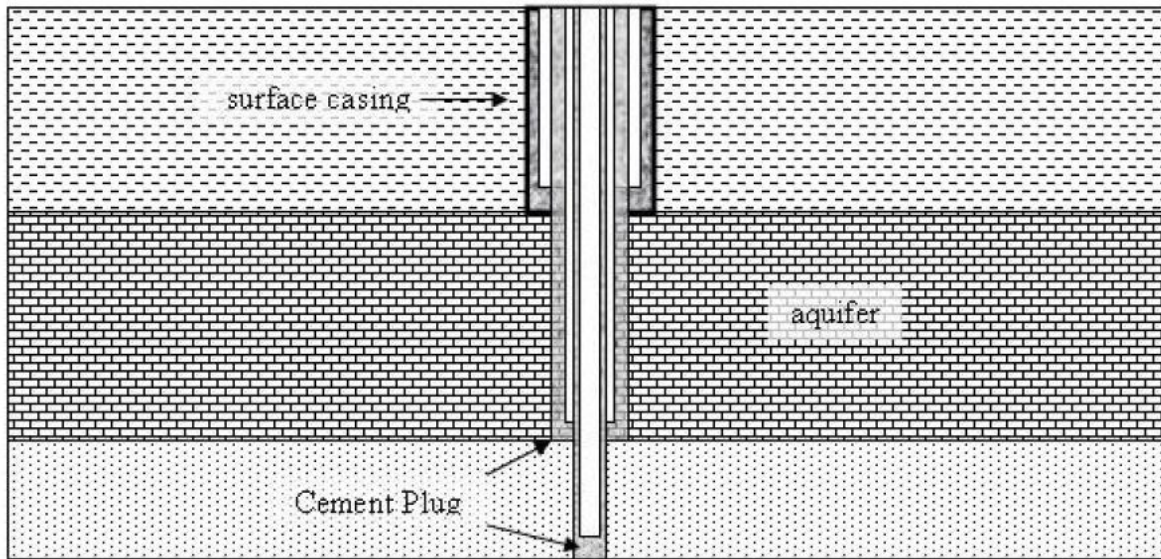
| Play | Technically Recoverable Resource | | Area (sq. miles) | | Average EUR | |
|-----------------------------|----------------------------------|--------------|------------------|----------|----------------|----------------|
| | Gas (Tcf) | Oil (BBO) | Leased | Unleased | Gas (Bcf/well) | Oil (MBO/well) |
| Eagle Ford | ... | 3.35 | 3,323 | | ... | 300 |
| Total Gulf Coast | ... | 3.35 | 3,323 | | ... | 300 |
| Avalon & Bone Springs | ... | 1.58 | 1,313 | | ... | 300 |
| Total Southwest | ... | 1.58 | 1,313 | | ... | 300 |
| Bakken | ... | 3.59 | 6,522 | | ... | 550 |
| Total Rocky Mountain | ... | 3.59 | 6,522 | | ... | 550 |
| Monterey/Santos | ... | 15.42 | 1,752 | | ... | 550 |
| Total West Coast | ... | 15.42 | 1,752 | | ... | 550 |
| Total Lower 48 U.S. | ... | 23.94 | 12,910 | | ... | 460 |

EIA estimates

Concerns and Mitigation Measures



Modified
NETL



- Better rock potential evaluation tools
- Better well course planning
- Better geosteering tools
- Advanced micro seismic monitoring

Today's Technology