Distinguished Lecturer Program

Primary funding is provided by

The SPE Foundation through member donations and a contribution from Offshore Europe

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Additional support provided by AIME

Distinguished Lecturer Program

First-Ever Environmental Characterization of Hydraulic Fracturing for Shale Oil and Gas Production

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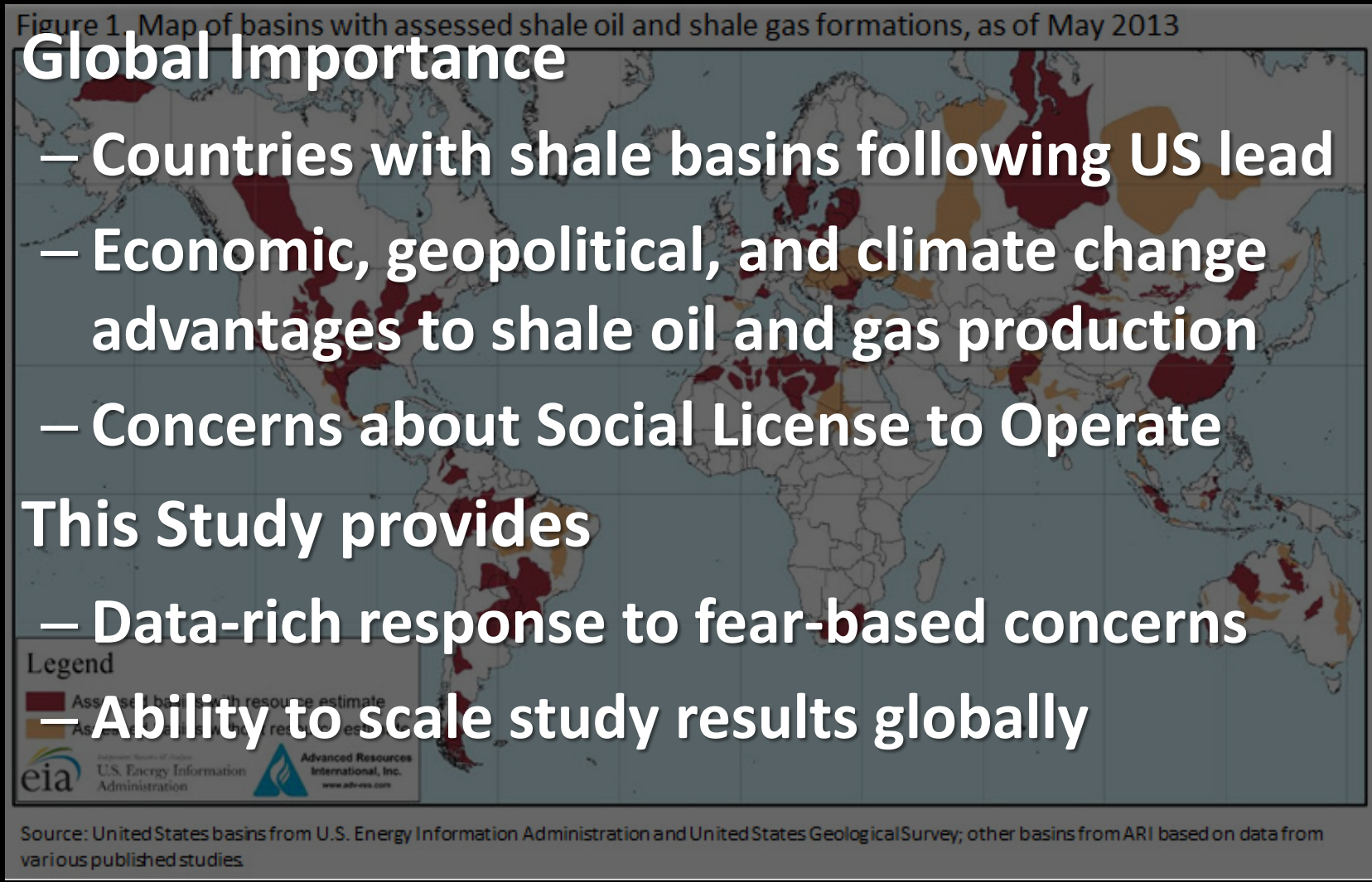
President
Catalyst Environmental Solutions Corporation
Los Angeles, California

Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl

Local Study With Global Implication

- Global Importance
  - Countries with shale basins following US lead
  - Economic, geopolitical, and climate change advantages to shale oil and gas production
  - Concerns about Social License to Operate
- This Study provides
  - Data-rich response to fear-based concerns
  - Ability to scale study results globally



Hydraulic Fracturing Environmental Study

- Largest urban oil field in the world, in the center of Los Angeles, California
- Feasibility and environmental impacts of hydraulic fracturing
- Peer-reviewed, data-driven information on the effects of hydraulic fracturing

Concerns of a diverse urban community required a comprehensive study design

Environmental Baseline:


Los Angeles Basin is the richest in oil worldwide by size
Inglewood
East Los Angeles
Downey
Norway
Fullerton
Torrance
Anaheim
Orange
Garden Grove
Santa Ana
Huntington Beach
Coast Mesa
A need for coexistence

Comprehensive Measurements before, during, and after hydraulic fracturing:

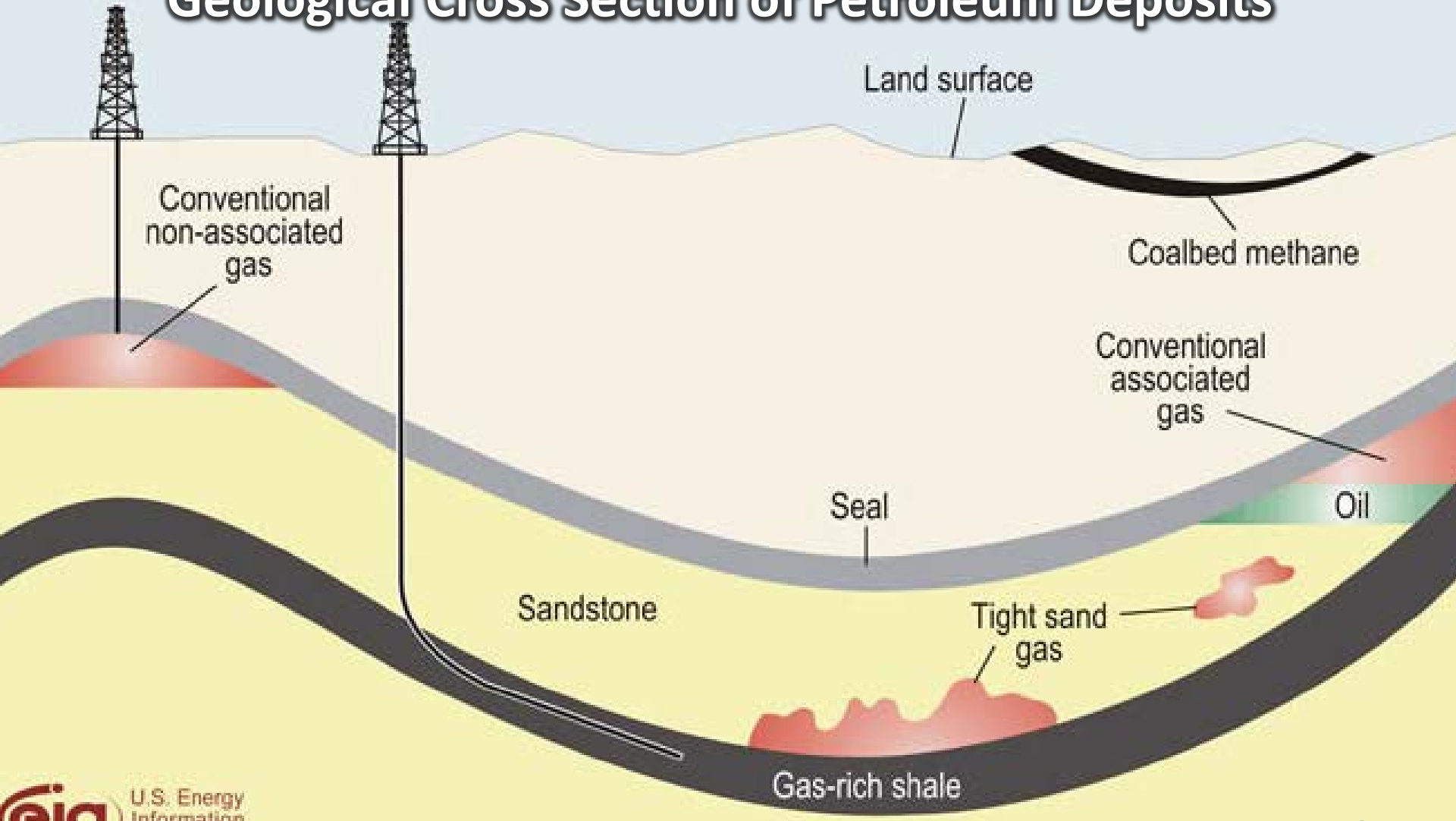
- ✓ Hydrogeology
- ✓ Water Use
- ✓ Water Quality
- ✓ Containment of Fractures
- ✓ Well Integrity
- ✓ Slope Stability
- ✓ Subsidence
- ✓ Ground Movement
- ✓ Induced Seismicity
- ✓ Methane
- ✓ Air Emissions
- ✓ Noise
- ✓ Vibration
- ✓ Community Health*

Results applicable to other parts of the world

www.eenews.net/assets/2012/10/11/document_ew_01.pdf

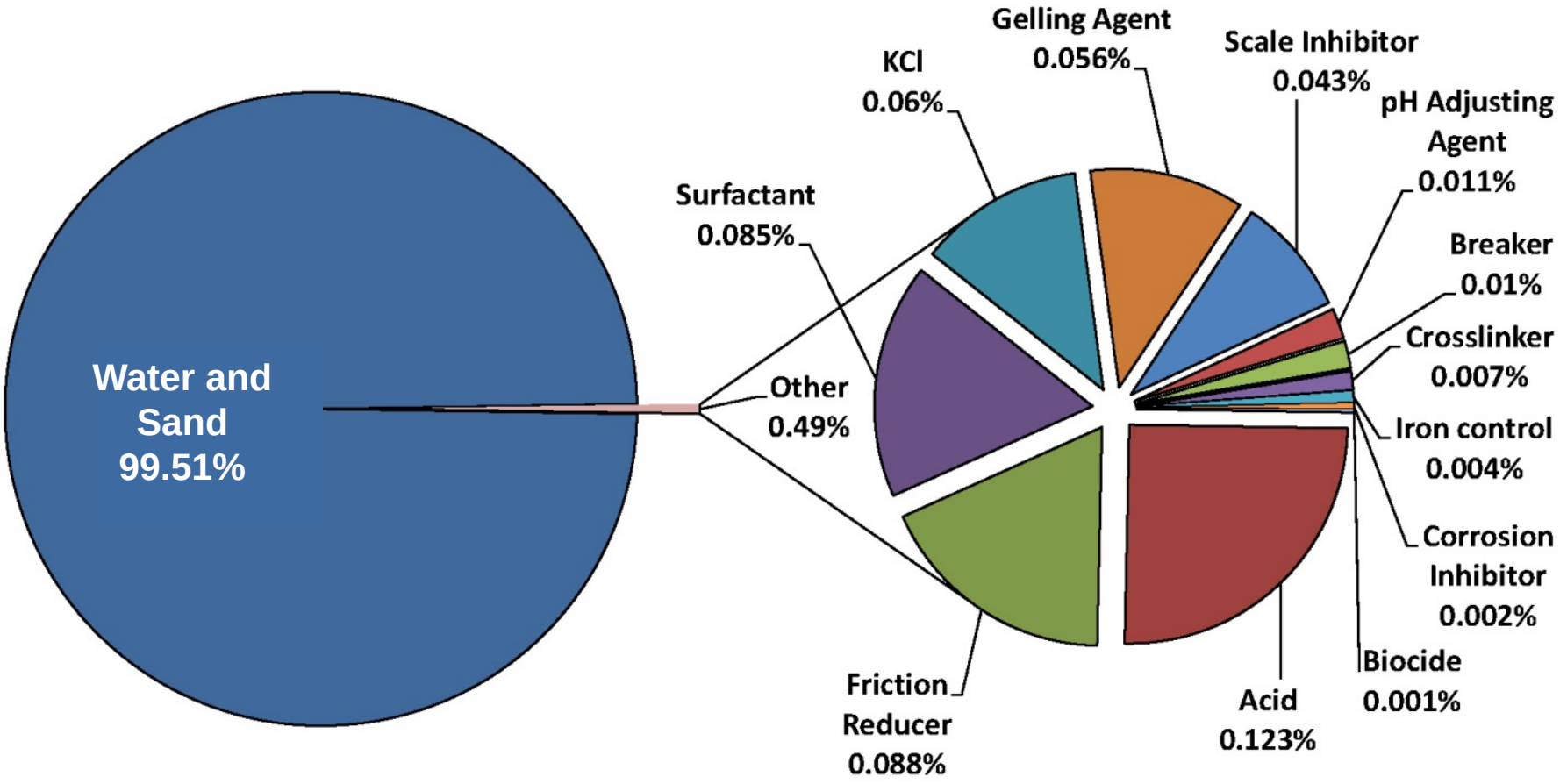
Hydraulic Fracturing of Shales

Geological Cross Section of Petroleum Deposits

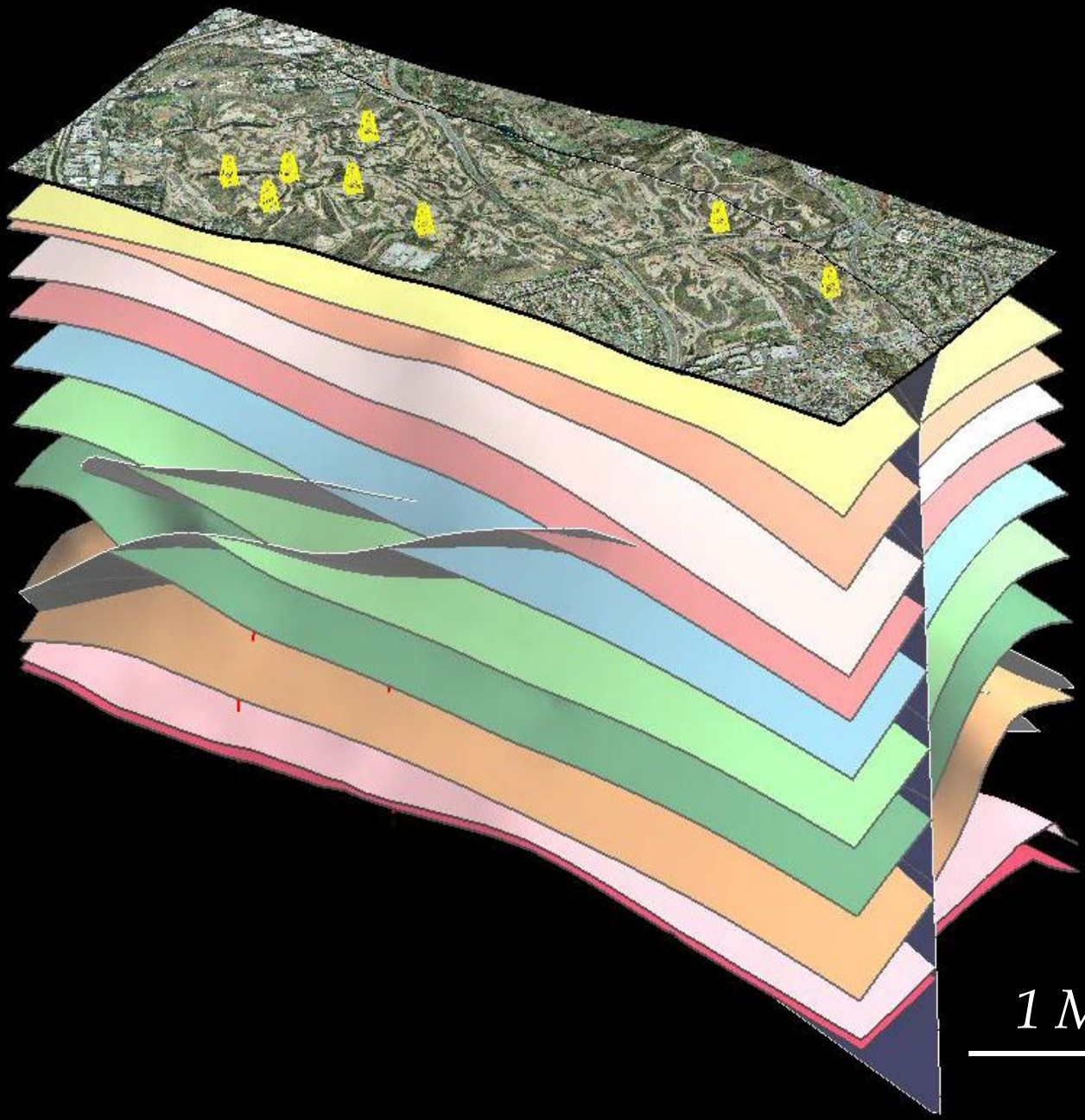


U.S. Energy Information Administration

Fluids Used in Hydraulic Fracturing

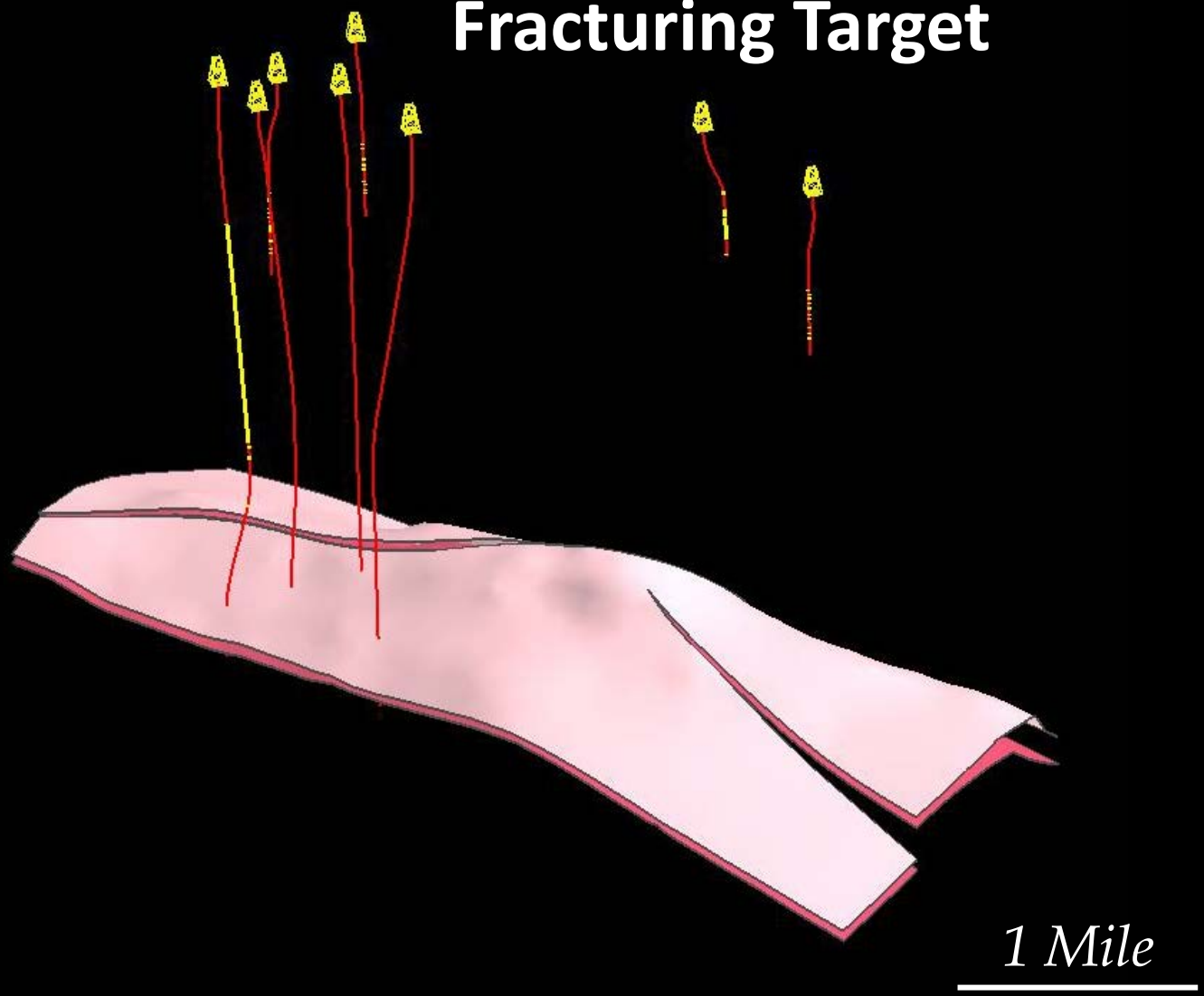


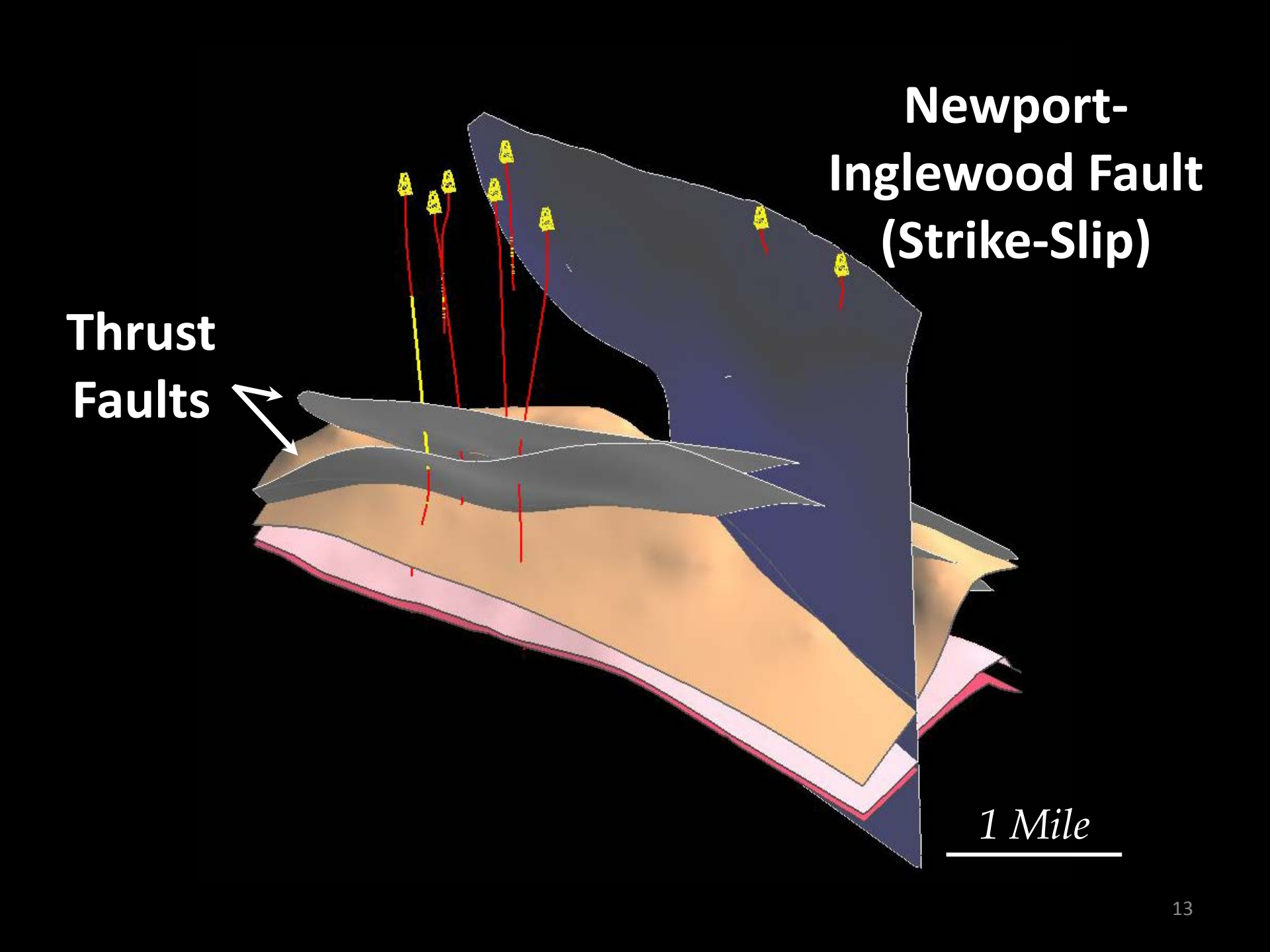
Full Report: http://www.hydraulicfracturingdisclosure.org/fracfocusfind/

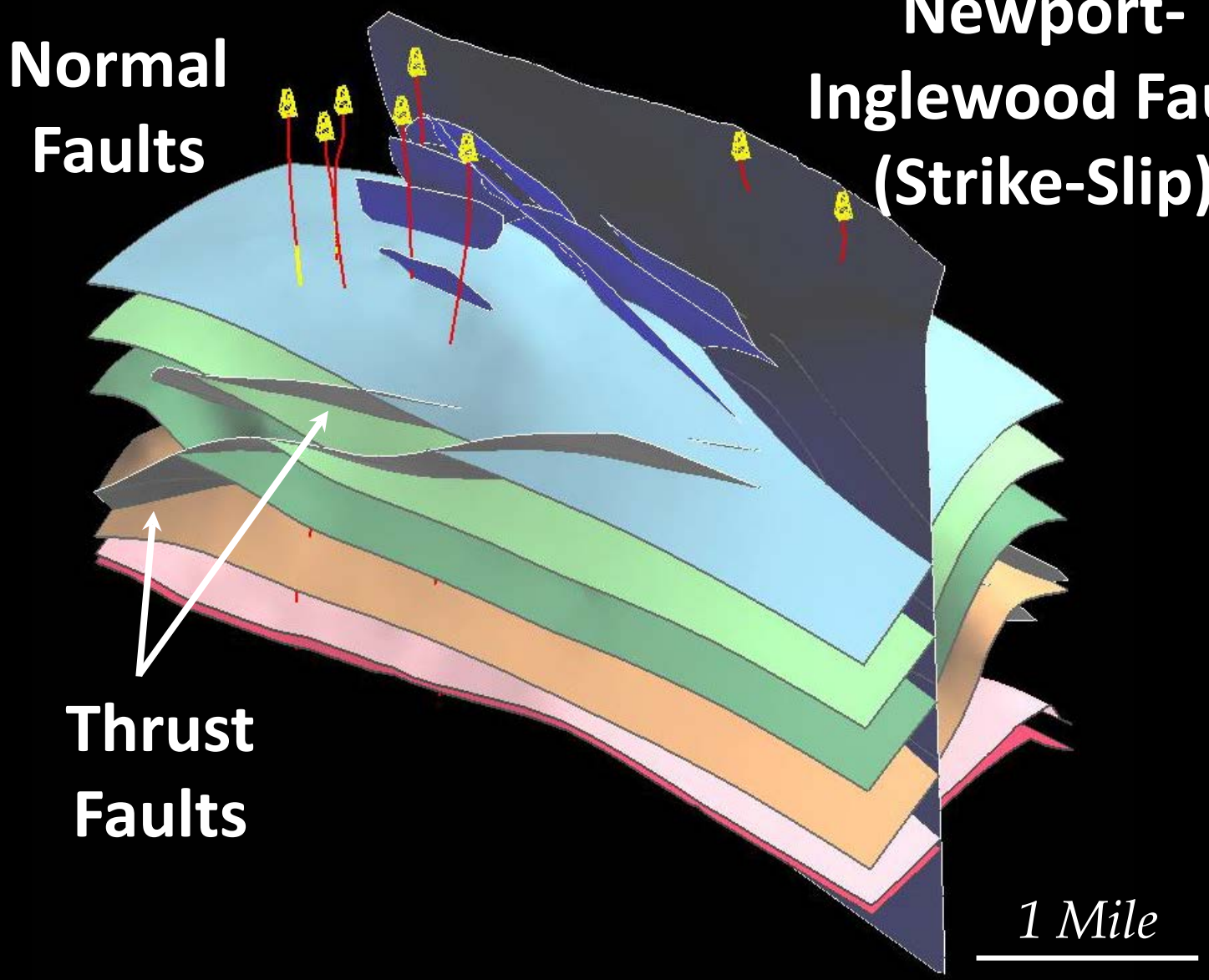


Oil Field consists of shales and sandstones, folded and faulted

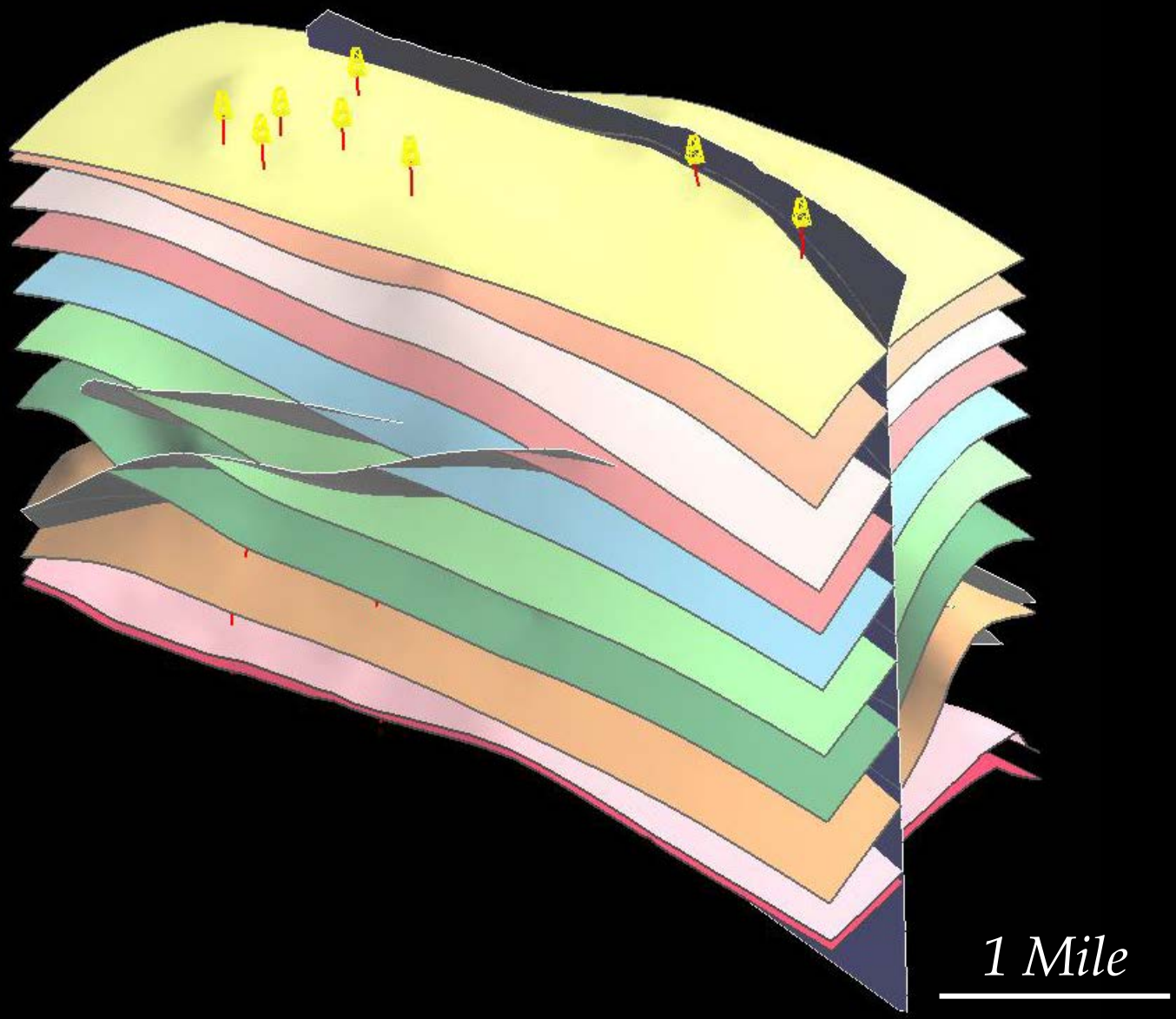
Nodular Shale: Fracturing Target



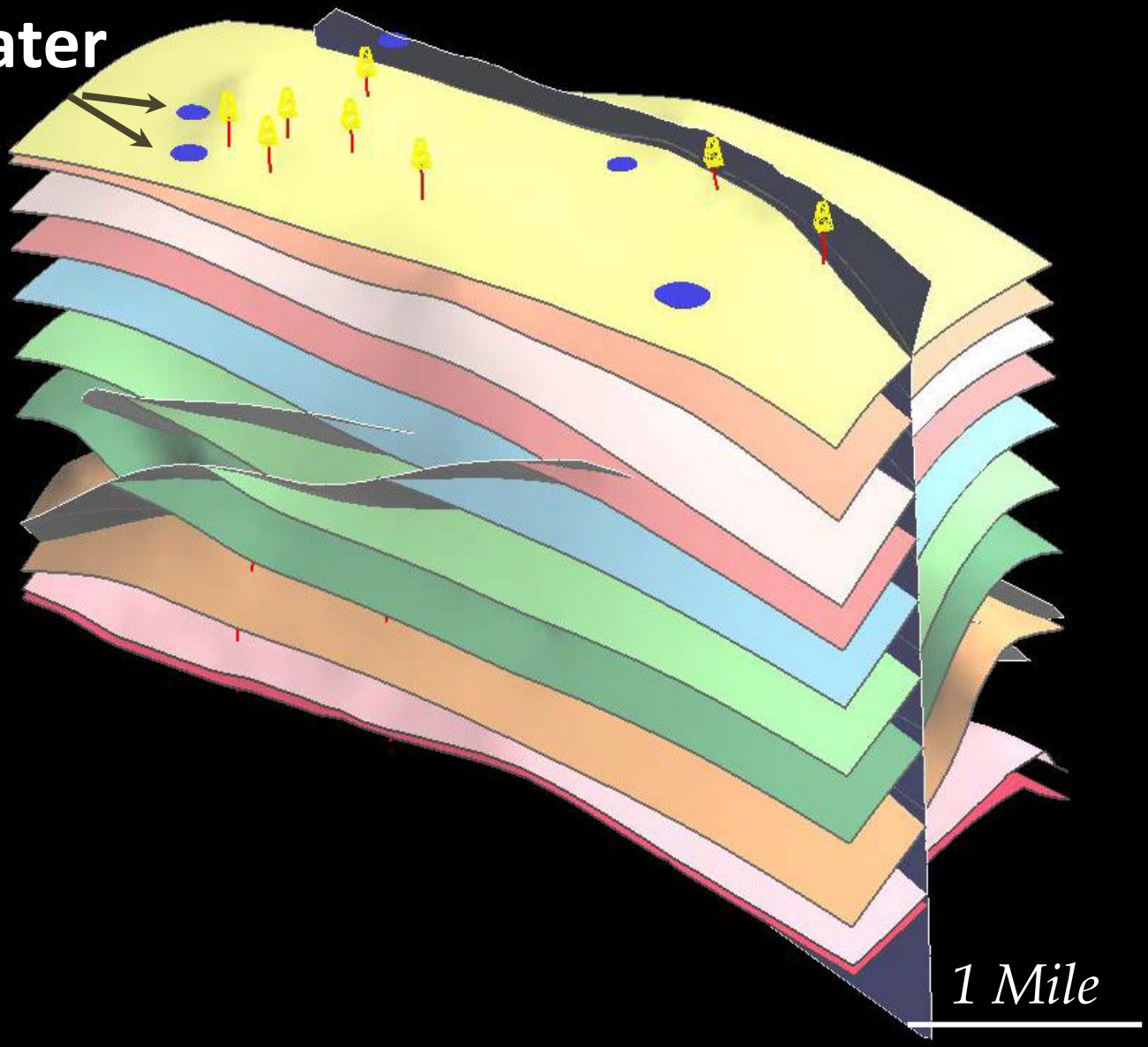

Newport-
Inglewood Fault
(Strike-Slip)
Thrust
Faults
1 Mile


Normal Faults
Newport-Inglewood Fault (Strike-Slip)
Thrust Faults
1 Mile

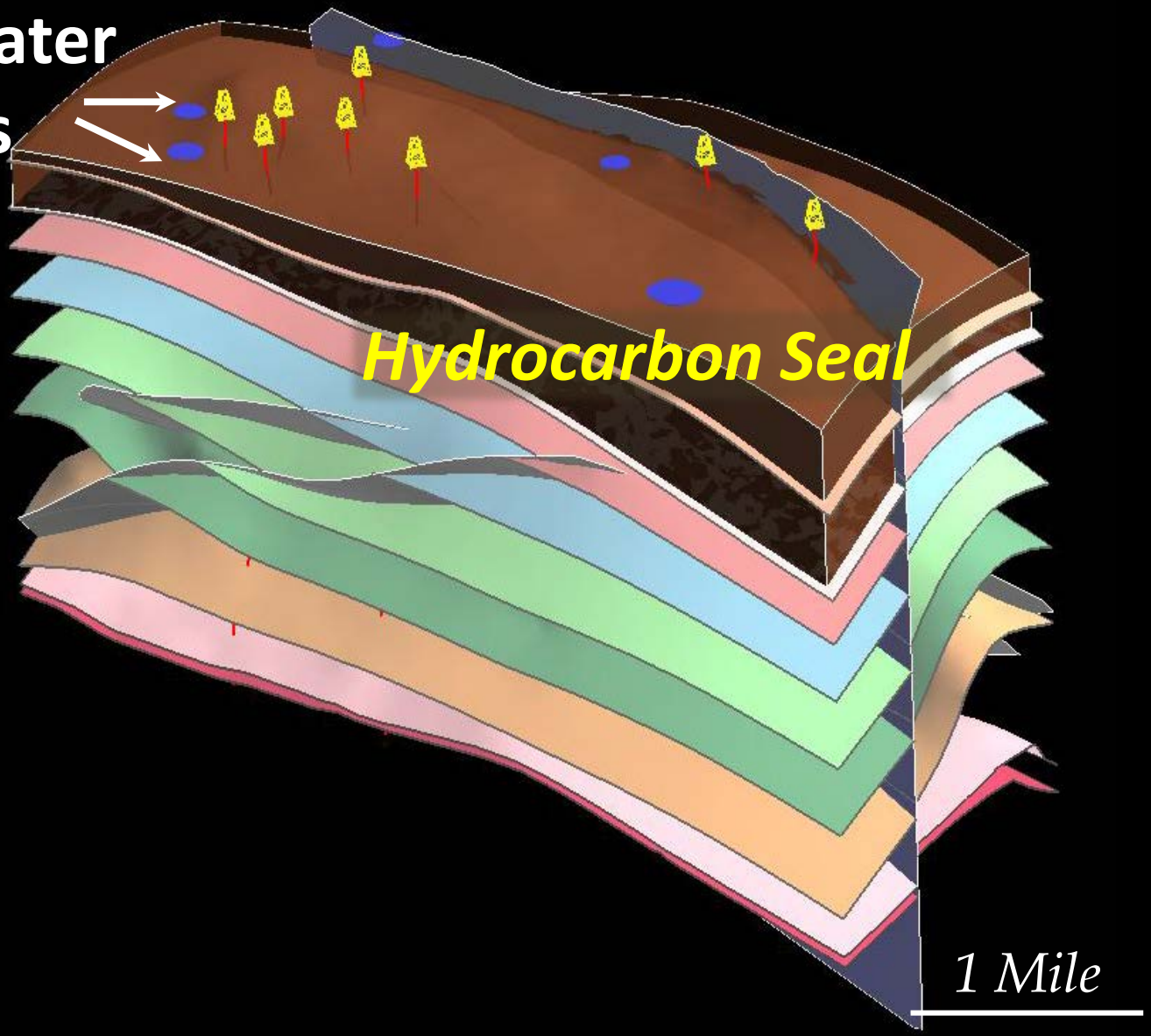
Base of Fresh Water

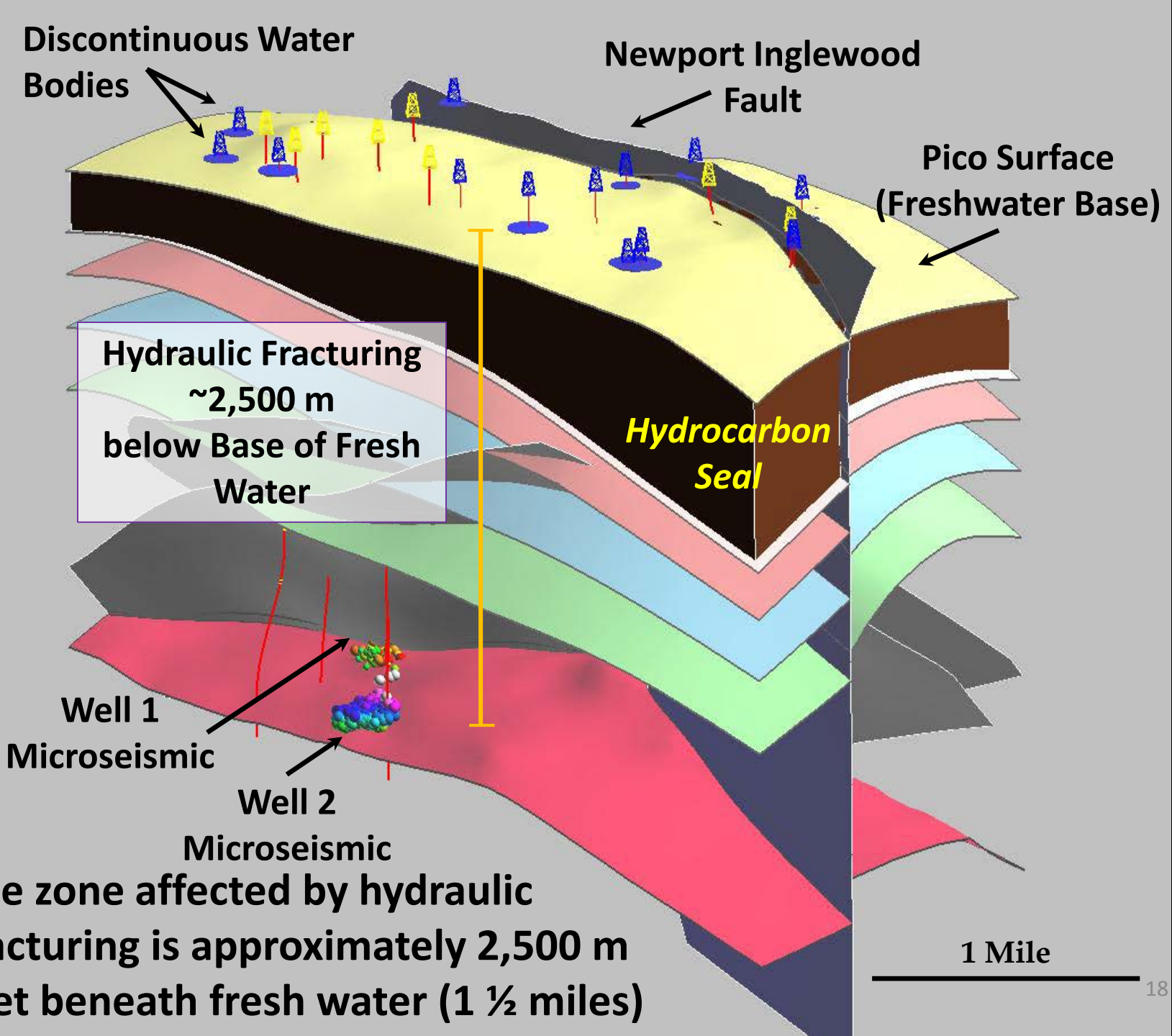


Discontinuous Groundwater Lenses

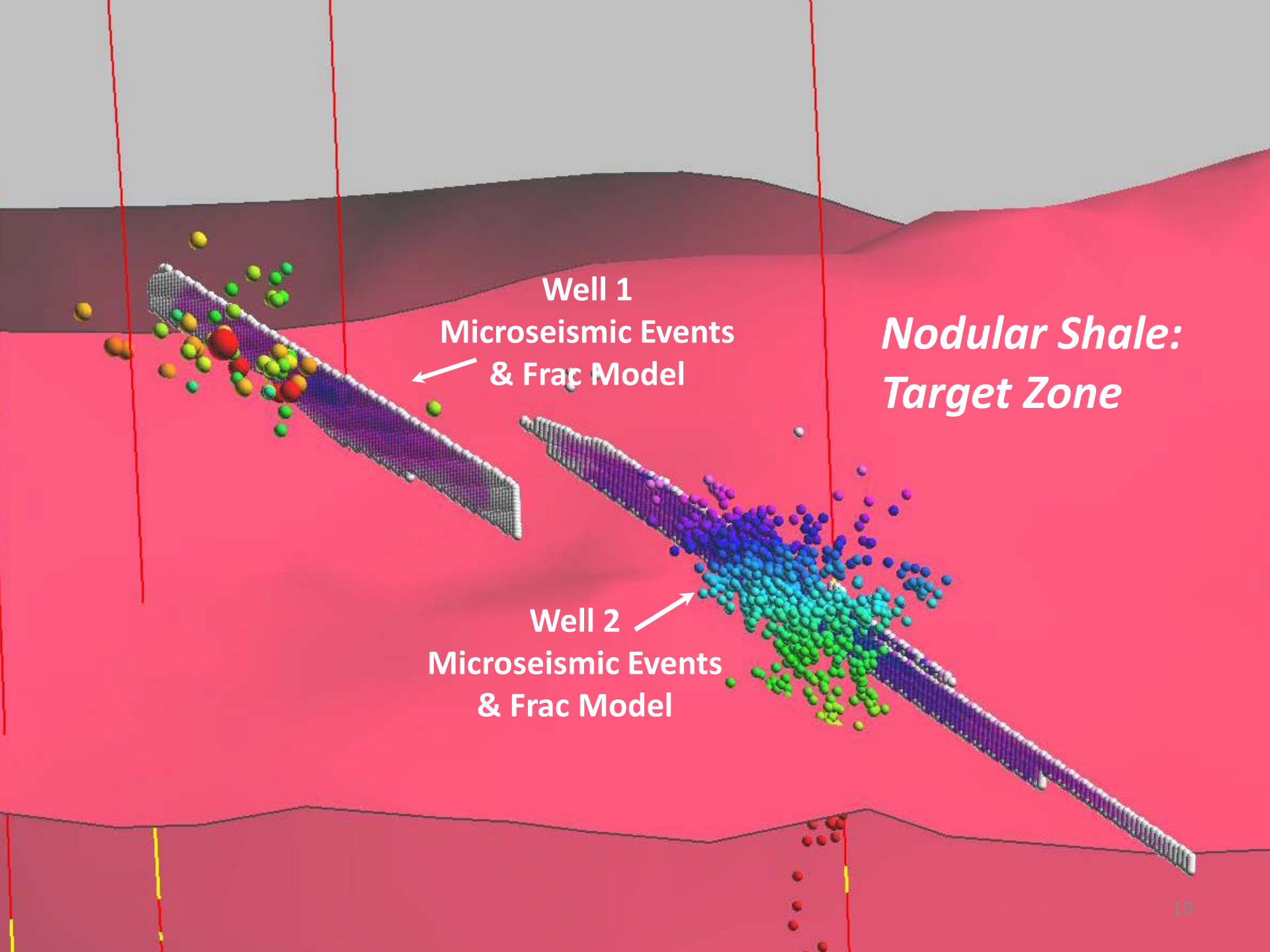


Discontinuous Groundwater Lenses

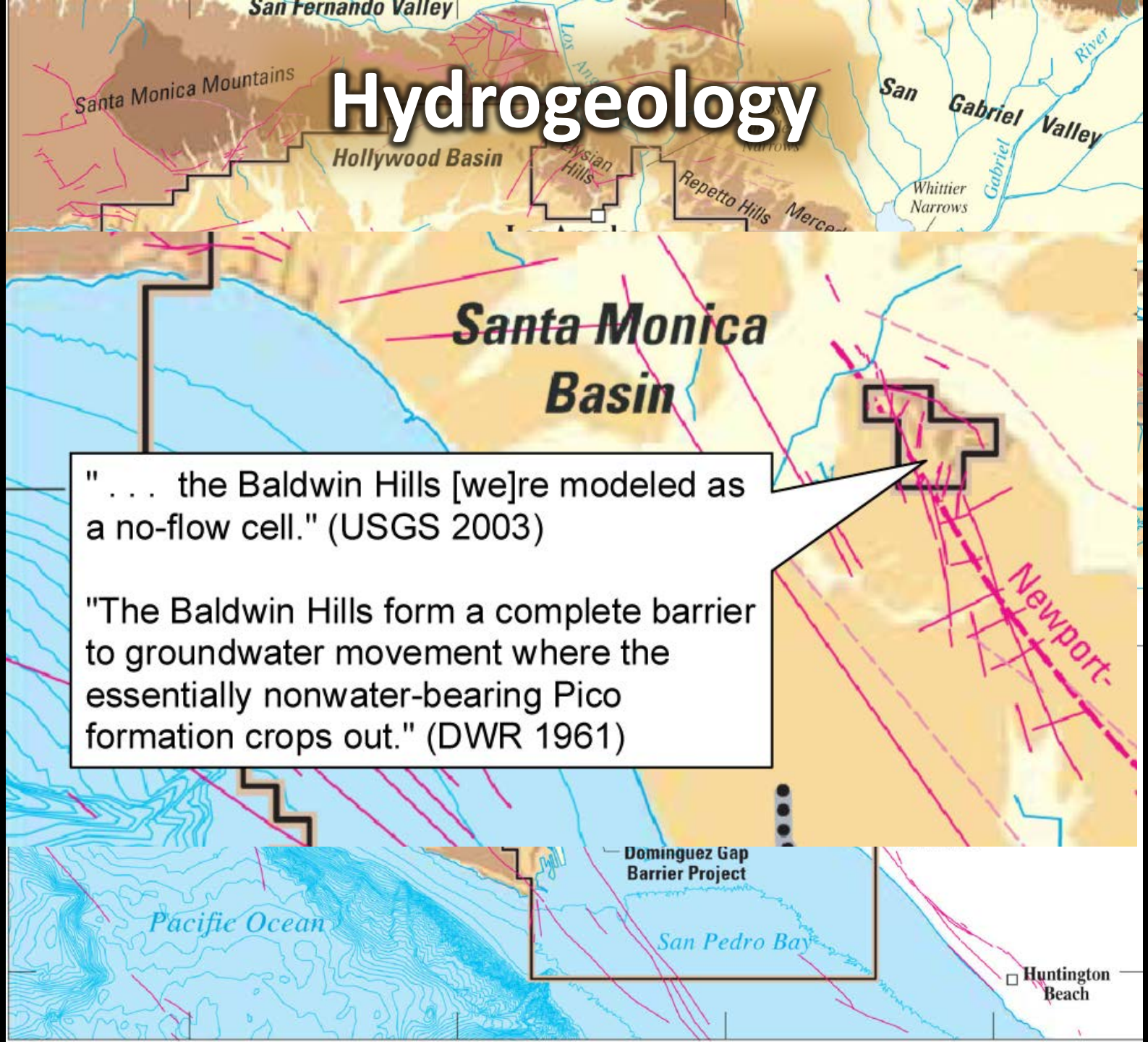




The zone affected by hydraulic fracturing is approximately 2,500 m feet beneath fresh water (1 ½ miles)


Well 1
Microseismic Events
& Frac Model
Nodular Shale:
Target Zone
Well 2
Microseismic Events
& Frac Model

Hydrogeology

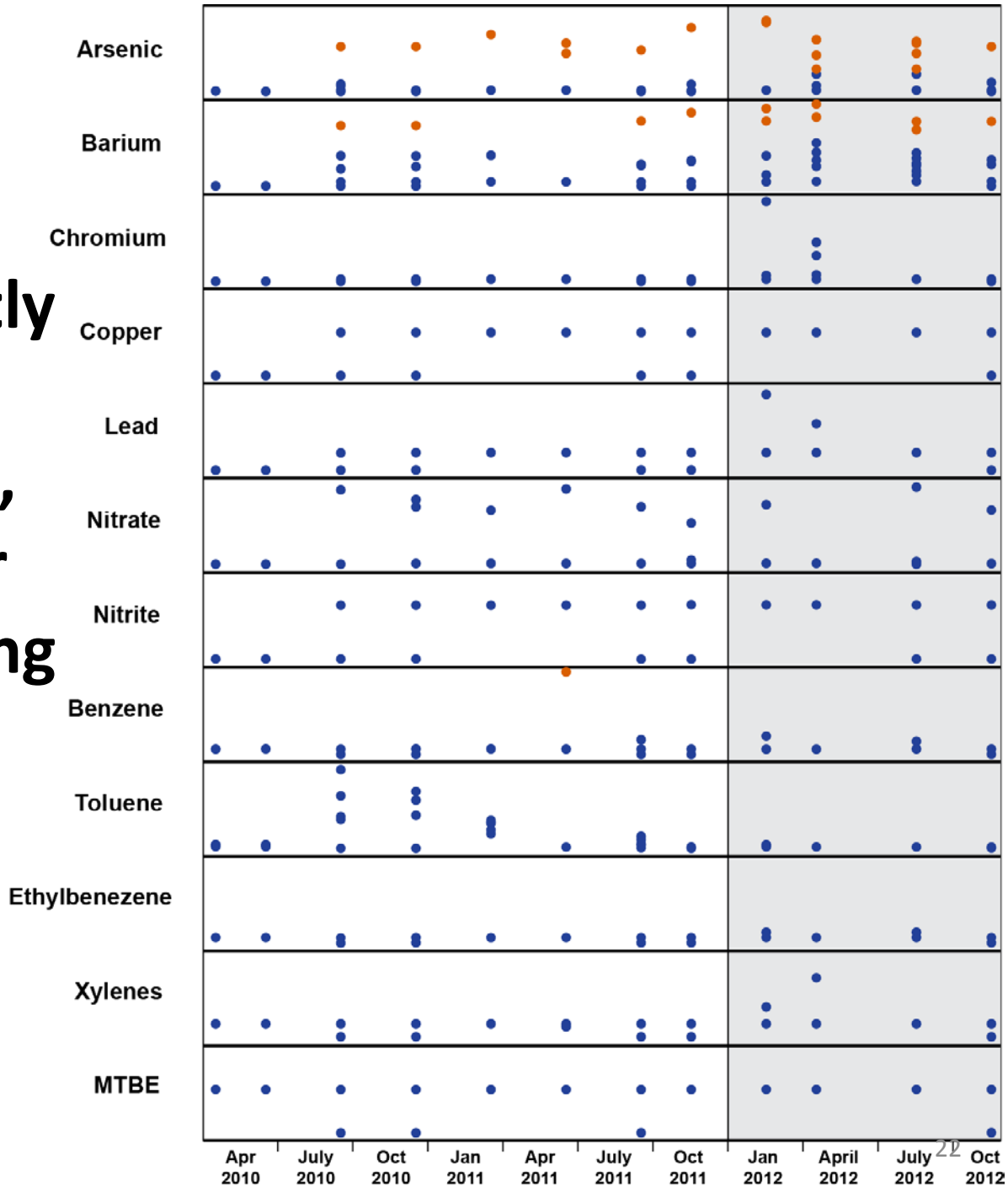


Water Quality

- 2/3 of water for the vicinity of Oil Field comes from 560 km (350 miles) away
- Remainder is from sources greater than 1.5 miles away
- All public water is:
  - Tested quarterly and reported
  - Must meet drinking standards

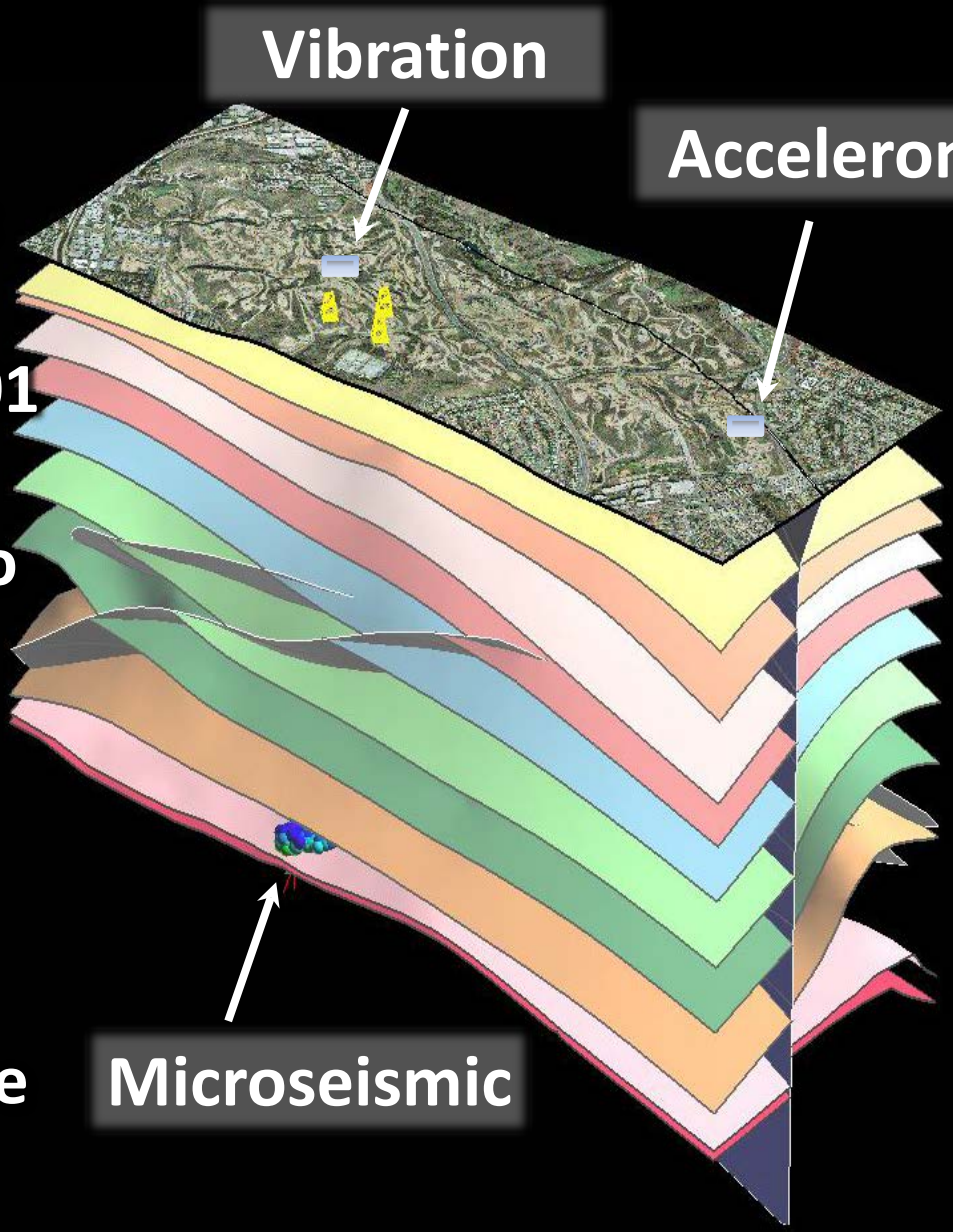
Further Information: http://www.westbasin.org/water-reliability2020/groundwater/overview

Groundwater quality consistently meets drinking water standards, before and after hydraulic fracturing



Ground Movement and Induced Seismicity

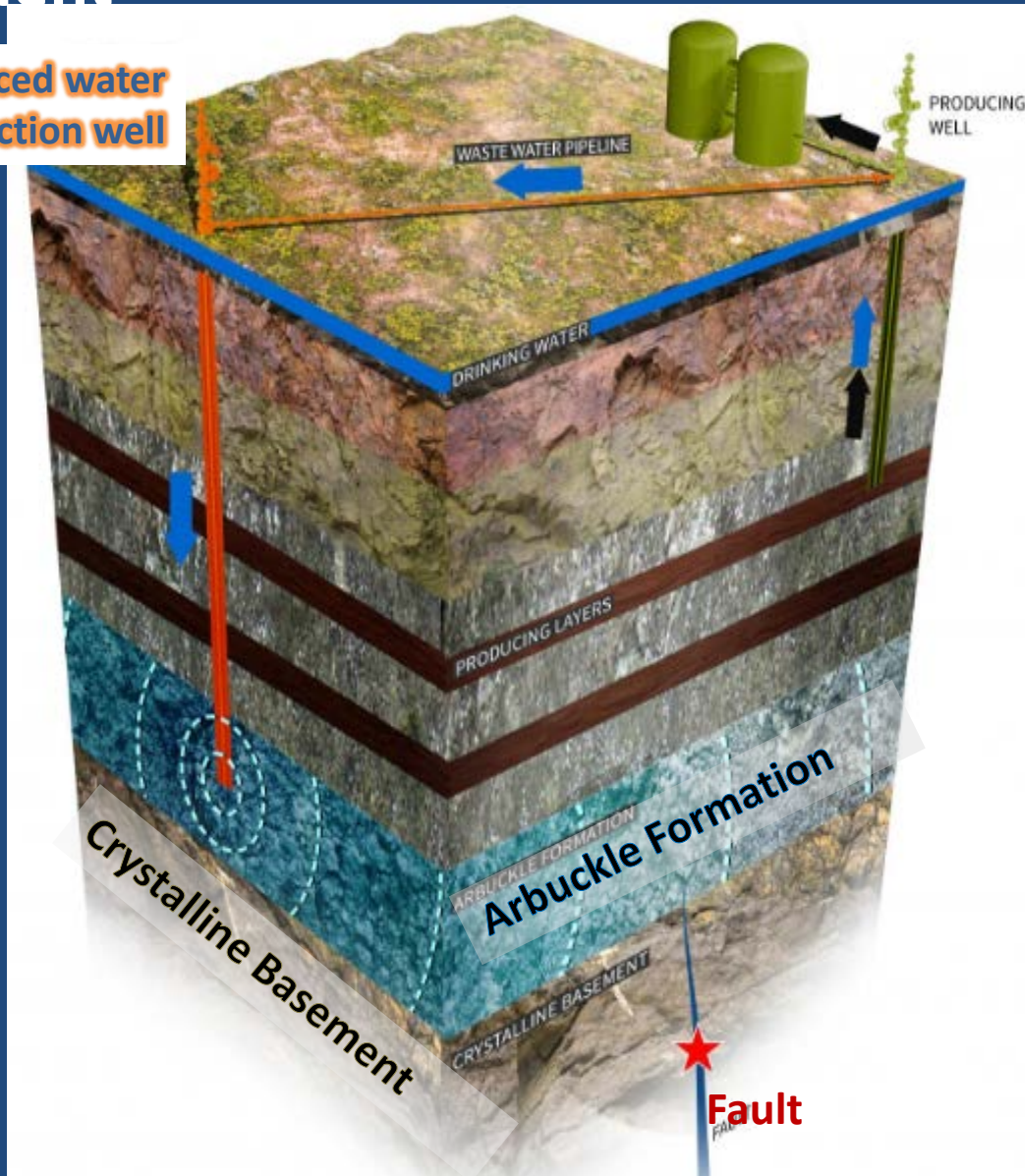
- Microseismic effects: Richter M 0.01 to 0.001
- Insufficient to induce tectonic earthquakes
- Tectonic quakes have deeper source

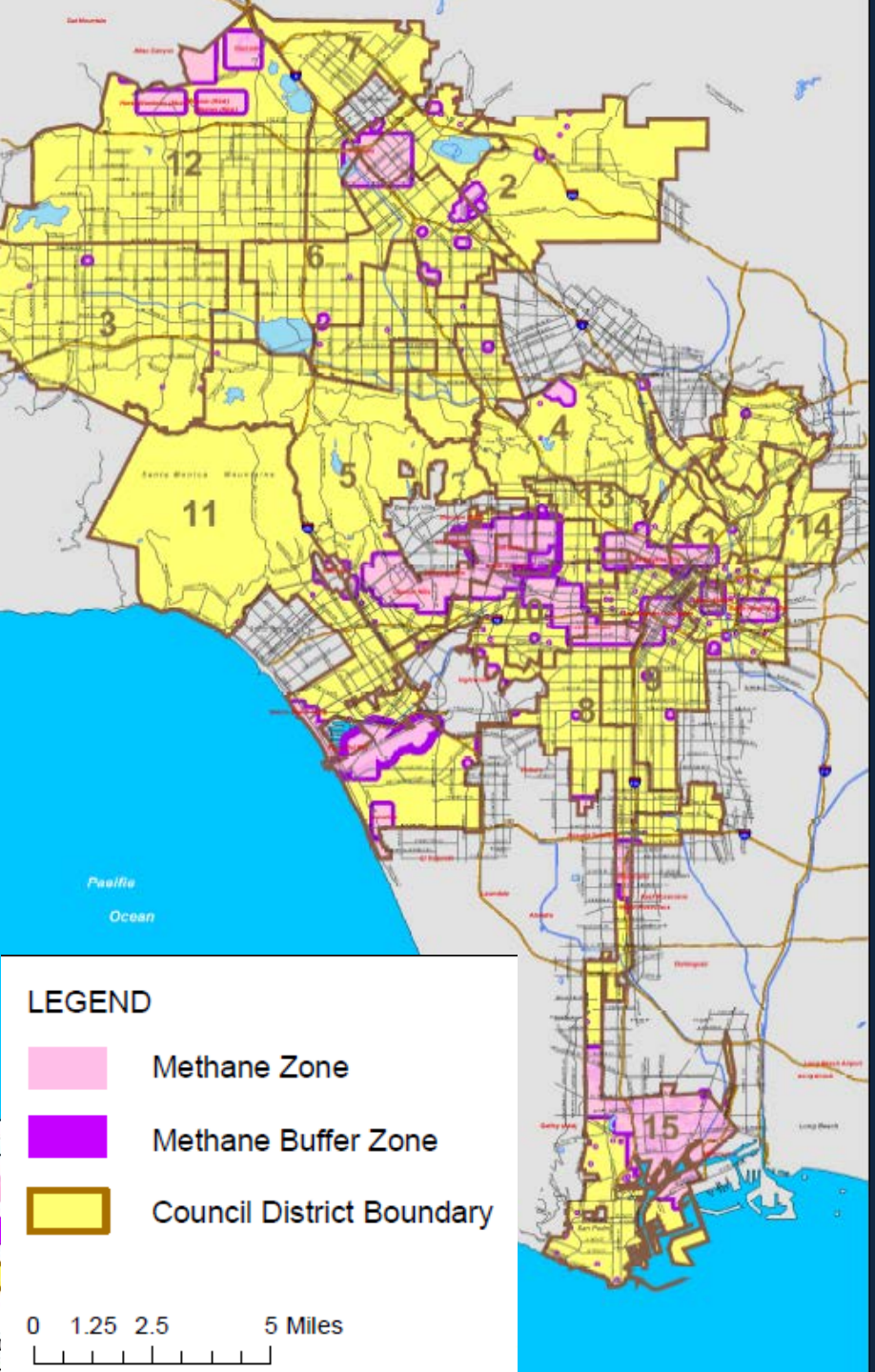


- Induced seismicity linked to injection at few sites
- Field has operated a water flood since 1971 without seismicity

Oklahoma seismicity linked to wastewater injection into deep formation overlying crystalline basement

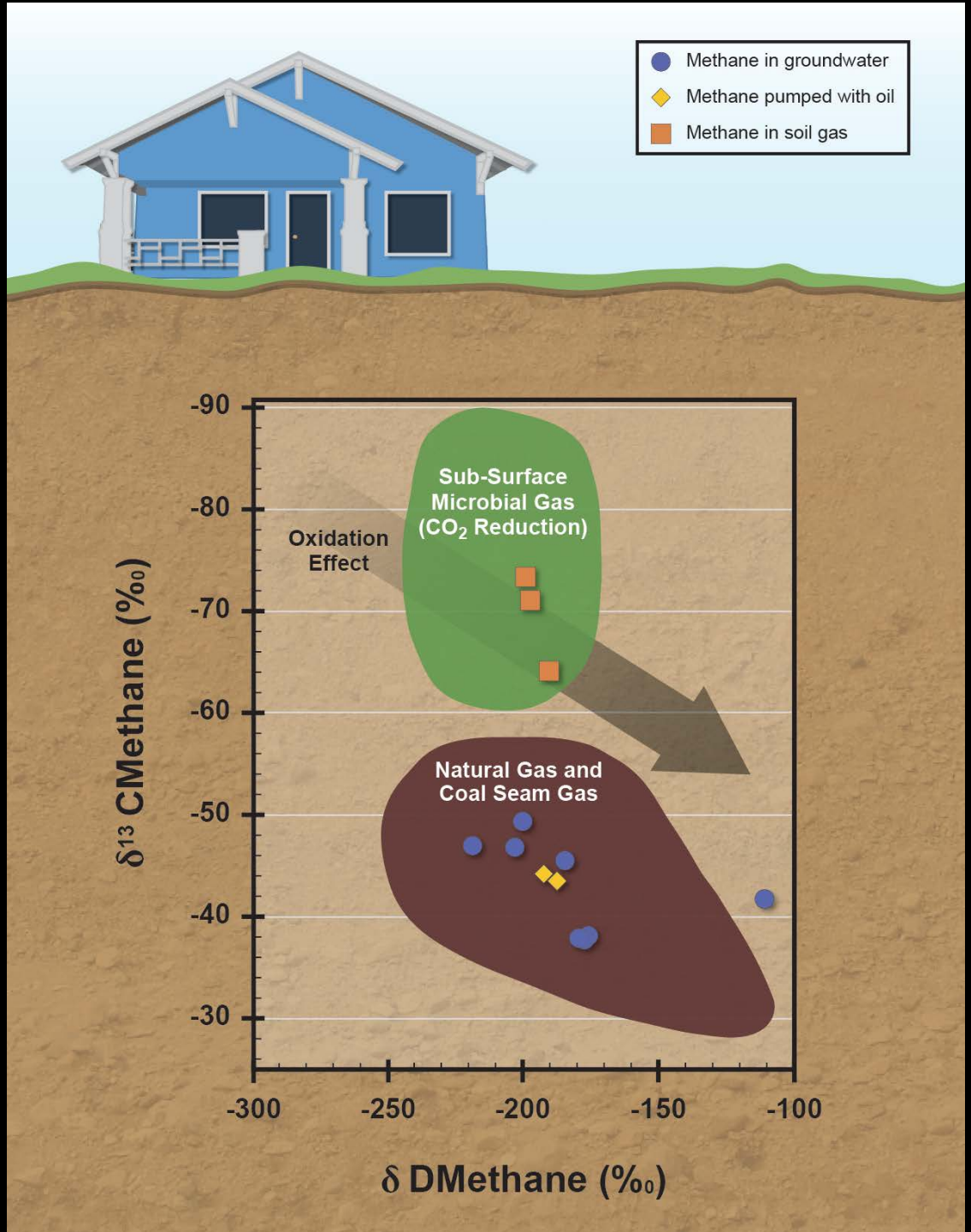
- Large volumes of produced water injected into Arbuckle formation, overlying crystalline baseline.
- Increased fluid pressure penetrates already-stressed existing faults in crystalline basement





Methane Migration

- Oil Field is adjacent to known “Methane Zone”
- Methane in shallow soil gas is biogenic
- Methane detected in groundwater has been thermogenic
- No change due to hydraulic fracturing


Methane in groundwater
Methane pumped with oil
Methane in soil gas
Sub-Surface Microbial Gas (CO_2 Reduction)
Oxidation Effect
Natural Gas and Coal Seam Gas
-90
-80
-70
-60
-50
-40
-30
δ^{13} CMethane (‰)
-300
-250
-200
-150
-100
δ DMethane (‰)

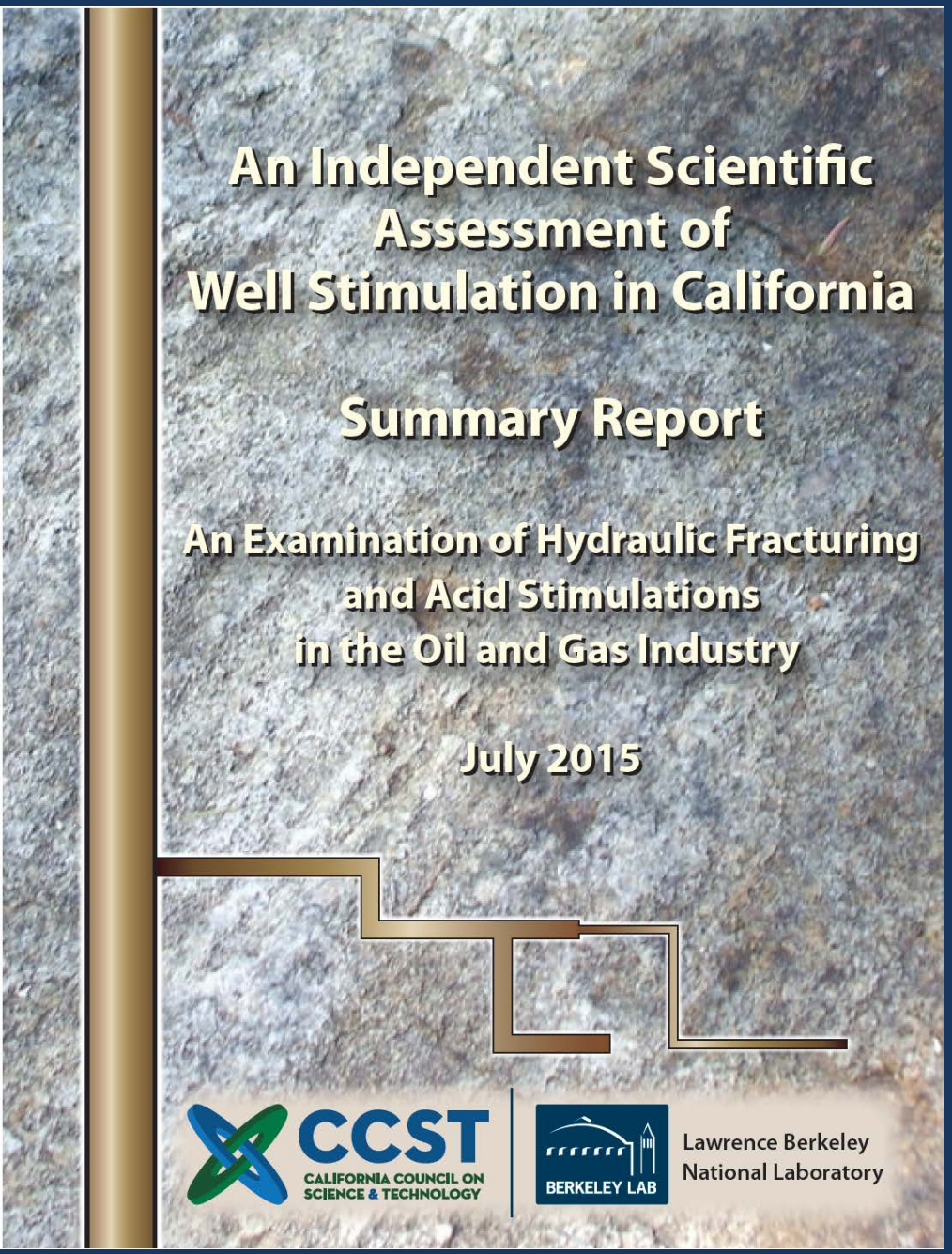
Measurements before, during, and after hydraulic fracturing did not detect effects to:

- ✓ Hydrogeology
- ✓ Water Use
- ✓ Water Quality
- ✓ Containment of Fractures
- ✓ Well Integrity
- ✓ Slope Stability
- ✓ Subsidence
- ✓ Ground Movement
- ✓ Induced Seismicity
- ✓ Methane (soil gas and groundwater)
- ✓ Air Emissions
- ✓ Noise
- ✓ Vibration
- ✓ Community Health*

Study Provides Data-Rich Source Responding to Public Concerns

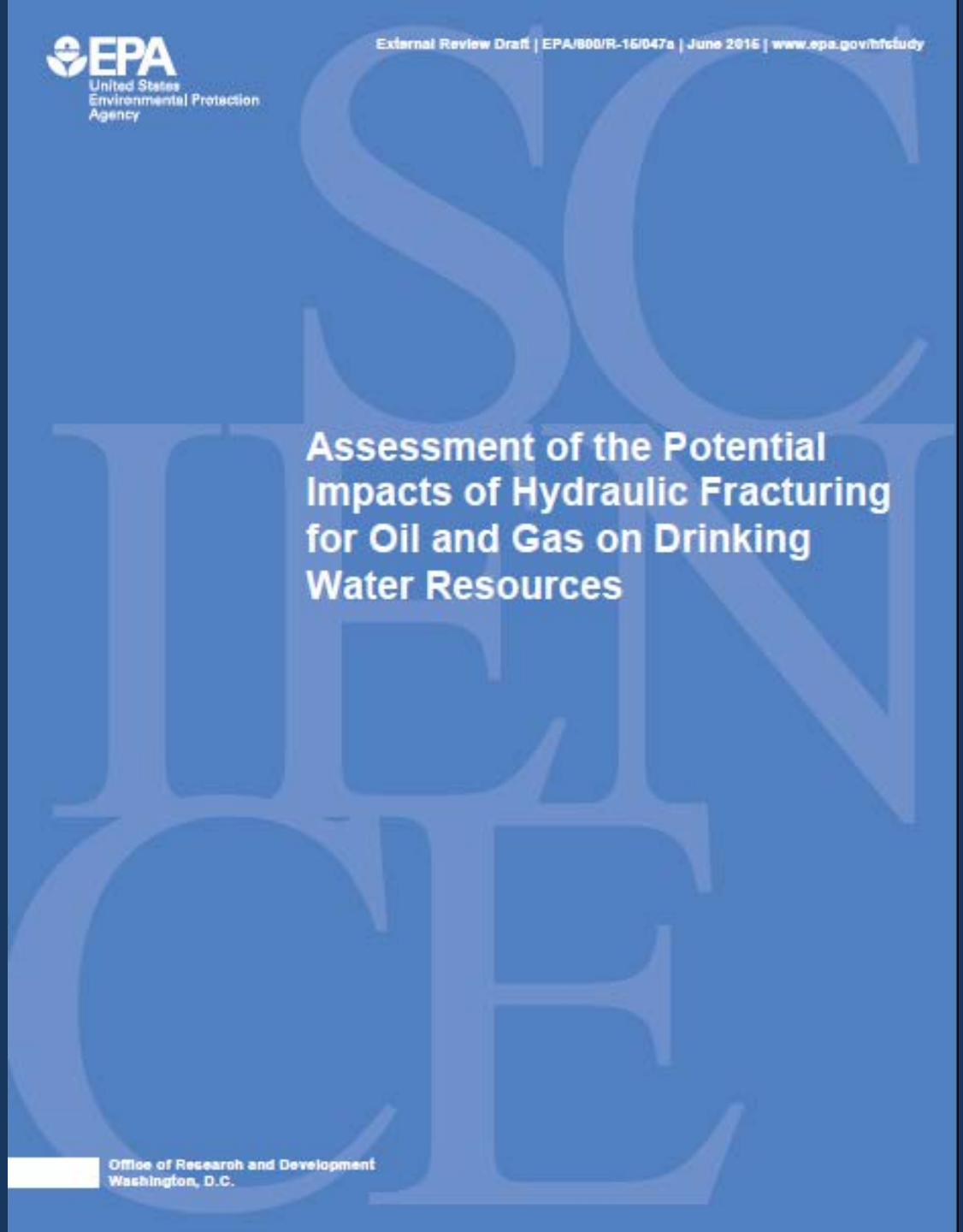
Application of the Study So Far

- First Study to address all environmental concerns of hydraulic fracturing quantitatively; finding no new adverse effects compared to current oil and gas operations
- Local public agency with jurisdiction over the Oil Field did not require additional protective measures for hydraulic fracturing



California Council on Science and Technology (Tormey co-lead):

- ***Effects of Hydraulic Fracturing are Small and Manageable***
- ***Indirect effects of oil and gas development warrant further study and regulation***



Review Draft EPA Report (2015):

Minor effects to water supply and water quality

Science and Data

Calculated Risk

Govern-ment License to Operate

Social License to Operate

Public Concern

Perceived Risk

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