

Fracking:

How cheap energy is reshaping America's environment

Jared Atkinson, MIT
Natasha Goss, Harvard
Jordan Wilkerson, Harvard

Controversy

Taxpayers Should Oppose Proposed Fracking Ban

Jobs, Revenues, and Energy Independence Depend on It

Saturday, August 2, 2014
by JORDAN CUNNINGHAM

Hormone-Disrupting Chemicals Linked to Fracking Found in Colorado River

Posted by [Sandra Postel](#) of National Geographic's Freshwater Initiative in [Water Currents](#) on December 20, 2013

U.S. Oil Output to Overtake Saudi Arabia's by 2020

By Lananh Nguyen | Nov 12, 2012 12:39 PM ET | [141 Comments](#) [Email](#) [Print](#)

Burleson: Denton fracking ban could lead to a crippled Texas economy

By Richard L. Burleson | August 1, 2014 | Updated: August 2, 2014 2:28pm

California's Fracking Controversy

Posted: 10/23/2014 4:42 pm EDT | Updated: 10/23/2014 4:59 pm EDT

Fracking in Water-Stressed Zones Increases Risks to Communities – and Energy Producers

Posted by [Sandra Postel](#) of National Geographic's Freshwater Initiative in [Water Currents](#) on February 6, 2014

Drilling in the dark: Biological impacts of fracking still largely unknown

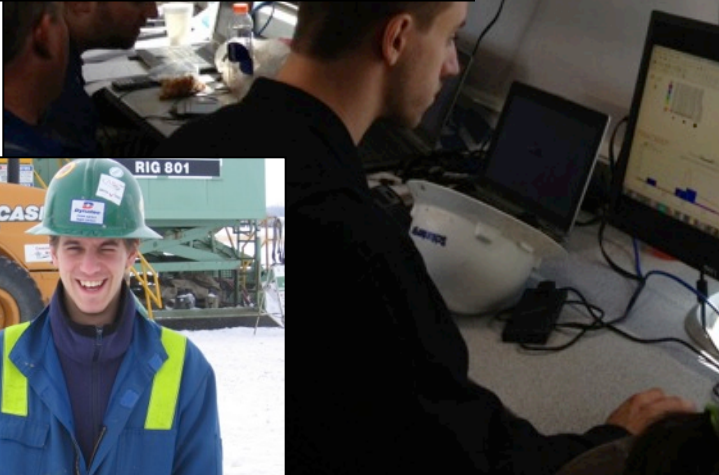
Aug. 1, 2014 | by [David Tenenbaum](#)

Loophole Allows Many Dangerous Chemicals In Fracking Fluids To Go Undisclosed: Report

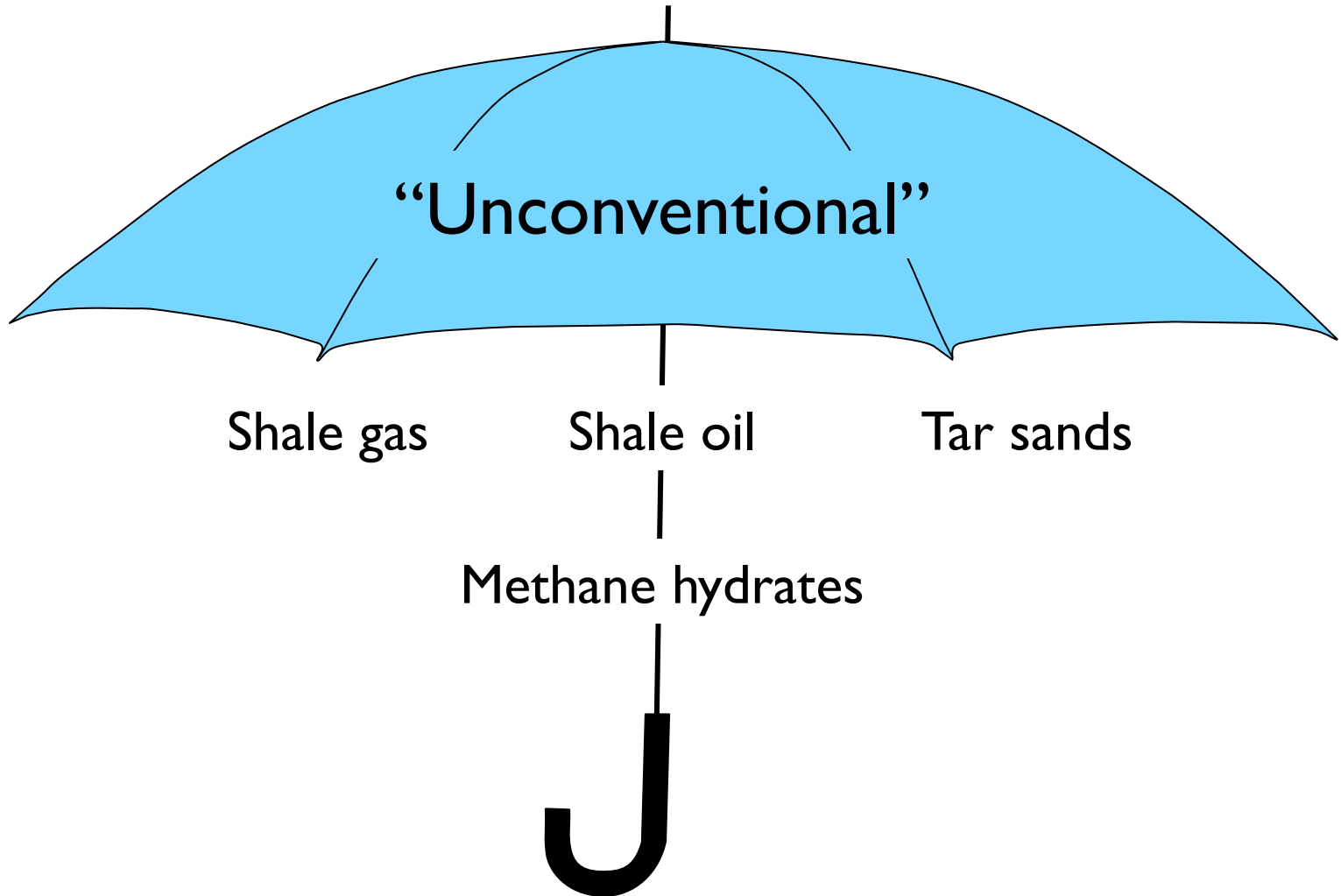
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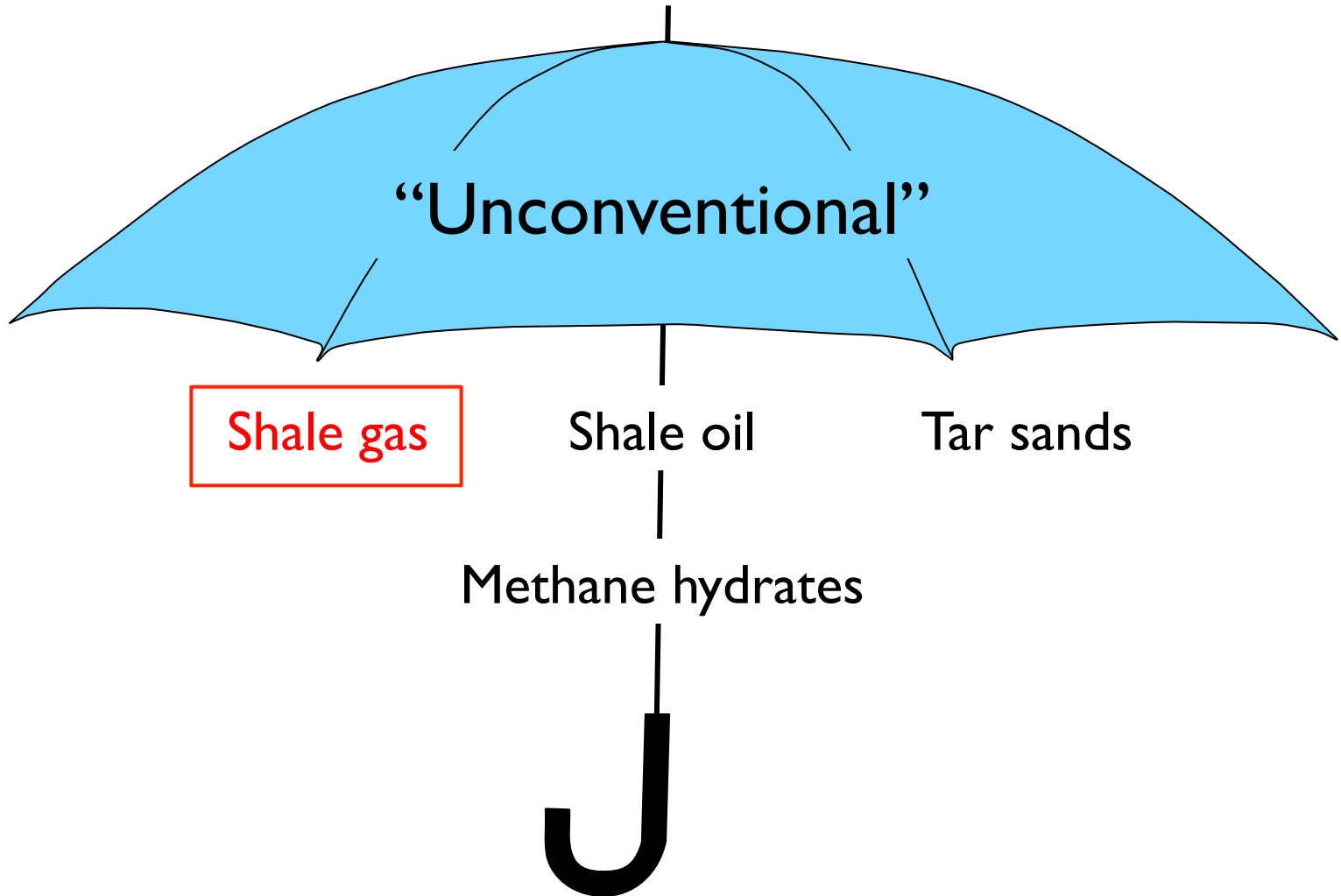
My Background



A note on semantics...



A note on semantics...



Roadmap for the evening

1. Hydraulic Fracturing: How...and Why?
2. Water Contamination and Induced Seismicity
3. Impact of Fracking on Climate Structure

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Hydraulic Fracturing: How...and Why?

1. Hydrocarbon basics
2. The F-word
3. Why are we doing this?

Hydraulic Fracturing: How...and Why?

1. Hydrocarbon basics

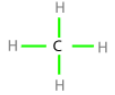

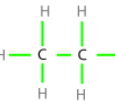
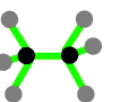
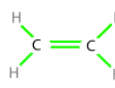
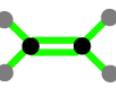
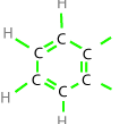
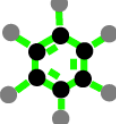
2. The F-word

3. Why are we doing this?

What is...

Hydrocarbon?

- An organic compound consisting of carbon and hydrogen

Hydrocarbon	Structural Formula	Ball-And-Stick Model
Methane CH ₄		
Ethane C ₂ H ₆		
Ethylene C ₂ H ₄		
Benzene C ₆ H ₆		

plastic ties	cameras	plastic flowerpots	hearing aids	baggies	shower doors	antifreeze
row cover	beach balls	hot tub covers	anesthetics	drinking straws	Formica• refrigerator lining	flat tire fix
irrigation piping	fishing poles	sails	artificial limbs	Styrofoam	vinyl wallpaper	street paving (asphalt)
polyethylene	hang gliders	snorkels• monkey bars	eyeglasses and	paper cup dispenser	curtains	car battery cases
polypropylene	vinyl cases	photo albums	sunglasses	measuring cups	kitchen carpet	coolant
bags and packaging	footballs	wet suits	antihistamines	Teflon coated pans	shag carpet	motor oil
pesticides and	glue containers	flippers	cortisone	table cloths	welcome mats	tires
herbicides	puzzles	tennis balls	vaporizers	refrigerator shelves	fan blades	loud speakers
food preservatives	darts	boats	denture adhesives	cologne	lamps	bearing grease
fertilizers	Frisbees	insulated boots	laxatives	hair brushes	shower curtain	sports car bodies
ballet tights	golf ball and golf bags	acrylic toys	Bactine	lipstick	patio furniture	traffic cones
nylon cord	shotgun shells	baby oil	oxygen masks	permanent wave curlers	swings	car enamel
polyester	ear plugs	laundry baskets	stethoscopes	perfume	linoleum	brake fluid
everything permanent	knitting needles•	waterproof pants	prescription glasses	hair color	upholstery	dashboards
press	waterproof clothing	baby aspirin	cough syrup	mascara• petroleum jelly	rugs	windshield wipers
beads	stadium cushions	bath soap	hearing aids	comb	caulking material	visors
bracelets	earphones	mittens	vinegar bottles	foam rubber curlers	light switch plates	car sound insulation
pantyhose	yarn	pacifiers	egg cartons	shampoo	plungers	oil filters
nylon zippers	kites	baby blankets	meat trays	contact lenses and	faucet washers	car seats
plastic hangers	tennis racquets	bibs	trash bags	cases	clotheslines	convertible tops
purses	fabric dye	rattles	breadboxes	hair spray	measuring tape	fan belts
thongs and flip flops	decoys	doubleknit shirts	freezer containers	hand lotion	polyurethane stain	gasoline
earrings	lifejackets	baby bottles	melamine dishware	shaving foam	water pipes	ash trays
ribbons	nylon strings	disposable diapers	tumblers	hair dryers	electric saws	dog food dishes
fake fur	face protectors	baby shoes	cake decorations	shoe inserts	paintbrushes	toolboxes• CDs and
windbreakers	volley balls	teething rings	jars	dentures	propane bottles	DVDs
sandals	model cars	nipples and binkies	microwave dishes	body lotion	wood floor cleaner/wax	balloons
garment bags	plastic water guns	dolls	utensils	face masks	vinyl electrical tape	dog leashes
shoe laces	fishing bobbers	stuffed animals	candles	skin cleanser	plastic pipe	tape recorders
rain coats	soccer balls	baby lotion	freezer bags	deodorants	shingles (asphalt)	synthetic rubber
iron-on patches	oil paints	allergy medication	milk jugs	moisturizing cream	light panels	bubble gum
sneakers	parachutes	cotton-tipped swabs	vacuum bottles	soap holders	garden hoses	dog toys
sweaters	fishing cylvume	inhalers	coasters	disposable razors	plastic wood spackling paste	flashlights
sofa pillow material• tote	light sticks	liquid Pepto-Bismol	gelatin molds	leather conditioner	awnings	nylon ropes
bags	earphones	aspirin	nylon spatulas	mouthwash	glazing compound	bungee straps
umbrellas	playing cards	first aid cream	wax paper	sunscreen	Plexiglas	flight bags
ball point pens	photographs	lancets	coffee pots	facial toner	spray paint	disposable lighters
diskettes	monofilament fishing	pill cases	ice cream scoops	lens cleanser	enamel	cassette player
thermometer	lines	band aids	oven bags	nail polish	epoxy paint	flea collars
Ink	diving boards	first aid kits• latex gloves	mops	sunscreen	artificial turf	flutes
computers	poker chips	prescription bottles	drinking cups	tooth brushes	folding doors• floor wax	lighter fluid
business card holders	goggles	burn lotion	ice trays	toothpaste tubes	glue	cigarette cases
copiers	rollerskate and	glycerin	plastic containers	vitamins	house paint	electric blankets
waste baskets	skateboard wheels	mosquito spray	fabric softener	synthetic wigs	paint rollers	tool racks
calculators	whistles	rubbing alcohol	detergent bottles	bubble bath	toilet seats	name tags
printer cartridges	guitar strings	chap stick	plastic table service	soap capsules	water pipes	
microfilm	picks	heart valve replacement	drain stoppers	carpet padding	putty	
name tags	rafts	nasal decongestant	dish drainers	Naugahyde	solvents	
binders	ice chests	surgical tape	lunch boxes	Venetian blinds	roofing material	
erasers	tents	syringes	pudding molds	TV cabinets	plywood adhesive	
		Vaseline	sponges	extension cords	sockets	
		antiseptics	dish scrubber	picture frames	propane	

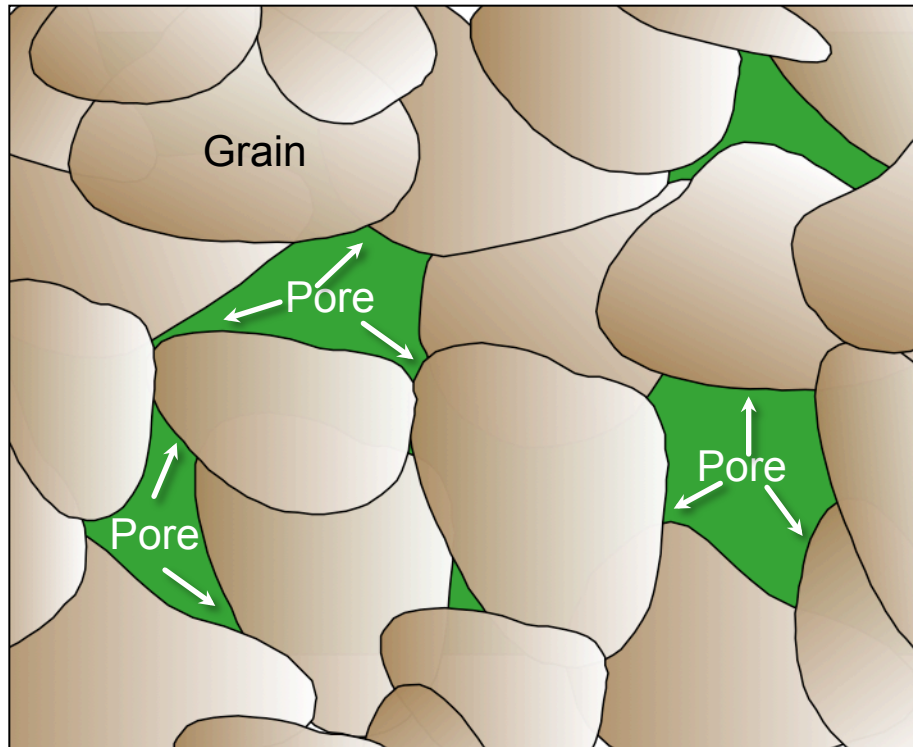


What is...

Hydraulic Fracturing?

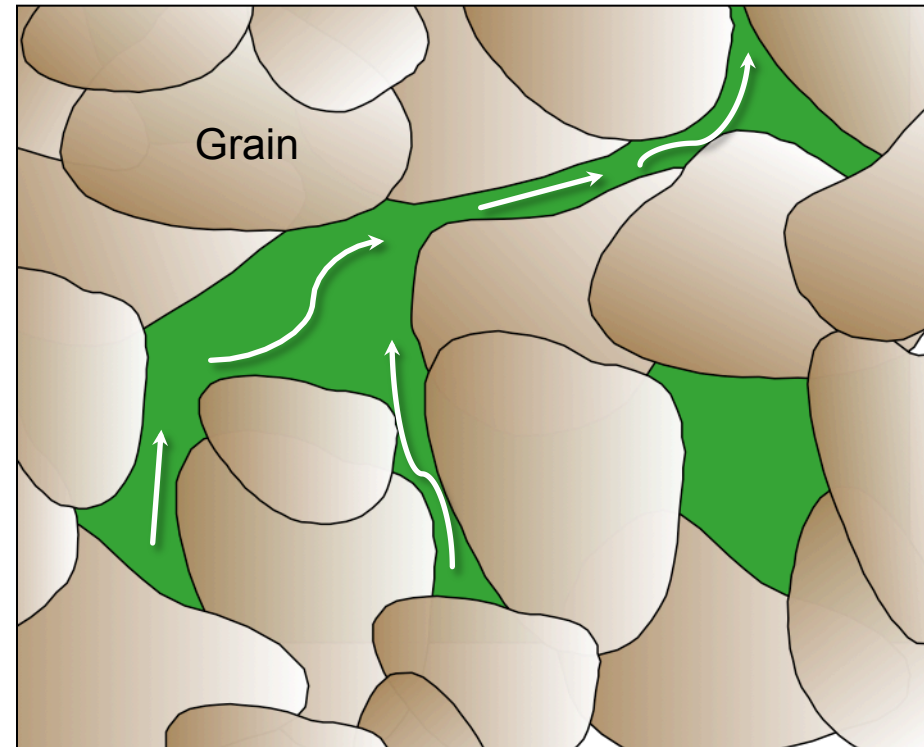
- AKA “Fracking”
- The fracturing of rock by pressurized liquid
- Well “stimulation” technique that enhances *permeability*

Porosity vs. Permeability



Porosity ✓

Permeability ✗

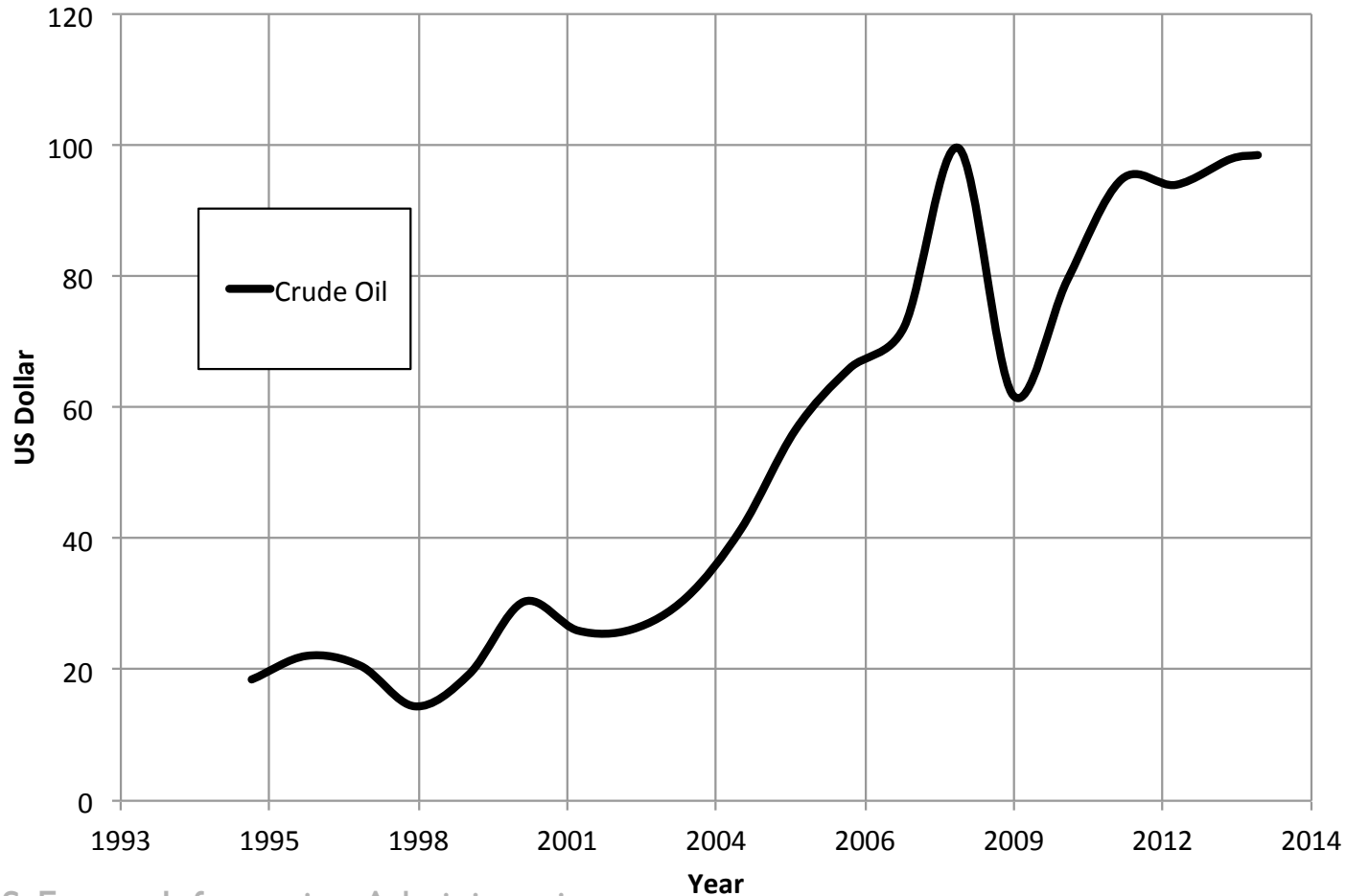


Porosity ✓

Permeability ✓

What is...

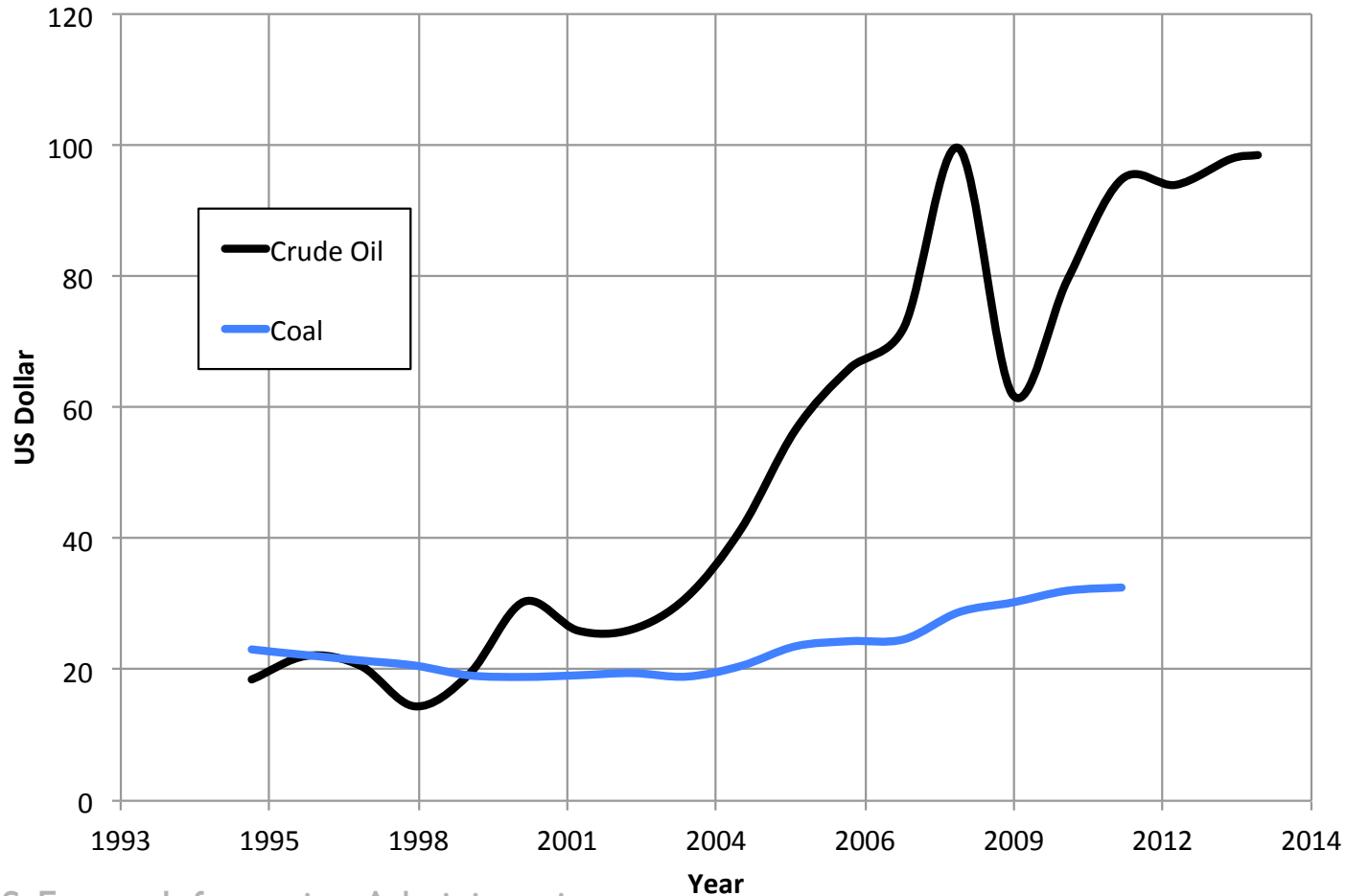
Cheap energy?



Data from U.S. Energy Information Administration

What is...

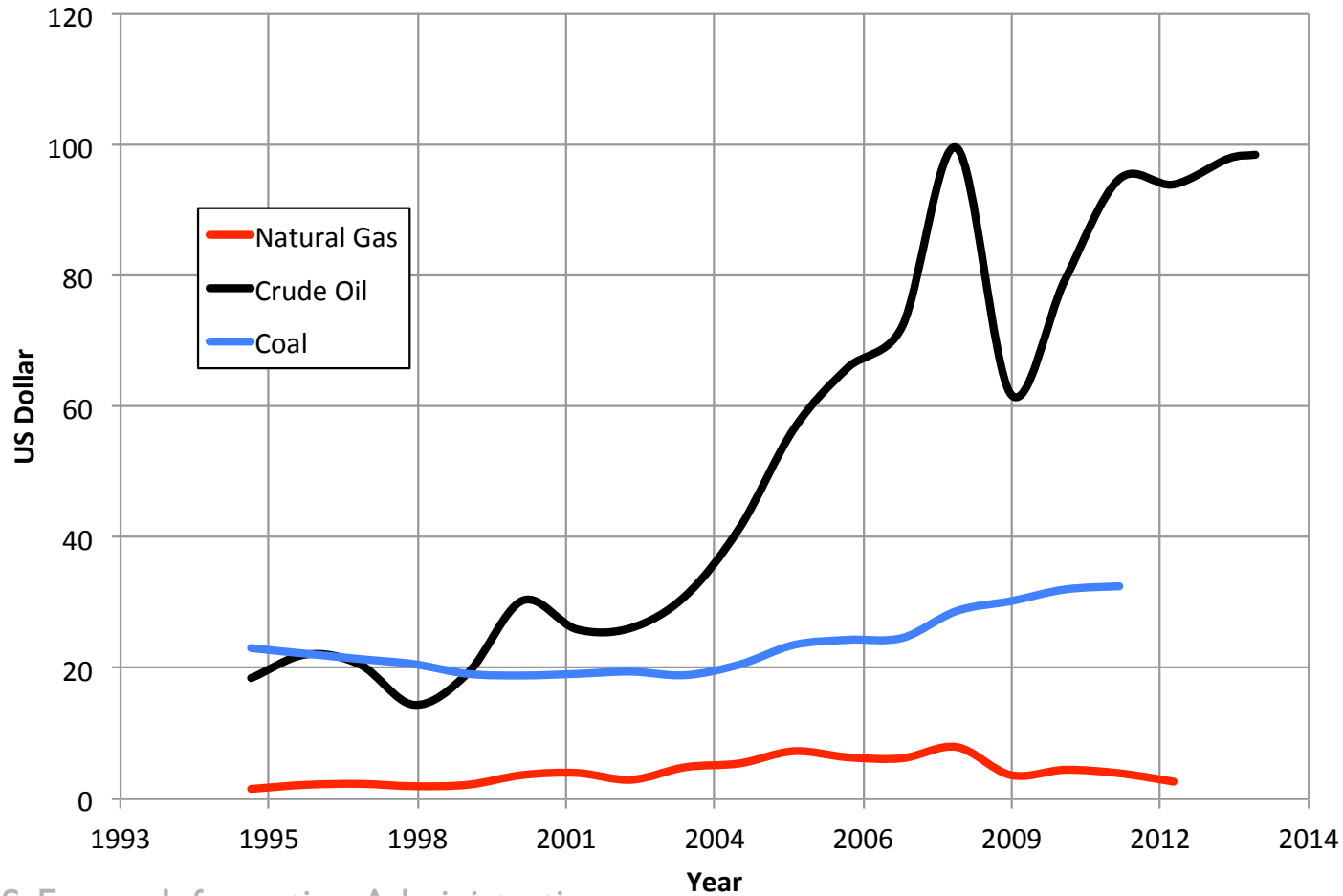
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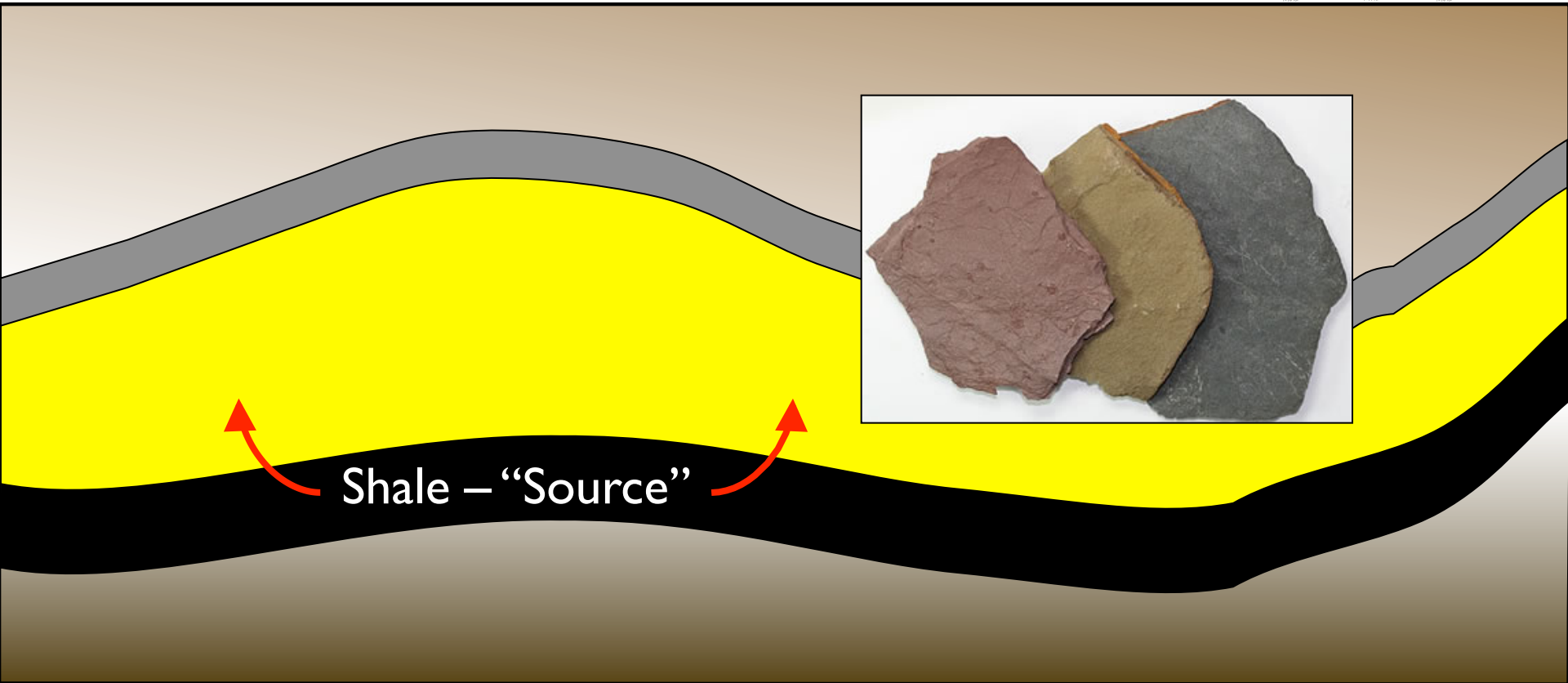
Cheap energy?



Data from U.S. Energy Information Administration



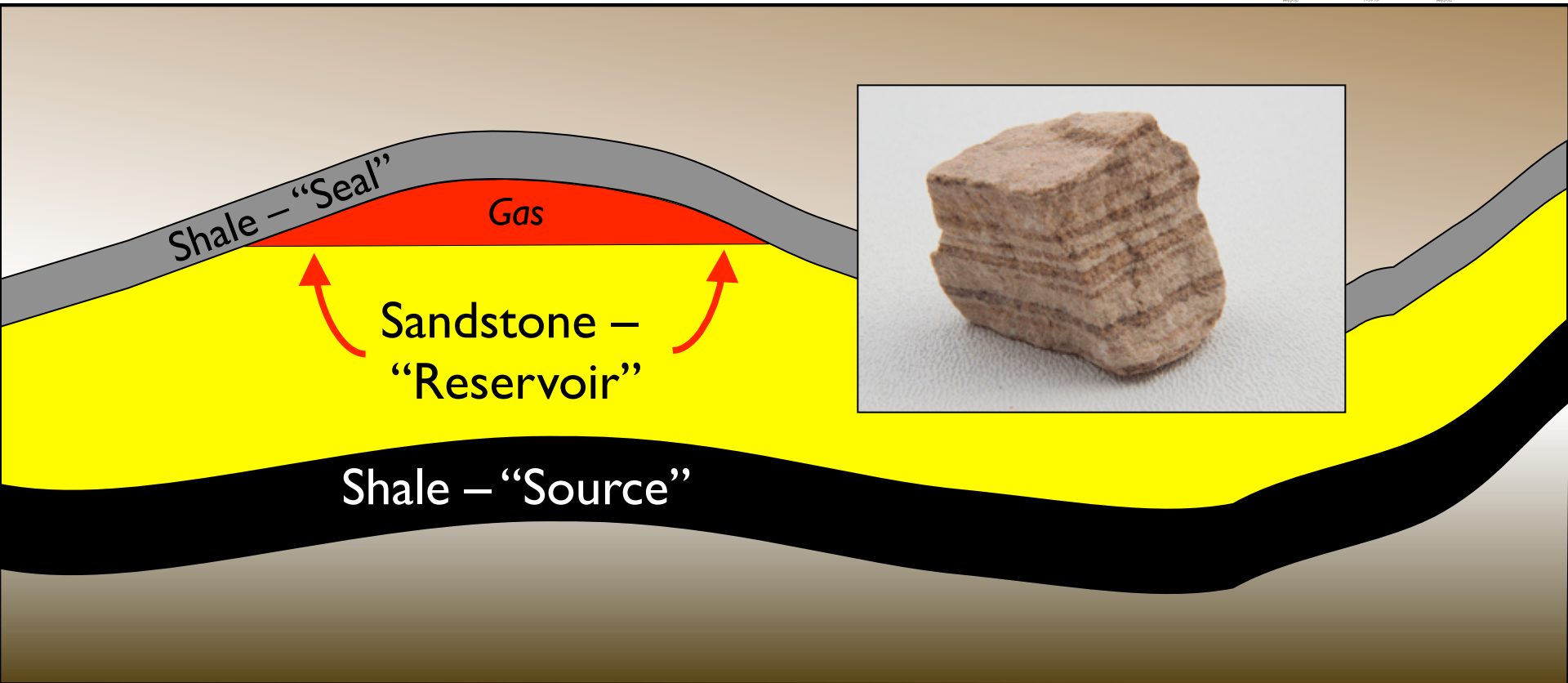
Hydrocarbon Basics



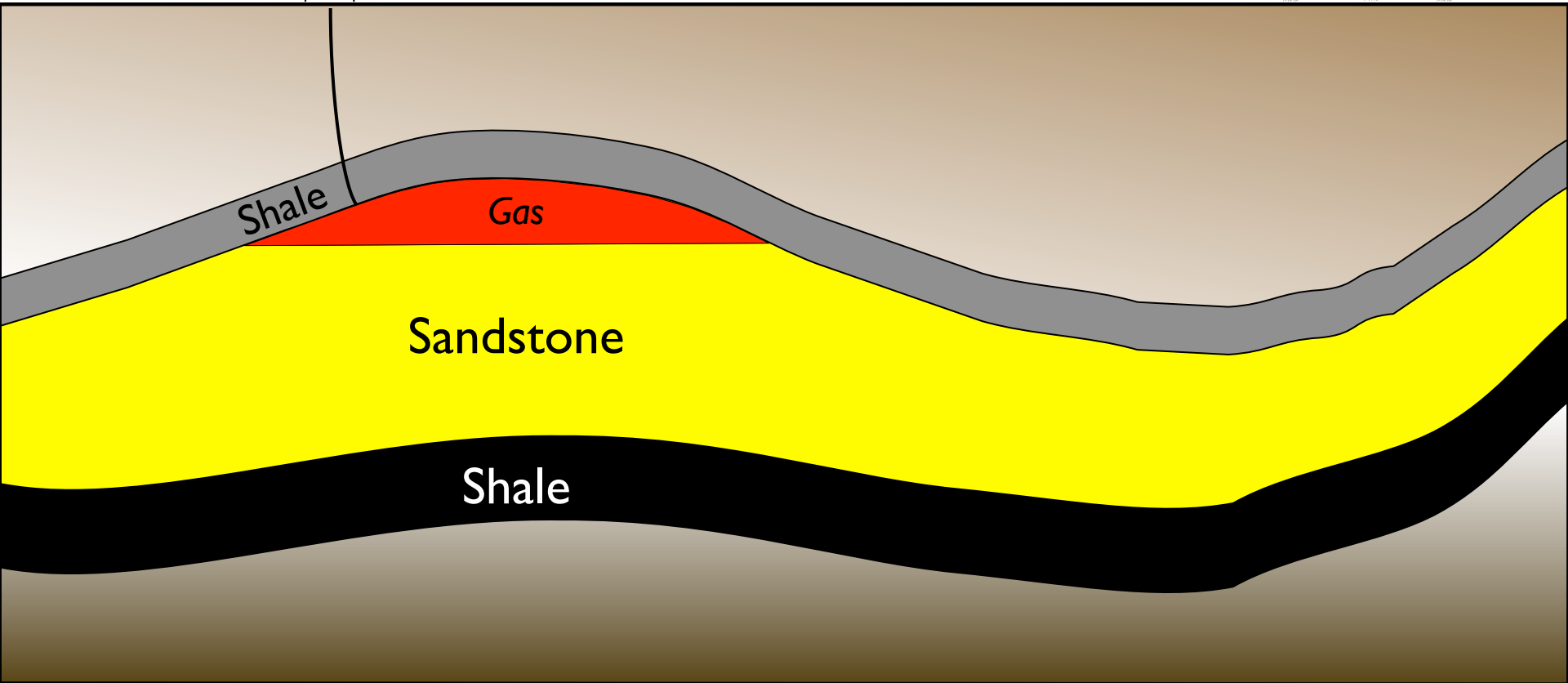
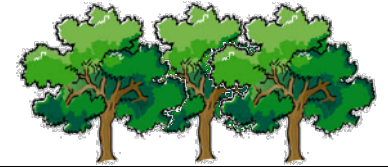
Shale – “Source”



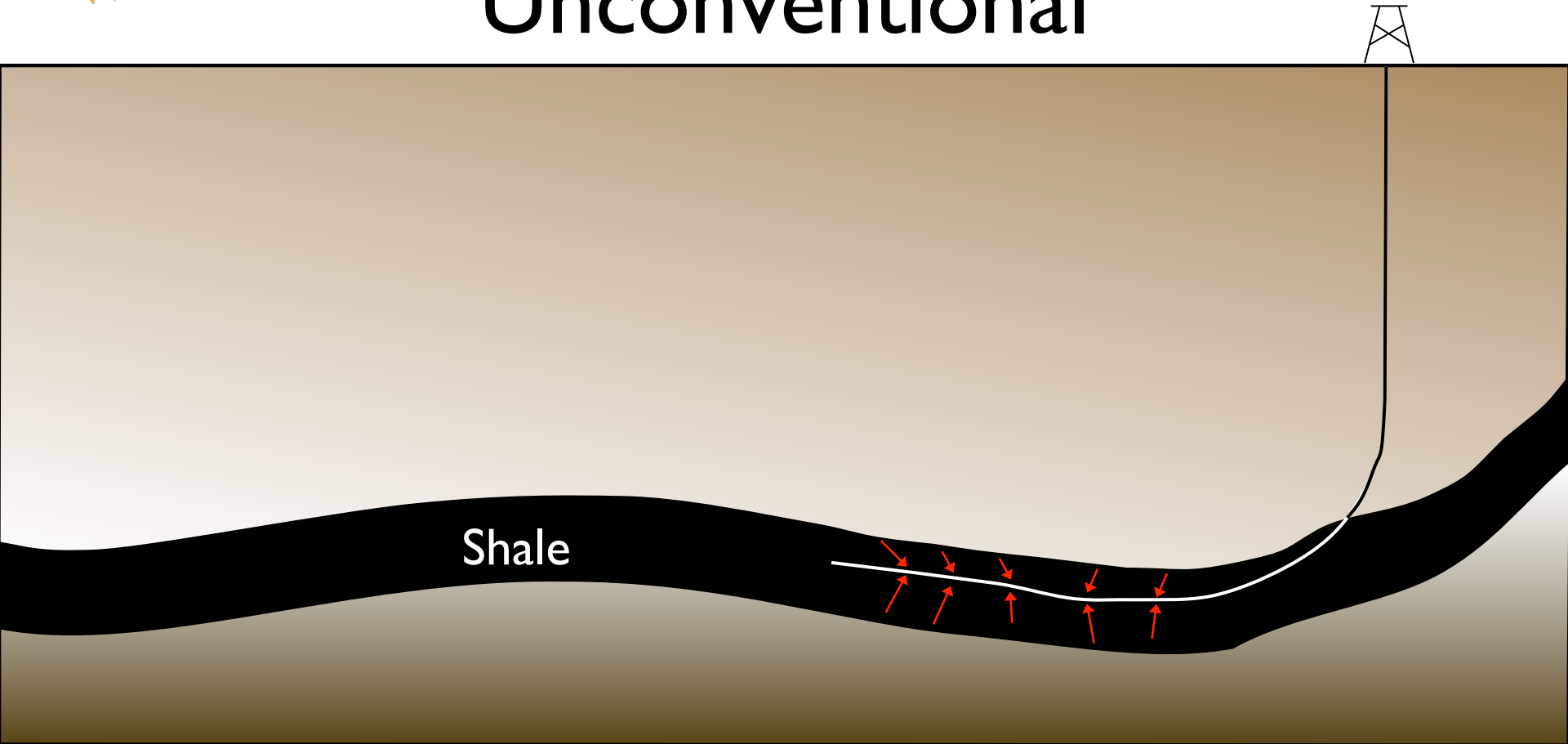
Hydrocarbon Basics



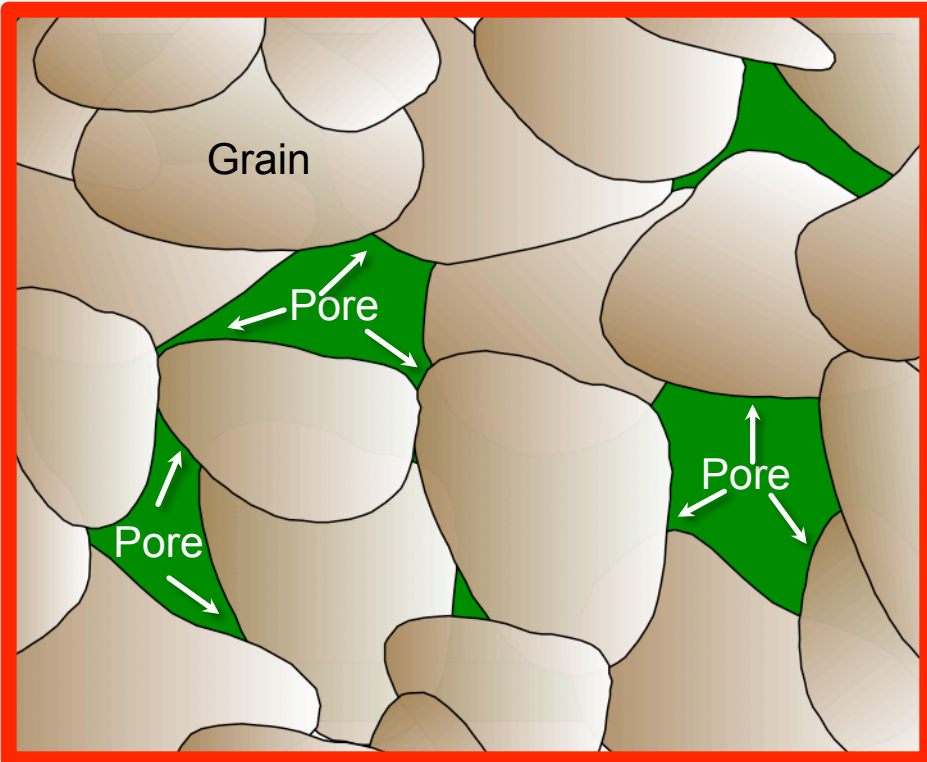
Hydrocarbon Basics: Conventional



Hydrocarbon Basics: Unconventional

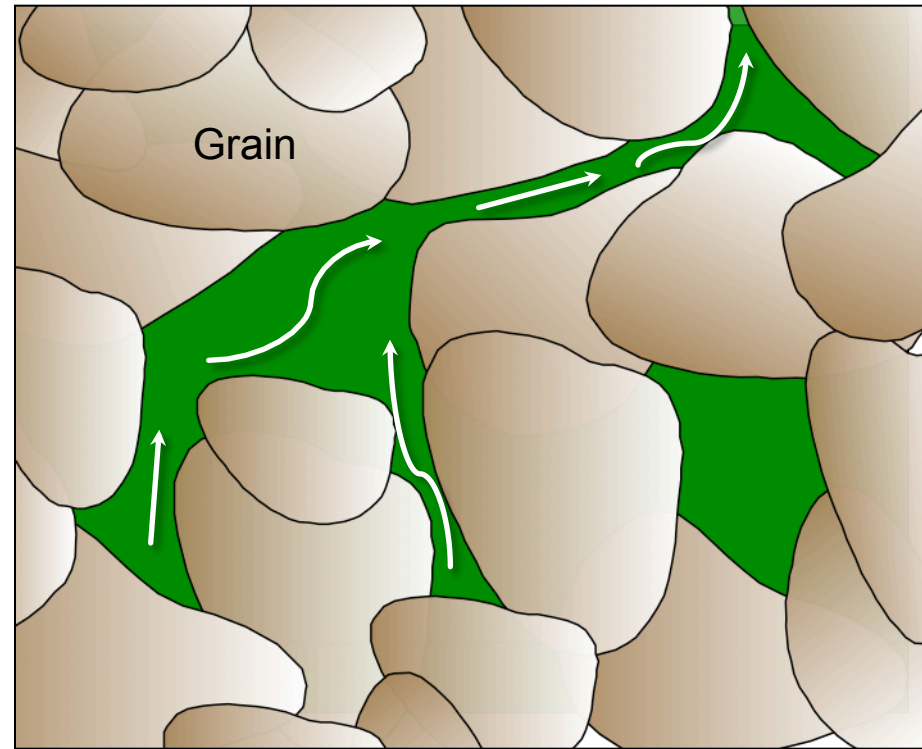


Is Shale Permeable?



Porosity ✓

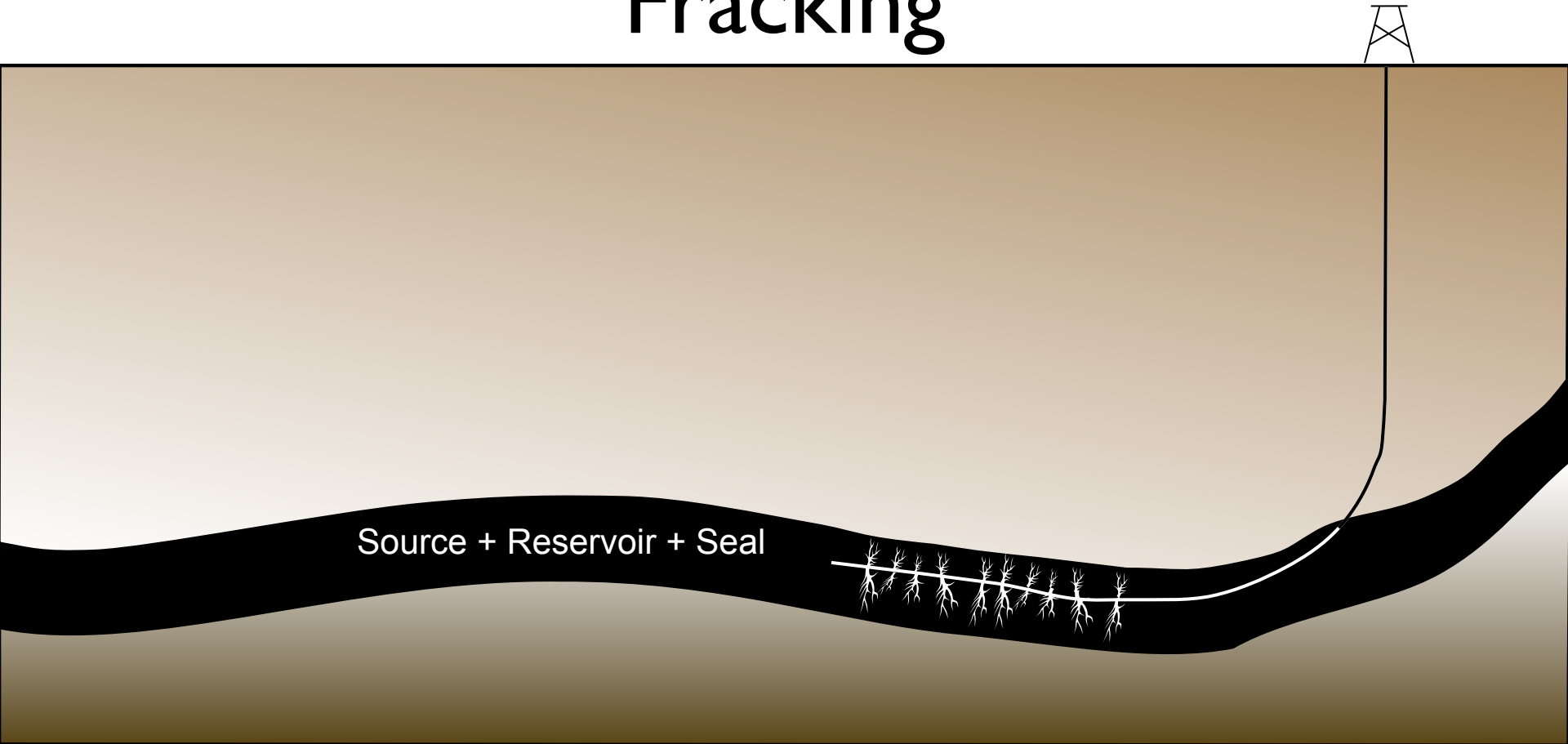
Permeability ✗



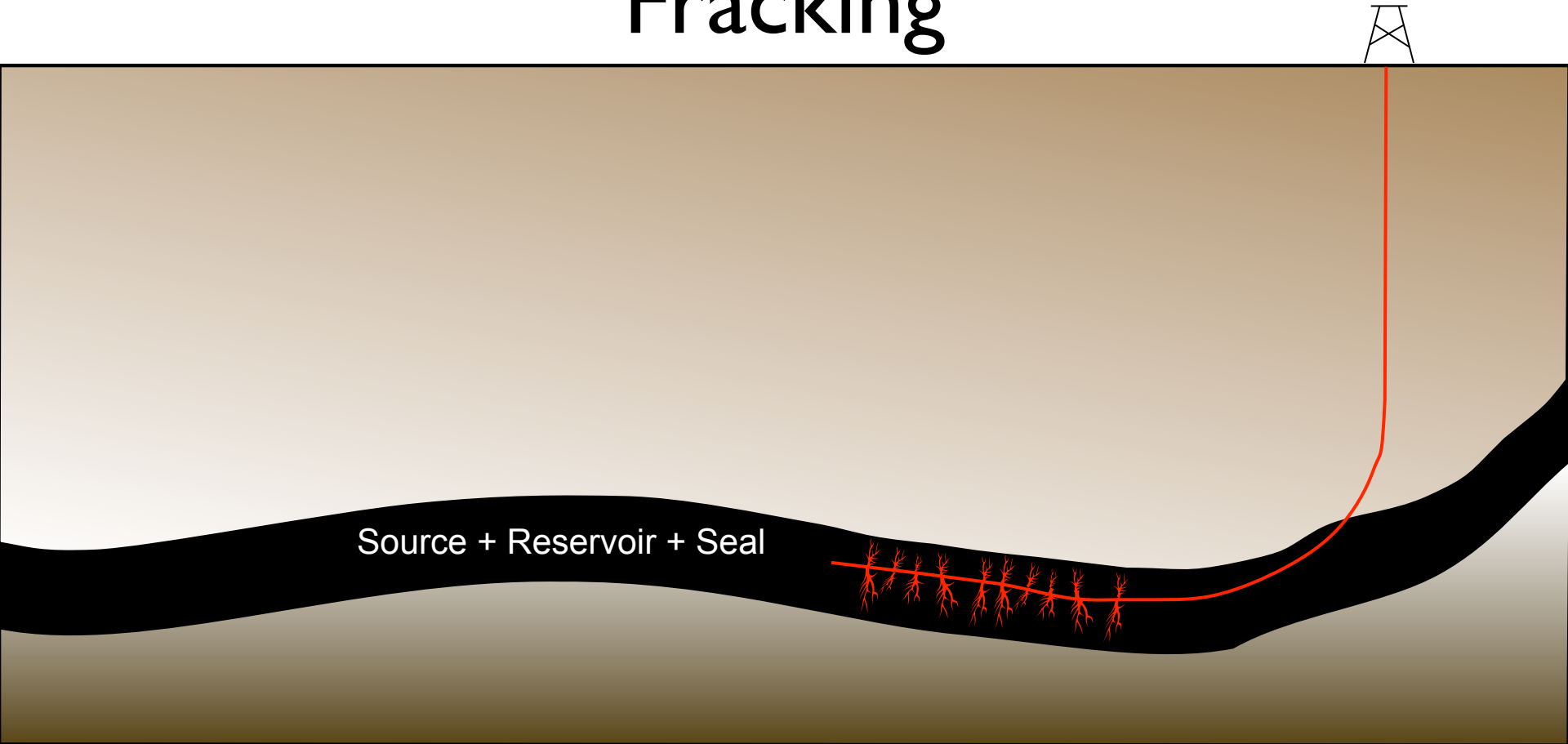
Porosity ✓

Permeability ✓

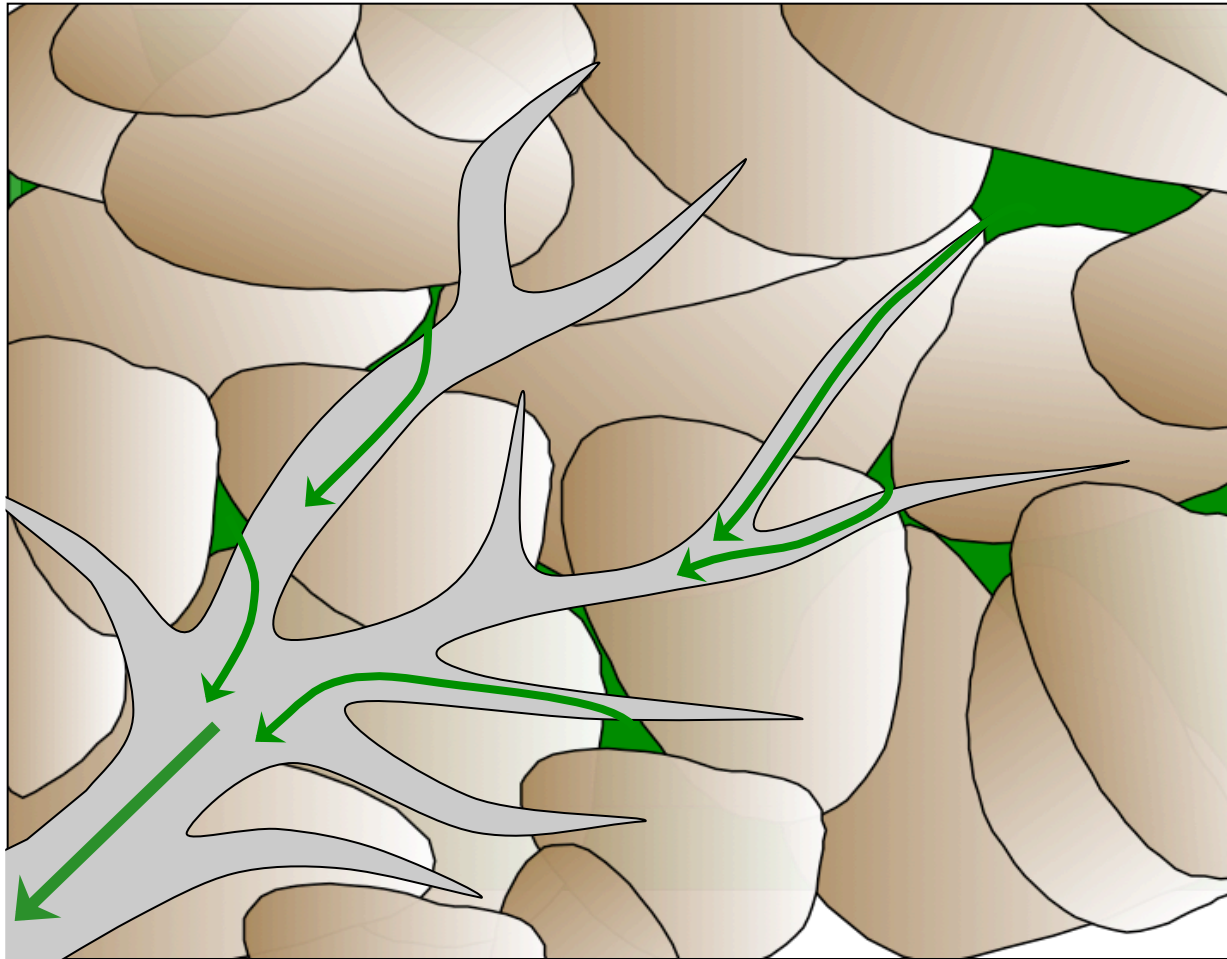
Hydrocarbon Basics: “Fracking”



Hydrocarbon Basics: “Fracking”



Fracturing & Permeability



Hydraulic Fracturing: How...and why?

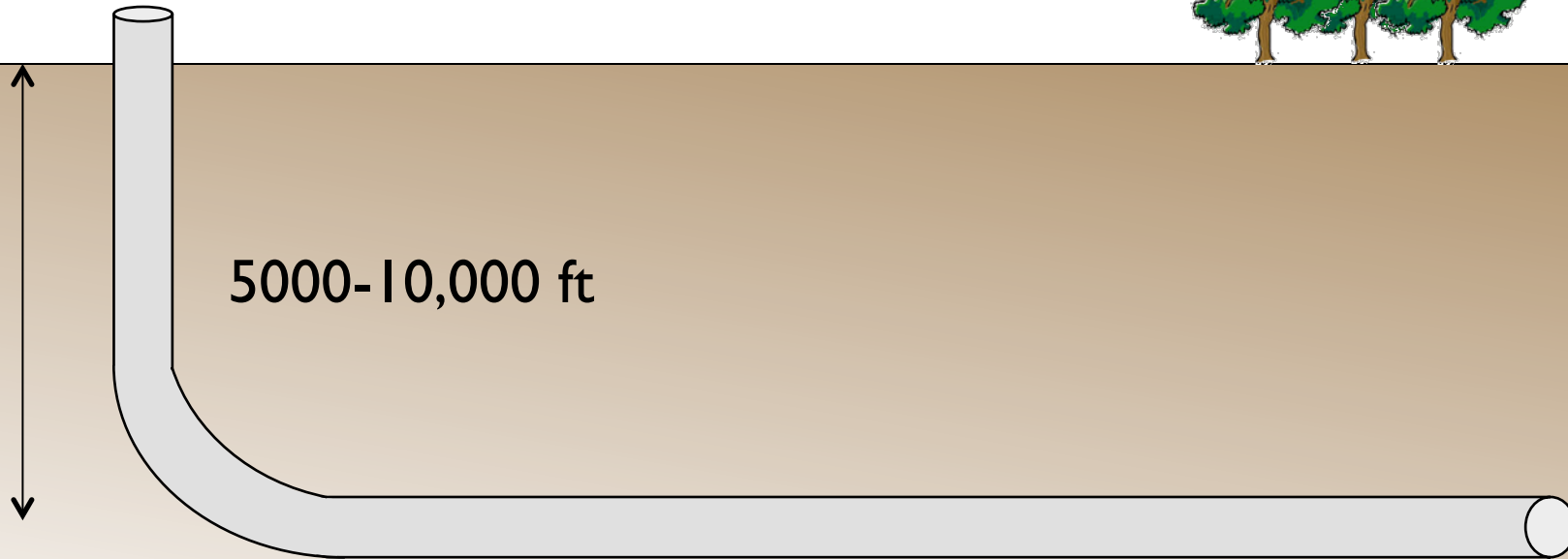
1. Hydrocarbon basics
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3. Why are we doing this?

Hydraulic Fracturing



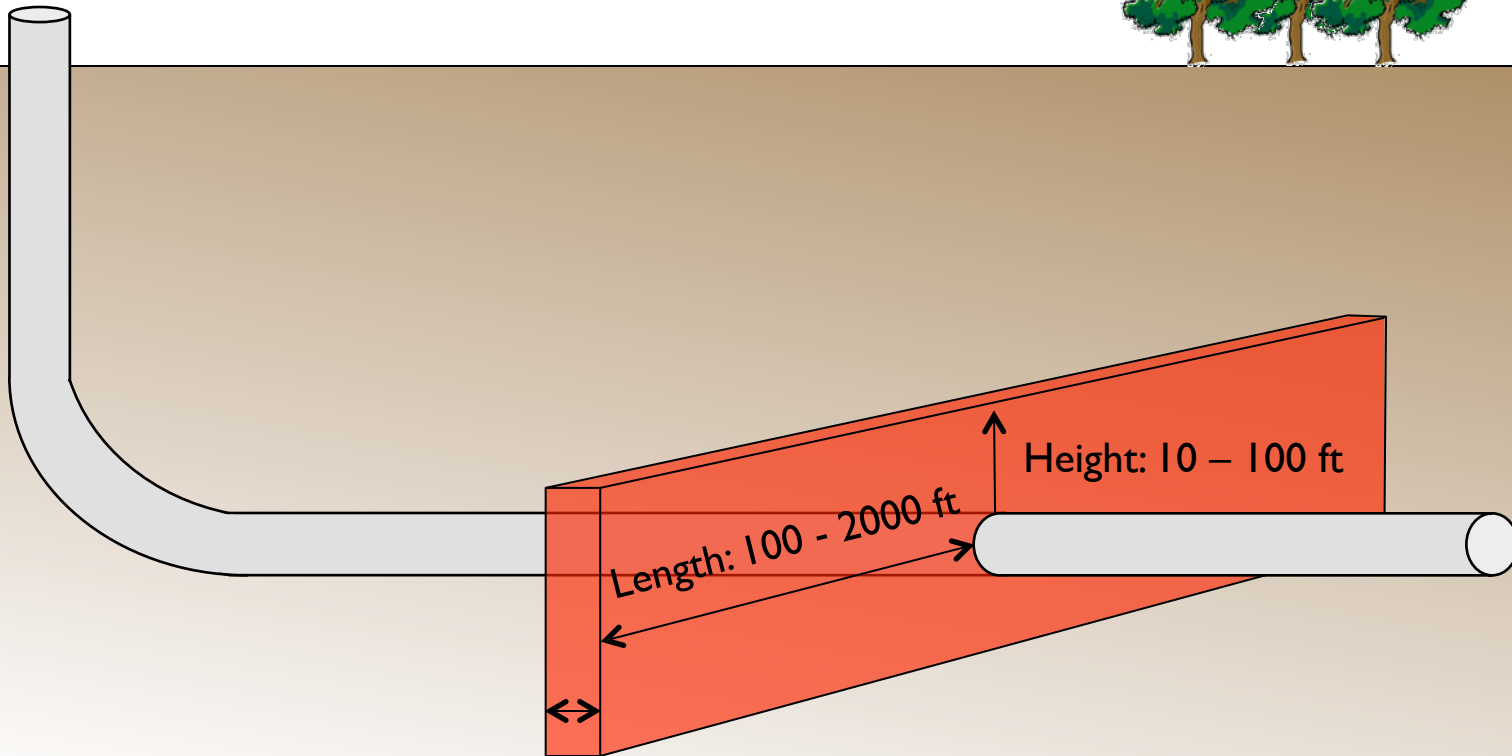
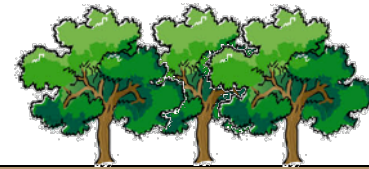


The F-Word: Frac Facts





The F-Word: Frac Facts



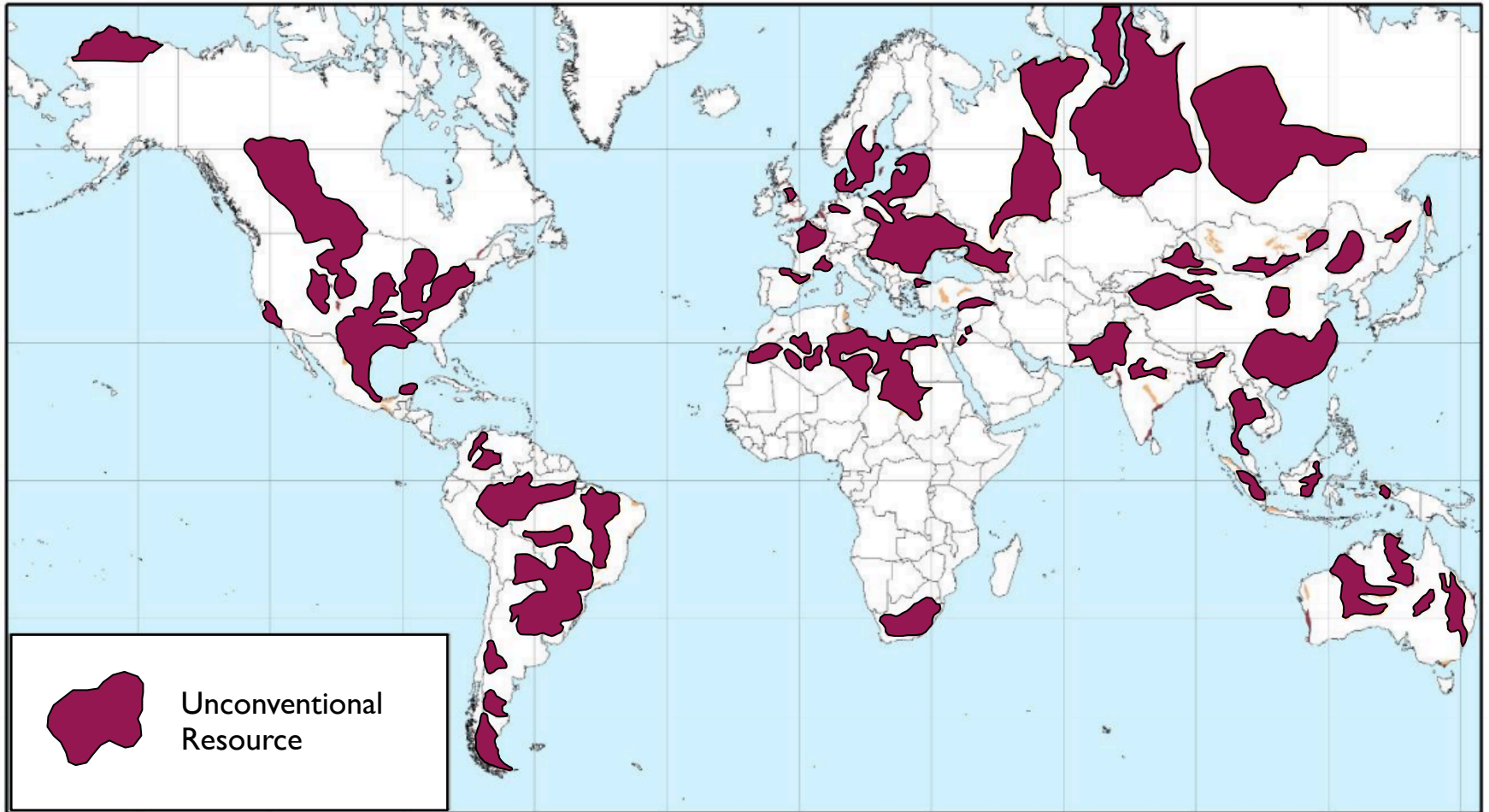
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Questions?

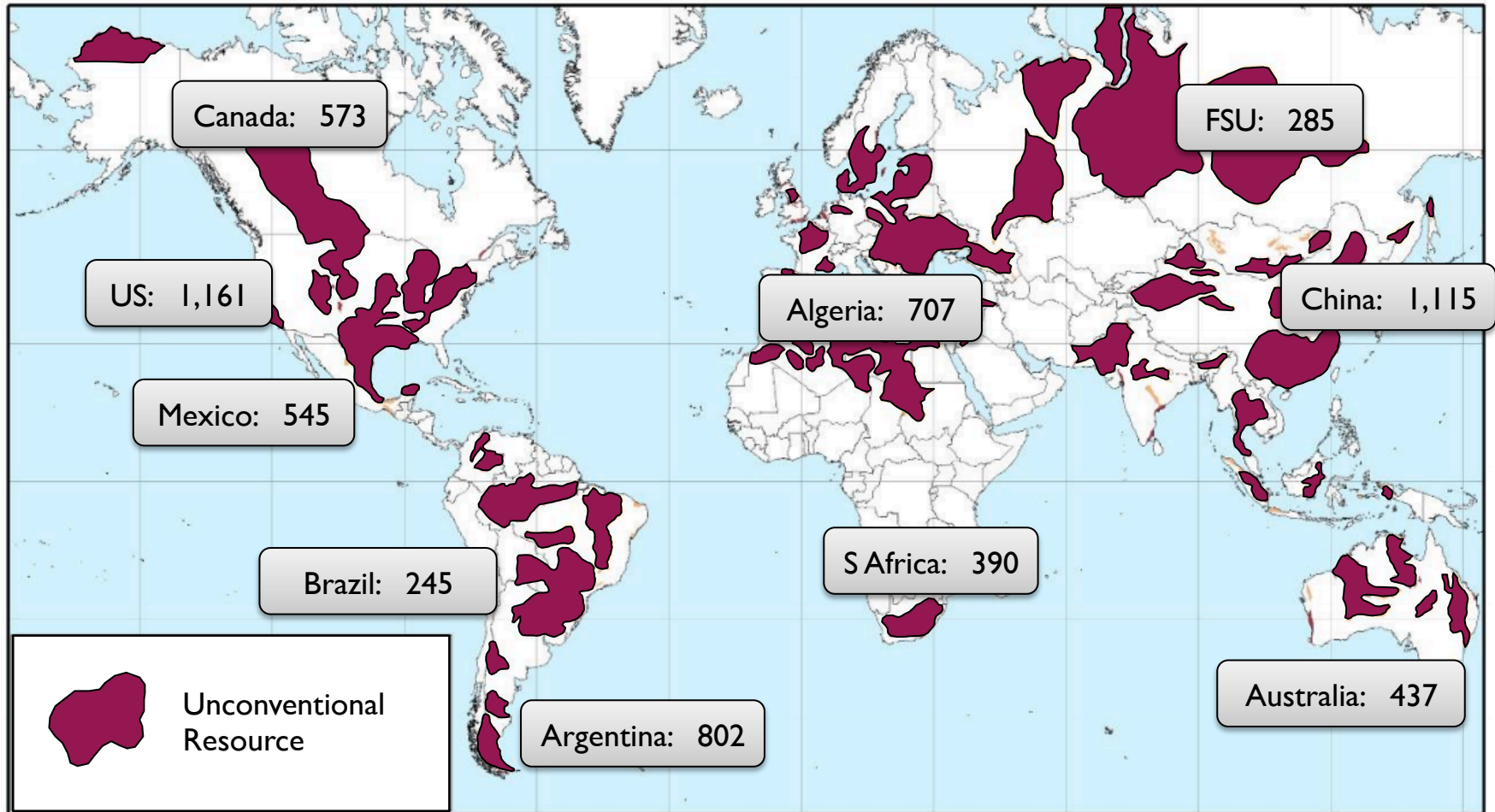
Hydraulic Fracturing: How...and Why?

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Why?



Why? Demand = Supply



Shale Gas (tcf)
World Total: 7,299

Why? Oh Why?

- Inclusion of shale gas increase the US hydrocarbon resources by 38%
- International Energy Agency (IEA) expects US to become energy independent by 2035
- The US could become a net *exporter* of natural gas

Hydraulic Fracturing: How...and Why?

- Conventional resources are globally scarce
- Unconventional resources are plentiful
- Hydraulic fracturing increases permeability, allowing production from unconventional rock
- Profit and energy independence are primary motivators

Hydraulic Fracturing: How...and Why?

We know how it's done
We know the motivation

What is the impact?

Questions?

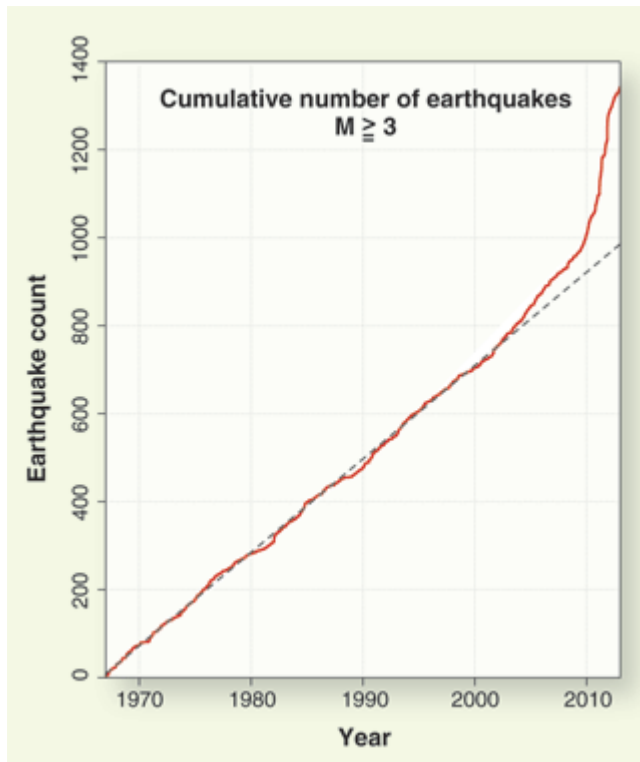
Roadmap for the evening

1. Hydraulic Fracturing: How...and Why?
- 2. Water Contamination and Induced Seismicity**
3. Impact of Fracking on Climate Structure

Water Contamination and Induced Seismicity

1. Does fracking cause earthquakes?
2. How much water does fracking use?
3. Does fracking contaminate drinking water?

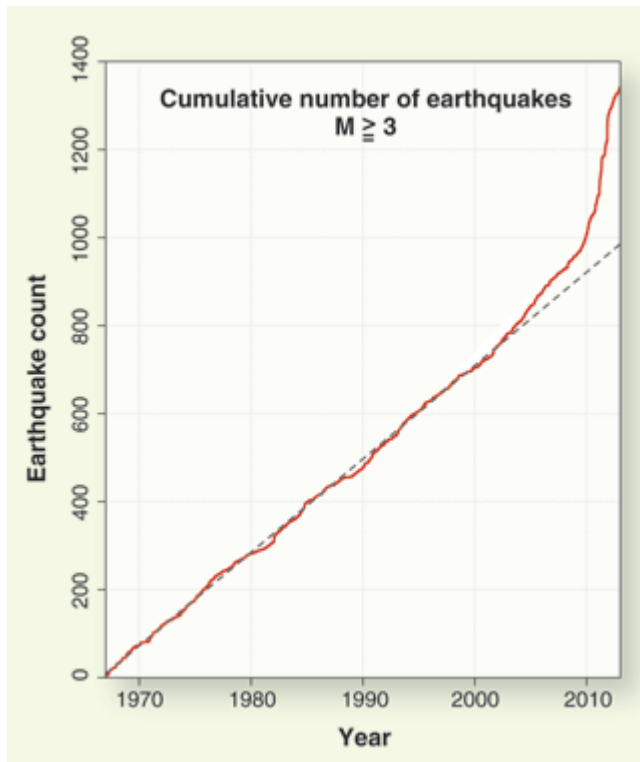
Earthquake frequency in the central US has increased since 2001



Before 2001: 21 “significant” US midcontinent quakes per year

After 2001: an increasing number of earthquakes peaking at 188 per year in 2011

Earthquake frequency in the central US has increased since 2001



Possible causes:

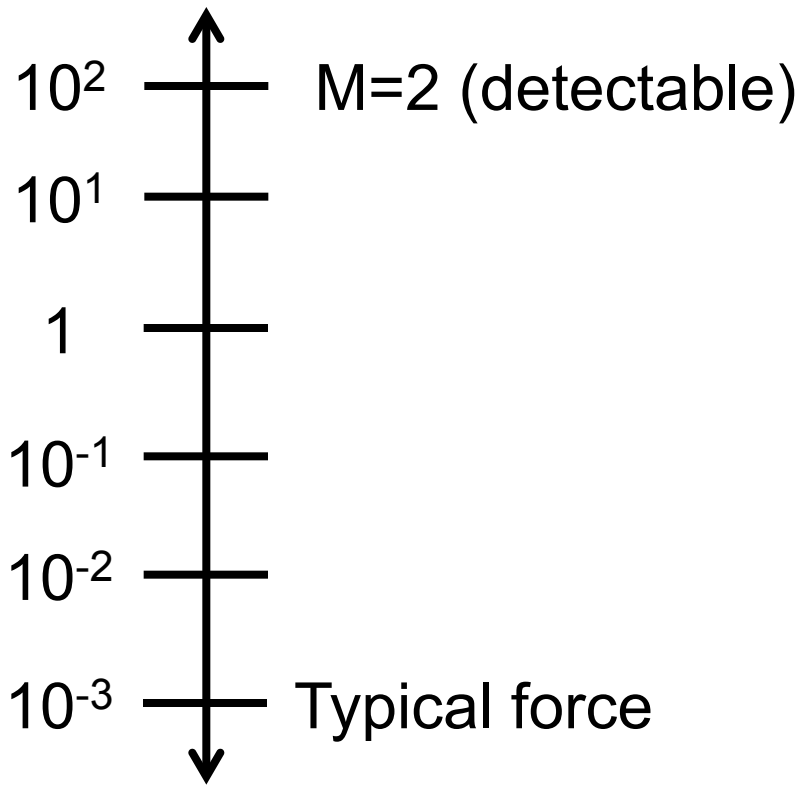
Improved detection?

Not for quakes of this magnitude post-1970

Human activity, specifically oil/gas extraction?

Accounts for at least part of the increase in seismic activity

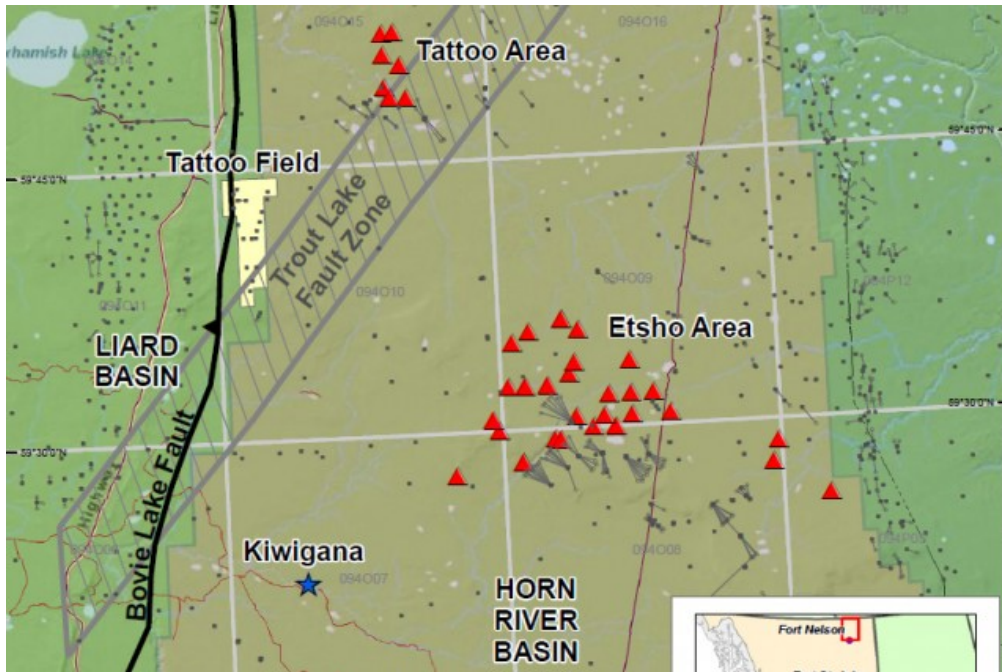
Fracking causes microtremors, but not large earthquakes



Magnitude scale

Small rock fractures are routinely produced during hydraulic fracturing, but unless the drilling intersects a fault and causes it to move, they are undetectable at the surface.

Fracking causes microtremors, but not large earthquakes



Largest to date: Horn River Basin, British Columbia (series of small quakes magnitude 2.2-3.8).

Wastewater injection can cause significant earthquakes

Wastewater from fracking is usually disposed of by injection into deep wells.

This step is more likely to cause large earthquakes because it leads to relatively large, rapid, and deep pressure changes.



2011 Oklahoma earthquake

Decreasing injection rates can reduce the magnitude and frequency of earthquakes.

Youngstown, Ohio

- Injection in proximity to fault lines led to earthquakes, the greatest magnitude 3.0
- In response to increasing seismicity, injection rate was reduced.
- Seismicity decreased significantly within a month of the change.

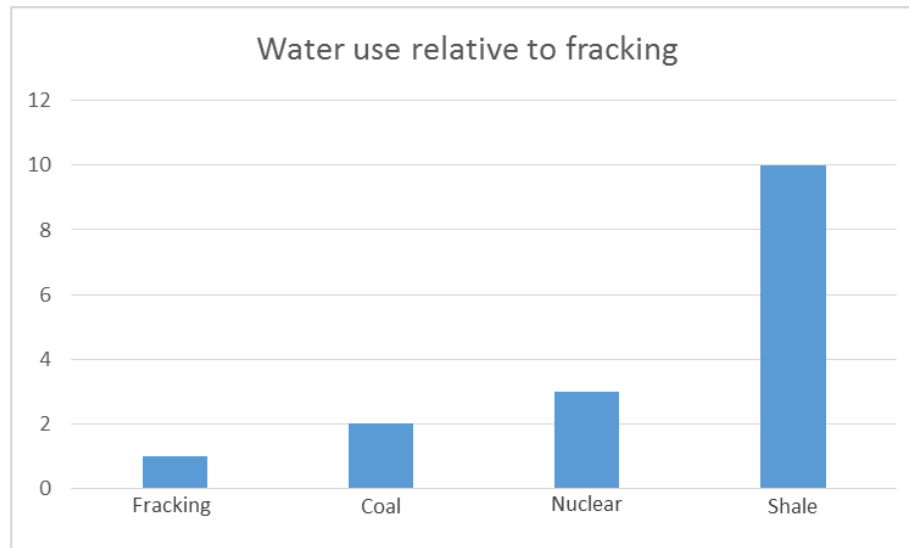
Questions?

Water Contamination and Induced Seismicity

1. Does fracking cause earthquakes?
2. How much water does fracking use?
3. Does fracking contaminate drinking water?

Fracking is not uniquely water-intensive

- More water-intensive than conventional natural gas and some renewables.
- Refracturing is more resource-intensive than initial fracturing.
 - Bakken Shale: twice as much water/30% gain in production.
- Less water-intensive than some other methods:



Fracking fluid often can't be recycled because of its composition

- Contains compounds other than water for purposes such as:
 - Corrosion inhibitors
 - Thickening agents
 - Friction reducers

Water Contamination and Induced Seismicity

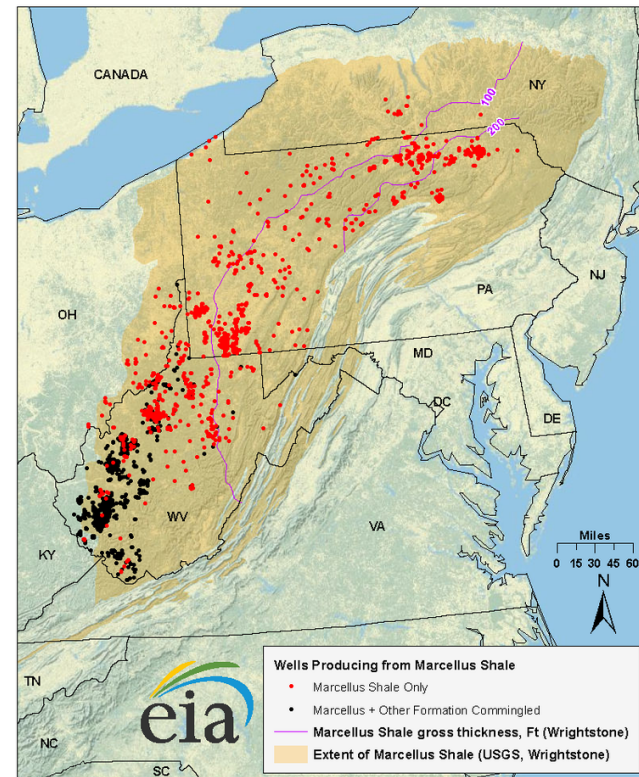
1. Does fracking cause earthquakes?
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To dispose of wastewater more safely, we need to know more about existing faults and how they're affected by adding stress and pressure from the injection of large volumes of wastewater.

Fracked wells have been linked to water contamination...

- Eight wells in Pennsylvania and Texas were recently linked by their “chemical fingerprints” to groundwater contamination.
- A paper published this August by Darrah et al. took a closer look at contaminated wells in Pennsylvania’s Marcellus Shale formation.

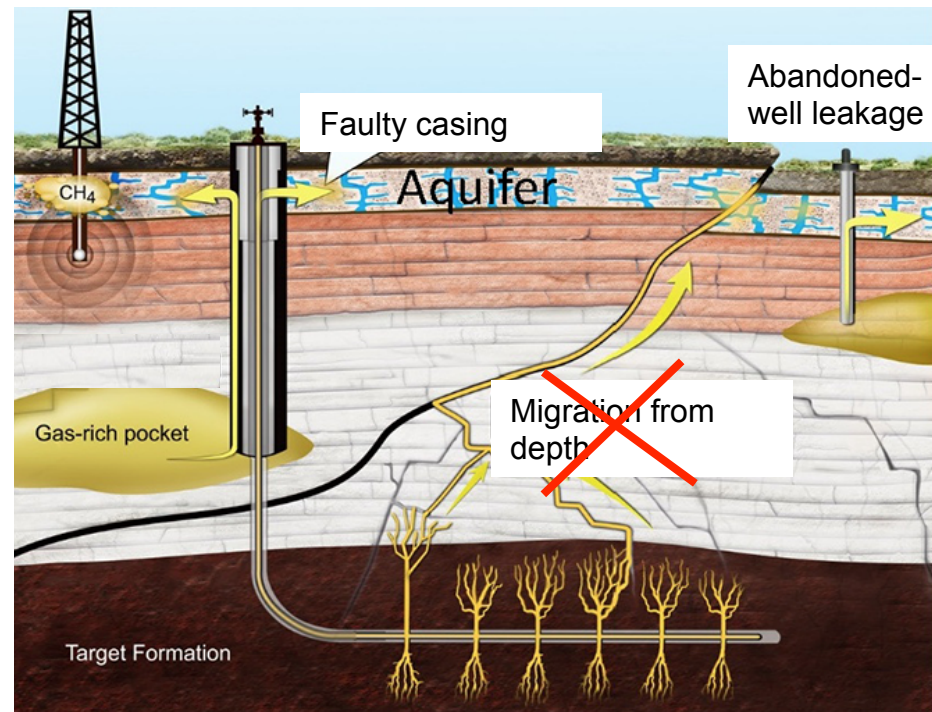
Marcellus Shale Gas Play, Appalachian Basin



Source: US Energy Information Administration based on data from WVGES, PA DCNR, OH DGS, NY DEC, VA DMMME, USGS, Wrightstone (2009). Only wells completed after 1-1-2003 are shown. Updated June 1, 2011

...Which likely results from lapses in well integrity such as leaky pipes and seals

Concentrations of helium, neon and argon in the methane-contaminated water weren't consistent with fracking, but were consistent with poor well integrity.



Water Contamination and Induced Seismicity

- Injecting wastewater near faults can lead to seismic activity.
 - Fracking itself is much less likely to do so
- Fracking uses less water than many other nonconventional fuel sources.
- Water contamination from fracked wells has been linked to problems with the well construction and not to the fracking process.

Questions?

Roadmap for the evening

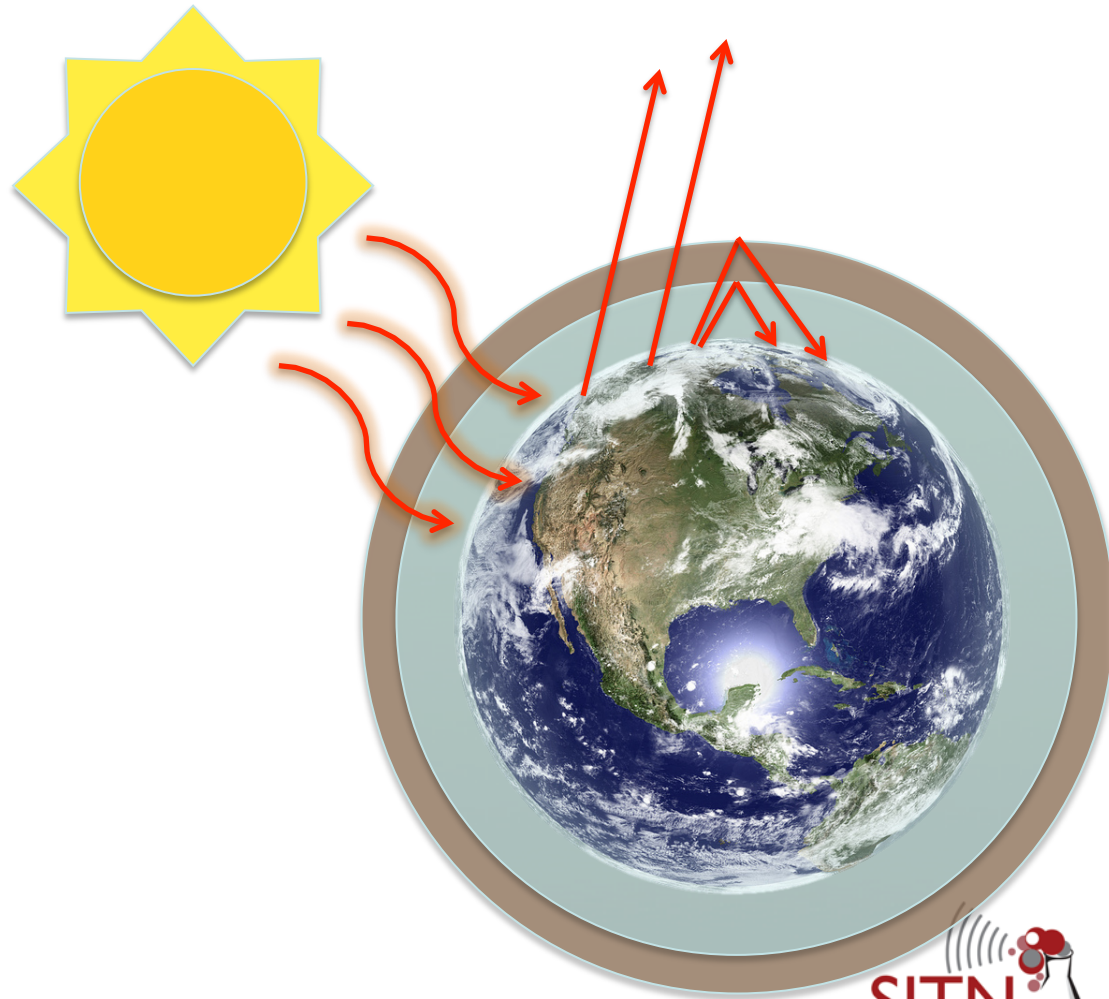
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Impact of Fracking on Climate Structure



What is a Greenhouse Gas?

- Gases in atmosphere retain some heat that Earth is radiating
- More heat absorbing gas = more heat retained



Transition to Renewable Energy



Coal



Natural Gas



Renewables

How does it compare to coal?



vs



1 kg CO₂ for every
kWh produced

emits half that amount!

And that's the end of that!

...or is it?

New Findings in 2011!

Shale Gas Isn't Cleaner Than Coal, Cornell Researchers Say

By MIKE SORAGHAN of [Greenwire](#)

Published: April 11, 2011

Replacing Coal With Gas Is No Panacea, Study Says

By JIM WITKIN SEPTEMBER 14, 2011 7:42 AM [17 Comments](#)

Natural gas

Cleaner, not cooler

Ever more growth in the use of natural gas is welcome for many reasons. But it is not a cure for global warming

Aug 6th 2011 | From the print edition



Leaking of Methane: the Other Greenhouse Gas

Amount of methane
released is *much* lower than
CO₂...

So why does it matter?



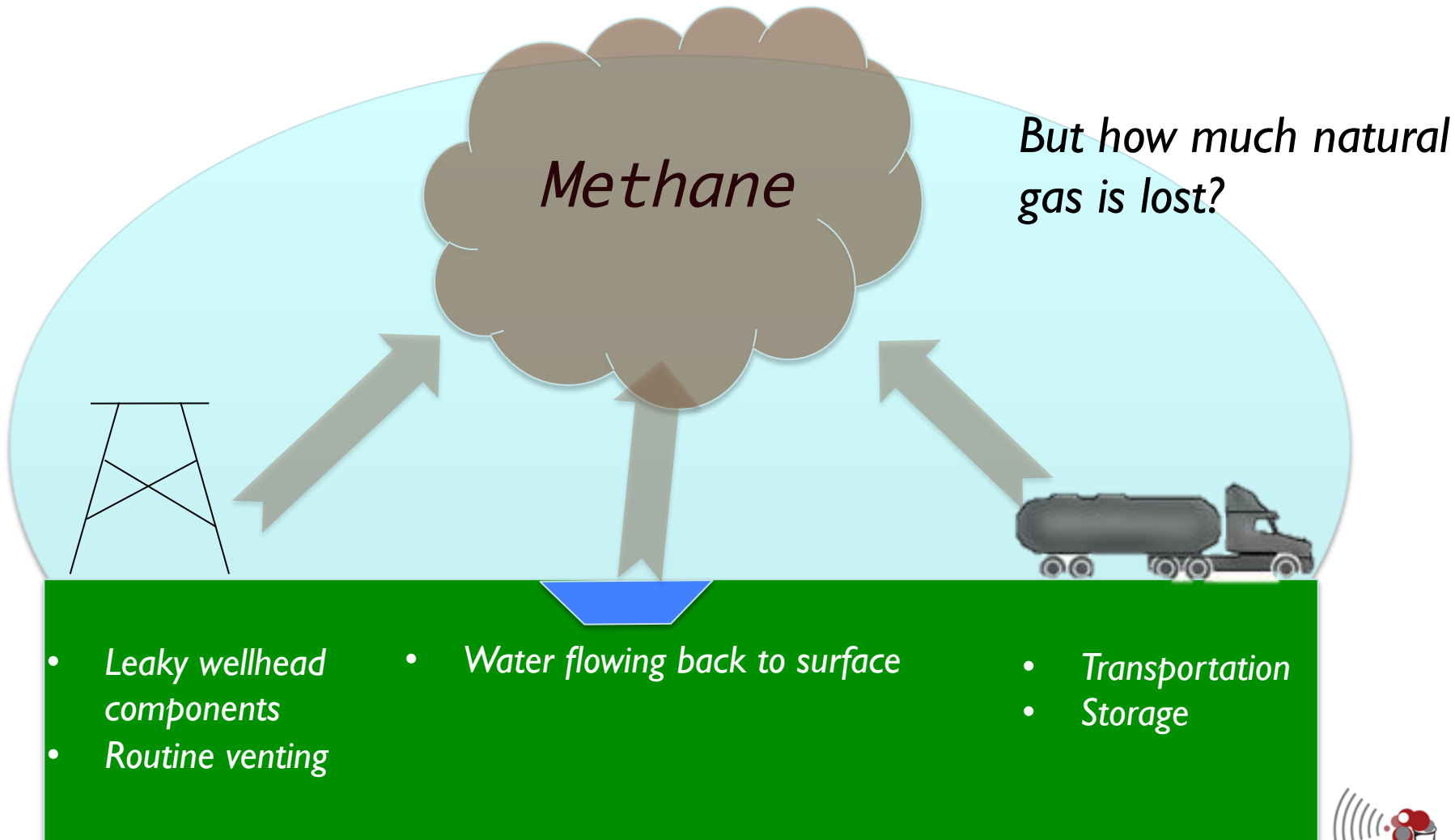
Not All Greenhouse Gases are Made Equal

- Global Warming Potential- amount of heat trapped by gas compared to CO₂ over a period of time
- Greenhouse gases often expressed as g CO₂ equivalents

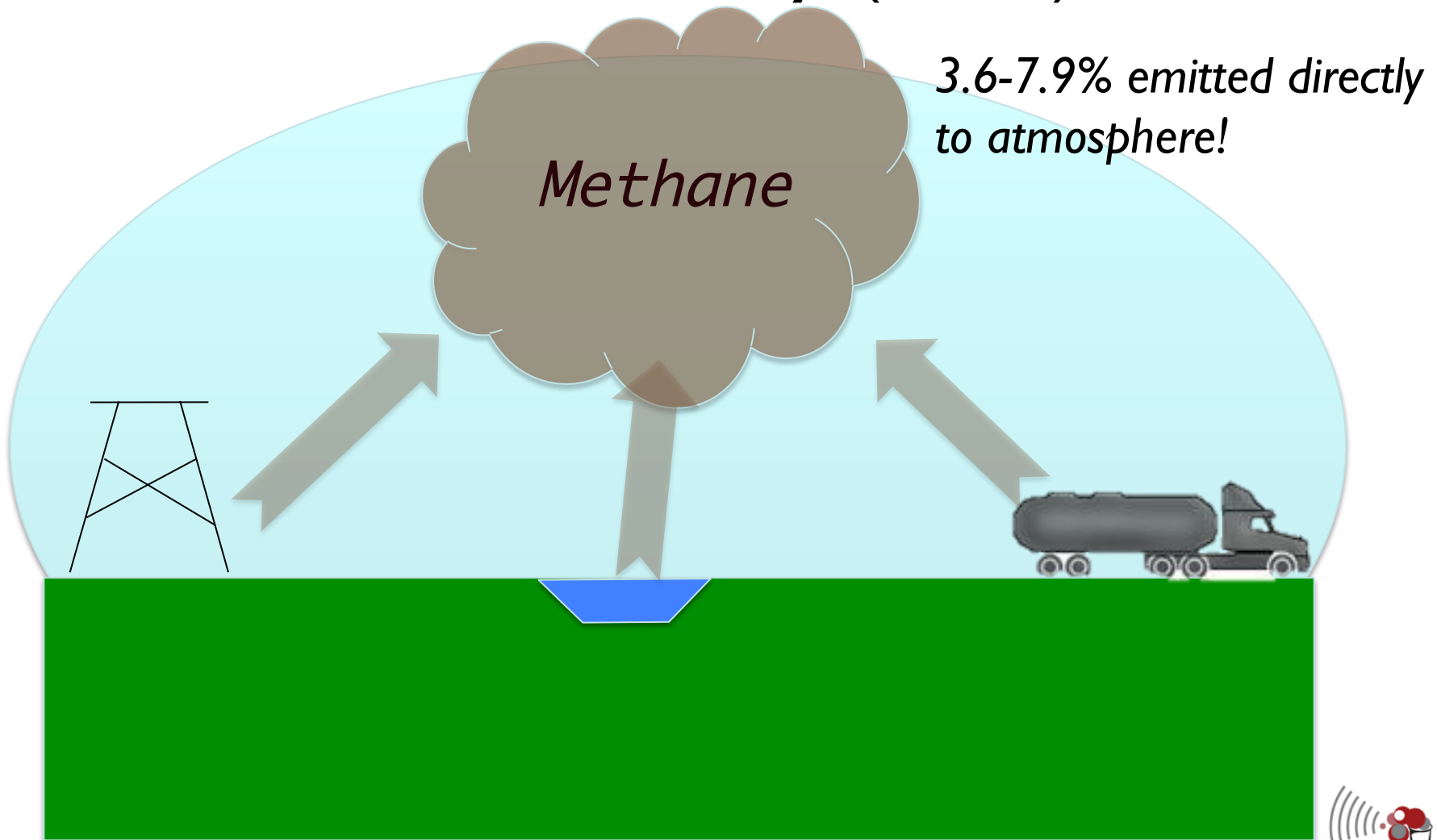
Greenhouse Gas	GWP (20 yrs)	GWP (100 yrs)	GWP (500 yrs)
CO ₂	1	1	1
CH ₄	70	25	10

Questions?

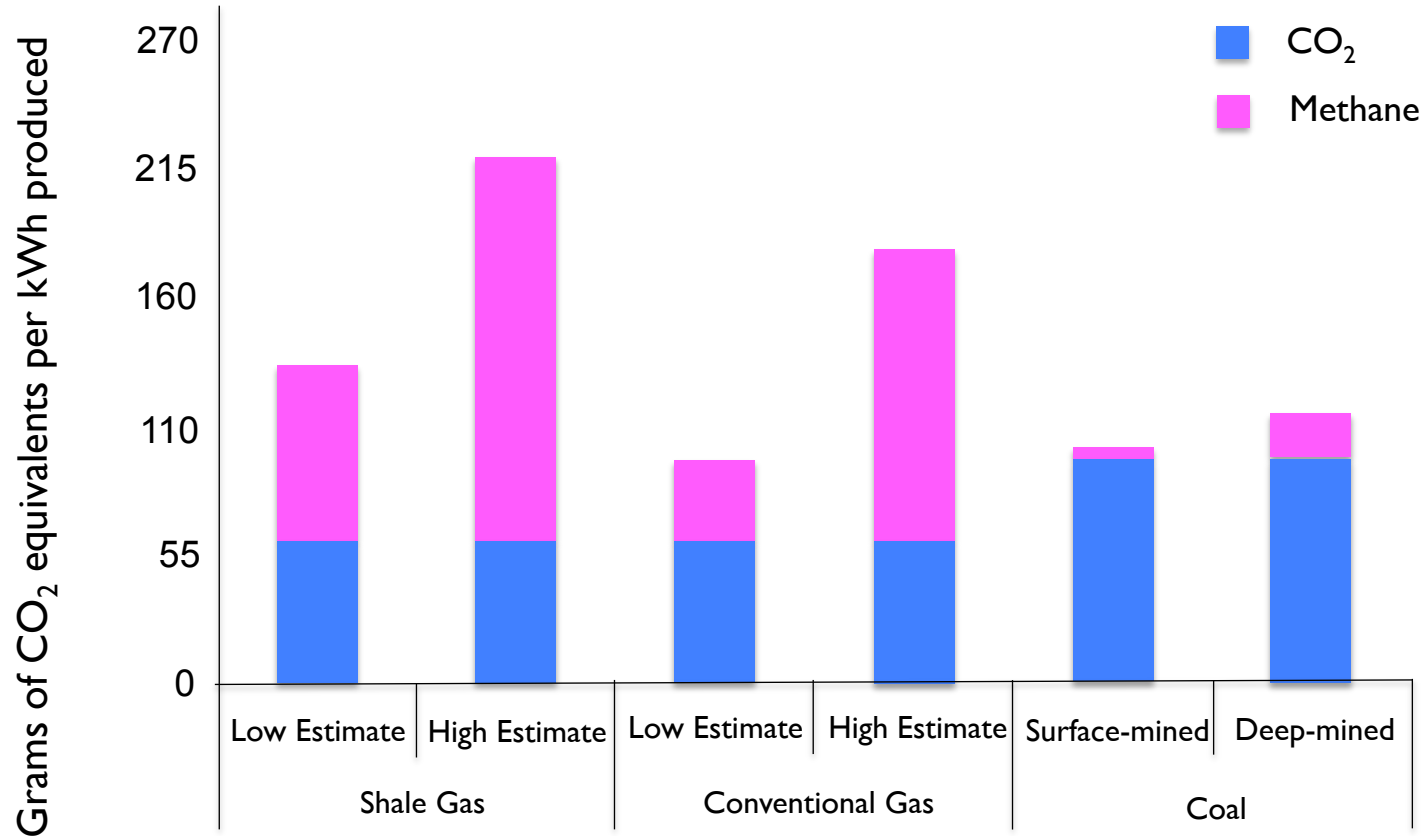
Where is the natural gas escaping?



The First Study (2011)



Let's Compare it to Coal!



*low estimate obtained assuming most advanced technology is used

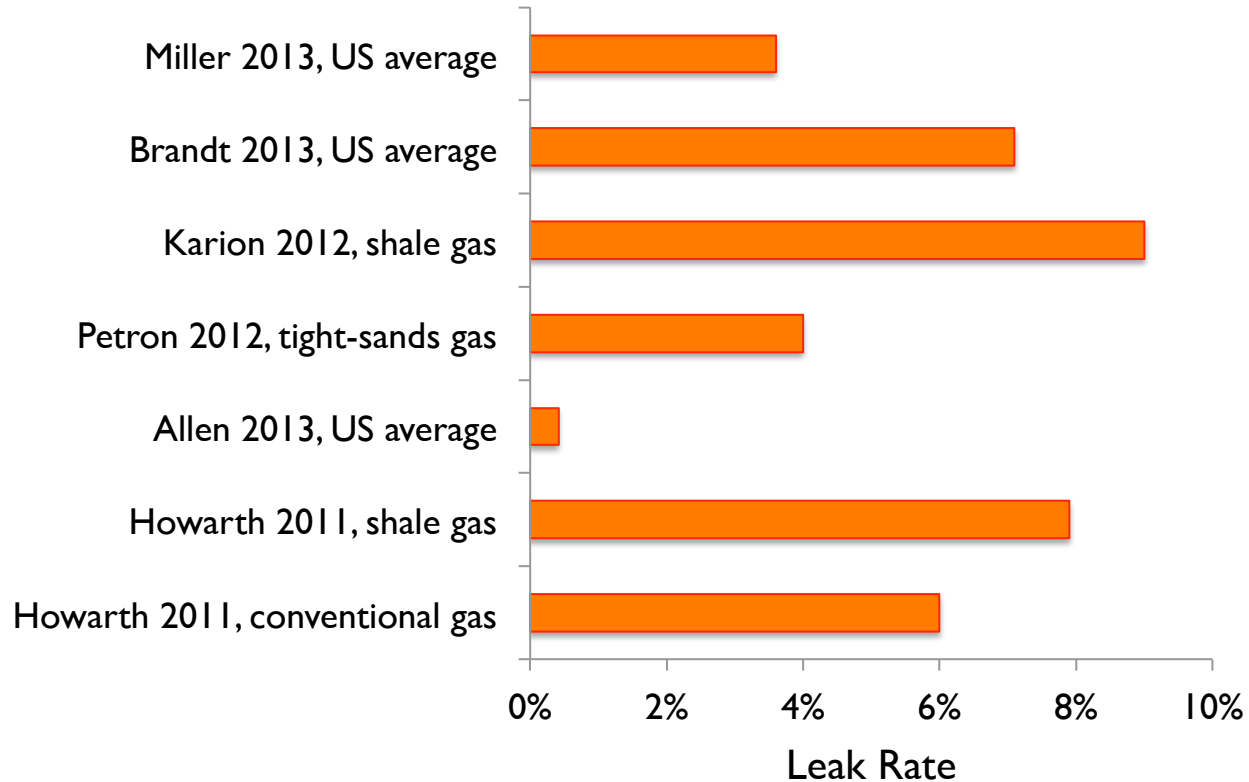
High Level of Uncertainty

- Relies on very limited amount of data
- Some of this data was collected as early as 1996
- Uses conservative estimates to offset this

Despite using conservative estimates...

- New study released by Allen et. al. in 2013 obtains value of only 0.42% natural gas release

High Variation Among Studies



Allen's data collection sites were selected by industry

Some Emissions Can be Reduced!

Capture and storage



Flaring



these only reduce emissions from venting

Reasons for High Uncertainty and Variation

- Data from a few sites applied to many sites
- Data collection occurs infrequently
- Advancing technology
- Many observation sites are selected by industry
- Global warming potentials might be calculated differently from study to study

Impact of Fracking on Climate Structure

Is natural gas better for the climate than coal?

Perhaps!

- natural gas emits half as much CO₂ as coal
- some emissions can be reduced by capture or flaring

Perhaps not...

- extraction processes release methane, a more potent greenhouse gas
- many emissions are accidental

Due to high uncertainty, climate improvement should probably not be a reason to rely on natural gas

Questions?