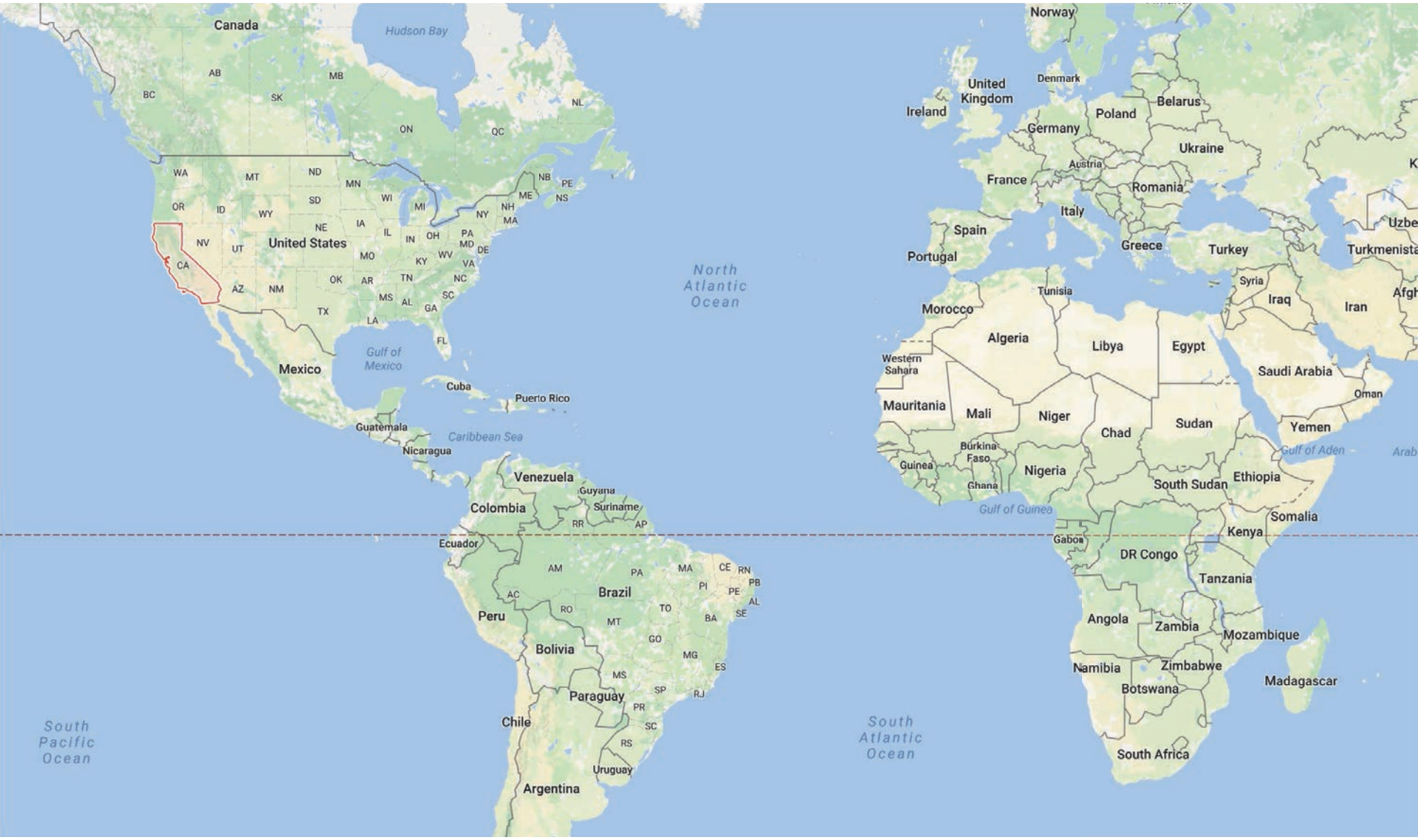
Oil and Natural Gas


Canada
Hudson Bay
AB
BC
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QC
NL
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PE
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PA
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DE
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NC
SC
GA
FL
WA
OR
CA
ID
NV
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WY
UT
AZ
ND
SD
NE
CO
NM
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
WV
OK
TX
United States
Mexico
Gulf of Mexico
Cuba
Puerto Rico
Caribbean Sea
Guatemala
Nicaragua
Venezuela
Guyana
Suriname
Colombia
Ecuador
Peru
Brazil
Bolivia
Paraguay
Chile
Argentina
Uruguay
AM
RR
AP
PA
TO
MA
CE
RN
PB
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AL
SE
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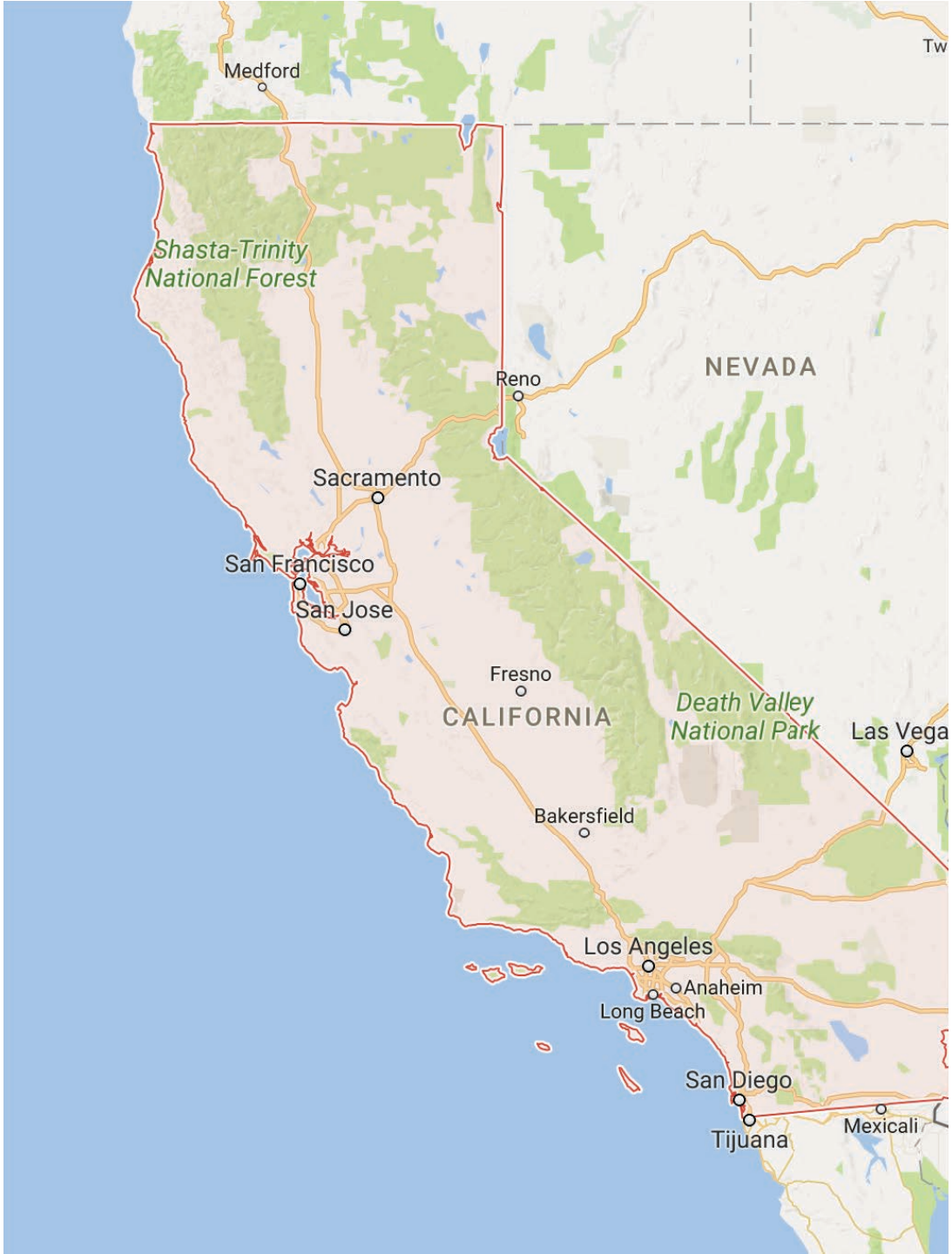
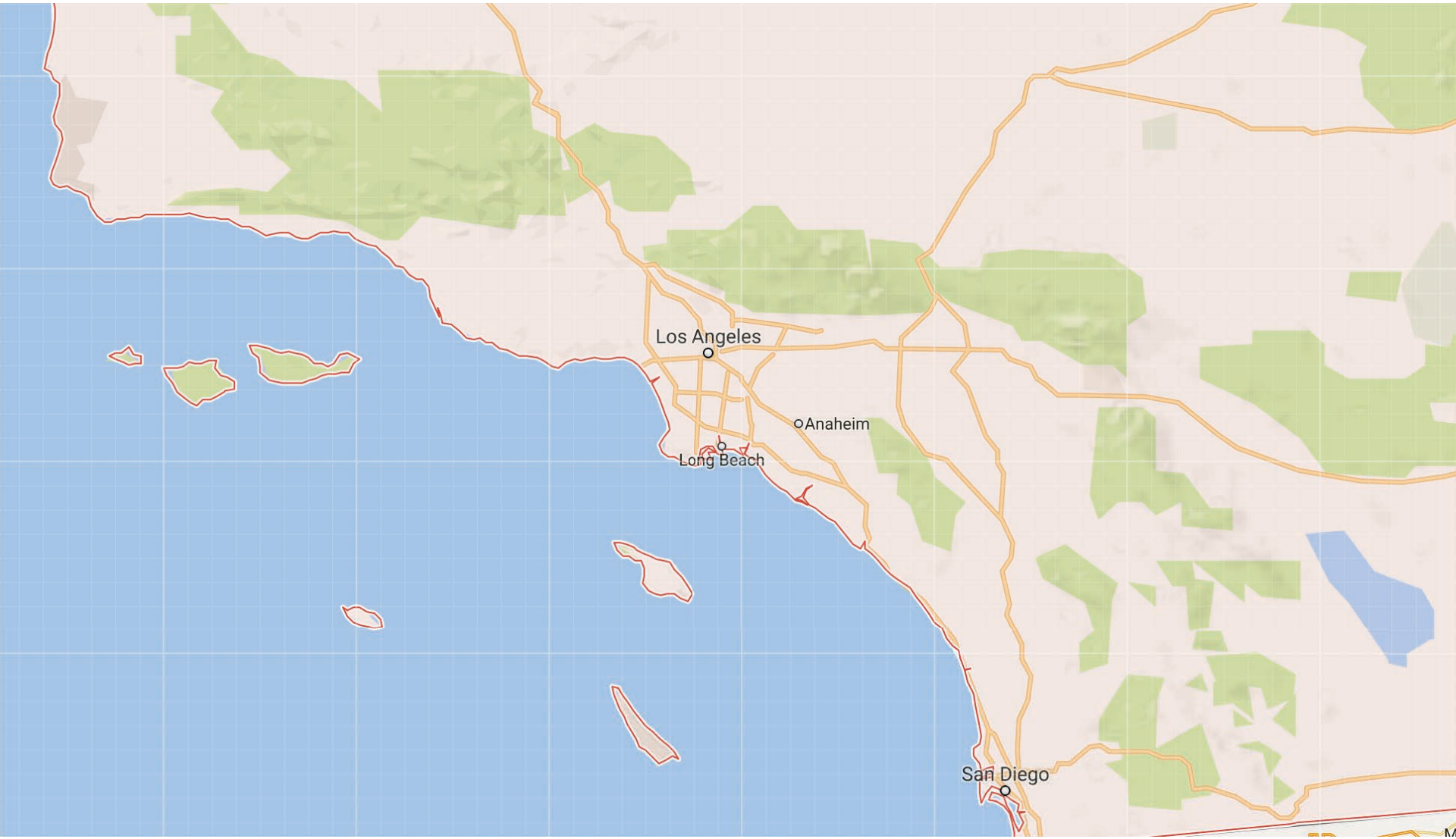
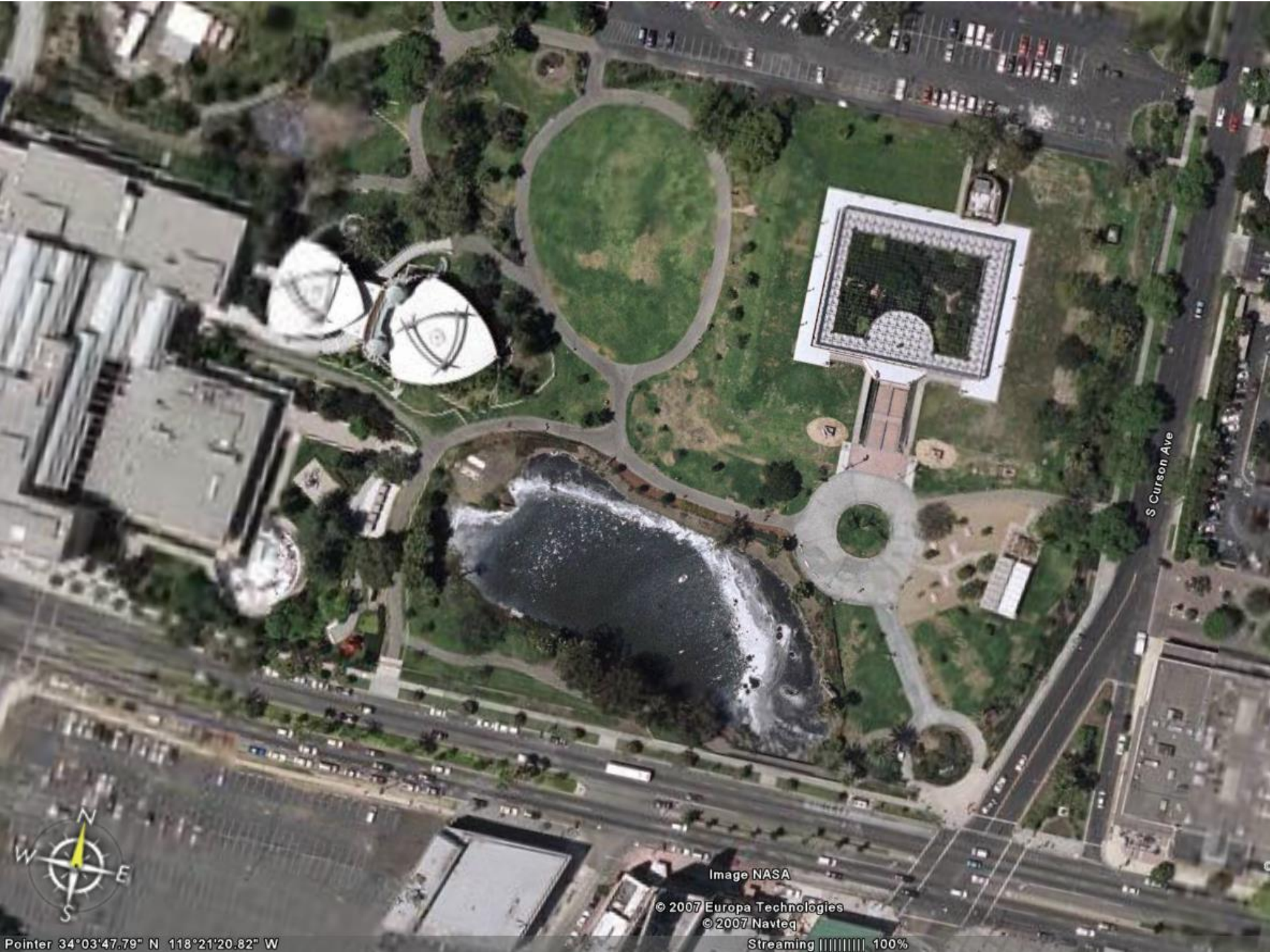
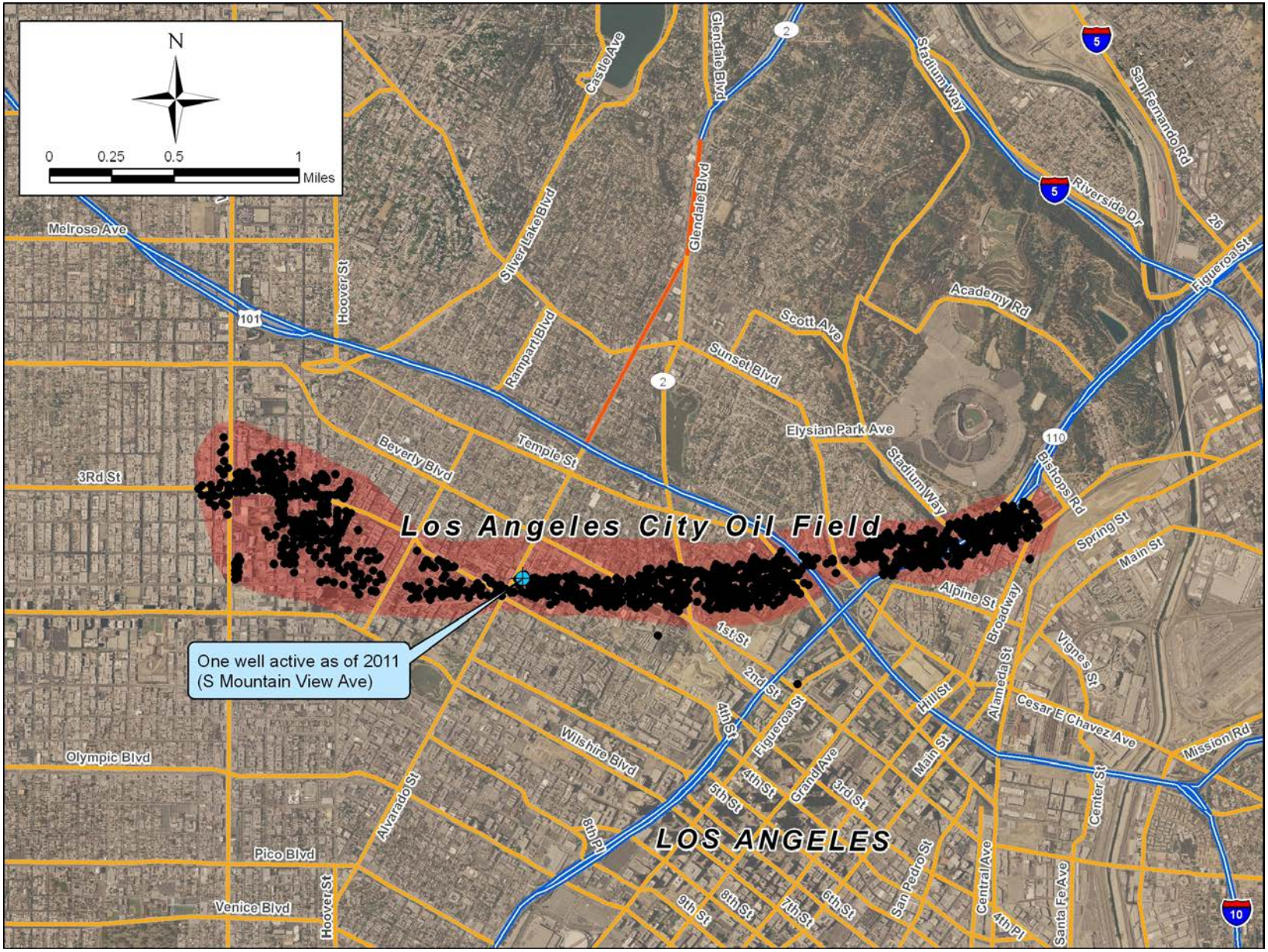
BA
AC
RO
MT
GO
MG
ES
MS
SP
RJ
PR
SC
RS
North Atlantic Ocean
South Pacific Ocean
South Atlantic Ocean
Norway
Denmark
United Kingdom
Ireland
Poland
Belarus
Germany
Ukraine
Austria
France
Romania
Italy
Spain
Portugal
Greece
Turkey
Syria
Iraq
Iran
Tunisia
Morocco
Algeria
Libya
Egypt
Western Sahara
Saudi Arabia
Oman
Mauritania
Mali
Niger
Chad
Sudan
Yemen
Gulf of Aden
Burkina Faso
Guinea
Nigeria
Ghana
South Sudan
Ethiopia
Gulf of Guinea
Somalia
Kenya
Gabon
DR Congo
Tanzania
Angola
Zambia
Mozambique
Namibia
Zimbabwe
Botswana
Madagascar
South Africa

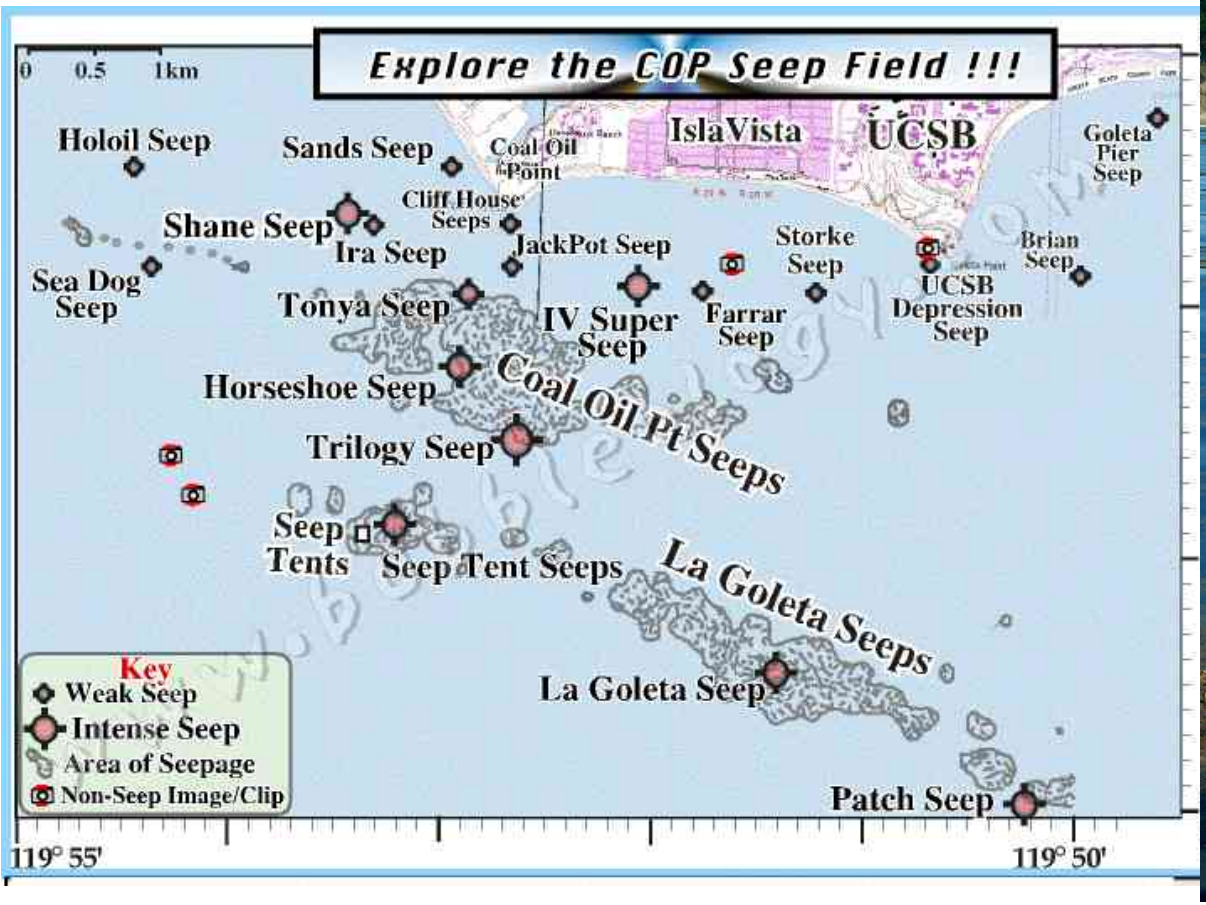

Medford
Shasta-Trinity
National Forest
Reno
NEVADA
Sacramento
San Francisco
San Jose
Fresno
CALIFORNIA
Death Valley
National Park
Las Vega
Bakersfield
Los Angeles
Anaheim
Long Beach
San Diego
Tijuana
Mexicali


Los Angeles
Anaheim
Long Beach
San Diego


S Curson Ave
N
W
E
S
Image NASA
© 2007 Europa Technologies
© 2007 Navteq
Pointer 34°03'47.79" N 118°21'20.82" W
Streaming |||||||||| 100%

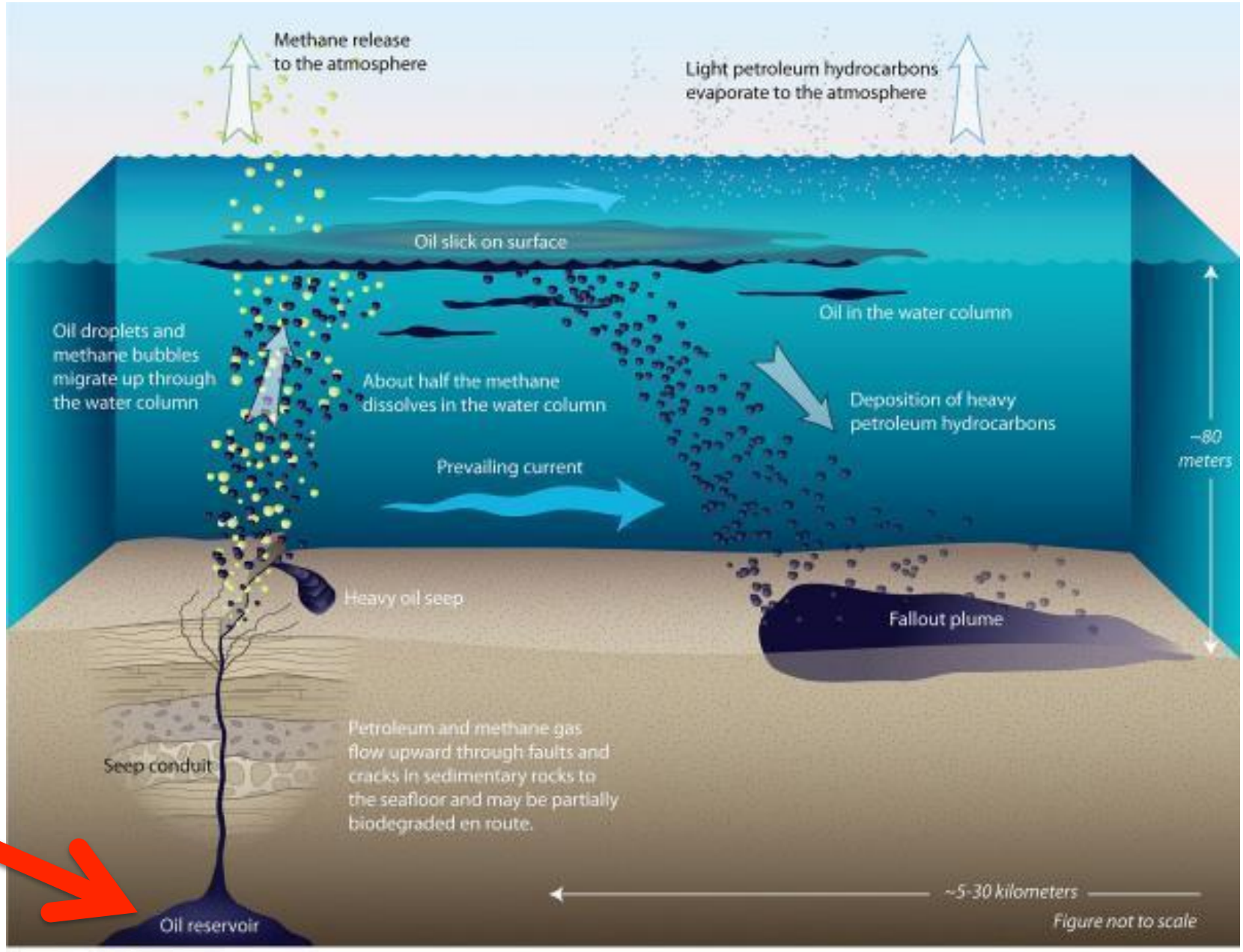

N
0
0.25
0.5
1
Miles
Los Angeles City Oil Field
One well active as of 2011
(S Mountain View Ave)
LOS ANGELES
Melrose Ave
Olympic Blvd
Pico Blvd
Venice Blvd
3Rd St
Beverly Blvd
Temple St
Wilshire Blvd
Sunset Blvd
Scott Ave
Elysian Park Ave
Academy Rd
Riverside Dr
Figueroa St
Stadium Way
Glendale Blvd
Silver Lake Blvd
Castle Ave
Rampart Blvd
Hoover St
Alvarado St
Bishops Rd
Spring St
Main St
Broadway
Alameda St
Vignes St
Cesar E Chavez Ave
Mission Rd
Alpine St
1st St
2nd St
4th St
5th St
6th St
7th St
8th St
9th St
Hill St
Grand Ave
3rd St
San Pedro St
Central Ave
Santa Fe Ave
Center St
San Fernando Rd
101
2
5
110
10

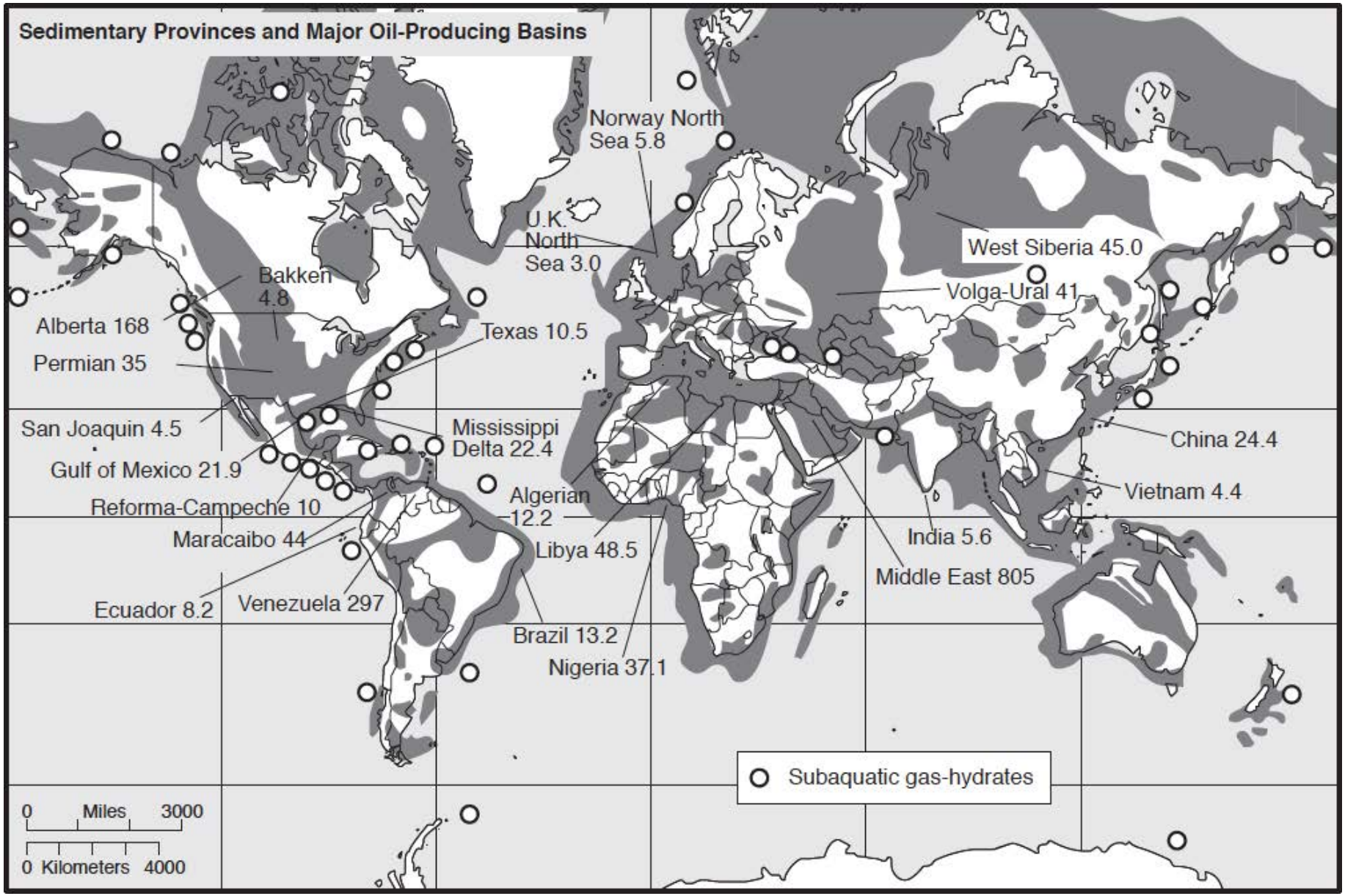

CALIFORNIA
Southern
California
Bight
SANTA YNEZ MOUNTAINS
Matilija Dam
Santa Barbara
Ventura
Point Conception
Coal Oil Point
Santa Barbara Channel
San Miguel
Santa Rosa
Santa
Cruz
Anacapa
Los Angeles
Santa Barbara
CHANNEL
San Nicolas
Santa Catalina
ISLANDS
PACIFIC OCEAN
San Clemente
San Diego
0
50
100 mi
0
100 km



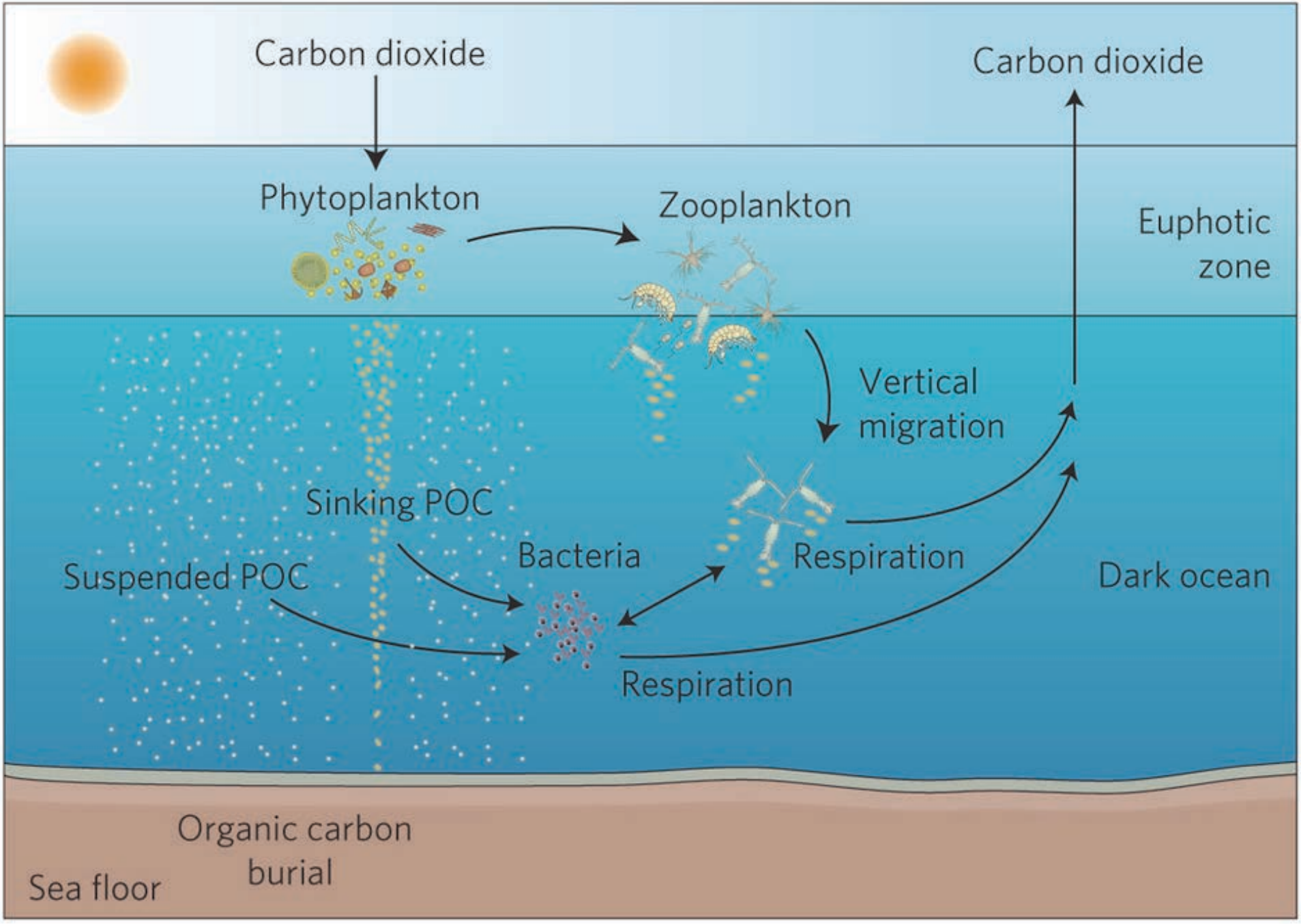
Natural oil seeps

Underwater Oil Seeps (natural)

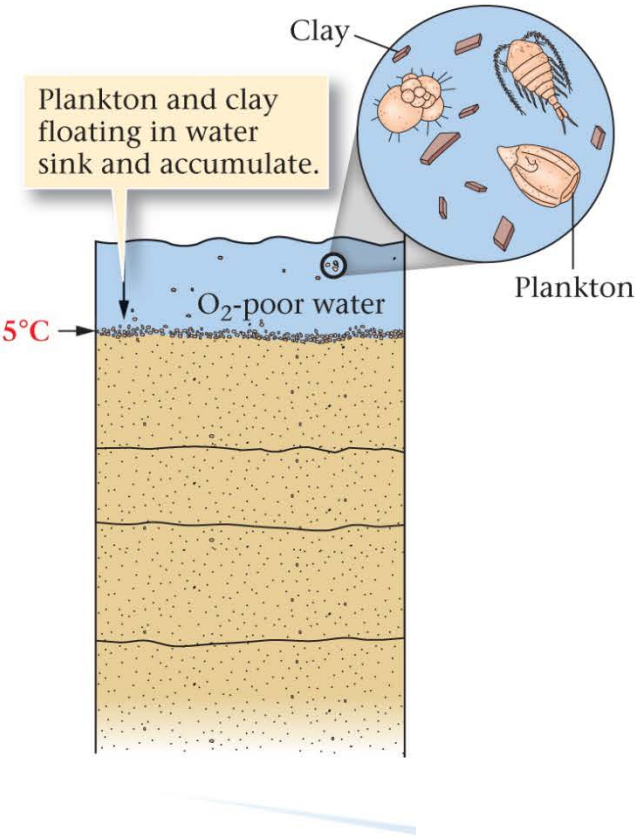


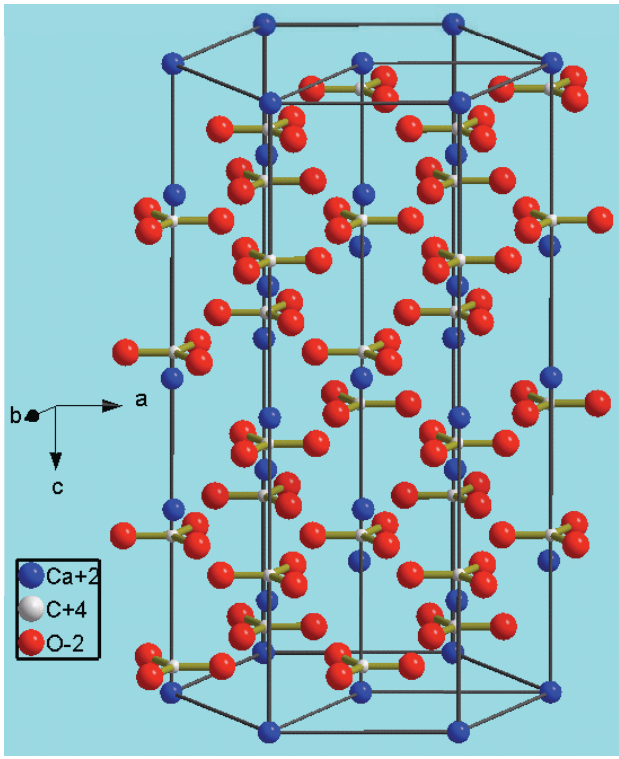


Distribution of sedimentary basins showing location of major oil and natural gas fields (reserves shown for oil in Billions of barrels, bbl). Note that many basins extend offshore into the continental shelf and slope.


Carbon dioxide
Carbon dioxide
Phytoplankton
Zooplankton
Euphotic zone
Vertical migration
Sinking POC
Bacteria
Respiration
Suspended POC
Dark ocean
Respiration
Organic carbon burial
Sea floor

Formation of hydrocarbons from heating
organic matter (decomposed from plankton, diatoms etc.)
into kerogen → oil → gas





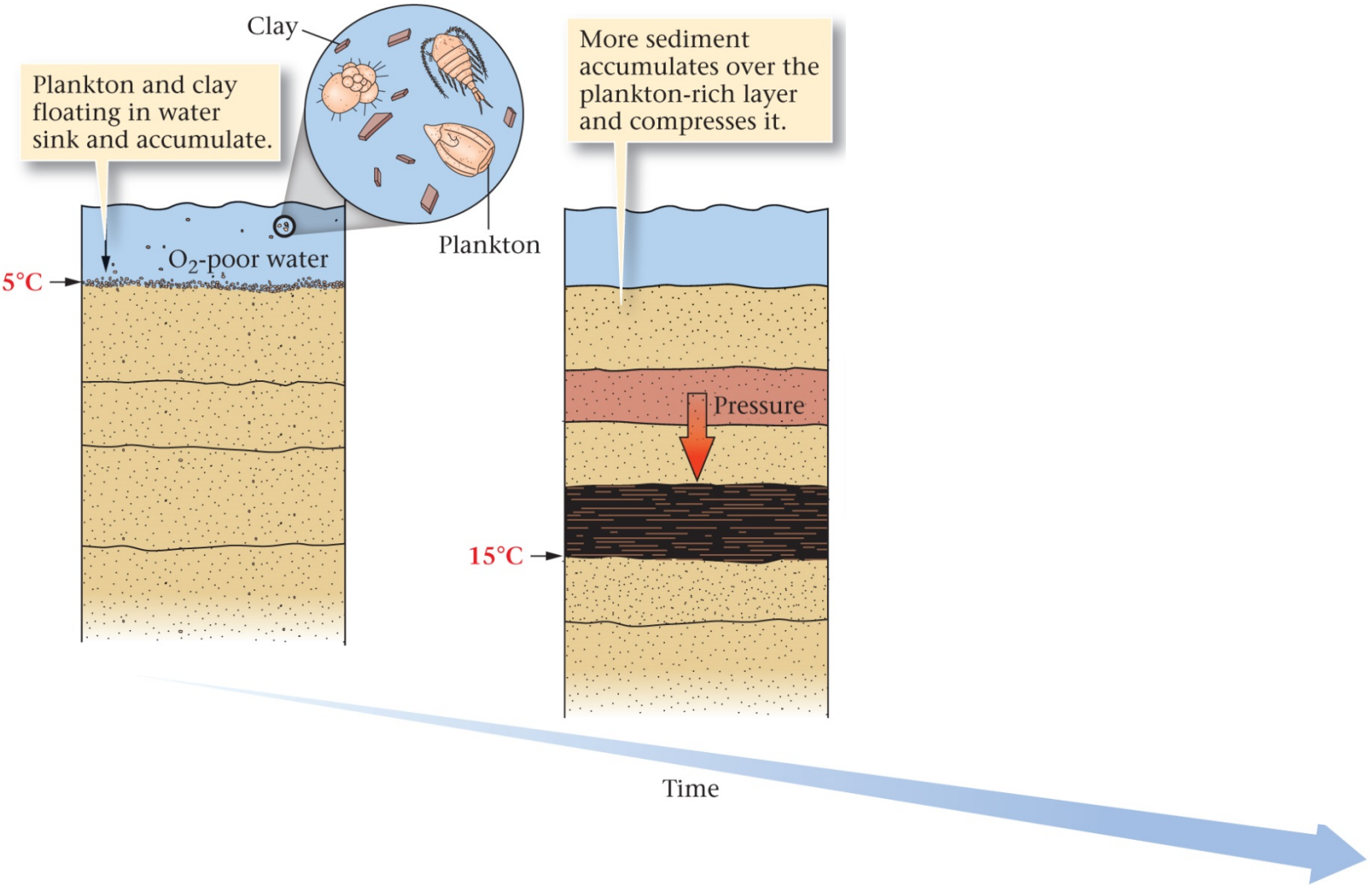
The Mississippi River Delta, showing the sediment plumes from the Mississippi and Atchafalaya Rivers, 2001.


Mississippi River entering
the Gulf of Mexico.

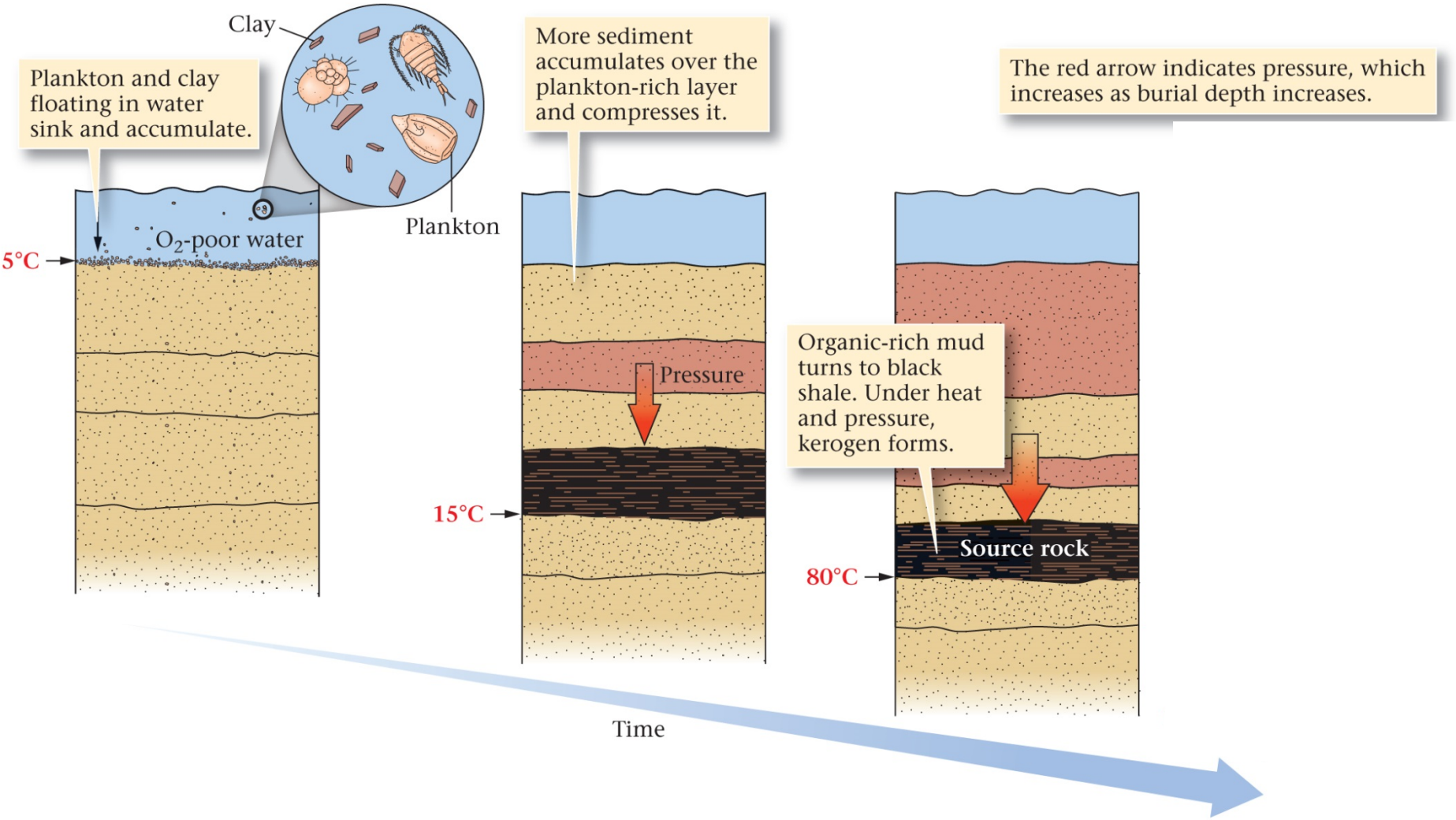

Zambezi River Delta

Mahakam River, Indonesia

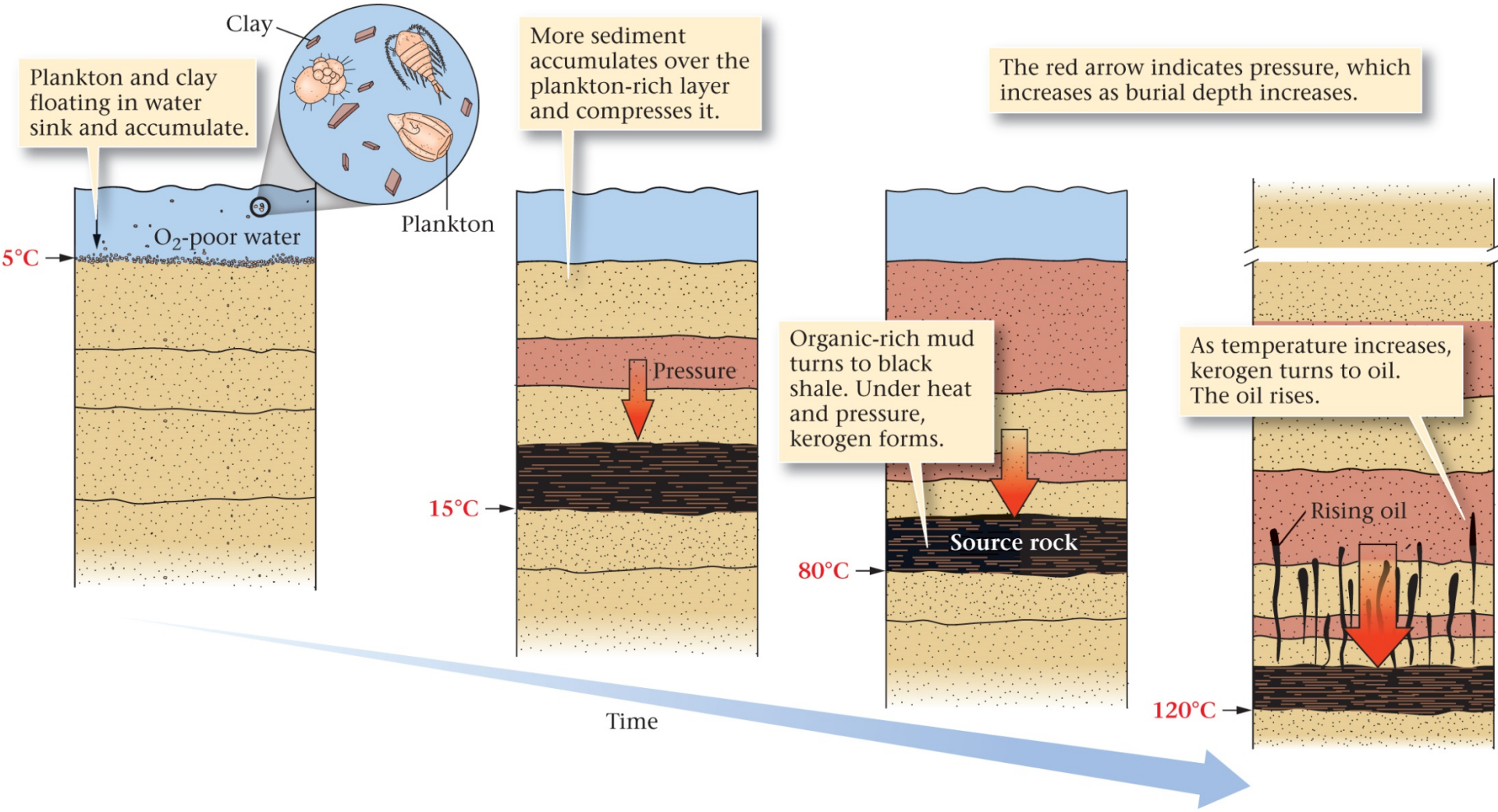
Formation of hydrocarbons from heating
organic matter (decomposed from plankton, diatoms etc.)
into kerogen → oil → gas

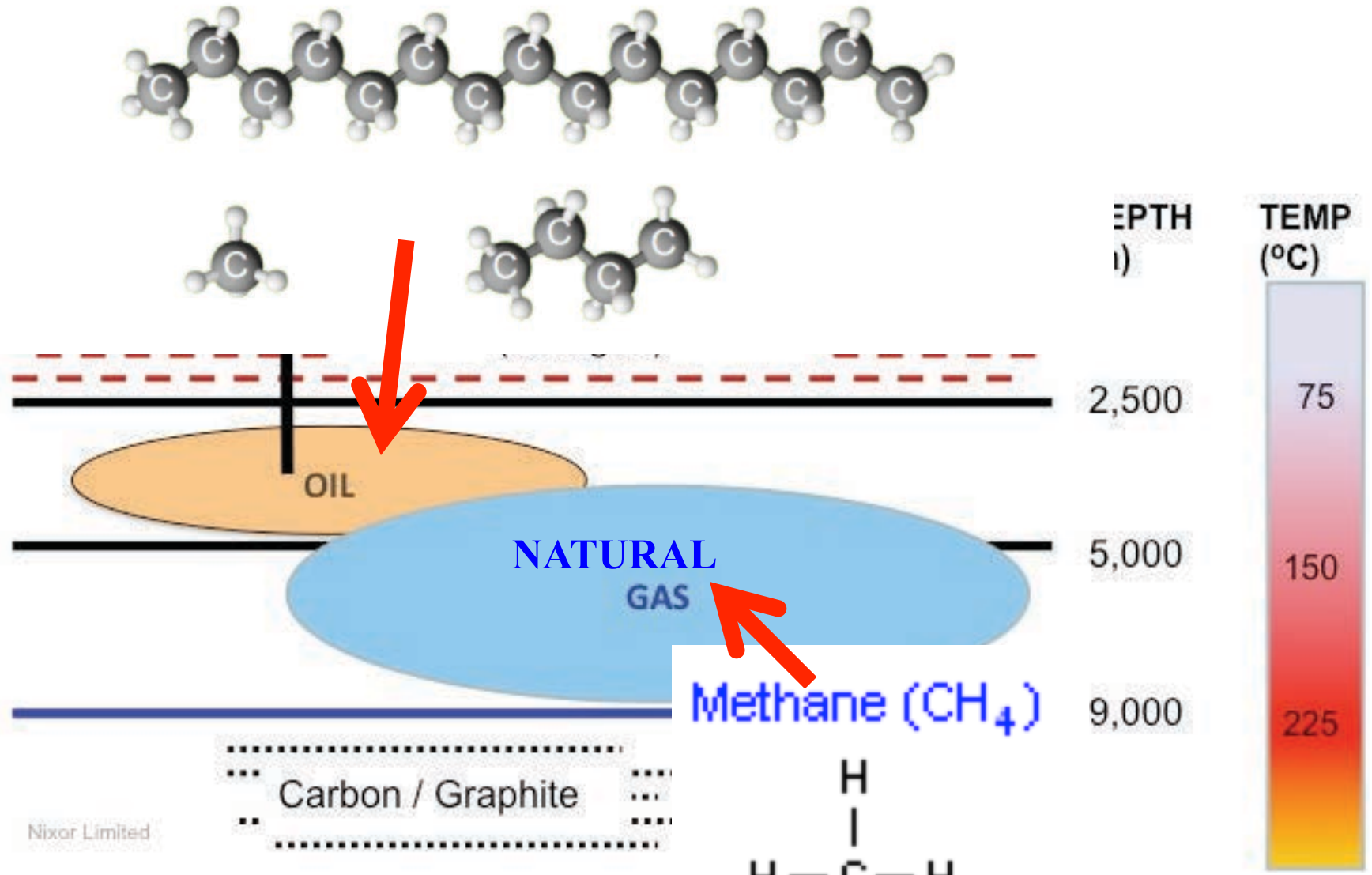


Formation of hydrocarbons from heating organic matter (decomposed from plankton, diatoms etc.) into kerogen → oil → gas



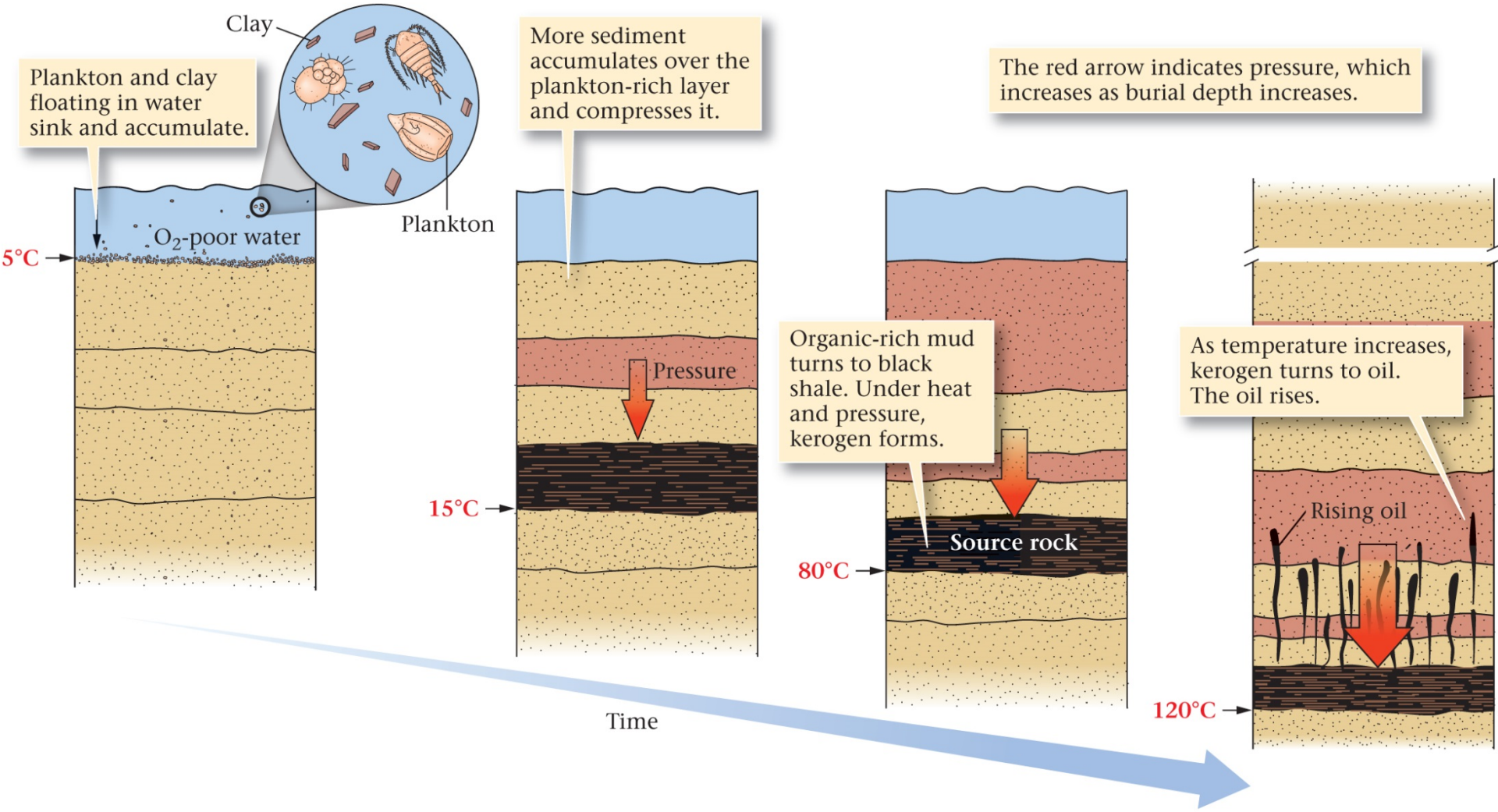
Formation of hydrocarbons from heating organic matter (decomposed from plankton, diatoms etc.) into kerogen → oil → gas

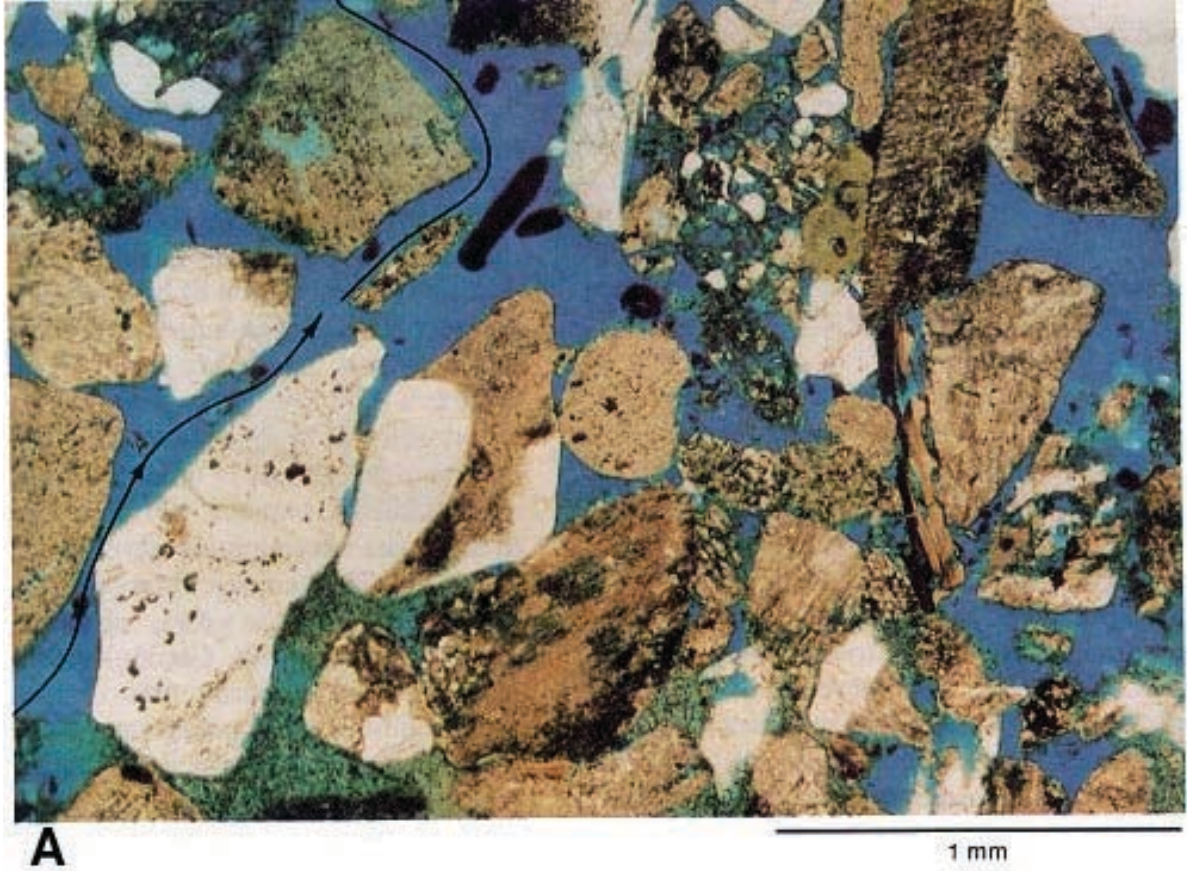



EPTH
)
TEMP
(°C)
2,500
5,000
9,000
75
150
225
OIL
NATURAL
GAS
Methane (CH_4)
Carbon / Graphite
Nixor Limited

CONVENTIONAL RESERVOIRS

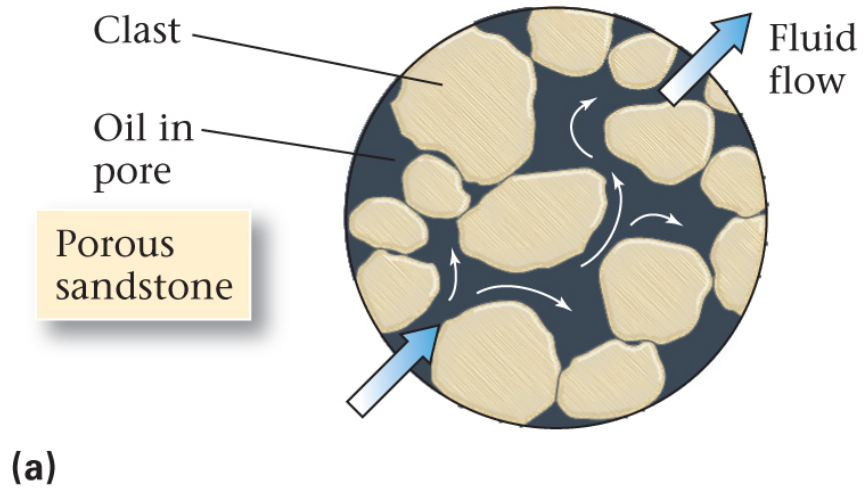
Formation of hydrocarbons from baking of organic matter (decomposed from plankton, diatoms etc.) into kerogen → oil, gas





A magnified image of a sandstone. The rock sample was injected with blue-colored epoxy that is seen here filling pores which are interconnected (permeable). The sample is very porous and permeable. The grains are loosely packed and there is very little cement filling the space between the grains. The arrow indicates possible pathways for fluid movement.

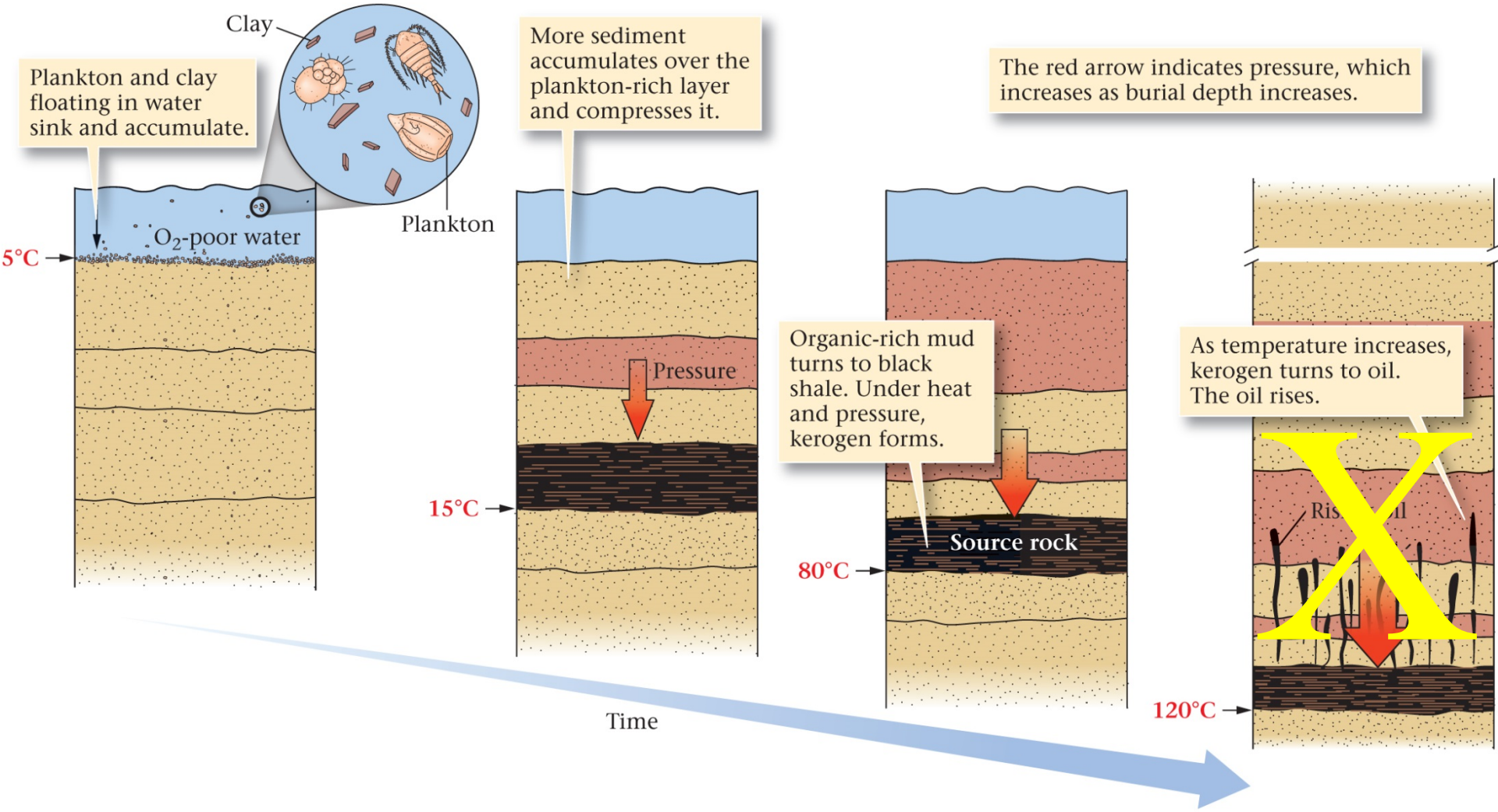
Source rock; good extraction from rocks with high porosity (storage) and high permeability (flow)

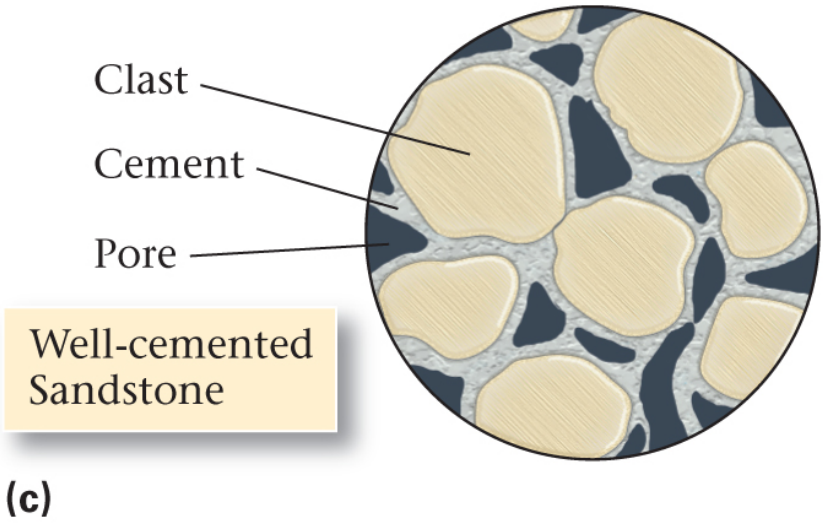


Conventional oil/gas reservoir

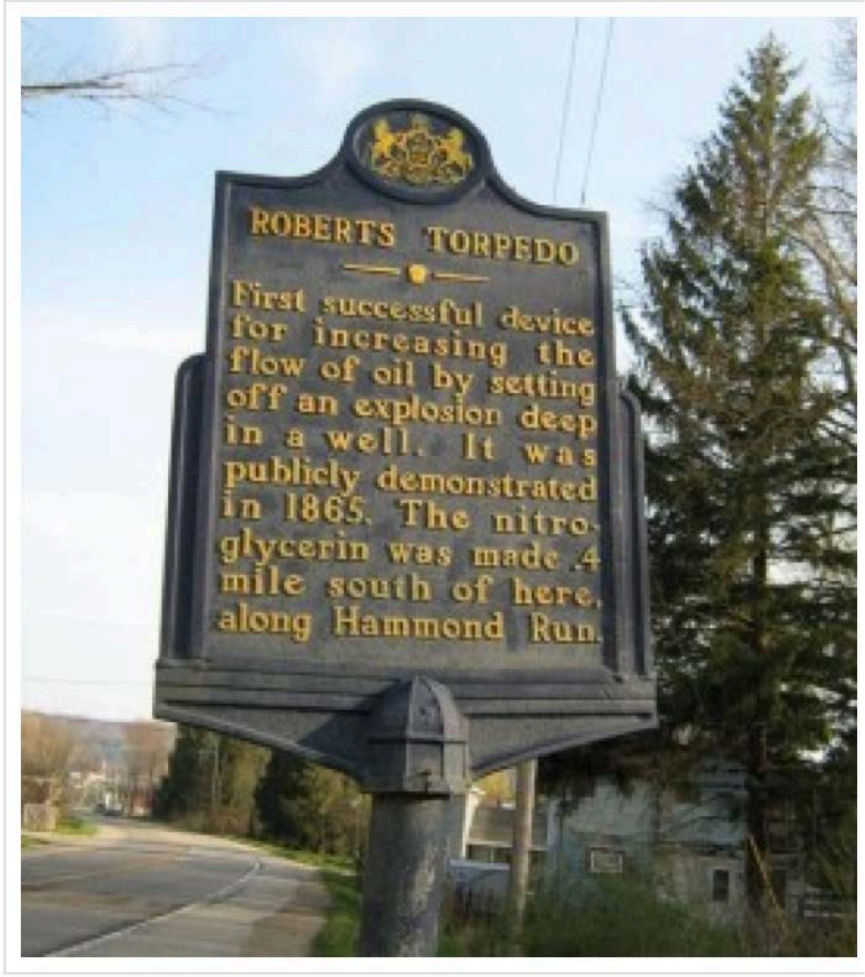
UNCONVENTIONAL RESERVOIRS

In an unconventional reservoir, the oil and gas never left their source rock; they are trapped in the source rock.

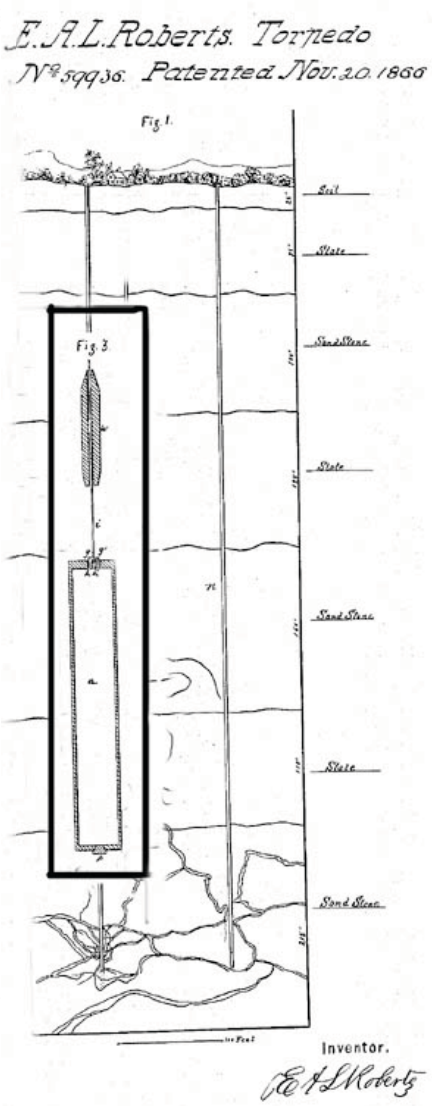


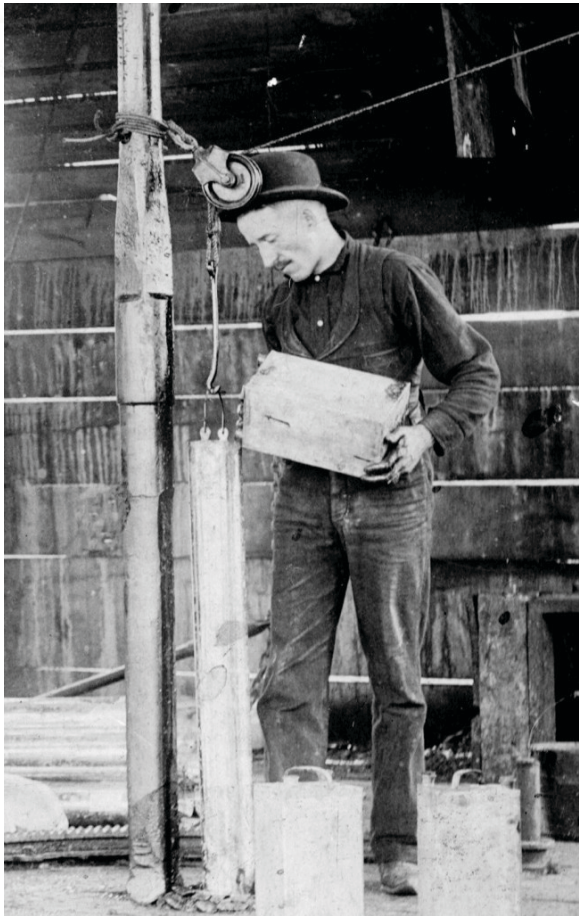


Unconventional oil/gas reservoir



A Pennsylvania historical marker near Titusville notes the 1865 demonstration of the invention Union Col. E.A.L. Roberts.

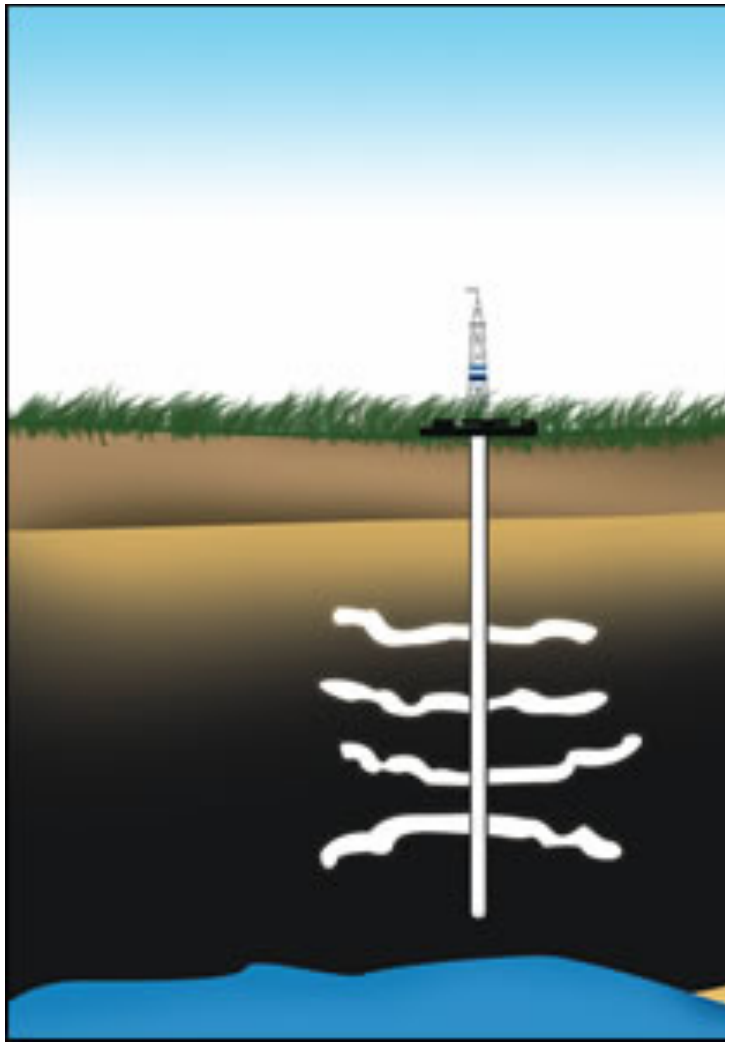




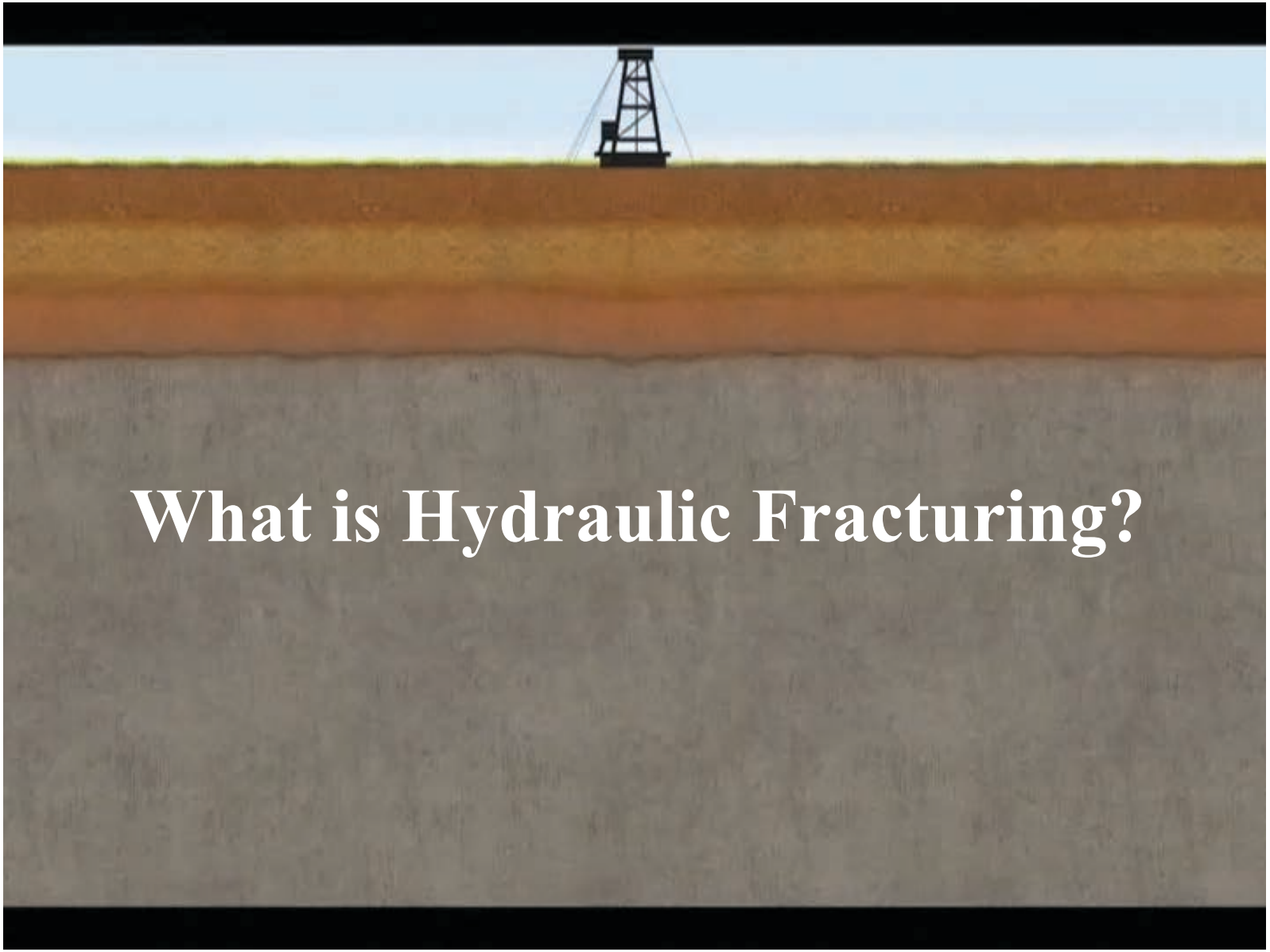
Pouring nitroglycerin was risky enough in the late 19th century oil patch. Doing it for an illegal well "shooting" led to the term "moonlighting,"

patents for "Improvement in Exploding Torpedoes in Artesian Wells" on April 25, 1865…production from some wells increased 1,200 percent within a week of being shot – and the Roberts Petroleum Torpedo Company flourished…$100 to $200 per torpedo and a royalty of one-fifteenth of the increased flow of oil.

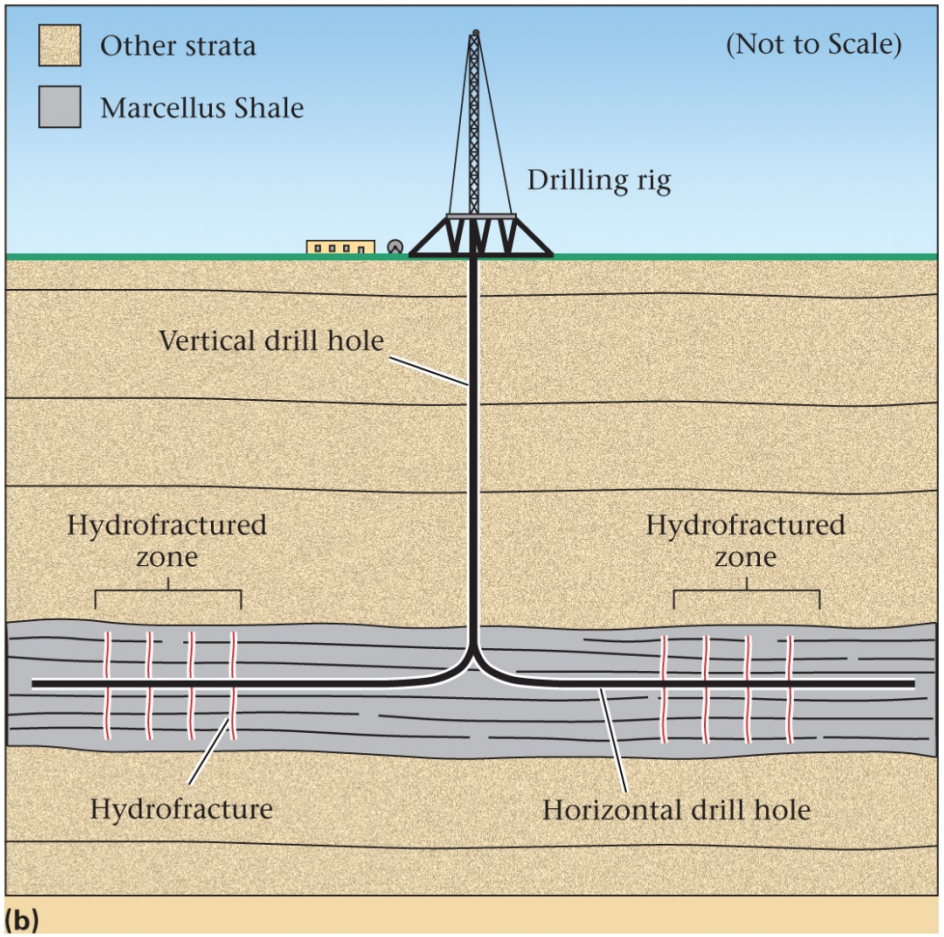
UNCONVENTIONAL RESERVOIRS REQUIRE "ENHANCED PERMEABILITY" FRACKING



Fracking engineered and used starting in the 1860s to enhance the permeability of vertical wells

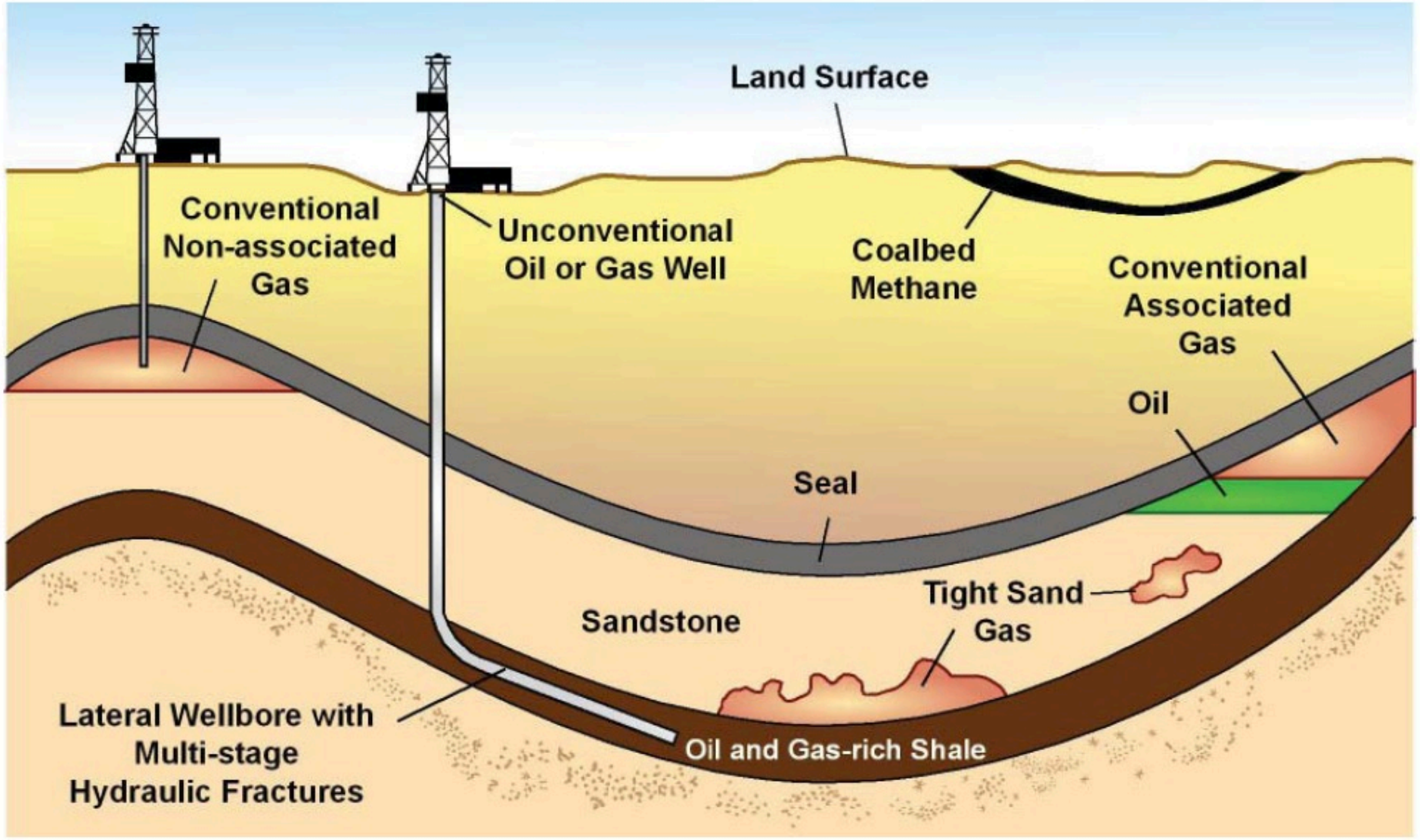

What is Hydraulic Fracturing?

Extract oil/gas from organic rich shales made possible by
1) directional drilling; 2) hydraulic fracturing



<u>Issues:</u>
fracturing fluid mix
waste water
contamination of fresh water reservoirs
earthquakes

The Geology of Conventional and Unconventional Oil and Gas

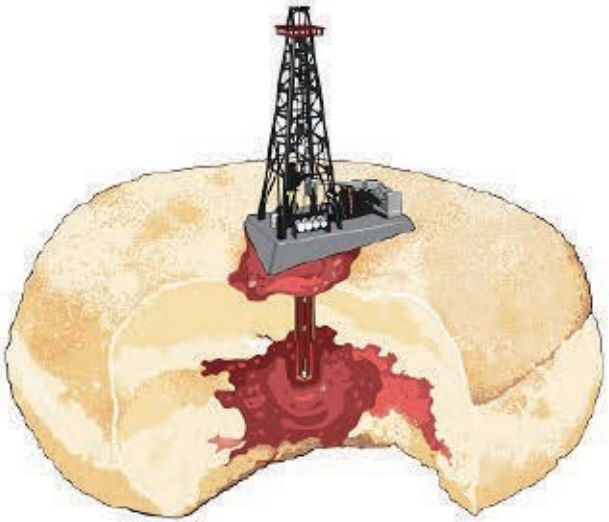


Source: EIA

Old Way of Drilling

Jelly Donut

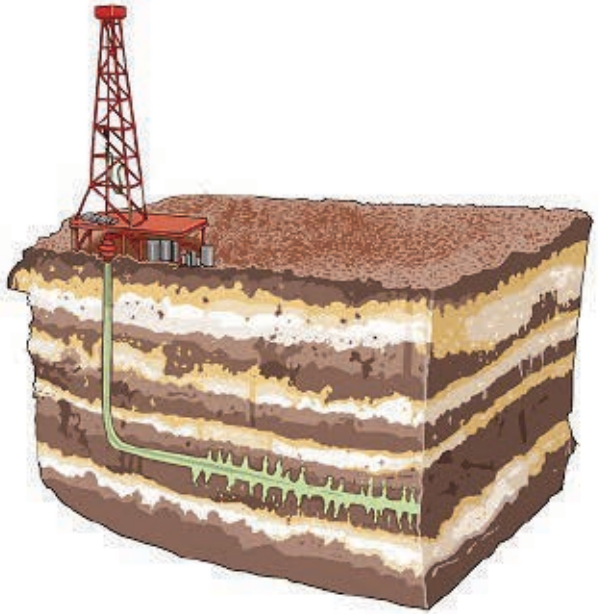
Conventional Drilling
Basic Vertical Penetration
Limited Formation Contact



New Way of Drilling

Tiramisu

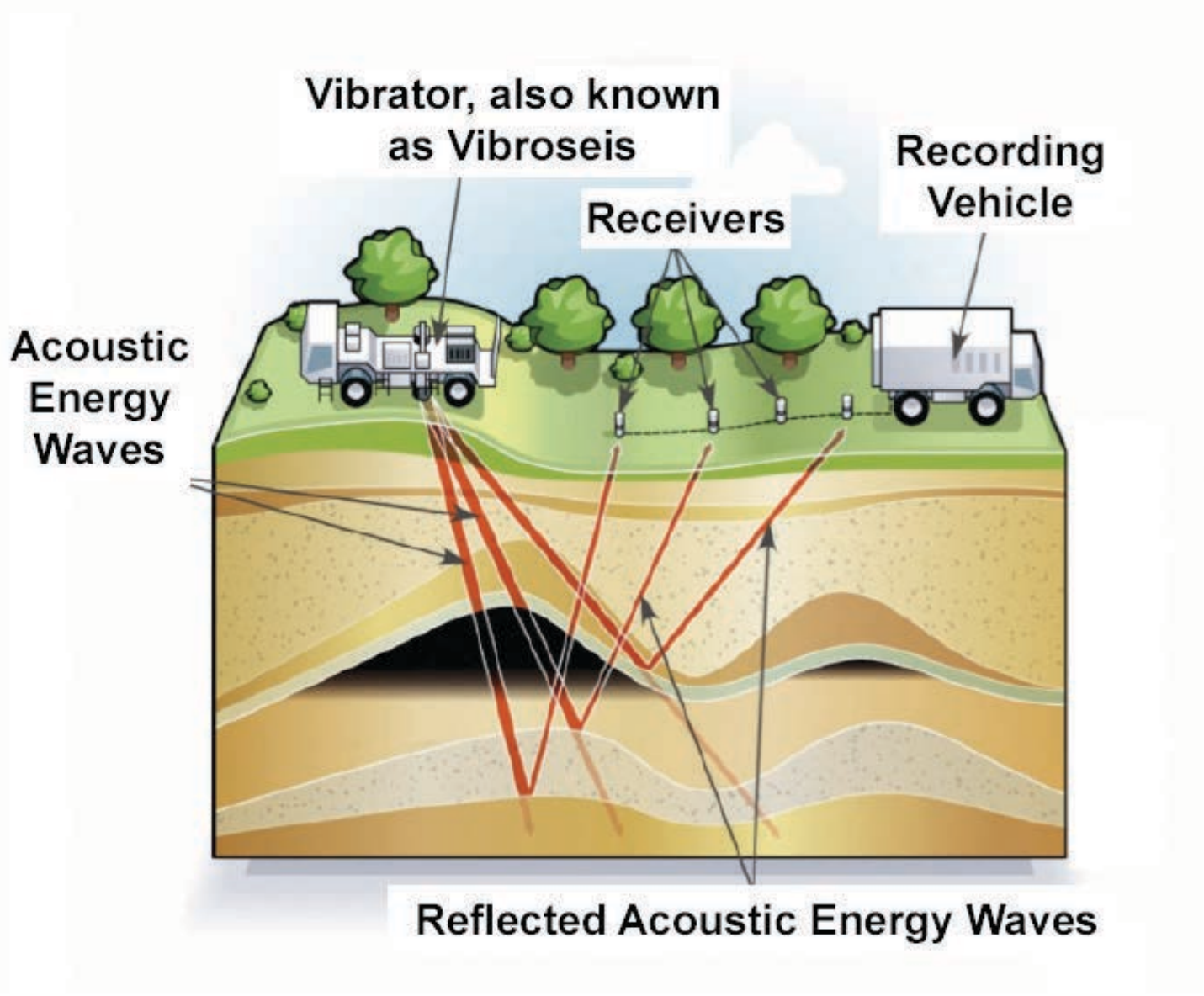
Unconventional Drilling
More Sophisticated Horizontal Penetration
Extensive Formation Contact

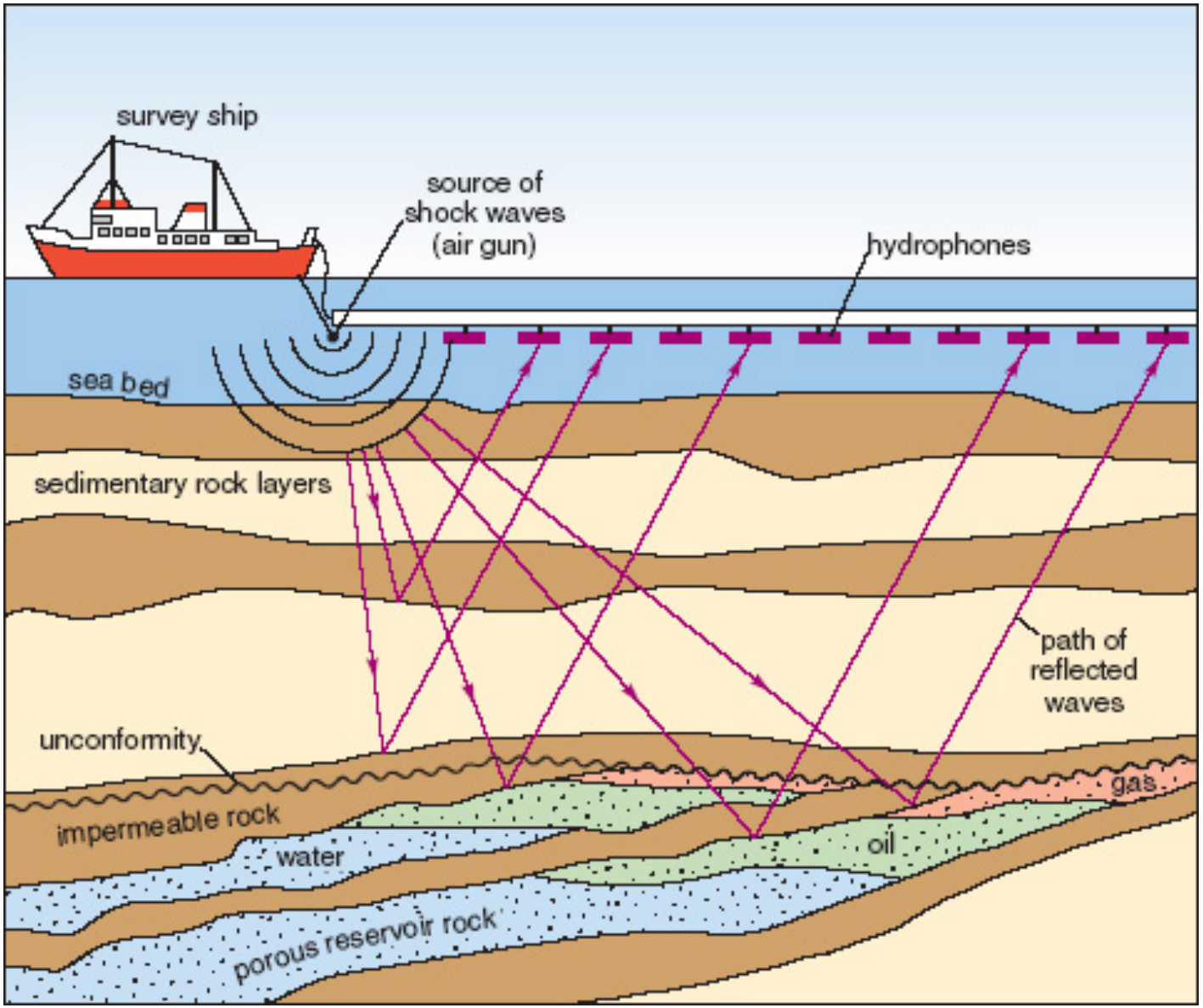


Wells can be spaced in 40-acre units or 16 wells per square mile

Finding Oil and Natural Gas

Seismic Reflection Imaging of Subsurface Structure

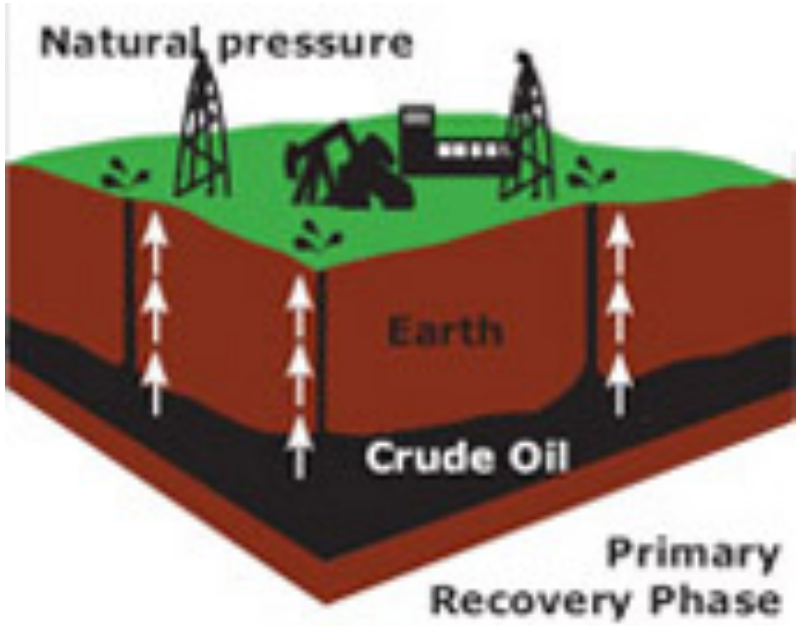


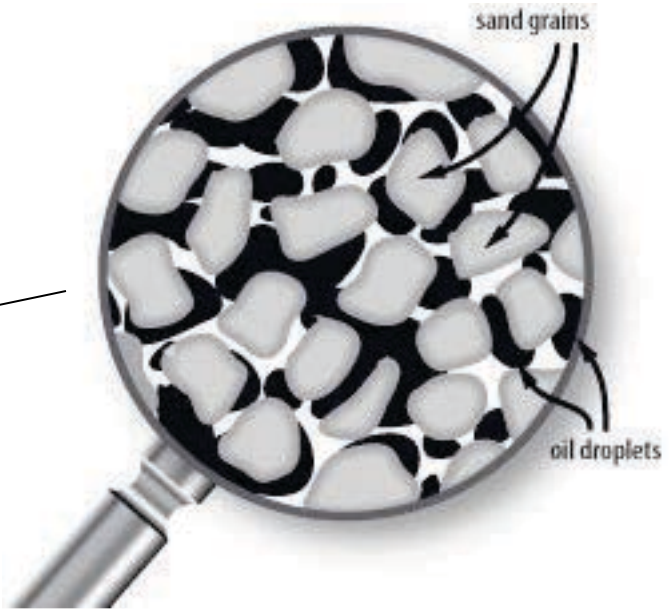


Active source seismology for oil and gas exploration

Extracting Oil and Natural Gas

Primary Oil Recovery



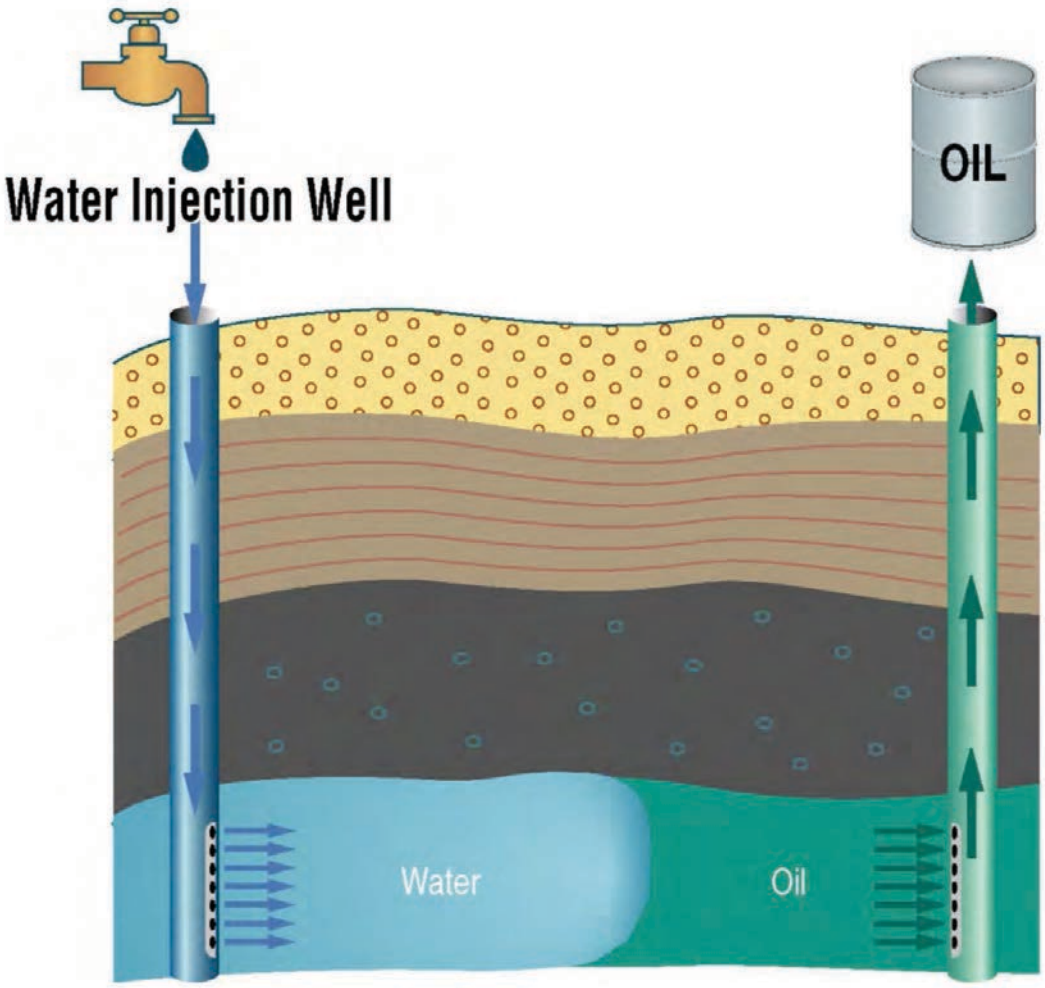


Uses natural pressure of the reservoir to push crude oil to the surface

Allows about 10% of the oil in the reservoir to be extracted

Pumpjack, oil recovery on dry land

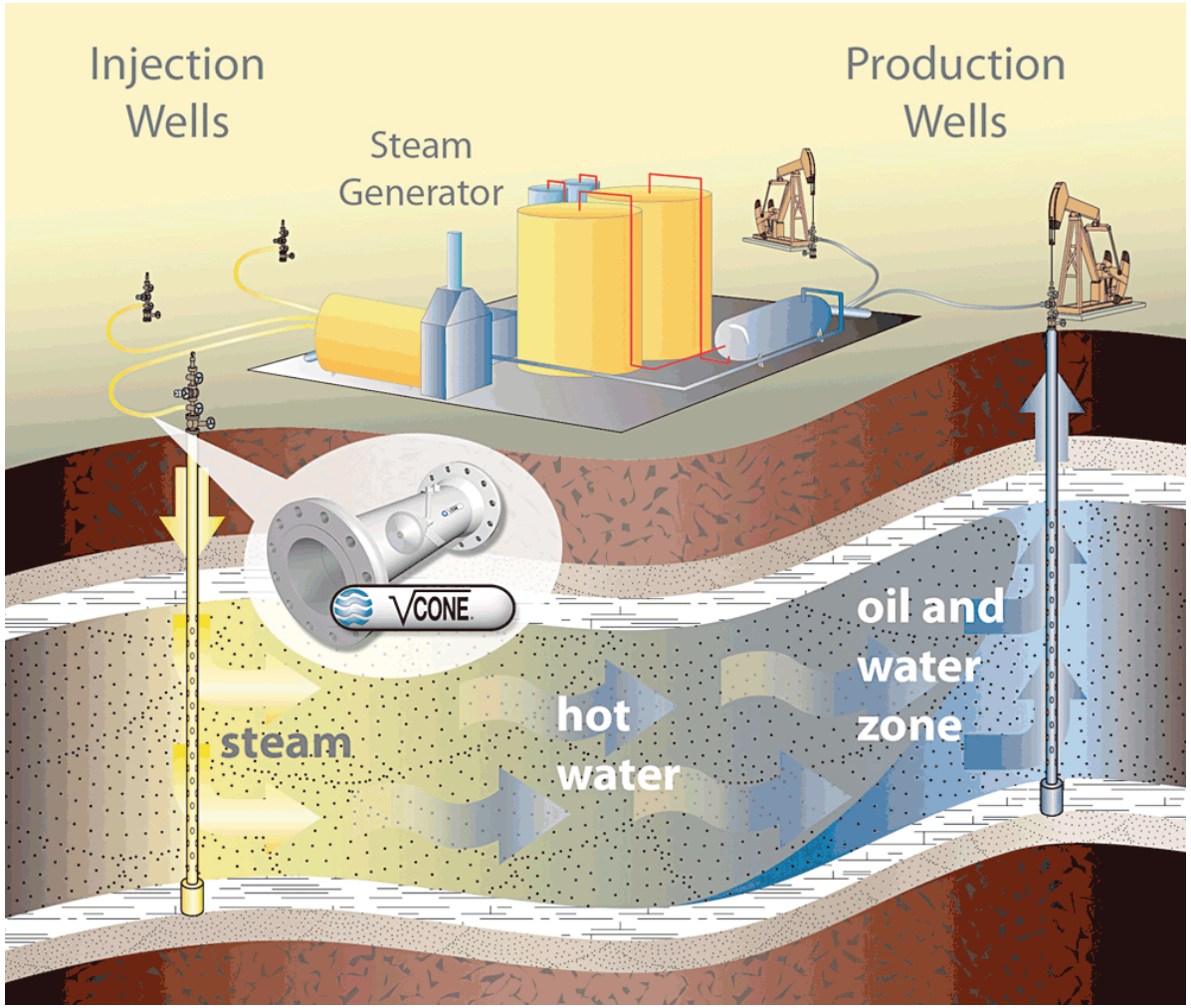
Waterflooding Recovery (secondary recovery)



Inject **water** to drive the residual crude oil and gas remaining after the primary oil recovery phase to the surface wells

Recovers additional 20 to 40% of oil originally in the reservoir. (leaving 50 to 70% still in the ground)

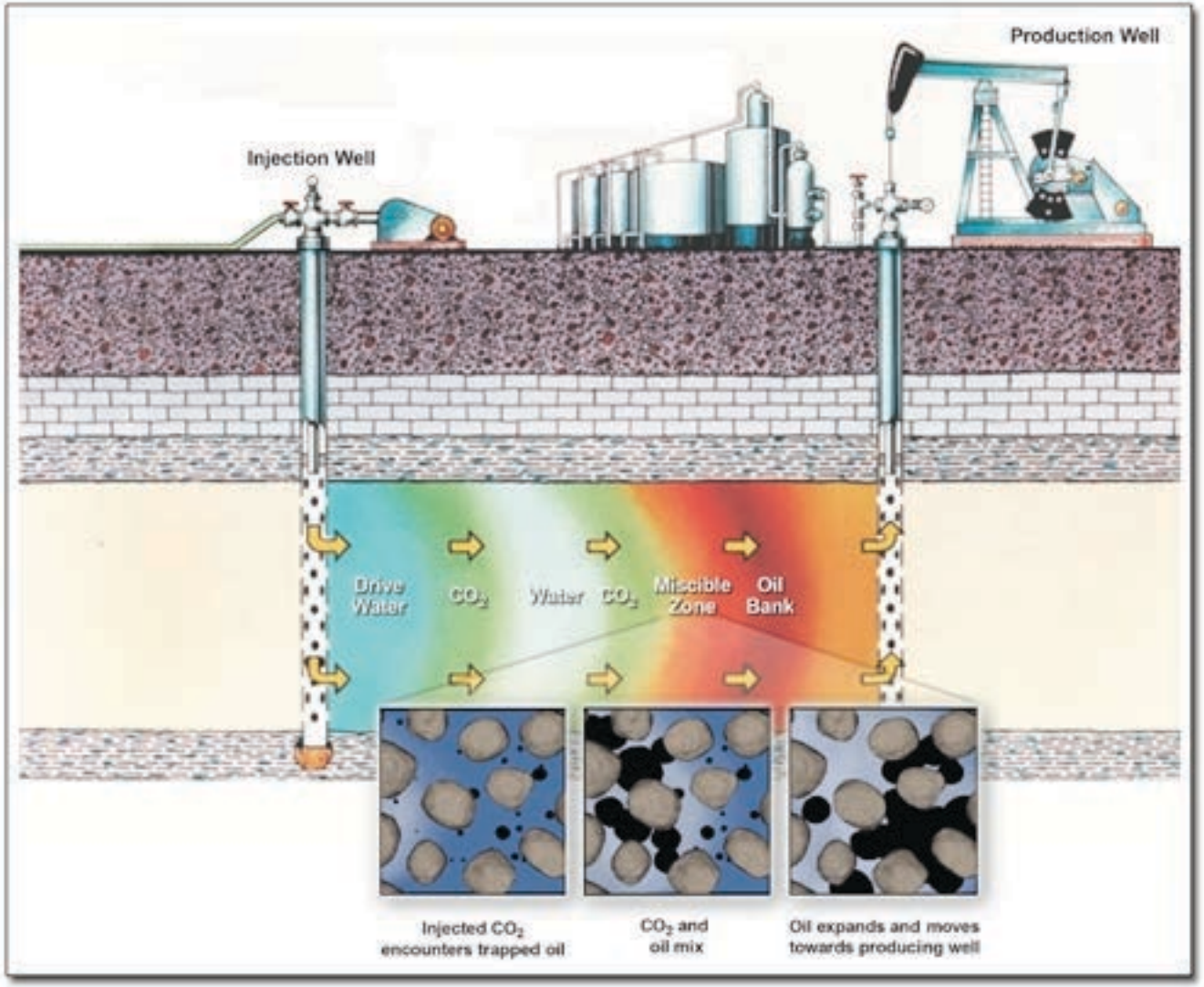
Steam Injection Recovery (tertiary recovery)



Inject **steam (superheated water)** to drive the residual crude oil and gas remaining after the primary oil recovery phase to the surface wells

Recovers up to an additional 80% of oil originally in the reservoir.

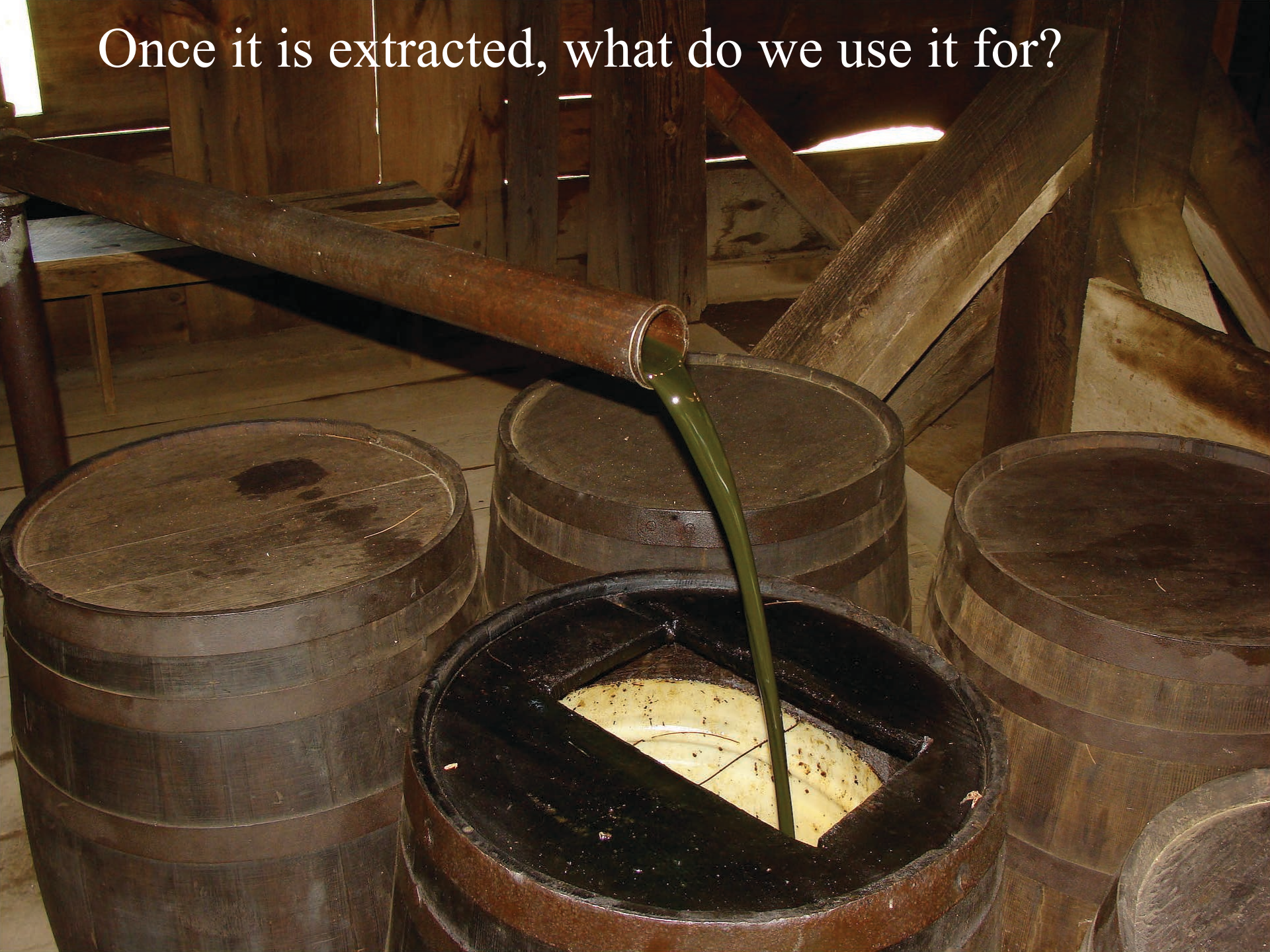
Enhanced Oil Recovery with Liquid CO_2 (tertiary recover)



CO_2 forces oil out of tight pore spaces;
In the U.S., there are ~125 active commercial CO_2 injection projects that together inject over 2 billion cubic feet of CO_2 and produce over 280,000 BOPD

Recovers up to an additional 50% of oil originally in the reservoir.

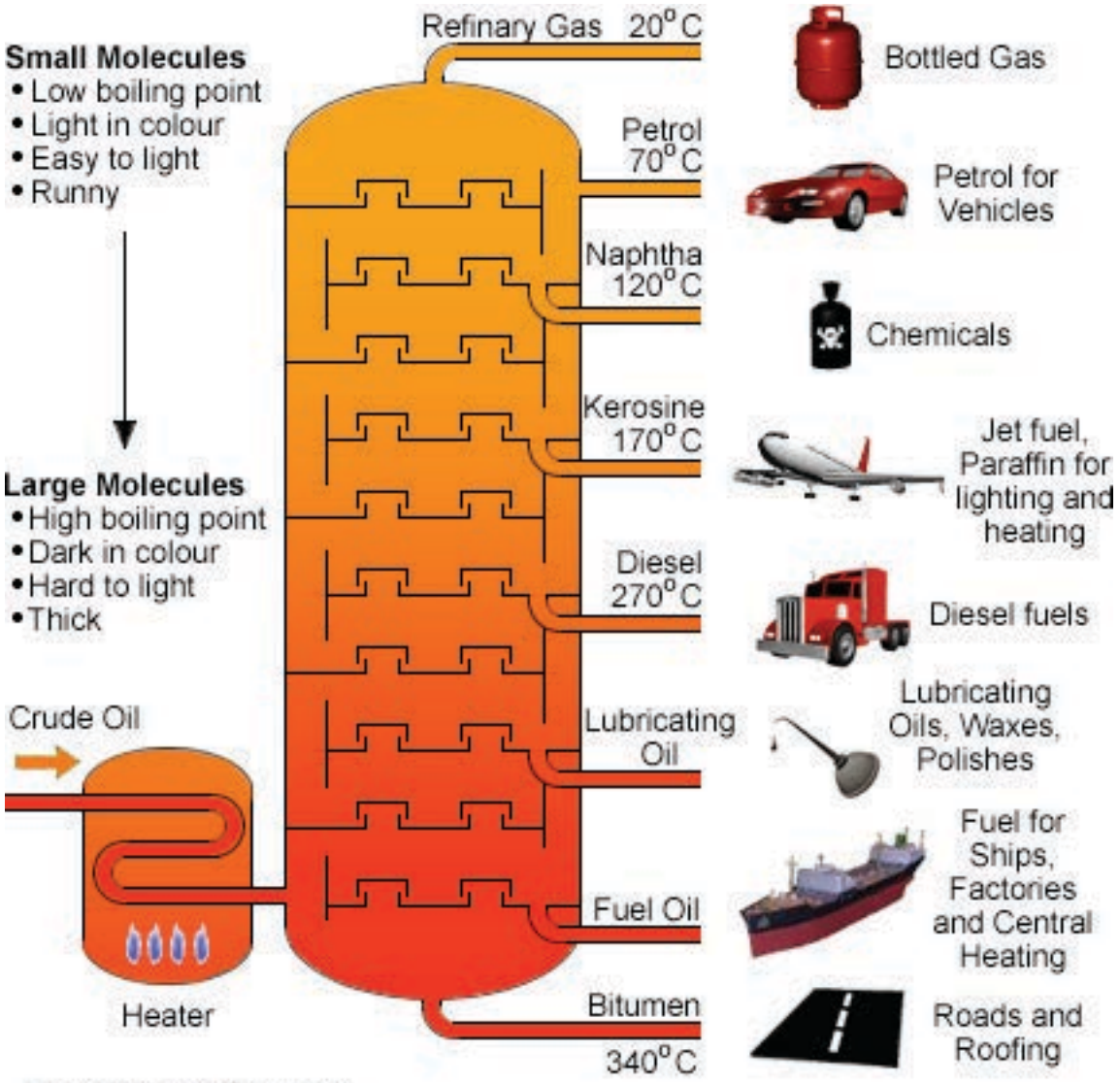
https://energy.gov/fe/science-innovation/oil-gas-research/enhanced-oil-recovery


Once it is extracted, what do we use it for?

Distillation (‘cracking’)

https://www.youtube.com/watch?v=VofKBcdZtjo

Distillation ('cracking')



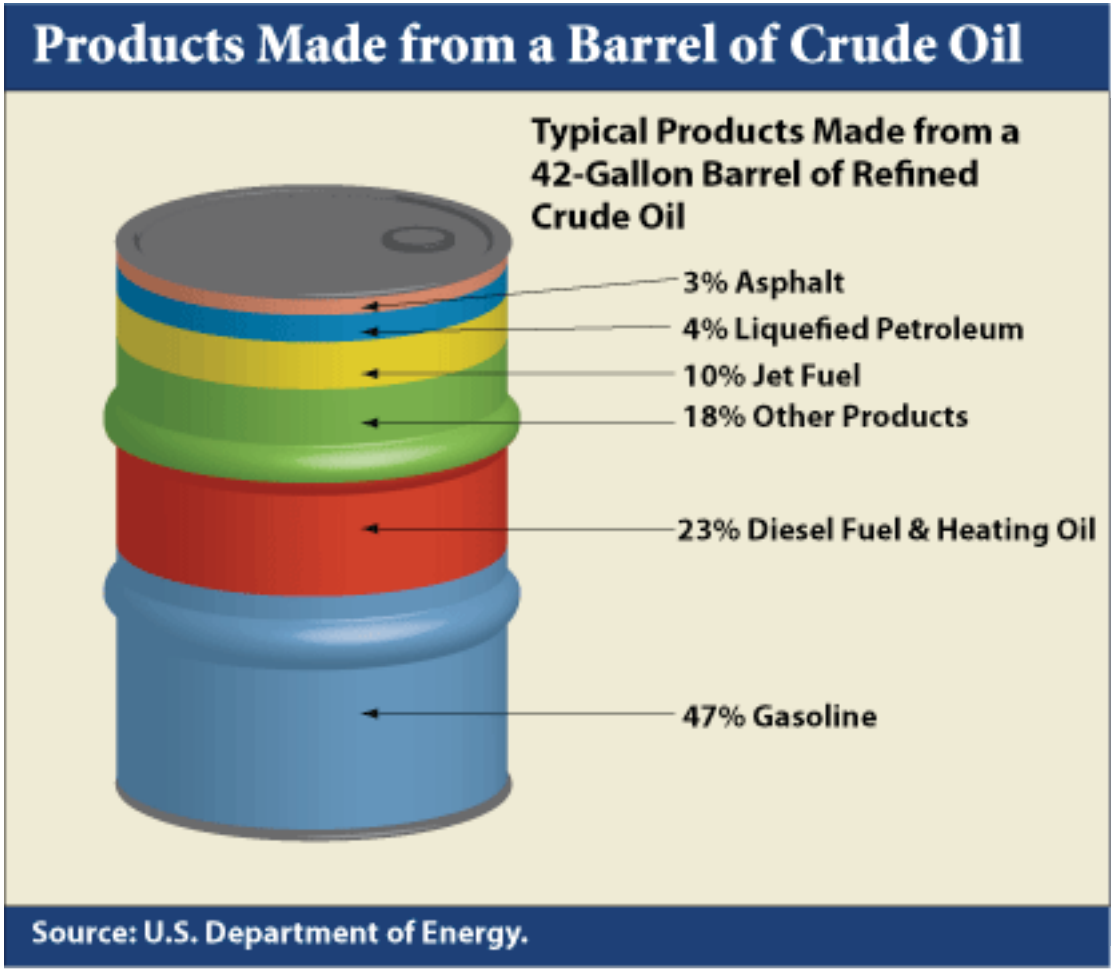
Auto gas = 5 to 10 C atoms

Naptha = 8 to 12 C atoms

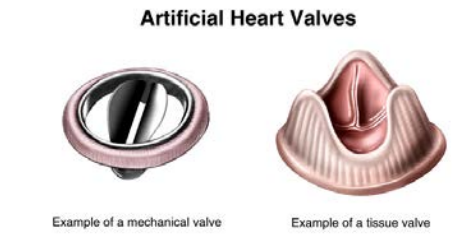
Kerosene = 10 to 16 C atoms

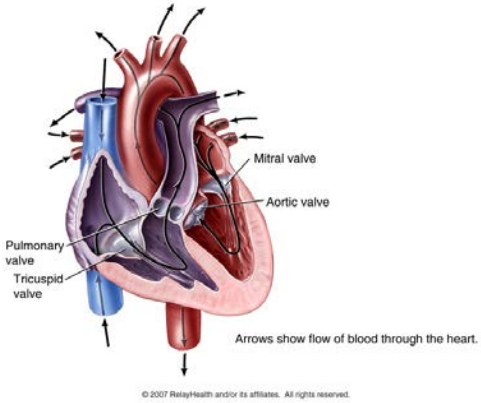
Diesel = 14 to 20 C atoms

Bitumen, fuel oil = >20 C atoms



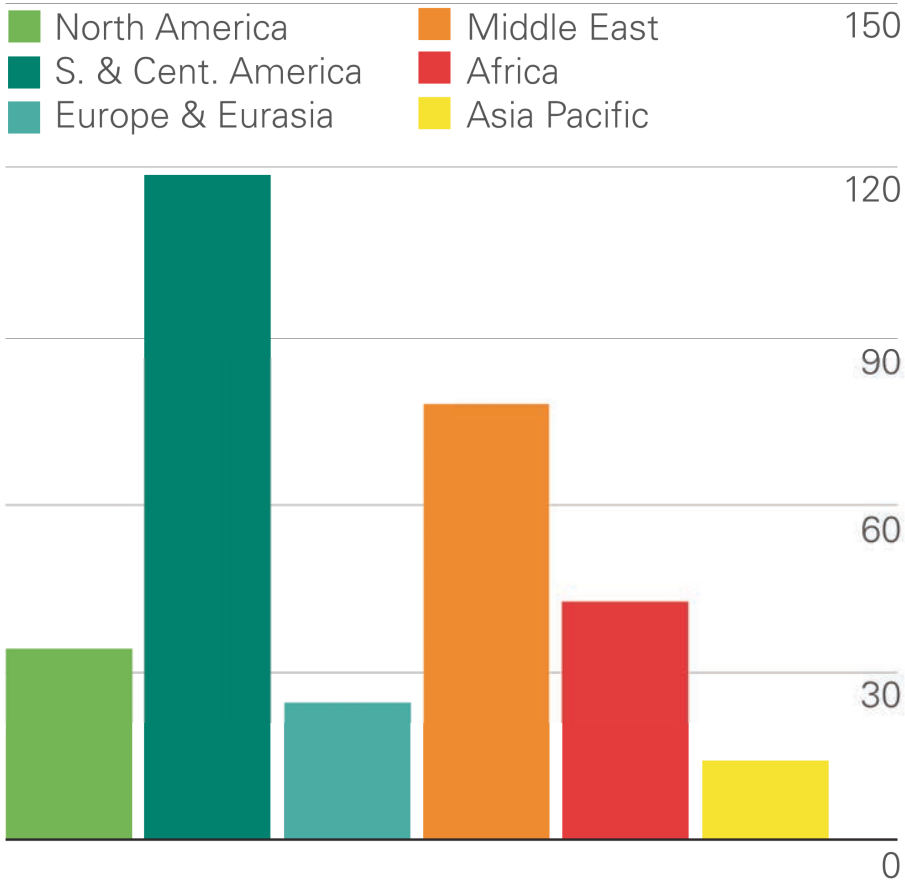
~75% used for transportation

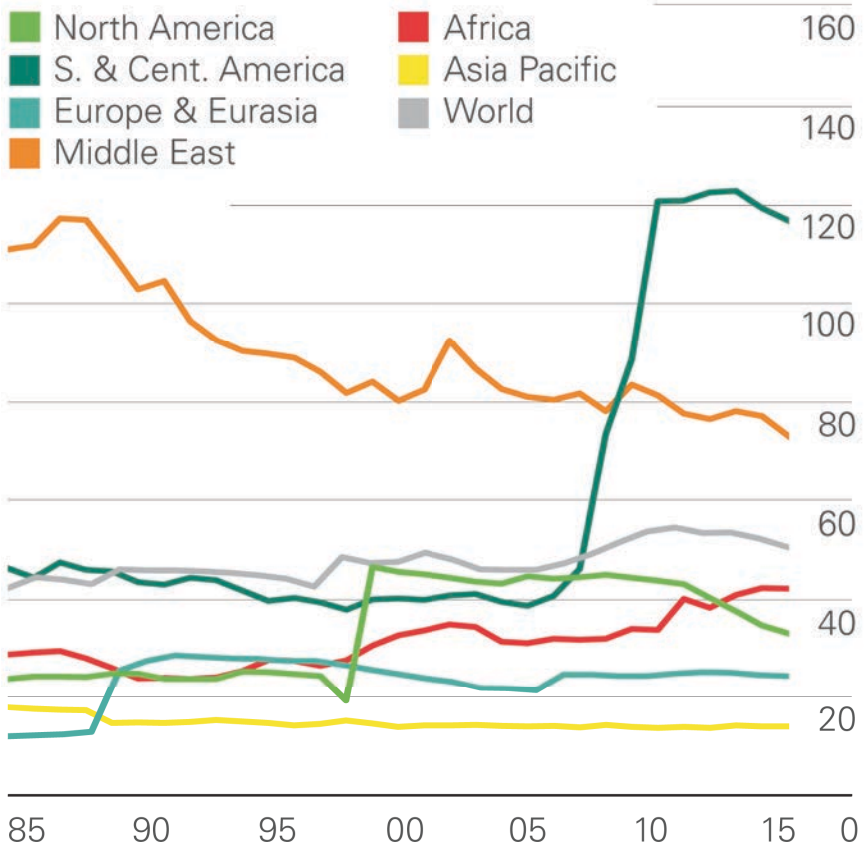




EVERYTHING PLASTIC
Is Made From Oil

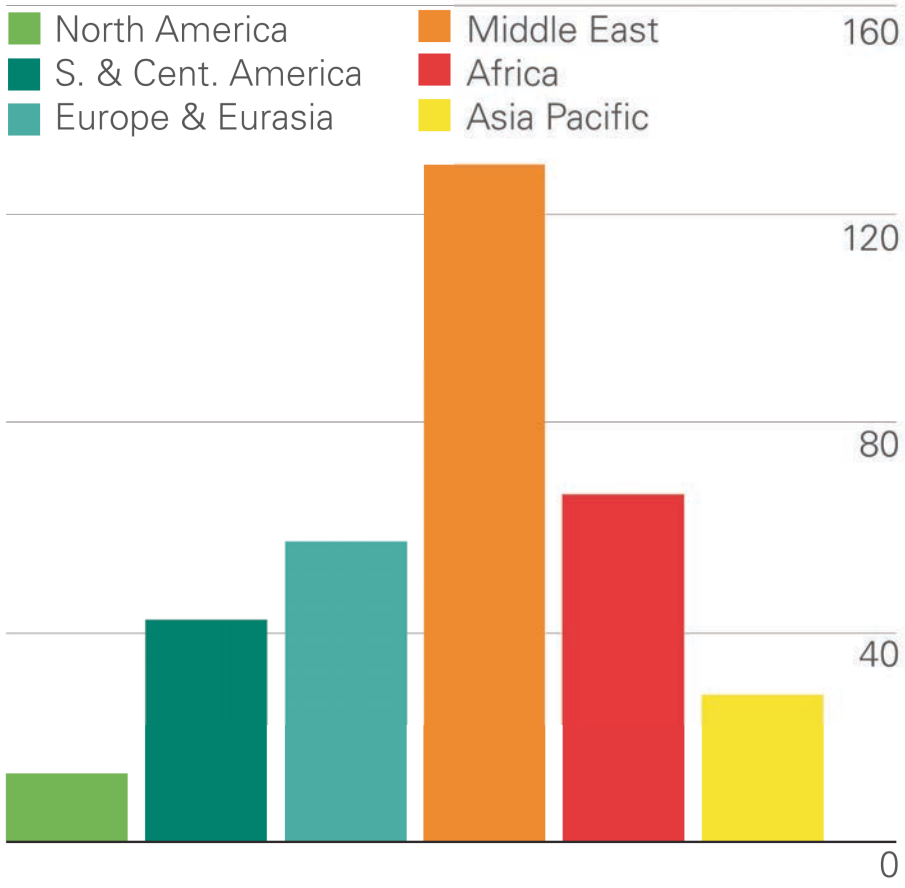
Remaining years of oil as of 2015

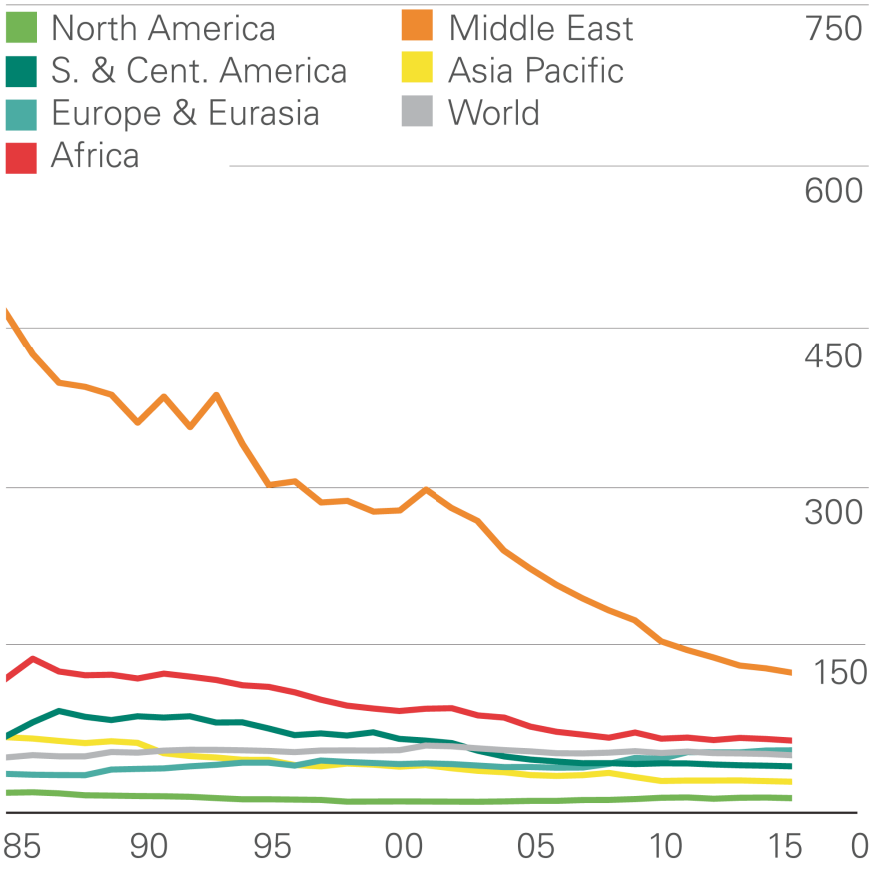




Calculated as: known quantity of oil in the ground / annual rate of oil consumption

Remaining years of natural gas (NG) as of 2015





Calculated as: known quantity of NG in the ground / annual rate of NG consumption