Fact Versus Fiction of the Technical Aspects of Hydraulic Fracturing

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Colorado School of Mines

August 2, 2012

Presentation Topics

- General hydraulic fracturing
- Why we do it
- Conventional vs. unconventional reservoirs
- Materials used
- Vertical vs. horizontal completions
- Wellbore construction and integrity
- Monitoring
- Final thoughts

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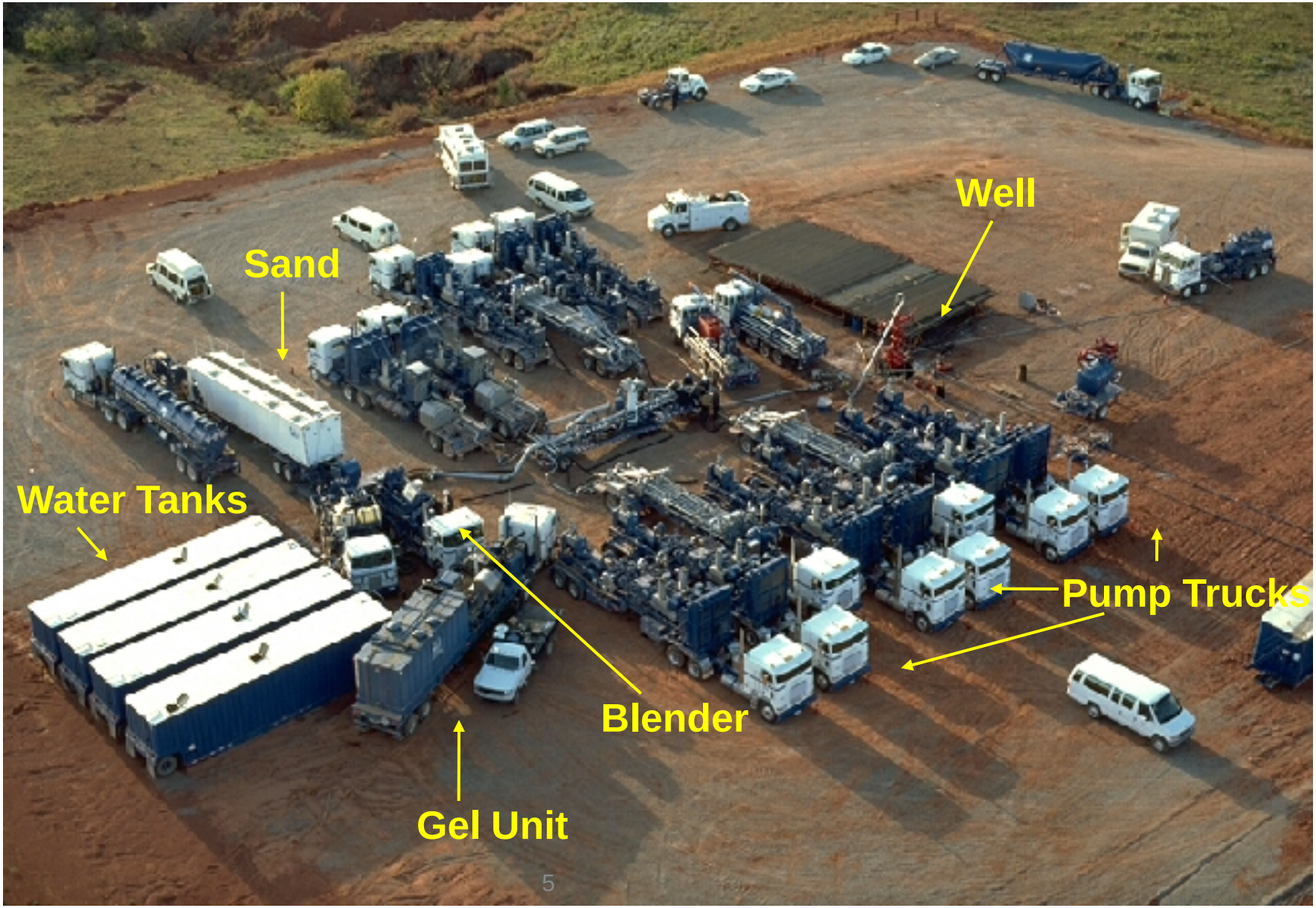
General Hydraulic Fracture Process

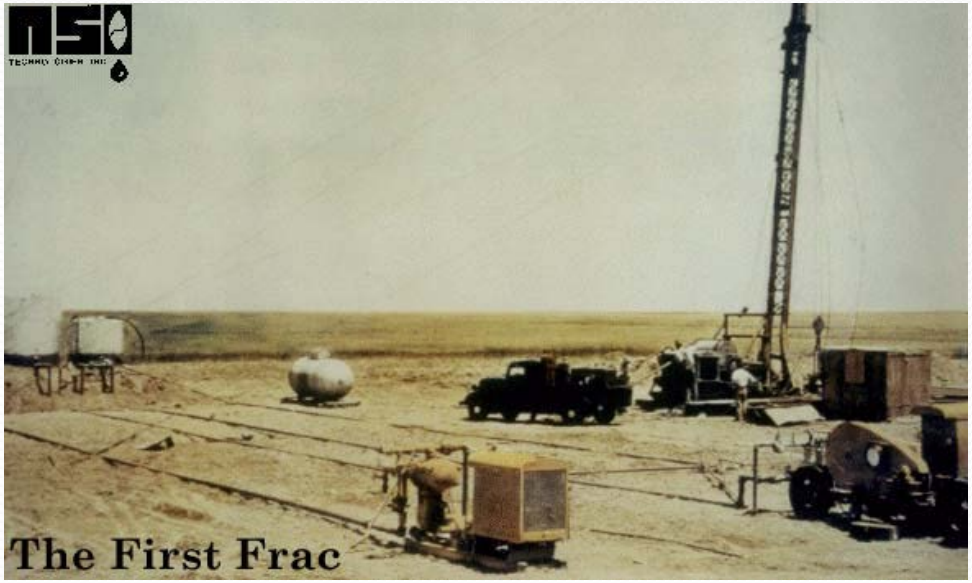
- Inject a “pad” (fluid, no solids) at a sufficient pressure and injection rate to breakdown (crack) the formation;
- Inject a “slurry” (fluid w/ proppant) to propagate and develop the fracture;
- Shut down the injection at the surface and allow the fracture to close around the injected proppant;
- Flow back the well to clean up the fluids; and,
- Start producing the well.

Typical Fracturing Equipment Layout



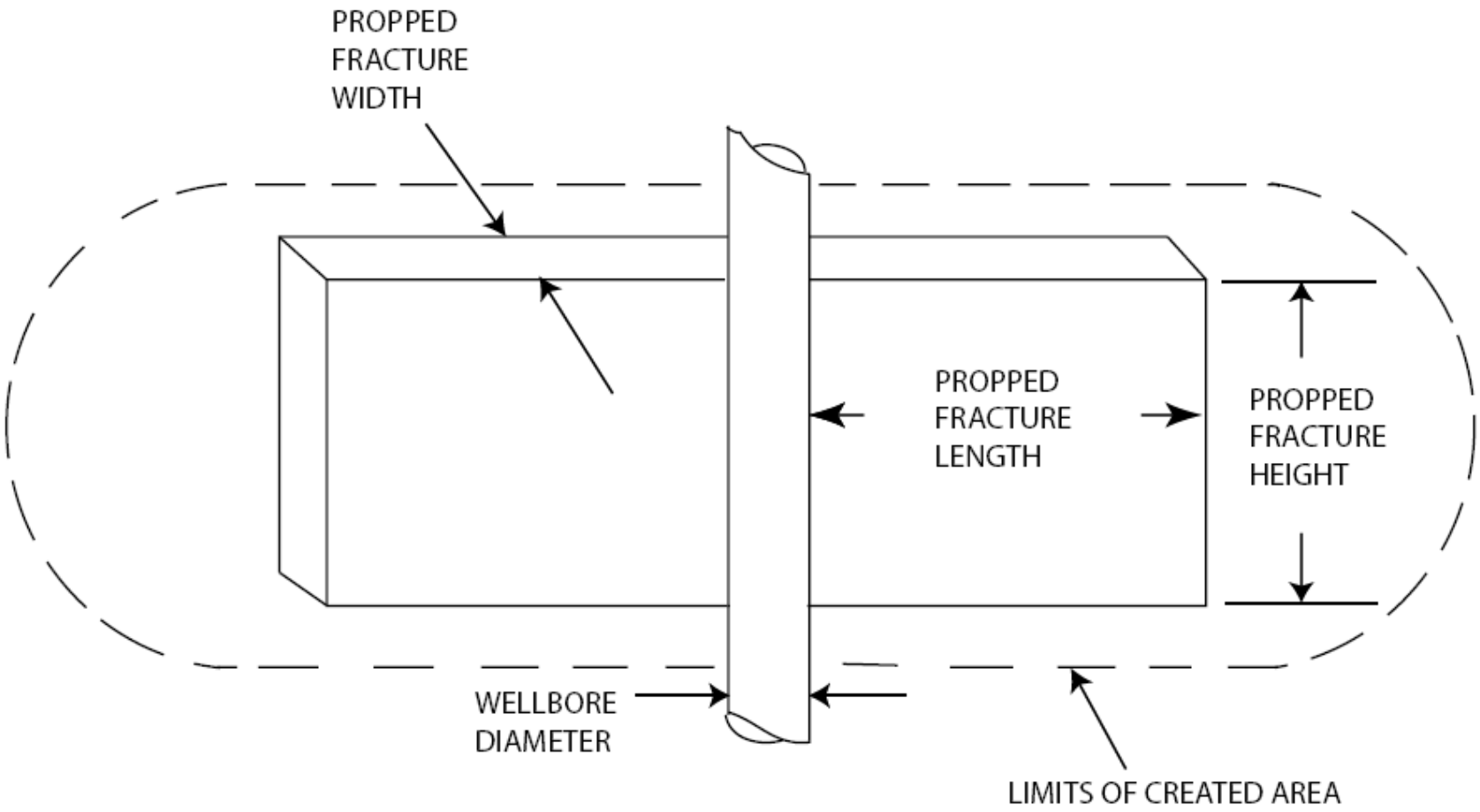
Oilfield Stimulation History

- Acidizing and nitroglycerin were the main stimulation services provided until the late 1940's.
- In 1947, the first intentional fracture treatment took place in the Hugoton gas field of western Kansas. It was pumped in the Klepper Gas Unit No. 1 well and was called it a "hydrofrac".
- +60-year technique used worldwide.



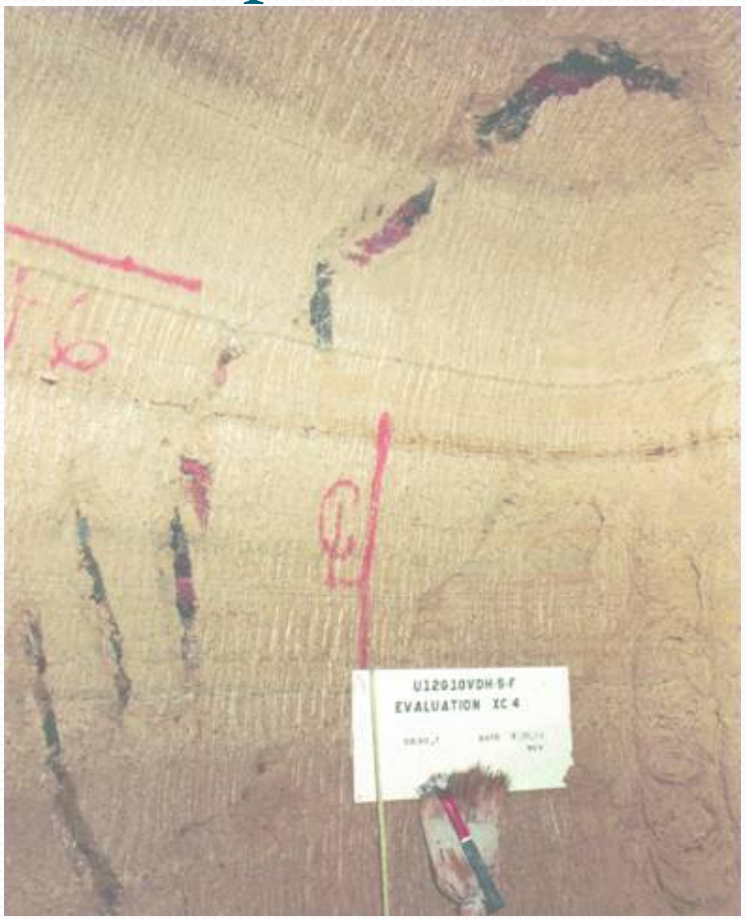
General Info

- Critical completion technique in low permeability formations.
  - Required in unconventional reservoirs for economic rates.
- In 1989, it was estimated that 35-40% of all wells completed worldwide were fractured and in the United States and that 25-30% of reserves would not be economically producible without hydraulic fracturing.
- In certain areas, +95% of wells are fractured.
- Over a million (1,000,000) wells have been hydraulically fractured worldwide.

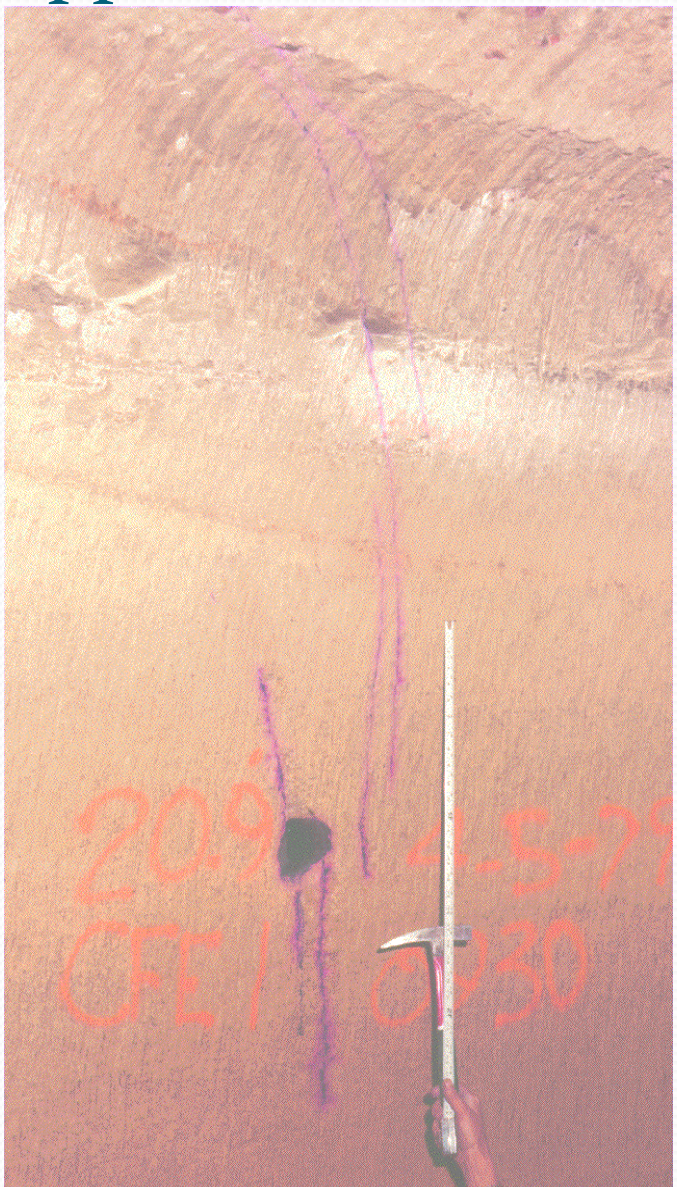

PROPPED
FRACTURE
WIDTH
PROPPED
FRACTURE
LENGTH
PROPPED
FRACTURE
HEIGHT
WELLBORE
DIAMETER
LIMITS OF CREATED AREA

NOT TO SCALE

Multiple Strands in a Propped Fracture



NEVADA TEST SITE MINEBACK



Courtesy: N.R. Warpinski, Sandia Labs

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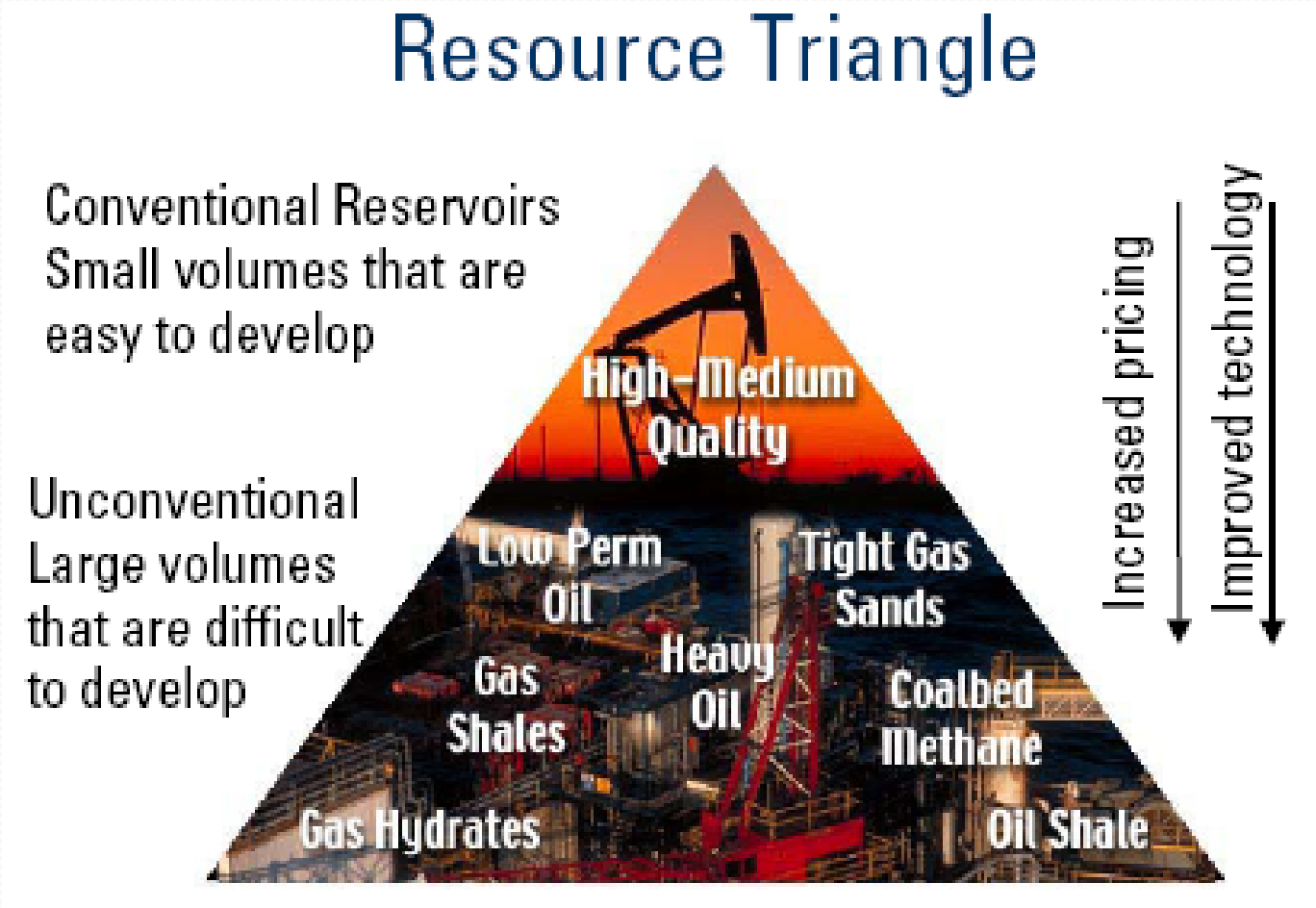
Why we do it?

- Bypass near-wellbore permeability loss
  - Rock can be plugged by drilling fluids
- Extend a conductive channel into reservoir
  - Increases/stimulates natural productivity of well
  - Required for “unconventional” reservoirs
- Reservoir management
  - Maximize recovery of hydrocarbons from a given reservoir

Conventional vs. Unconventional



Holditch, 2001

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

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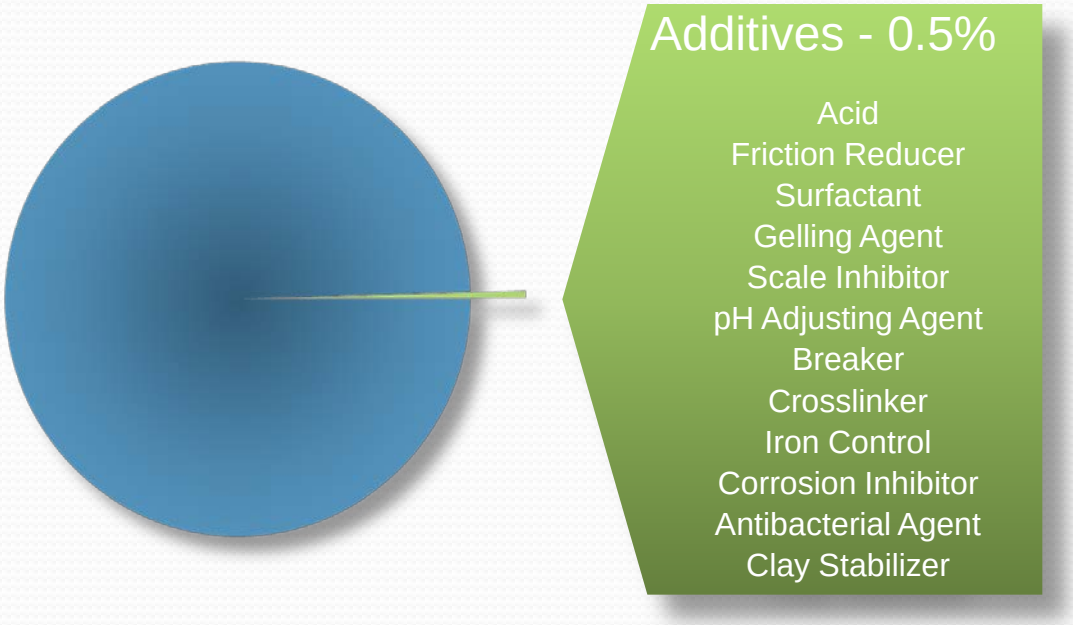
Slickwater Frac Fluid Design

- Slickwater systems:
  - Are simpler designs
  - Consist of water, sand, and friction reducer
  - Rely on fluid velocity to transport sand
- Friction reducer to help maximize pumping rate
- Surfactants, clay stabilizer, and scale inhibitors can be used as required



Fracturing Fluid Components

Product Category	Main Ingredient	Purpose	Other Common Uses
Fluid and Proppant	99.50%		
Water	H20	Create fracture and deliver sand	
Sand (Proppant)	Silica	Prop fractures open to enable gas production	Drinking water filtration, glass, foundry casting, concrete, brick mortar
Other	0.50%		
Gel	Guar Gum	Thickens water to suspend the sand	Cosmetics, baked goods, ice cream, toothpaste, sauces, salad dressings
Friction Reducer	Polyacrylamide	Minimize friction between fluid & pipe	Water treatment, soil conditioners
Crosslinker	Borate Salts or Zirconium	Greatly increases base gel viscosity	Laundry detergents, hand soaps, cosmetics
Anti-Bacterial Agents	Glutaraldehyde	Eliminates bacteria in water that produces corrosive by-products	Disinfectant, sterilizer for medical and dental equipment
Breaker	Ammonium or Sodium Persulfate	Breaks gel to lower viscosity	Hair coloring, disinfectant, food preservation, dyes
Corrosion Inhibitor	n,n-dimethyl Formamide	Preventscorrosion of the pipe	Pharmaceuticals, acrylic fibers, plastics
Iron Control	Citric Acid	Prevents metal oxides precipitation	Food additive, food and beverages, lemon juice ~7% citric acid
Clay Stabilizer	Potassium or Quarternary Chloride	Creates a brine carrier fluid	Road de-icer, low-sodium table salt substitute, medicines, IV fluids
pH Adjusting Agent	Sodium Hydroxide or Potassium Carbonate	Maintains desired pH for crosslinker effectiveness	Laundry detergents, soap, water softener, dish washer detergents
Surfactant	Isopropanol	Used for water recovery and preventing emulsions	Rubbing alcohol, glass cleaner, multi-surface cleanser, antiperspirant, deodorants, hair-color

Hydraulic Fracturing Fluid Product Component Information Disclosure

*Taken from GWPC/IOGCC ppt

Fracture Date	12/1/2012
State:	Pennsylvania
County:	Susquehanna
API Number:	37-115-20299
Operator Name:	Test C Appalachia
Well Name and Number:	Test Well 1
Longitude:	-76.052537
Latitude:	41.719388
Long/Lat Projection:	NAD27
Production Type:	Gas
True Vertical Depth (TVD):	7,157
Total Water Volume* (gal):	4,764,606

Hydraulic Fracturing Fluid Composition:

Trade Name	Supplier	Purpose	Ingredients	Chemical Abstract Service Number (CAS #)	Maximum Ingredient Concentration in Additive (% by mass)**	Maximum Ingredient Concentration in HF Fluid (% by mass)**	Comments
Water		Carrier / Base Fluid			100.00%	87.19000%	
Sand (Proppant)		Proppant			100.00%	11.89718%	
Acid, Hydrochloric (1	PP CO	Acid Package	Hydrochloric Acid	007647-01-0	15.00%	0.11853%	
A999	PP CO	Acid Corrosion Inhibitor	Methanol	67-56-1	40.00%	0.00050%	
			Fatty Acid	Proprietary	30.00%	0.00037%	
			Prop-2-yn-ol	107-19-7	10.00%	0.00012%	
			Aliphatic alcohols, ethoxylated #1	Proprietary	30.00%	0.00037%	
L058	PP CO	Iron Control Agent	Sodium Erythorbate	6381-77-7	100.00%	0.00474%	
B999	PP CO	Friction Reducer	Distillates (petroleum), hydrotreated ligl	64742-47-8	30.00%	0.01275%	
			Aliphatic alcohol, glycol ether	Proprietary	5.00%	0.00213%	
B-88	SPEC CHEM	Anti Bacterial Agent	Glutaraldehyde	111-30-8	27.00%	0.00992%	
			n-Alkyl dimethyl benzyl ammonium chlo	68424-85-1	5.50%	0.00202%	
			Ethanol	64-17-5	4.00%	0.00147%	
			Didecyl dimethyl ammonium chloride	7173-51-5	8.00%	0.00294%	
TS-00	SPEC CHEM	Scale Inhibitor	Sodium polyacrylate	Proprietary	30.00%	0.00325%	

*Total Water Volume sources may include fresh water, produced water, and/or recycled water

** Information is based on the maximum potential for concentration and thus the total may be over 100%

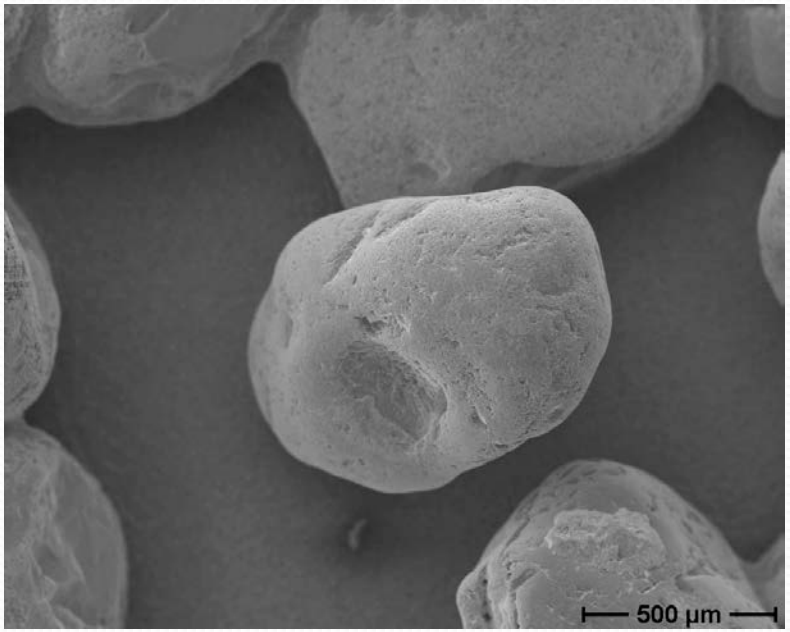
All component information listed was obtained from the supplier's Material Safety Data Sheets (MSDS). As such, the Operator is not responsible for inaccurate and/or incomplete information. Any questions regarding the content of the MSDS should be directed to the supplier who provided it. The Occupational Safety and Health Administration's (OSHA) regulations govern the criteria for the disclosure of this information. Please note that Federal Law protects "proprietary", "trade secret", and "confidential business information" and the criteria for how this information is reported on an MSDS is subject to 29 CFR 1910.1200(i) and Appendix D.

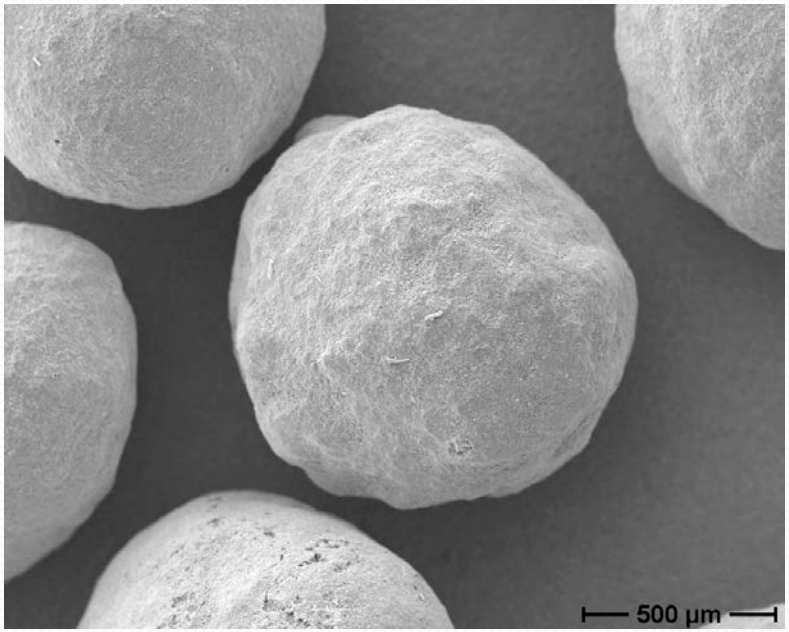
Water Usage/Sources

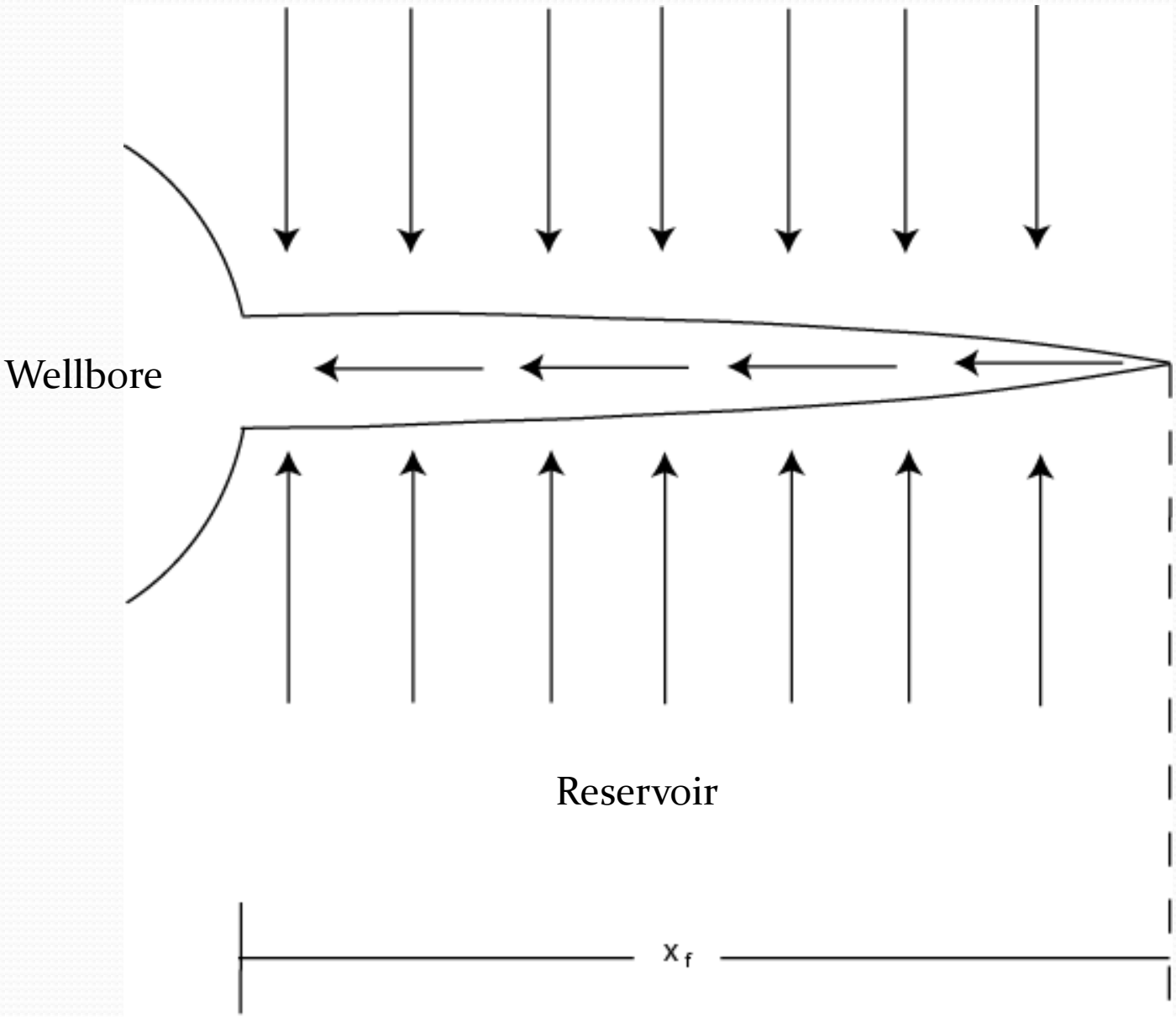
- Reuse and recycling
- Using minimum amounts of fresh water
- Using recycled produced and frac water
- Recycling techniques
  - Reverse osmosis
  - Filtered and treated
- Disposal into UIC permitted disposal wells or evaporation
- Key emphasis – taking substandard water and making it reusable (90-95% recycling in many Rocky Mountain areas)

Generic Proppant Types

- Sand
- Artificial or ceramics






Wellbore
Reservoir
x_f

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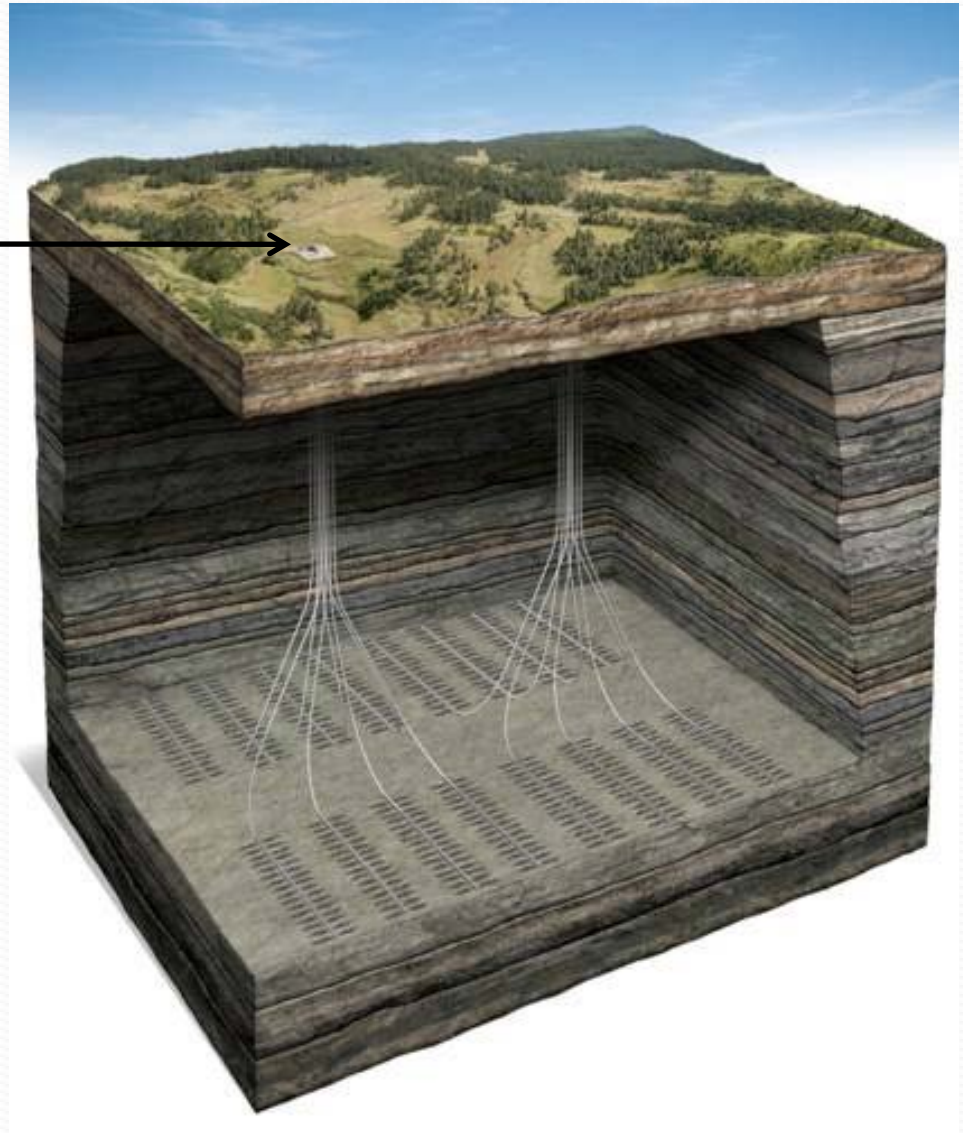
Pad Drilling – Tight Gas

Piceance Basin, Western Colorado, USA

From www.csug.ca, 2010

Horizontal Well – Multiple Laterals

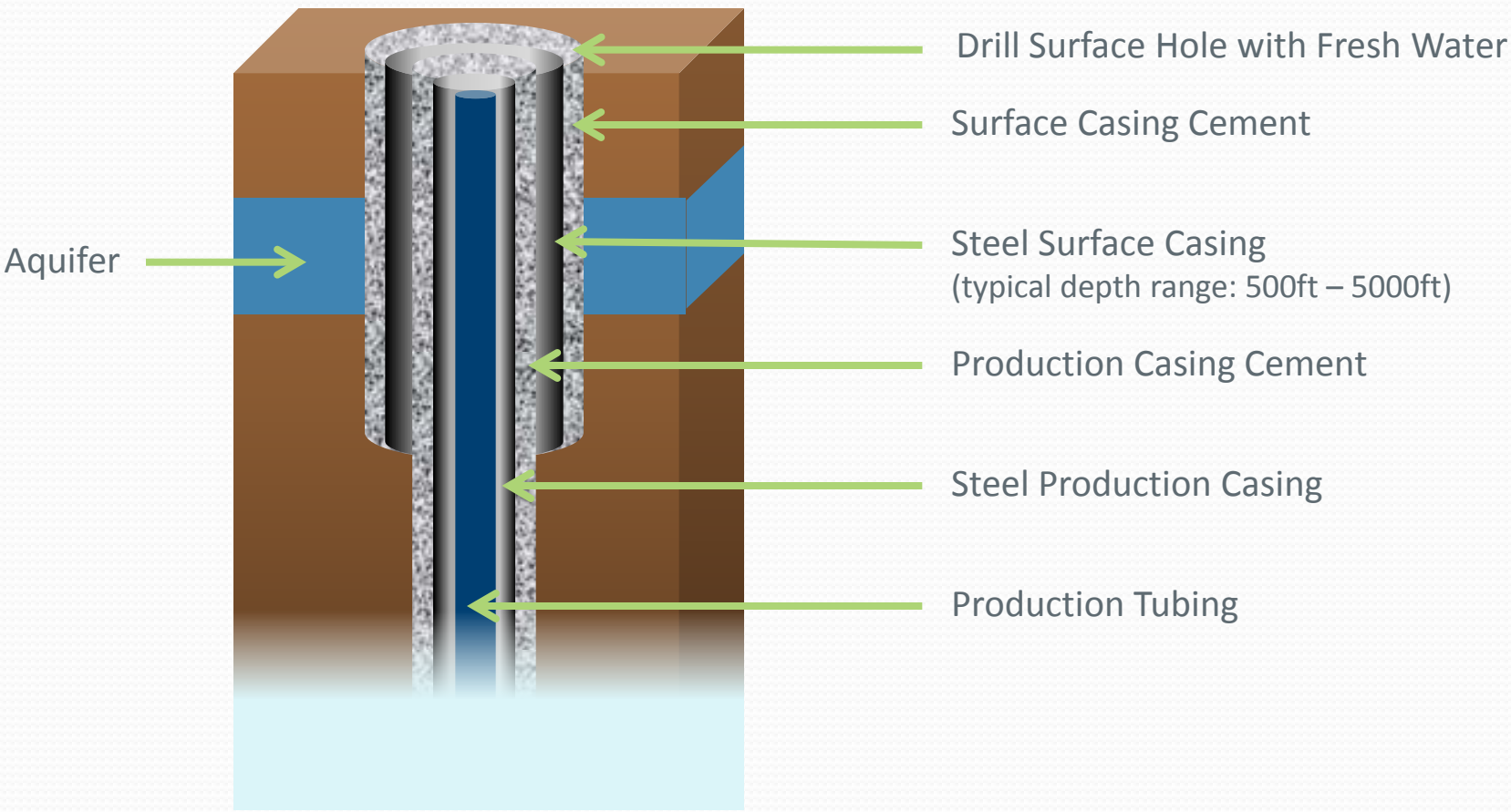
Pad



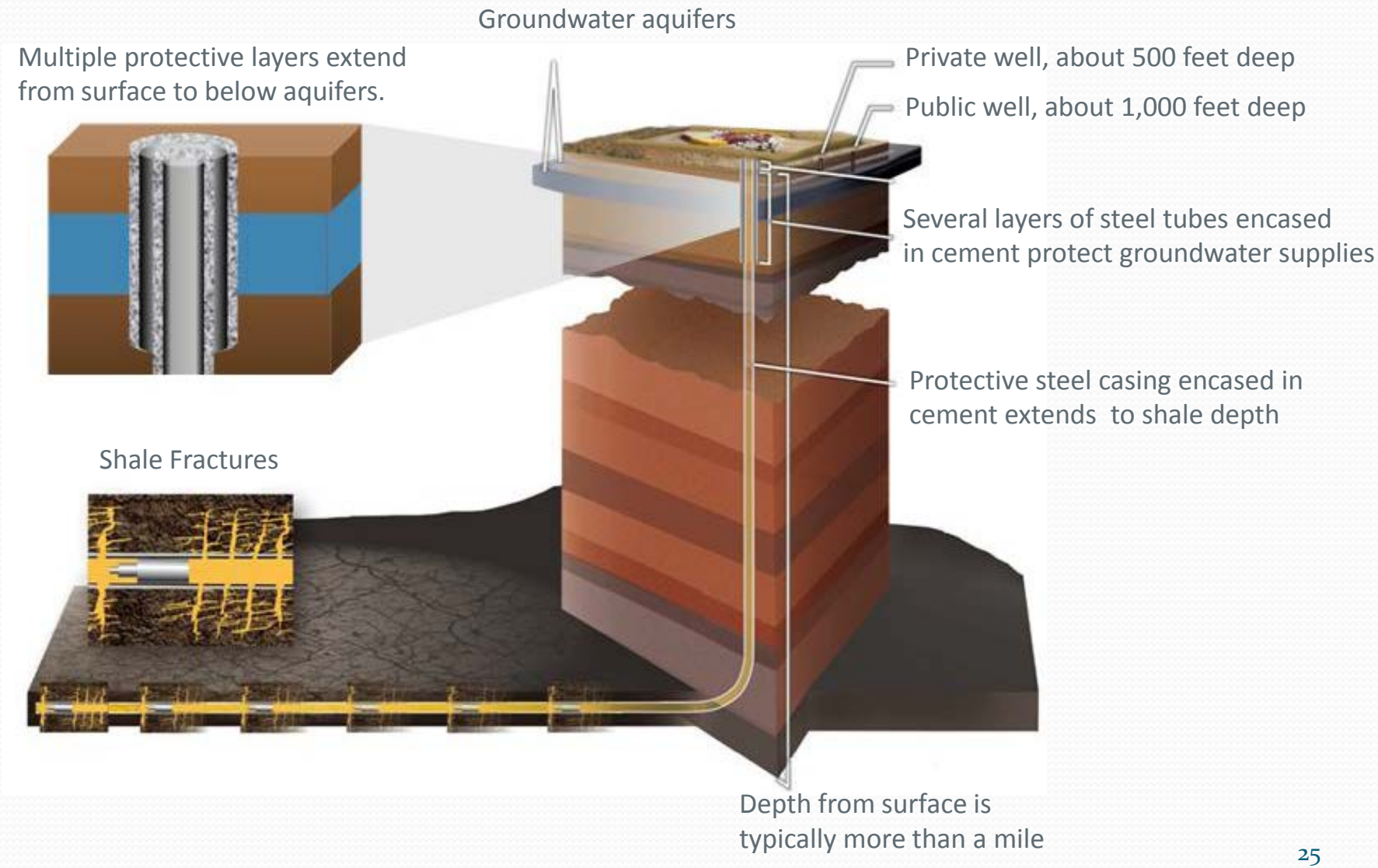
Courtesy of PETROBAKKEN

Wellbore Construction

Multiple Layers of Groundwater Protection



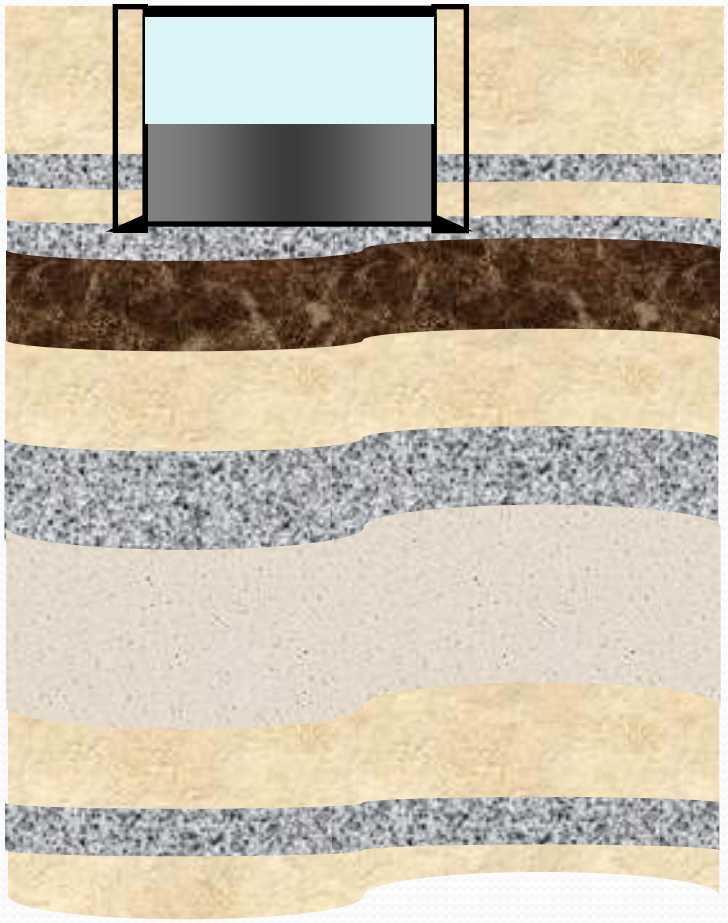
Fracture Stimulation and Gas Production are Completely Isolated from Fresh Water



Surface Casing

- **Set surface casing at a depth adequate to protect groundwater**
- **Cement to surface**

Surface Casing



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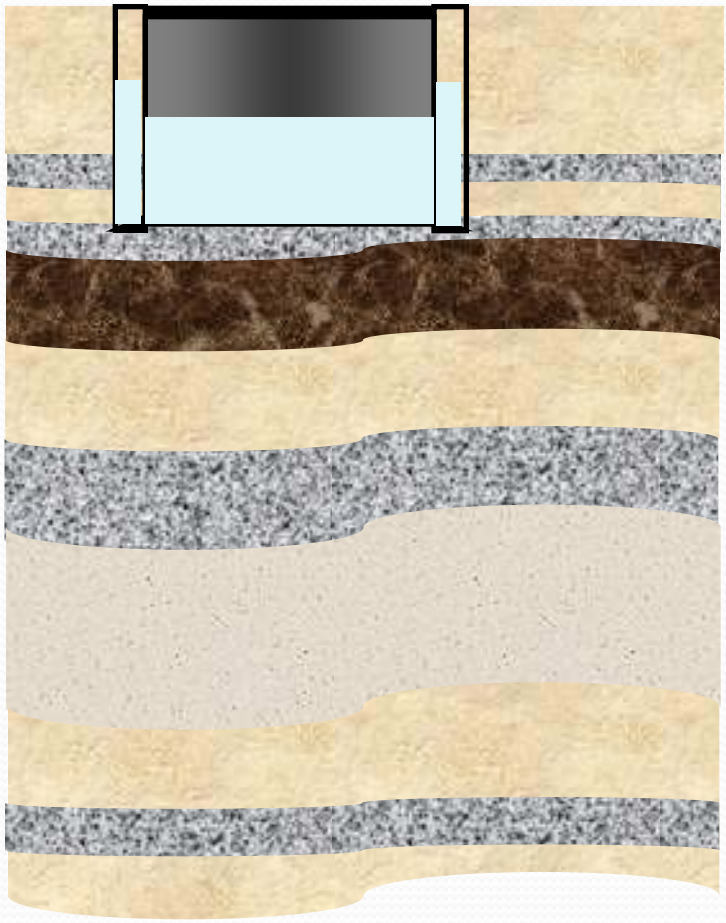

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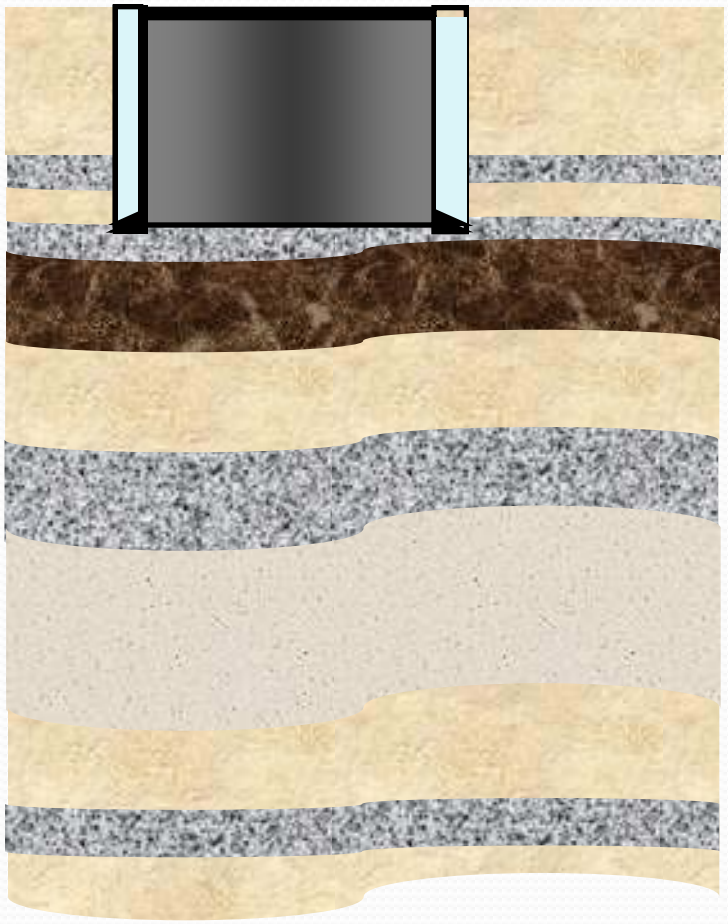

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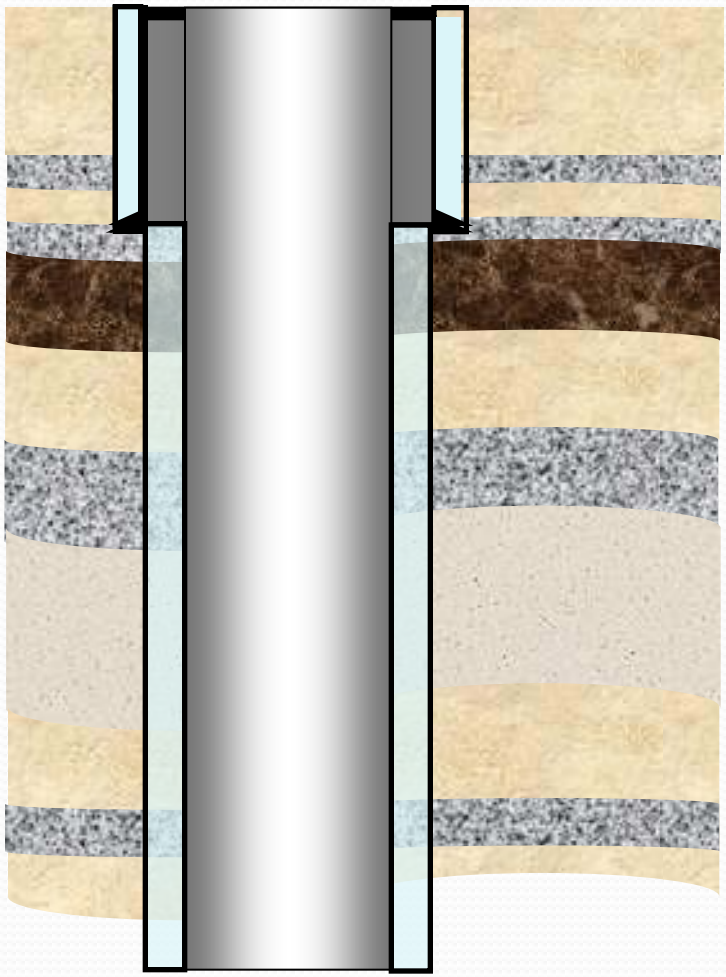
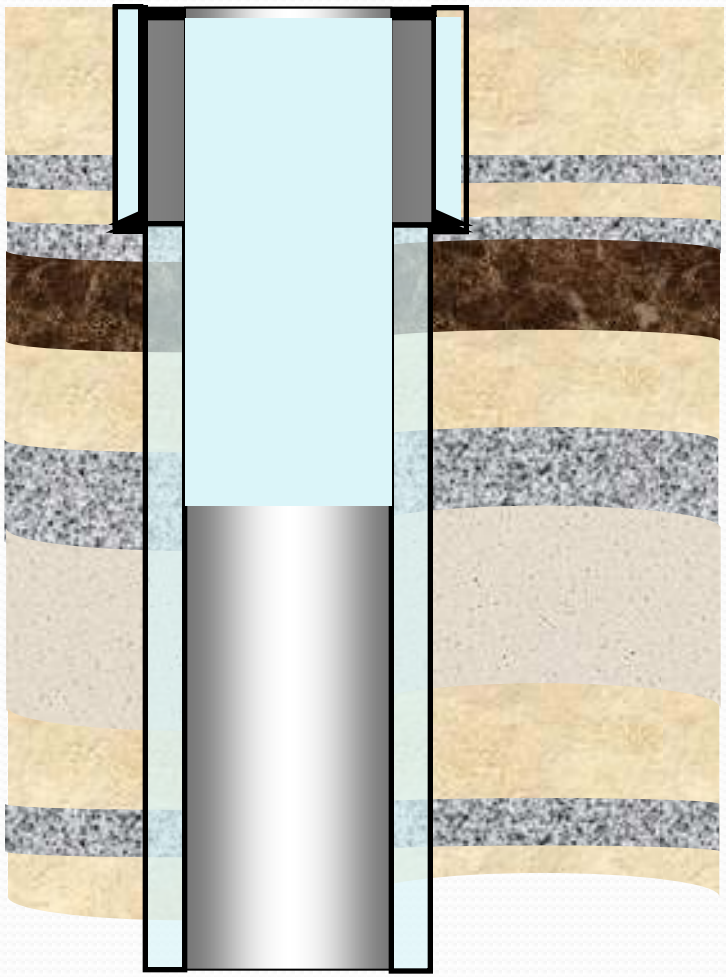
Production Casing



- **Set production casing at T.D.**
- **Cement to isolate productive interval**

Production Casing



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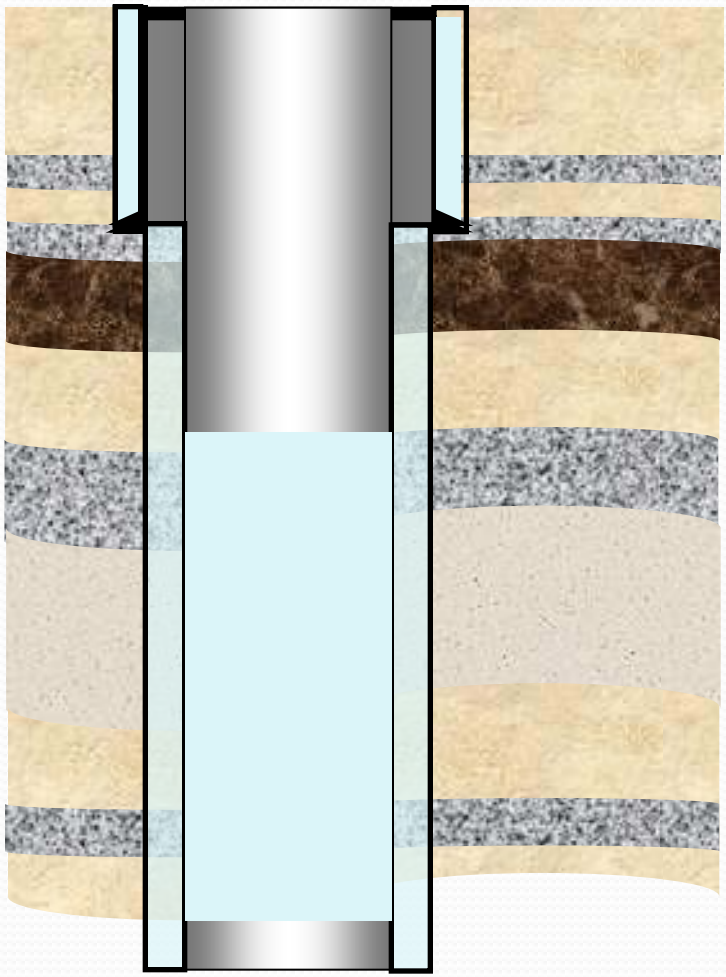

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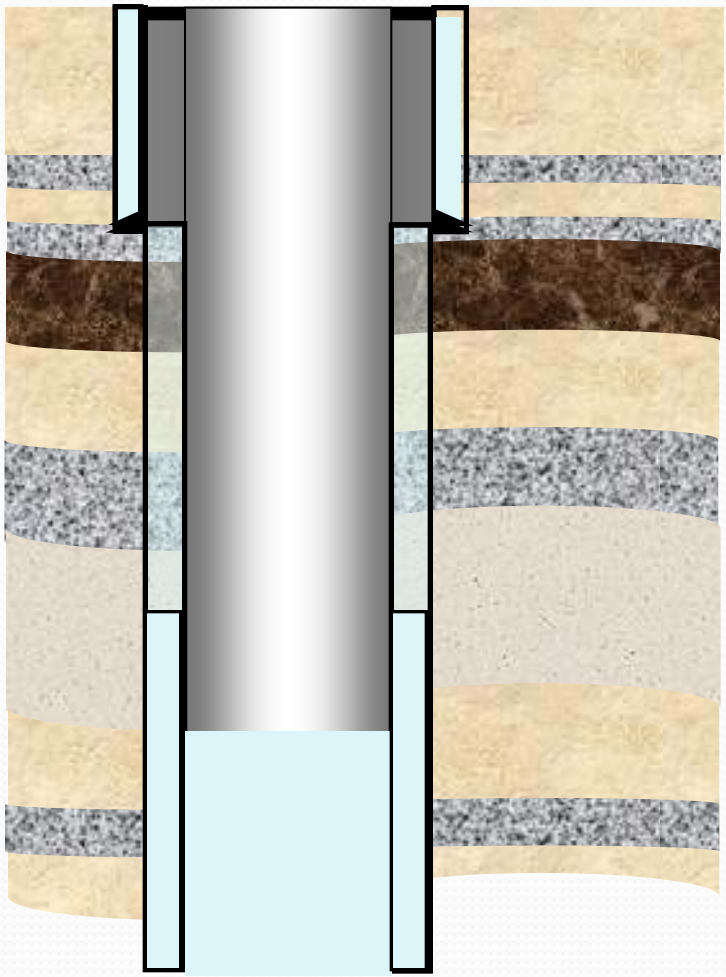

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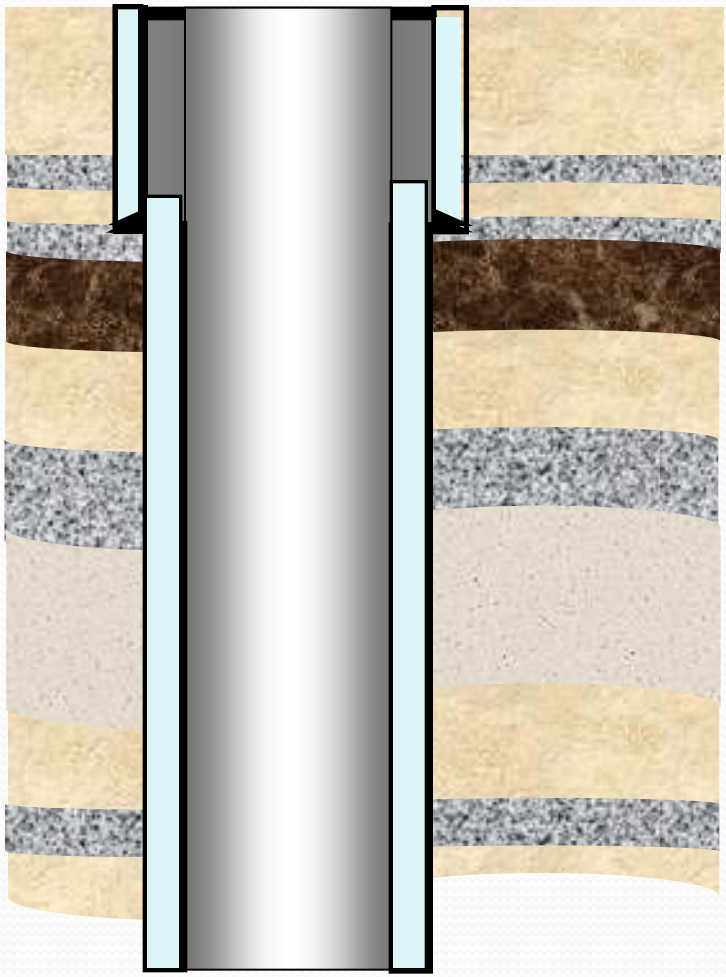

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- **Cement to isolate productive interval**

Oil Well Cement

- Not concrete – does not contain sand, gravel or rock
- Not construction grade cement
- Specially formulated for oil and gas well applications
- Small particle size
- Designed to build compressive strength quickly

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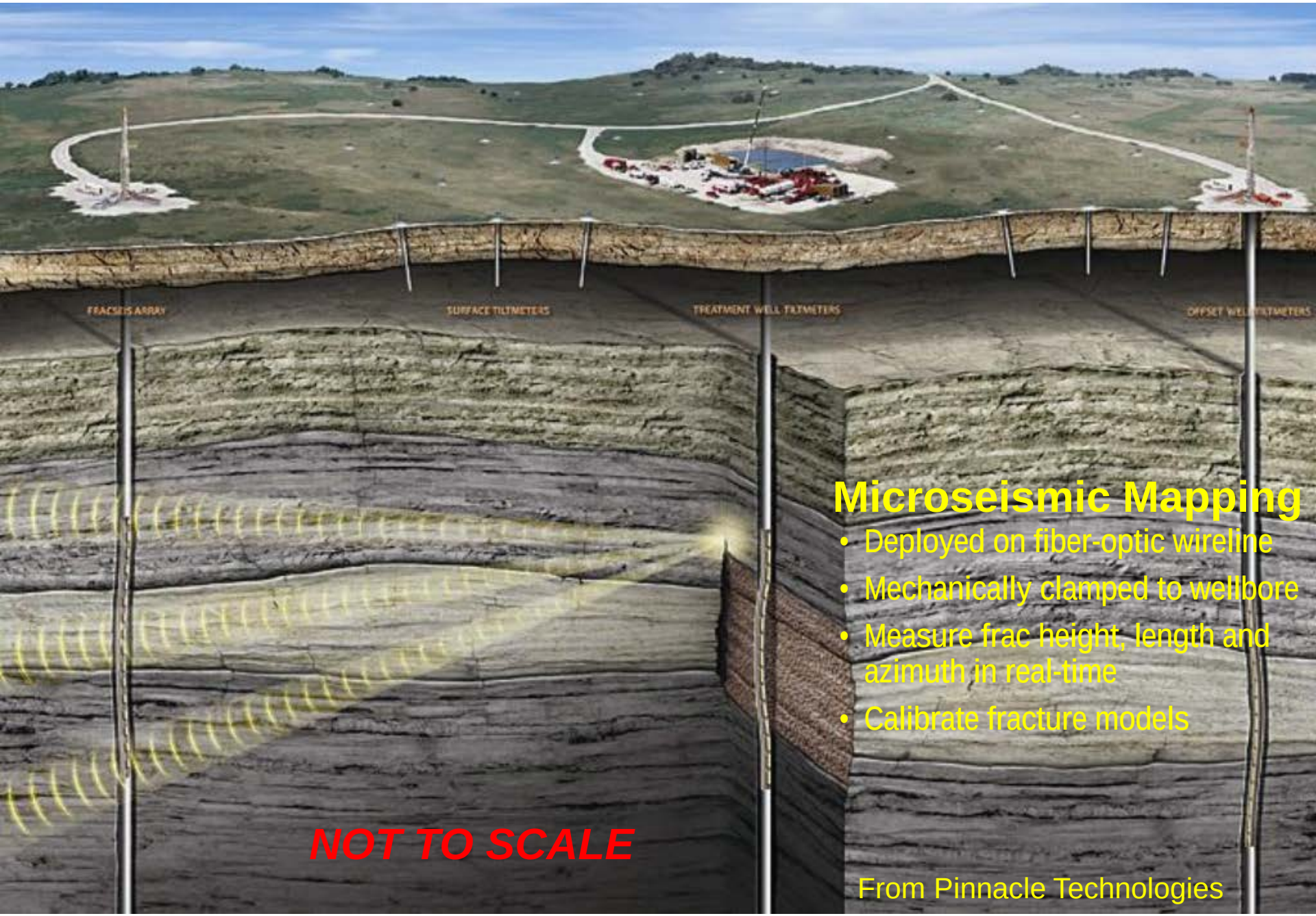
Fracture "Microseismic"

- Seismic phones are lowered into nearby non-producing well
- Seismic tools "hear" tiny shear slippages caused by fracturing
- Triangulates position of seismic activity
- All geologic basins have a preferred stress direction
- Tool for early exploration



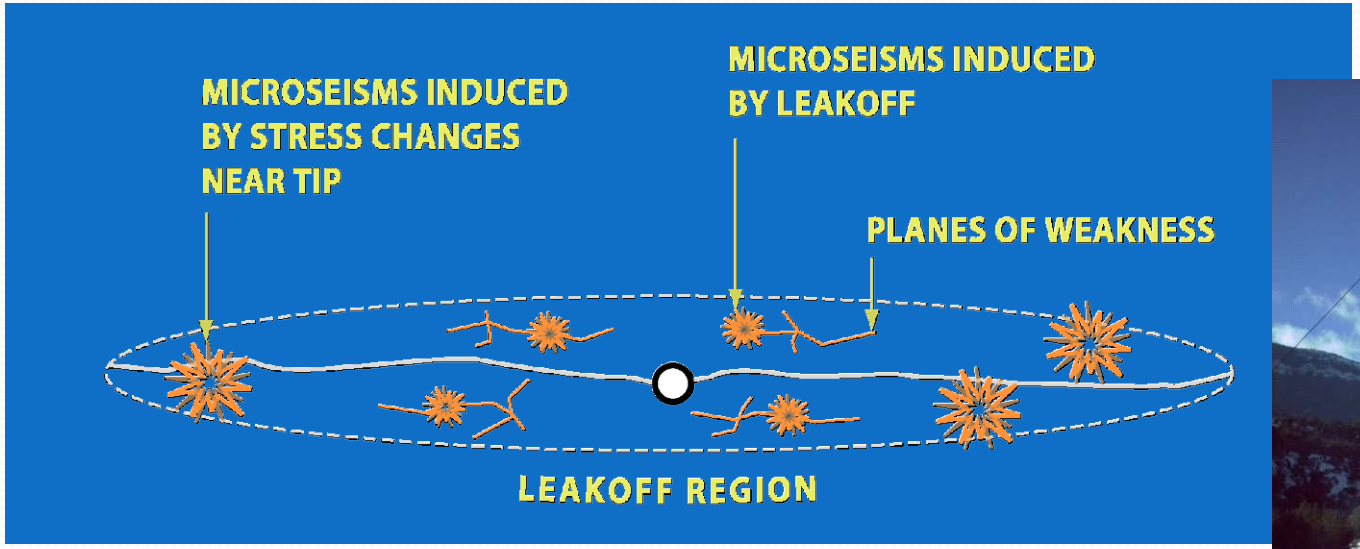
Microseismic Mapping

- Deployed on fiber-optic wireline
- Mechanically clamped to wellbore
- Measure frac height, length and azimuth in real-time
- Calibrate fracture models

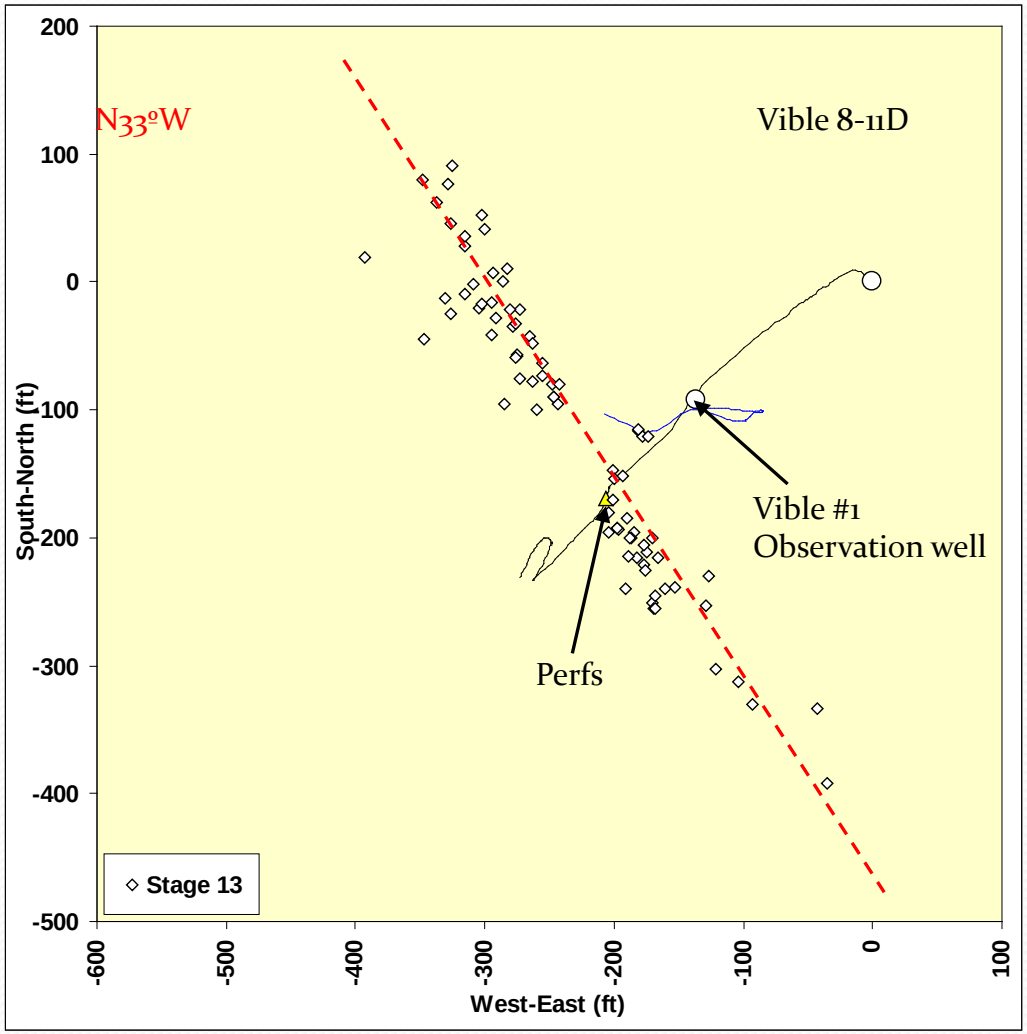
From Pinnacle Technologies

Microseismic Fracmapping

- Measure frac height, length and azimuth in real-time

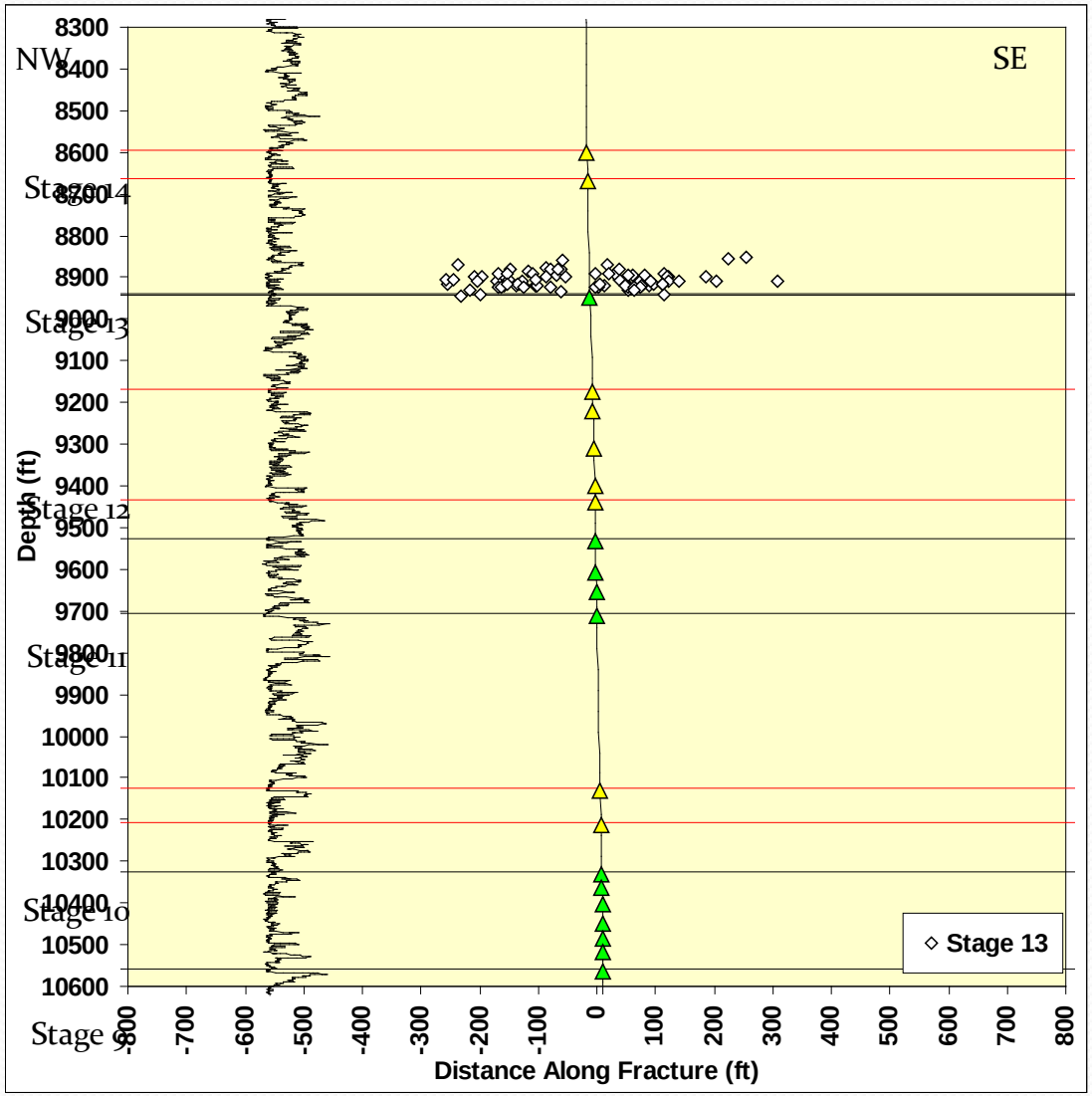


Vible 8-11D Stage 13 – Plan View



- Near-planar fracture geometry
- Fracture Azimuth: N33°W
- Observed Fracture Half-Lengths: ~300'

Vible 8-11D Stage 13 – Side View



- Micro-seismic Fracture Height: 100’
- Fracture Half-Lengths: ~300’

“Micro” or Very Small Seismic Events

Moment Mag	Comments	Recording Range (feet)	Moment (MNm)	Slip and Area	Equivalent Explosive Charge
-4	Smallest we can record	<100'	001	10 µm .003 m²	1 mg
-3		~1500'	.04	40 µm .03 m²	30 mg
-2	Big for Barnett	~2500'	1	.1 mm .3 m²	1 g (blasting cap)
-1	Biggest in Barnett	~5000'	40	.4 mm 3 m²	30 mg
0	Limit of "microseismic" Biggest at Ekofisk	>10000'	1,000	1 mm 30 m²	1 kg stick of explo-sive
1	Largest event Habanero geothermal		40,000	4 mm 300 m²	30 kg
2			1,000,000	1 cm 3,000 m²	1 ton
3	Felt earthquake		40,000,000	4 cm .03 km²	30 ton

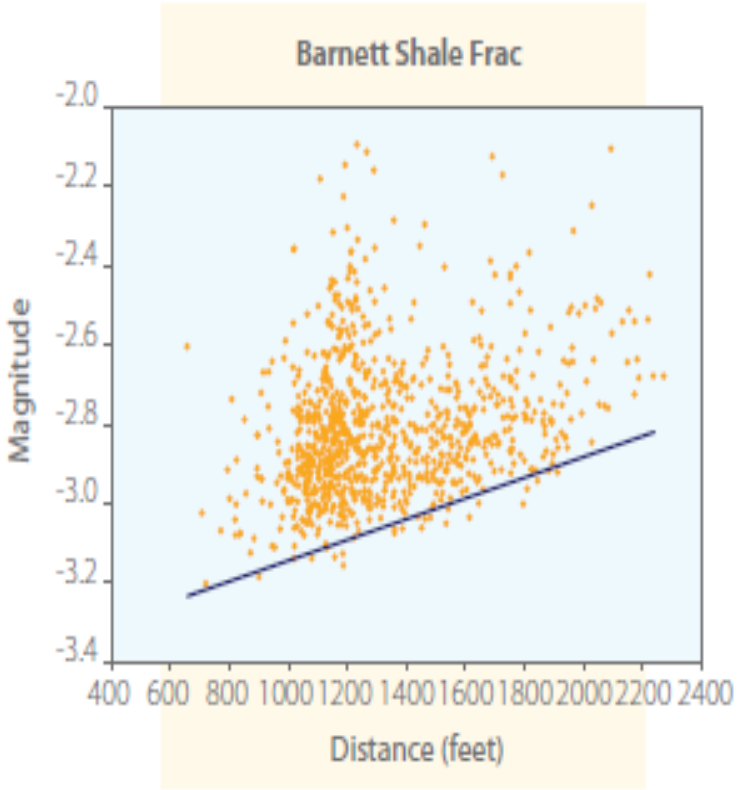
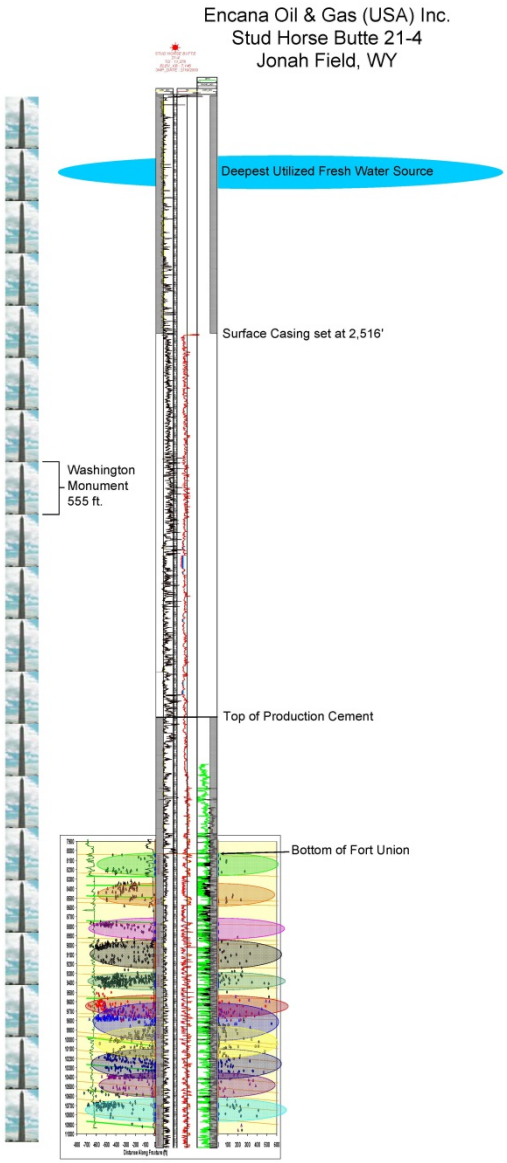


Figure 1. Magnitude versus distance plot indicating complete detection.

Pinnacle

Jonah Well Schematic (to scale)



Courtesy of Encana

Final thoughts…

- Stimulation technique used in multiple reservoir types but specifically unconventional reservoirs
- Applied in vertical and horizontal wells
- Strong history of engineering
- Regulated
- Well engineered
- Physics/mechanics well understood
- Is a top priority of the industry
  - Monitoring
  - Minimizing fluid requirements
  - Minimizing environment aspects
  - Minimizing footprints

Thank you for your time - Questions?