

# **Gas Well / Water Well Subsurface Contamination\***

**Rick Railsback<sup>1</sup>**

Search and Discovery Article #80339 (2013)\*\*

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## **Abstract**

With the advent of horizontal drilling and frac technologies which allow the commercial production of oil and gas from very low permeability rocks, onshore North America is undergoing a historic drilling boom. The industry is now drilling in areas never drilled before – densely populated and often with significant, beneficial-use aquifers in the shallow subsurface. Is oil and gas drilling, fracing, and production endangering the nation's groundwater supplies? Are water wells and aquifers being contaminated with oil and gas, drilling mud, and/or frac fluids? Numerous tools and methods of investigation can be used to answer these questions:

- proximity;
- timing of the impact;
- other contaminant sources;
- oil and gas well records;
- pressure data from the gas well and water well;
- data on frac geometry;
- natural gas, condensate, and water composition;
- seismic data;
- cement bond logs;
- noise logs;
- temperature logs;
- gamma ray logs;
- radioactive tracers;
- pressure interference tests; and
- installation of monitoring wells.

Effective use of these tools will solve the problem of whether or not an oil or gas well has contaminated a water well. Operators can utilize these tools to educate the public and landowners, to promote and defend drilling programs, and in litigation support.

# GAS WELL/WATER WELL SUBSURFACE CONTAMINATION

**Rick Railsback**

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CURA Environmental & Emergency Services

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# Shale Gas Plays, Lower 48 States



Source: Energy Information Administration based on data from various published studies  
 Updated: May 28, 2009



“And ye shall know the truth and the truth shall make you free.”

- Oil companies –  
“it has never been proven that an oil or gas well has contaminated an aquifer.”



“And ye shall know the truth and the truth shall make you free.”

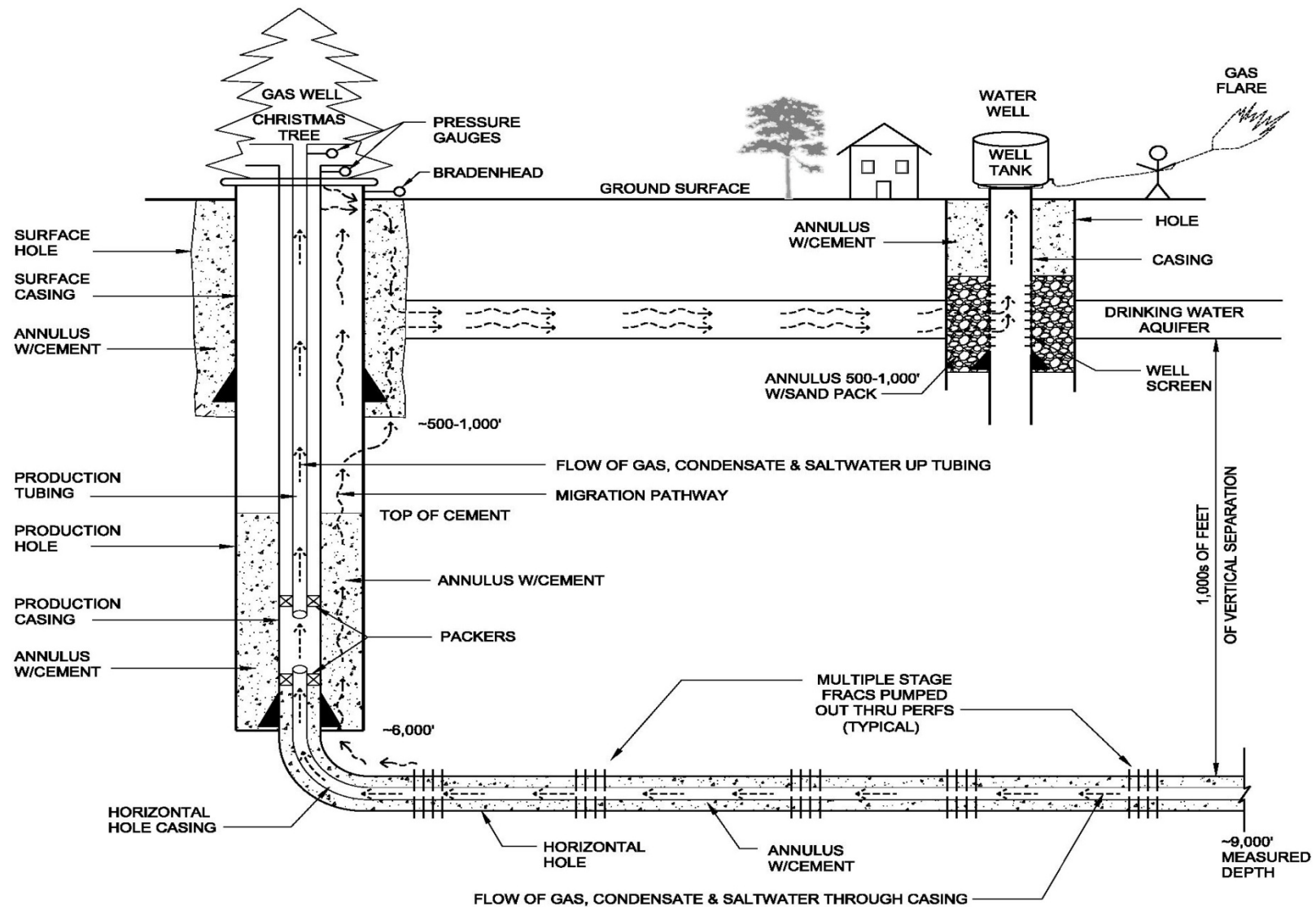
- Environmentalists
  - “every oil and gas well has contaminated all our aquifers.”



“And ye shall know the truth and the truth shall make you free.”

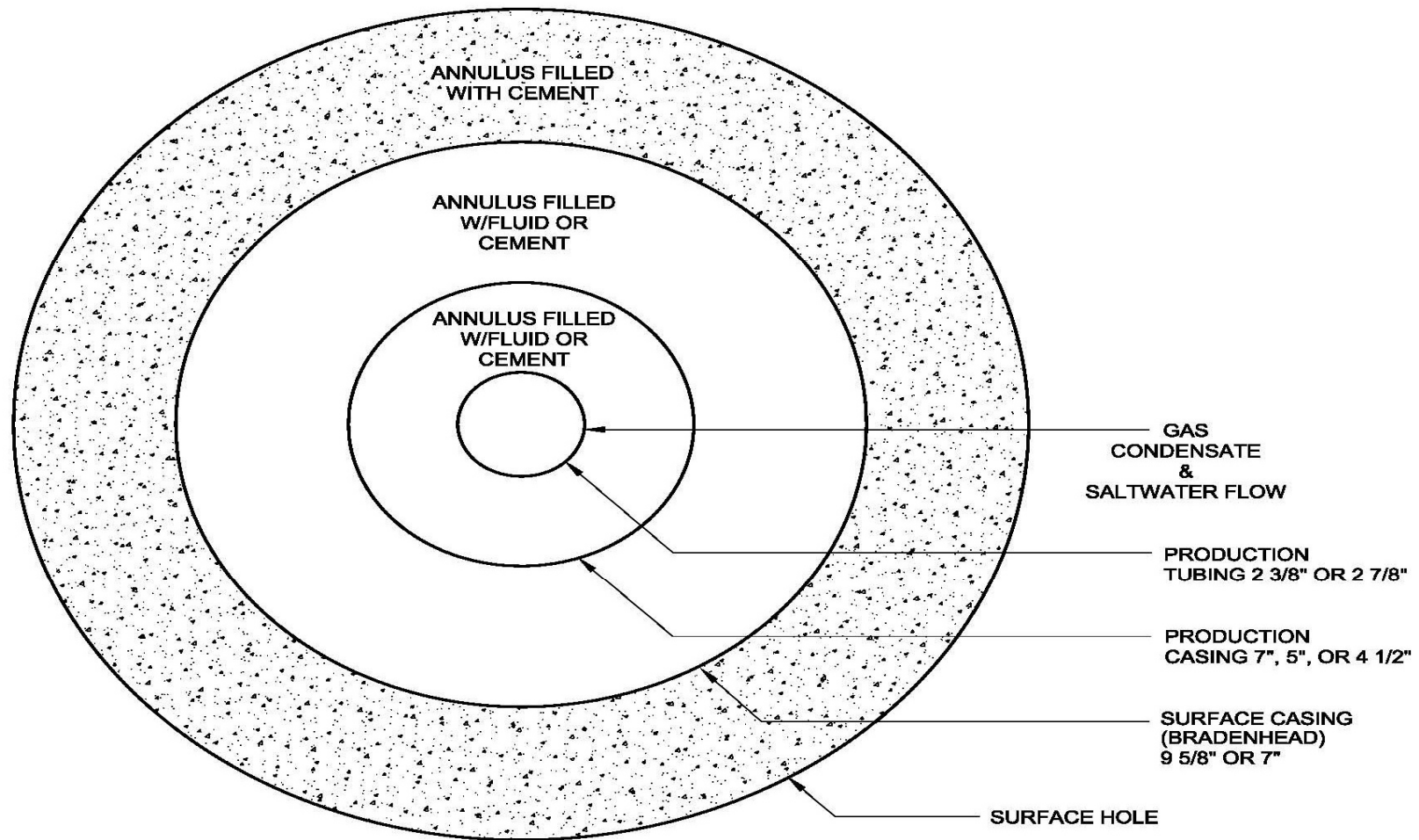
- Oil companies – “it has never been proven that an oil or gas well has contaminated an aquifer.”
- Environmentalists – “every oil and gas well has contaminated all our aquifers.”

# The Physical System

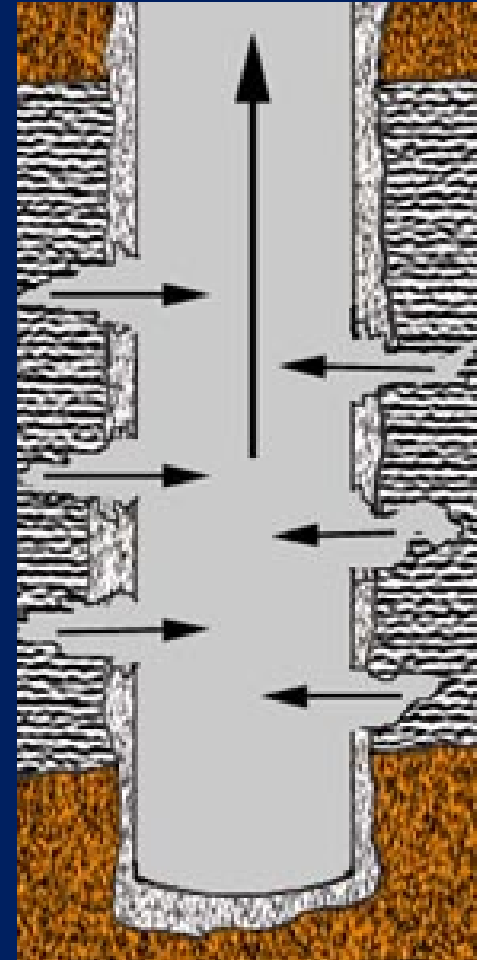
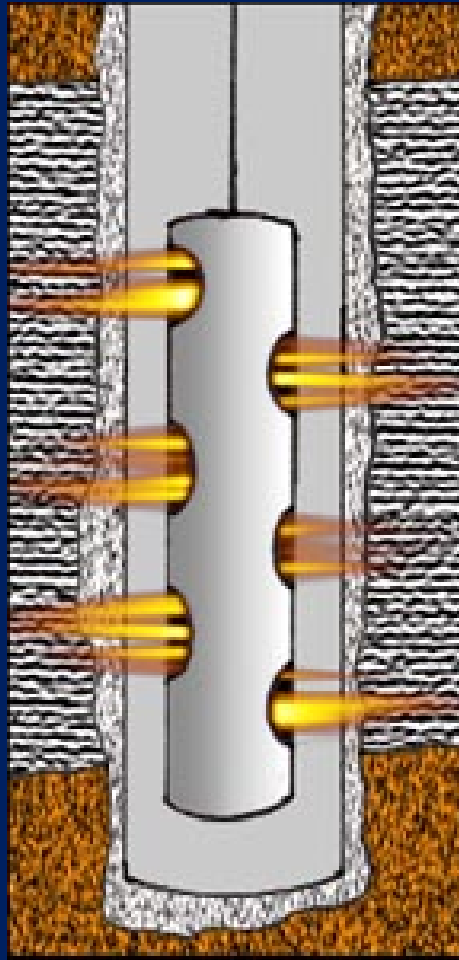
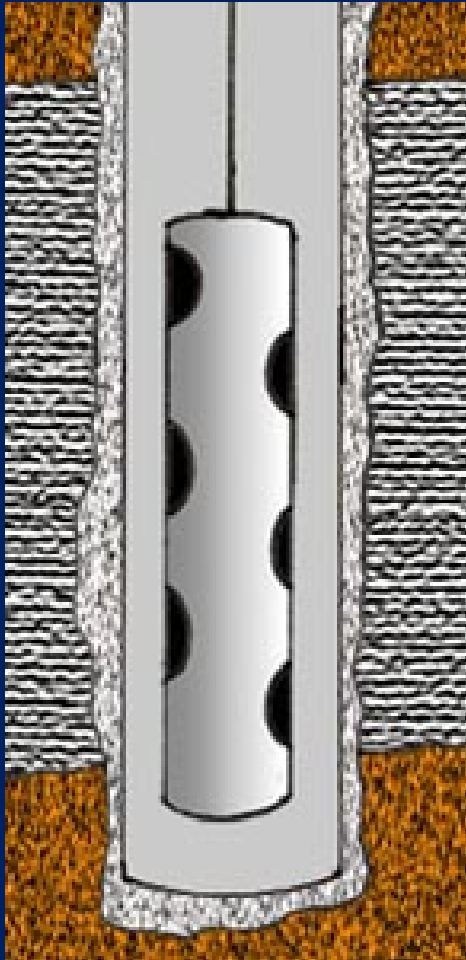




# Well Geometry (view looking down on the wellhead)



# Jet Perforation



# Well Site during Frac



# Litigation Support

- Tools & methods for investigation
- Generally presented from  
simplest tools to more complex  
least expensive to most expensive



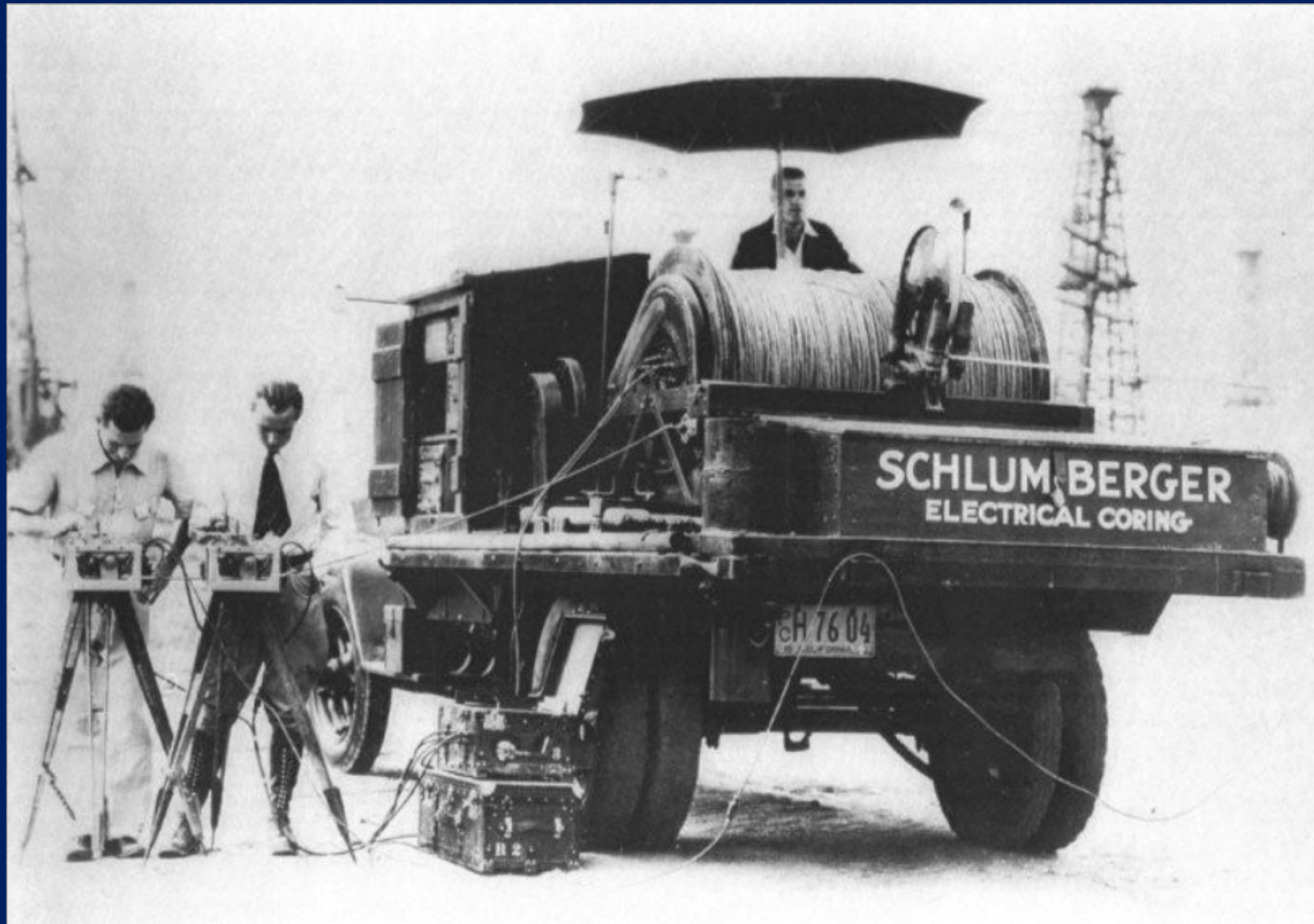
# Plan for Investigation

- Proximity
- Timing of the impact
- Other contaminant sources
- Oil & gas well records
- Pressure data from the gas well
- Pressure data from the water well

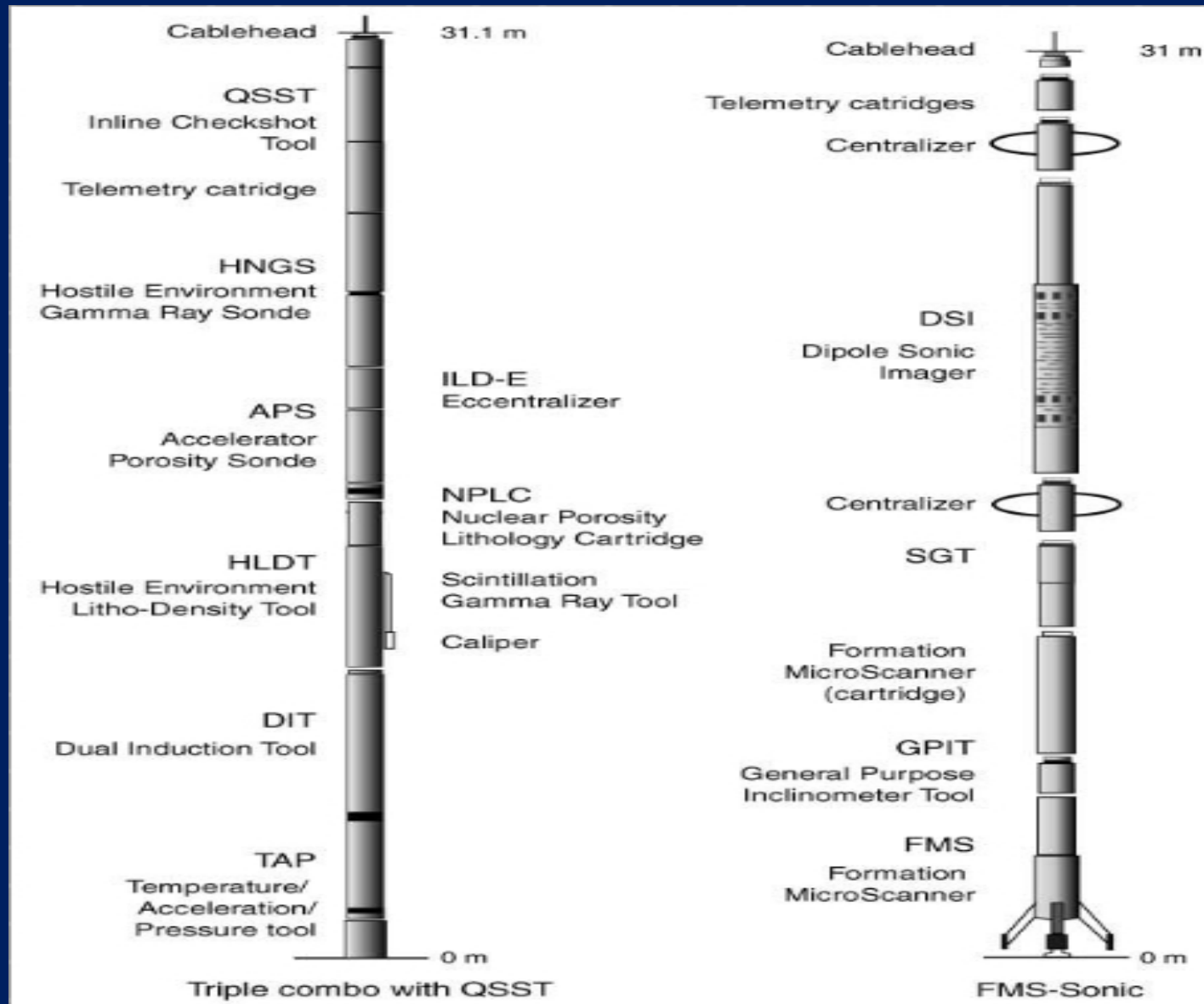
# Plan for Investigation

- Data on frac geometry
- Natural gas composition
- Condensate composition
- Water composition
- Seismic data
- Cement bond logs

# Wireline Logging Truck

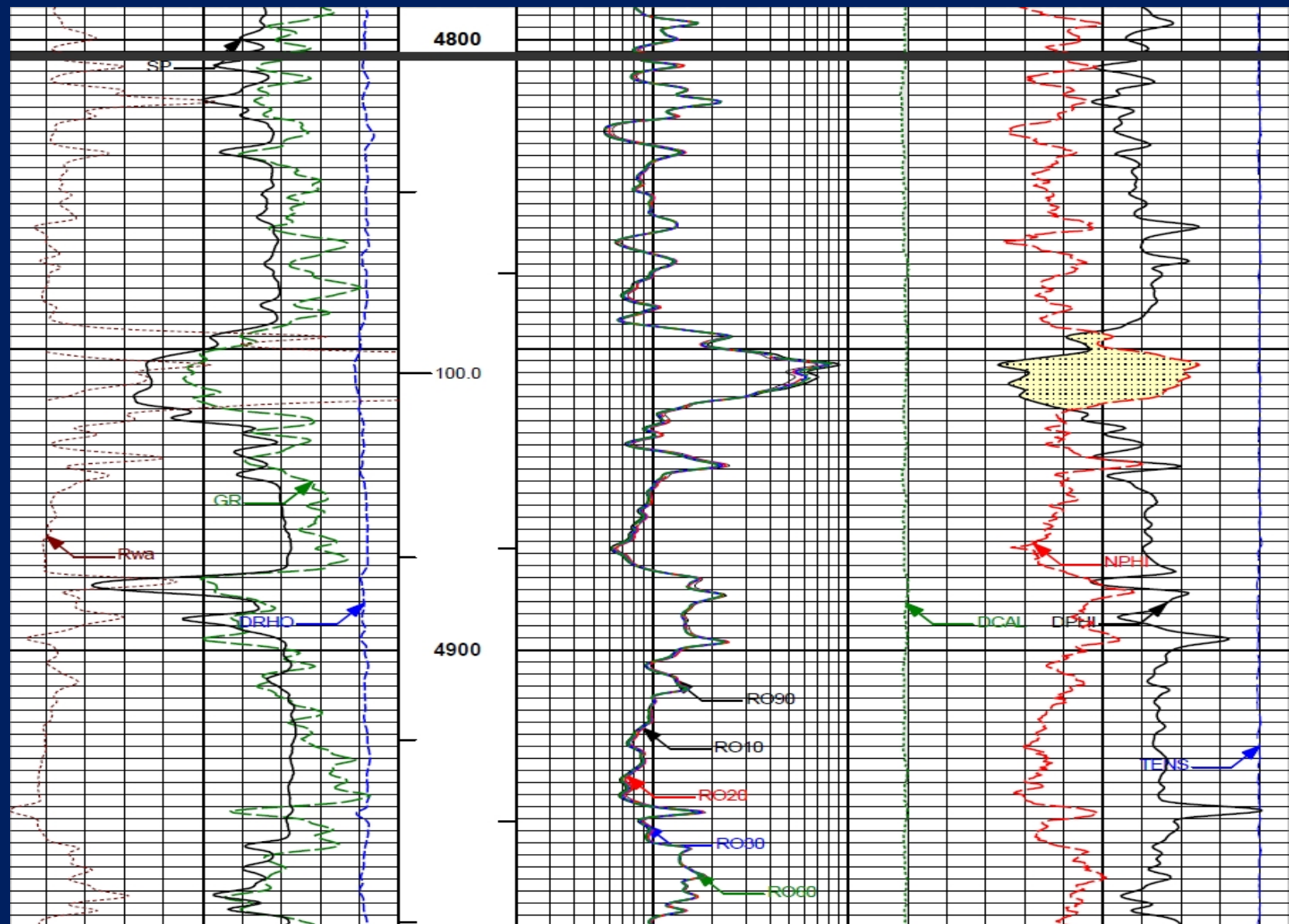


# Wireline Logging Tool





# Well Log



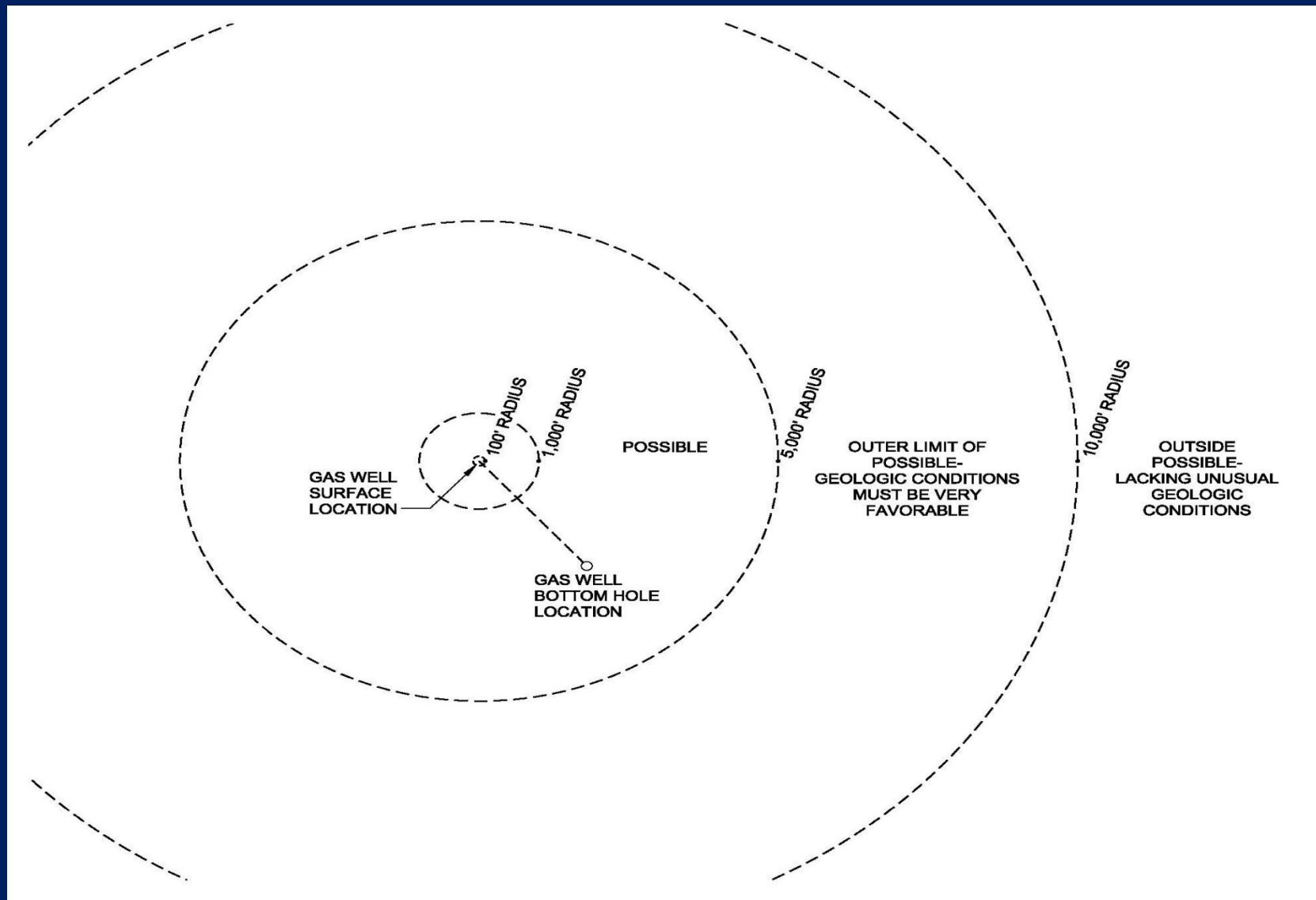
# Plan for Investigation

- Noise logs
- Temperature logs
- Gamma ray logs
- Radioactive tracers
- Pressure interference tests
- Installation of monitoring wells

# Proximity

- Radius of influence of wells dependent upon geology:
  - Porosity (void space in the rock that is filled with fluids and/or gas)
  - Permeability (ability of the rock to transmit fluids and/or gas)
  - Pressure gradients
  - Special geologic conditions (faults, fractures, etc.)

# Proximity

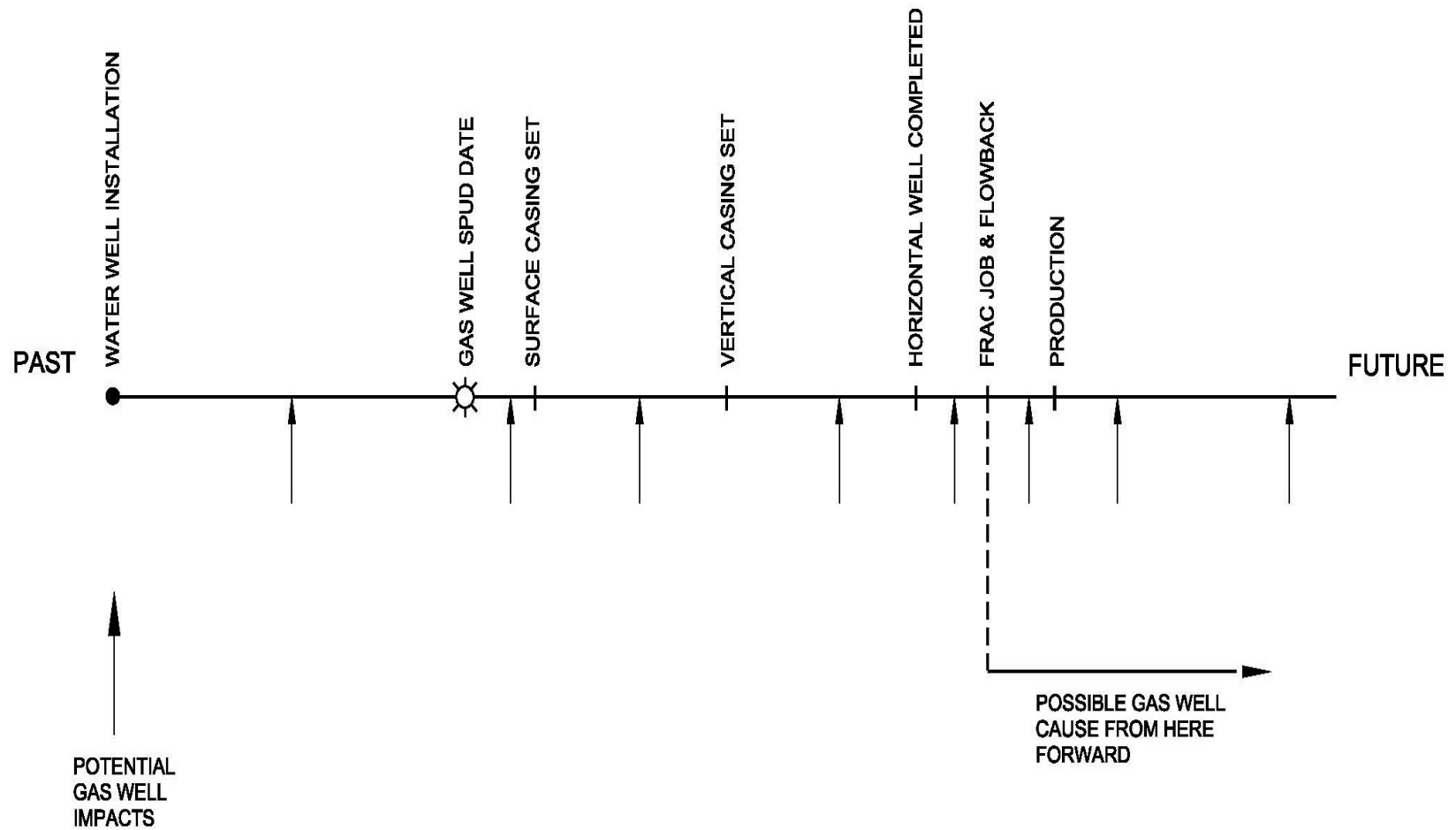




# Timing

- Water well installation
- Gas well installation:
  - Spud date
  - Surface casing set
  - Vertical casing set
  - Horizontal well completed & casing set
  - Frac job and flow back
  - Production
- Time of impact to water well

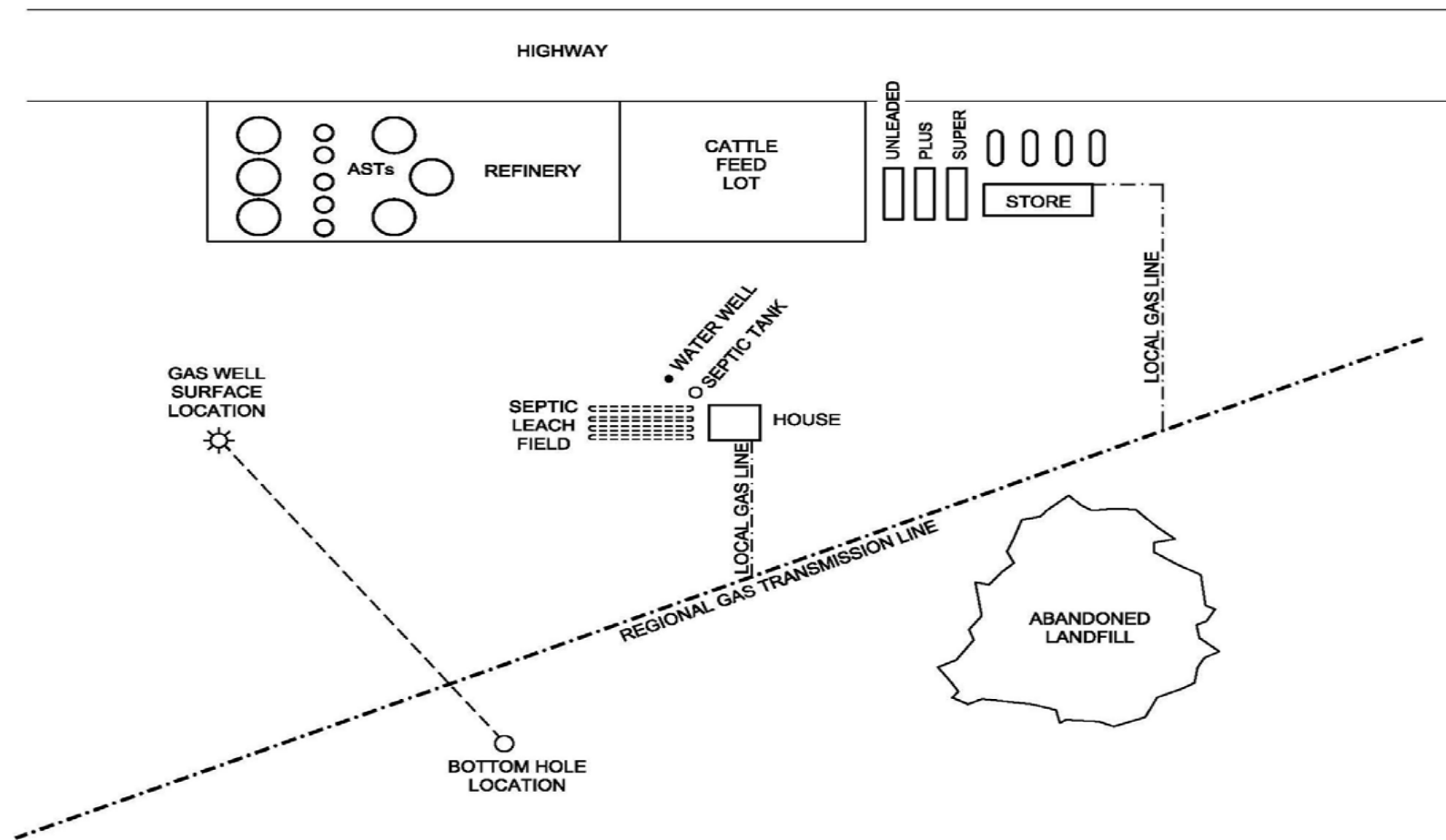
# Timing



# Other Contaminant Sources

- A variety of other sources may be available
- Common sources are usually shallow – within 50 feet of surface
- Impact to deeper aquifers from shallow sources unlikely due to shallow water table & impermeable layers
- Minor amounts of methane occur naturally in aquifers & may be generated by organics in the water well & equipment

# Other Contaminant Sources



# Oil & Gas Well Records

- W-1 Drilling Permit Application
- G-1 or W-2 - Gas or Oil Well Completion Test
- G-5 Gas Well Classification Report
- Railroad Commission Online Research
  - <http://www.rrc.state.tx.us/data/index.php>
- Railroad Commission Public GIS Map Viewer
  - <http://gis2.rrc.state.tx.us/public/startit.htm>

Type or print only

RAILROAD COMMISSION OF TEXAS  
Oil and Gas DivisionForm G-1  
Rev. 4/1/83 DBC1297Gas Well Back Pressure Test,  
Completion or Recompletion Report, and Log

1. FIELD NAME (as per RRC Records or Wildcat) <b>Newark, East (Barnett Shale)</b>		2. LEASE NAME <b>Butler Unit</b>		7. RRC District No. <b>09</b>	
3. OPERATOR'S NAME (Exactly as shown on Form P-5, Organization Report) <b>Range Production Company</b>		RRC Operator No. <b>691703</b>		8. RRC Gas ID No. <b>253732</b>	
4. ADDRESS <b>100 Throckmorton, Suite 1200 Fort Worth, TX 76102</b>		10. County of well site <b>Hood</b>		9. Well No. <b>1H</b>	
5. Location (Section, Block, and Survey) <b>Sec Blk Atwood, J B A-802</b>		5b. Distance and direction to nearest town in this county. <b>13.8 miles S from Weatherford</b>		11. Purpose of filing Initial Potential <input checked="" type="checkbox"/> Retest <input type="checkbox"/> Reclass <input type="checkbox"/> Well record only (Explain in remarks) <input type="checkbox"/>	
6. If operator has changed within last 60 days, name former operator		12. If workover or reclass, give former field (with reservoir) & Gas ID or oil lease no. <b>FIELD &amp; RESERVOIR</b>		13. Pipe Line Connection <b>Peregrine Pipeline Company L.P.</b>	
14. Completion or recompletion date <b>08/14/2009</b>		15. Any condensate on hand at time of workover or recompletion? <input type="checkbox"/> Yes <input type="checkbox"/> No		16. Type of Electric or other Log Run. <b>GR</b>	

Section I GAS MEASUREMENT DATA											
Date of Test <b>08/31/2009</b>		Gas Measurement Method (Check One) Orifice Meter <input checked="" type="checkbox"/> Flange Taps <input checked="" type="checkbox"/> Pipe Taps <input type="checkbox"/>		Positive Choke <input type="checkbox"/>	Orifice Vent Meter <input type="checkbox"/>	Pitot Tube <input type="checkbox"/>	Critical-flow Prover <input type="checkbox"/>	Gas produced during test <b>7224</b> MCF			
Run No	Line Size	Orif. or Choke Size	24 Hr Coeff Orif. or Choke	Static P <sub>w</sub> or Choke Press	Diff. h <sub>w</sub>	Flow Temp. °F	Temp. Factor F <sub>t</sub>	Gravity Factor F <sub>g</sub>	Compress Factor F <sub>pv</sub>	Volume MCF/DAY	
1	4.026	1.750	19764.05	232	82	117	0.9493	0.9054	1.020	2390	
2											
3											
4											

Section II FIELD DATA AND PRESSURE CALCULATIONS											
Gravity (Dry Gas) <b>.732</b>		Gravity Liquid Hydrocarbon Deg. API		Gas-Liquid Hydro Ratio CF/Bbl		Gravity of Mixture G <sub>mix</sub> = <b>.732</b>		Avg. Shut-in Temp <b>150 °F</b>		Bottom Hole Temp. <b>163°F @ 9097' (Depth)</b>	
$D_{eff}^{8/3} = 26.149$		$\sqrt{T_f} = \sqrt{600} = 24.49$		$\sqrt{GL} = \sqrt{\quad} = 65.24$							
$C_{wf} = \frac{1118 \times (D_{eff})^{8/3}}{\sqrt{T}} = 1193.50$		$\sqrt{\frac{GL}{C}} = \frac{65.24}{1193.50} = 0.0547$									
Run No	Time of Run Min.	Choke Size	Wellhead Press. PSIA P <sub>w</sub>	Wellhead Flow Temp. °F	P <sub>w</sub> <sup>2</sup> (Thousands)	R	R <sup>2</sup> (Thousands)	P <sub>1</sub>	P <sub>w</sub> /P <sub>1</sub>		
Shut-In											
1	4320	64/64	330	117	109	130.6	17.1	354.9	0.9298		
2											
3											
4											
Run No	F	K	S = $\frac{1}{z}$	E <sub>ks</sub>	P <sub>f</sub> and P <sub>s</sub>	P <sub>f</sub> <sup>2</sup> and P <sub>s</sub> <sup>2</sup> (thousands)	P <sub>f</sub> <sup>2</sup> - P <sub>s</sub> <sup>2</sup> (thousands)	Angle of Slope			
Shut-In											
1	0.9653	0.1294	1.134	1.1580	984	969		θ .... 45.0°			
2					409	167	801.7	n .... 1.000			
3								Absolute Open Flow ... 2889 MCF/DAY			
4											

WELL TESTER'S CERTIFICATION: I declare under penalties prescribed in Sec. 91.143, Texas Natural Resources Code, that I conducted or supervised this test and that data and facts shown in Sections I and II above are true, correct, and complete, to the best of my knowledge. Bottomhole temperature and the diameter and length of flow string were furnished by the operator of the well.

Signature: Well Tester

Cetco Services  
Name of Company

RRC Representative

OCT 02 2009

O&G  
ABILENE, TX

OPERATOR'S CERTIFICATION: I declare under penalties prescribed in Sec. 91.143, Texas Natural Resources Code, that I am authorized to make this report, that I prepared or supervised and directed this report, and that data and facts stated therein are true, correct, and complete, to the best of my knowledge.

Signature: Melanie Dennis  
Operator's representativeRegulatory Analyst, 09/30/2009  
Title

(817) 869-4158

SECTION III DATA ON WELL COMPLETION AND LOG (Not Required on Retest)									
17 Type of Completion: <input checked="" type="checkbox"/> New Well <input checked="" type="checkbox"/> Deepening <input type="checkbox"/> Plug Back <input type="checkbox"/> Other <input type="checkbox"/>					18 Permit to Drill, Plug Back or Deepen <input checked="" type="checkbox"/> DATE 05/20/2009 PERMIT NO. 679671 Rule 37 <input checked="" type="checkbox"/> CASE NO. Exception 05/20/2009 0261368 Water Injection PERMIT NO. Permit Salt Water Disposal PERMIT NO. Permit Other PERMIT NO.				
19. Notice of Intention to Drill this well was filed in Name of <b>Range Production Company</b> <input checked="" type="checkbox"/>									
20 Number of producing wells on this lease in this field (reservoir) including this well <b>1</b>				21. Total number of acres in this lease <b>202.980</b>					
22 Date Plug Back, Deepening, Workover or Drilling Operations <b>06/15/2009</b>		Commenced <b>06/15/2009</b>		Completed <b>06/29/2009</b>		23. Distance to nearest well, Same Lease & Reservoir <b>NA</b>			
24. Location of well, relative to nearest lease boundaries of lease on which this well is located <b>666</b> Feet From <b>N Off Lease</b> and <b>986</b> Feet from <b>SE Off Lease</b> of the <b>Butler Unit</b>				25. Elevation (DF, RKB, RT, GR, ETC.) <b>789' GR</b>					
26. Was directional survey made other than inclination (Form W-12)? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No				27. Top of Pay <b>5719' TVD</b> 28. Total Depth <b>5852' TVD</b> 29. P.B. Depth <b>5855' TVD</b> 30. Surface Casing Determined by: <b>Field</b> <input type="checkbox"/> Recommendation of T.D.W.R. <input checked="" type="checkbox"/> Rules <input type="checkbox"/> Railroad Commission (Special) <input type="checkbox"/>					
31. Is well multiple completion? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No				32. If multiple completion, list all reservoir names (completions in this well) and Oil Lease or Gas ID No <b>FIELD &amp; RESERVOIR</b>				33. Intervals Drilled by: <input checked="" type="checkbox"/> Rotary Tools <input checked="" type="checkbox"/> Cable Tools	
34. Name of Drilling Contractor <b>Hi Tex</b>				35. Cementing Affidavit Attached? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No					
36 CASING RECORD (Report All Strings Set in Well)									
CASING SIZE	WT #/FT.	DEPTH SET	MULTISTAGE TOOL DEPTH	TYPE & AMOUNT CEMENT (sacks)	HOLE SIZE	TOP OF CEMENT	SLURRY VOL cu ft.		
<input checked="" type="checkbox"/> 7"	20#	<input checked="" type="checkbox"/> 394' GR	43 Sx	35:65 Poz A	<input checked="" type="checkbox"/> 9 7/8"	<input checked="" type="checkbox"/> Surface	<input checked="" type="checkbox"/> 307		
<input checked="" type="checkbox"/> 4 1/2"	11.6#	<input checked="" type="checkbox"/> 9073'	191 Sx	2 1/2 Ca Cl A	<input checked="" type="checkbox"/> 6 1/8"	<input checked="" type="checkbox"/> 4580'	<input checked="" type="checkbox"/> 606		
37. LINER RECORD									
Size		Top		Bottom		Sacks Cement		Screen	
38. TUBING RECORD									
Size		Depth Set		Packer Set		39. Producing Interval (this completion) Indicate depth of perforation or open hole			
						From <b>6253' MD/5821' TVD</b> To <b>6514' MD/5816' TVD</b>			
						From <b>6565' MD/5814' TVD</b> To <b>6826' MD/5821' TVD</b>			
						From <b>6877' MD/5822' TVD</b> To <b>7138' MD/5827' TVD</b>			
						From <b>7189' MD/5828' TVD</b> To <b>7450' MD/5833' TVD</b>			
40. ACID, SHOT, FRACTURE, CEMENT SQUEEZE, ETC.									
Depth Interval				Amount and Kind of Material Used					
<b>6253' MD/5821' TVD-8698' MD/5864' TVD</b>				<b>41K gal acid + 99K Bbls. water +</b>					
				<b>2.877mm # 100 mesh + 801K # 40/70</b>					
41. FORMATION RECORD (LIST DEPTHS OF PRINCIPAL GEOLOGICAL MARKERS AND FORMATION TOPS)									
Formations		Depth		Formations		Depth			
<b>Base Cretaceous</b>		<b>175' MD/TVD</b>							
<b>Mid-Atoka</b>		<b>5458' MD/5457' TVD</b>							
<b>Barnett Shale</b>		<b>5814' MD/5719' TVD</b>							
REMARKS <b>#39 Producing Interval Continued: From: 7501' MD/5835' TVD To: 7762' MD/5843' TVD</b>									
<b>7813' MD/5844' TVD 8074' MD/5853' TVD</b>									
<b>8125' MD/5854' TVD 8386' MD/5861' TVD</b>									
<b>8437' MD/5862' TVD 8698' MD/5864' TVD</b>									

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DEC 18 2009  
VALID PERMIT



RAILROAD COMMISSION OF TEXAS  
Oil and Gas DivisionGAS WELL  
CLASSIFICATION REPORT

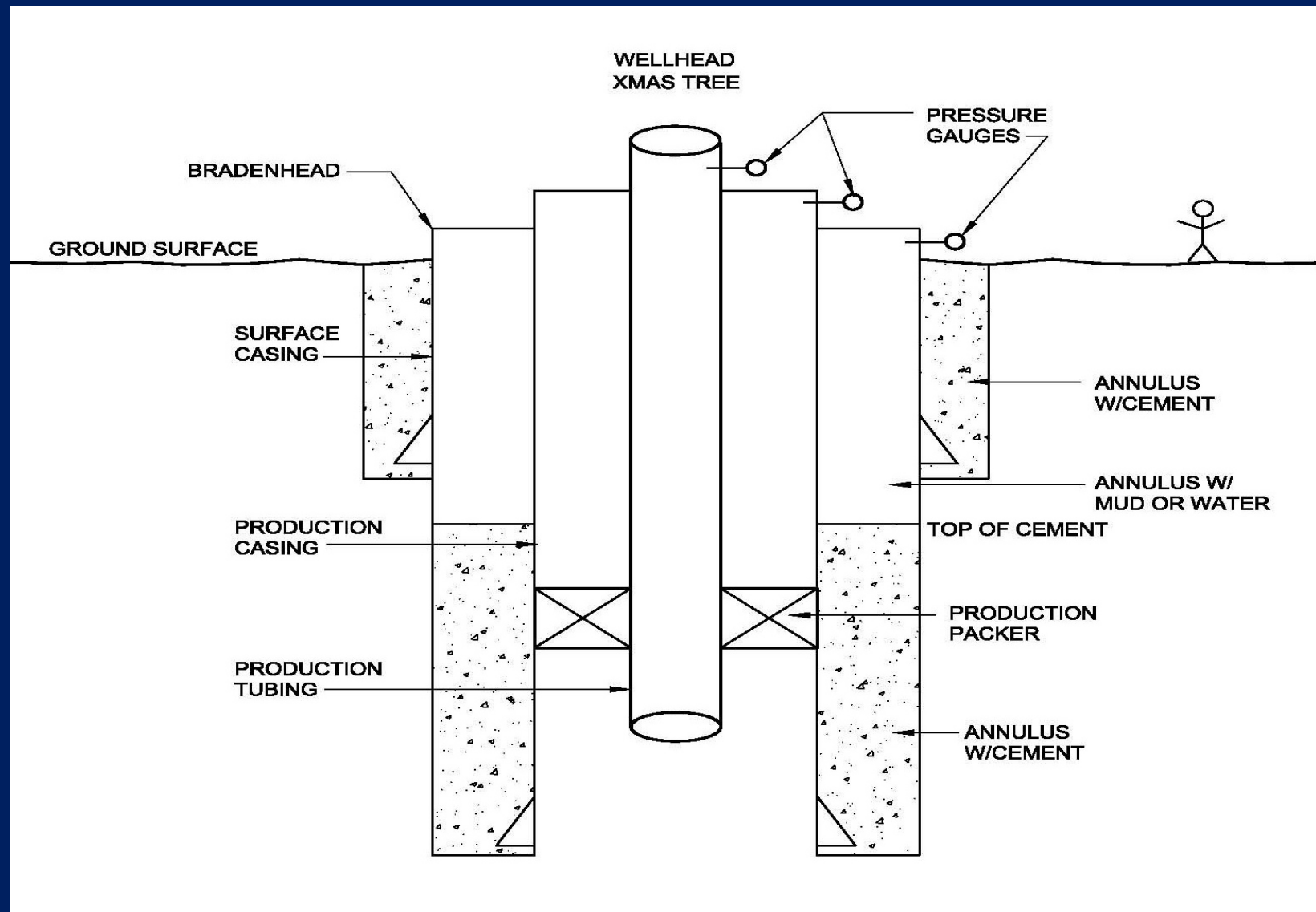
Form G-5

Rev. 01/01/86  
DBCI297

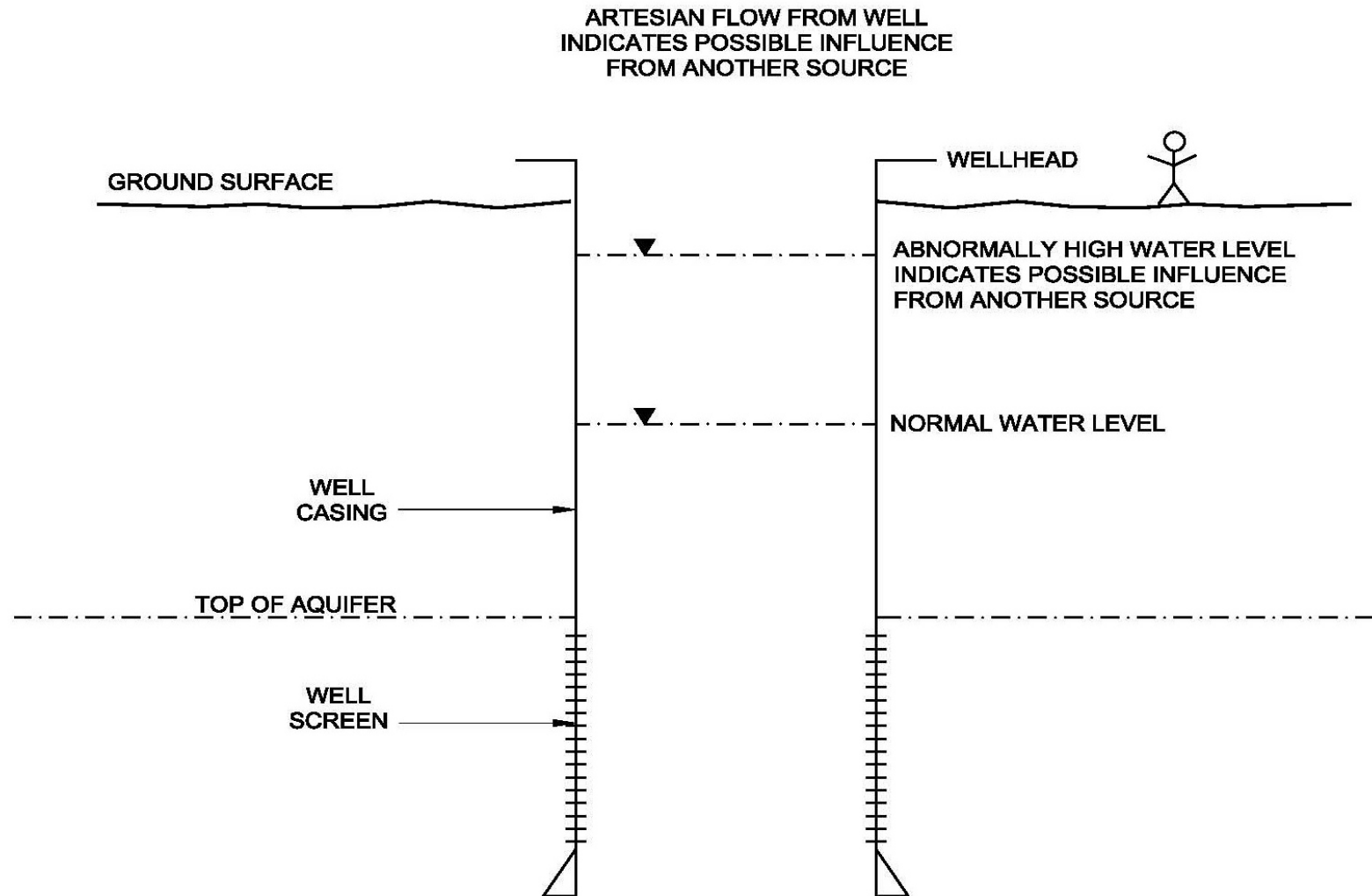
READ INSTRUCTIONS ON BACK

1. OPERATOR NAME (Exactly as shown on Form P-5 Organization Report) Range Production Company		3. RRC DISTRICT NO. 09	4. OIL LEASE NO. OR GAS WELL ID NO.
2. MAILING ADDRESS 100 Throckmorton, Suite 1200 Fort Worth, TX 76102		5. WELL NO. 1-H	6. API NO. 42-221-31798
7. COUNTY OF WELL SITE Hood			
8. FIELD NAME (as per RRC Records) Newark, East (Barnett Shale)		9. LEASE NAME Teal Unit	
10. LOCATION (Section, Block, and Survey) Sec Blk Atwood, J B A-802		11. PIPELINE CONNECTION OR USE OF GAS Paragrine Pipeline Company L.P.	
I. PRODUCTION TEST AT RATE ELECTED BY OPERATOR (Data on 24-hour basis)		II. A.S.T.M. DISTILLATION OF LIQUID SAMPLE. Distillation test is required for gas wells ONLY if the producing gas-liquid hydrocarbon ratio is less than 100,000 CF/boil.	
A. Date of Test: 08/31/2009		Data Liquid Sample Obtained: 8/31/09	
B. Gas Volume: 2015 (Mcf)		Where Obtained: <input type="checkbox"/> Separator <input type="checkbox"/> Stock Tank	
C. Oil or Condensate Volume: 22.0 (Bbl)		% Over Temp. (deg. F)	
D. Water Volume: 898 (Bbl)		Initial Boiling Temp. 160.7	
E. Gas/Liquid Hydrocarbon Ratio: 91591 (CCF/Bbl)		60 416	
F. Flowing Tubing Pressure: 365 (psia)		70 506	
G. Choke Size: 64/64 (in.)		80 614	
H. Casing Pressure: 1115 (psia)		90 620	
I. Shut-in Wellhead Pressure— Tubing: 1315 (psia)		95 622	
J. Separator Operating Pressure: 236 (psia)		End Point: 622 ✓	
K. Color of Stock Tank Liquid: green		Total Recovery: 95.80 percent	
L. Gravity of Separator Liquid: 52.0 °API		Residue: 4.00 ✓ percent	
M. Gravity of Stock Tank Liquid: 52.0 °API		Loss: 1.00 percent	
N. Specific Gravity of the Gas (Air = 1): .738			
I declare under penalties prescribed in Sec. 91.143, Texas Natural Resources Code, that I am authorized to make this report, that this report was prepared by me, or under my supervision and direction, and that data and facts stated therein are true, correct, and complete to the best of my knowledge.		RECEIVED RRC OF TEXAS JAN 06 2010 RECEIVED RRC OF TEXAS JAN 06 2010 O&G AUSTIN TX SJR 1/7/10	
DATE: 9/23/09		Melanie Dennis NAME (Type or Print) SIGNATURE: Melanie Dennis Regulatory Analyst TITLE: Melanie Dennis (817) 869-4158 CONTACT PERSON: PHONE NUMBER	

# Pressure Data from Gas Well



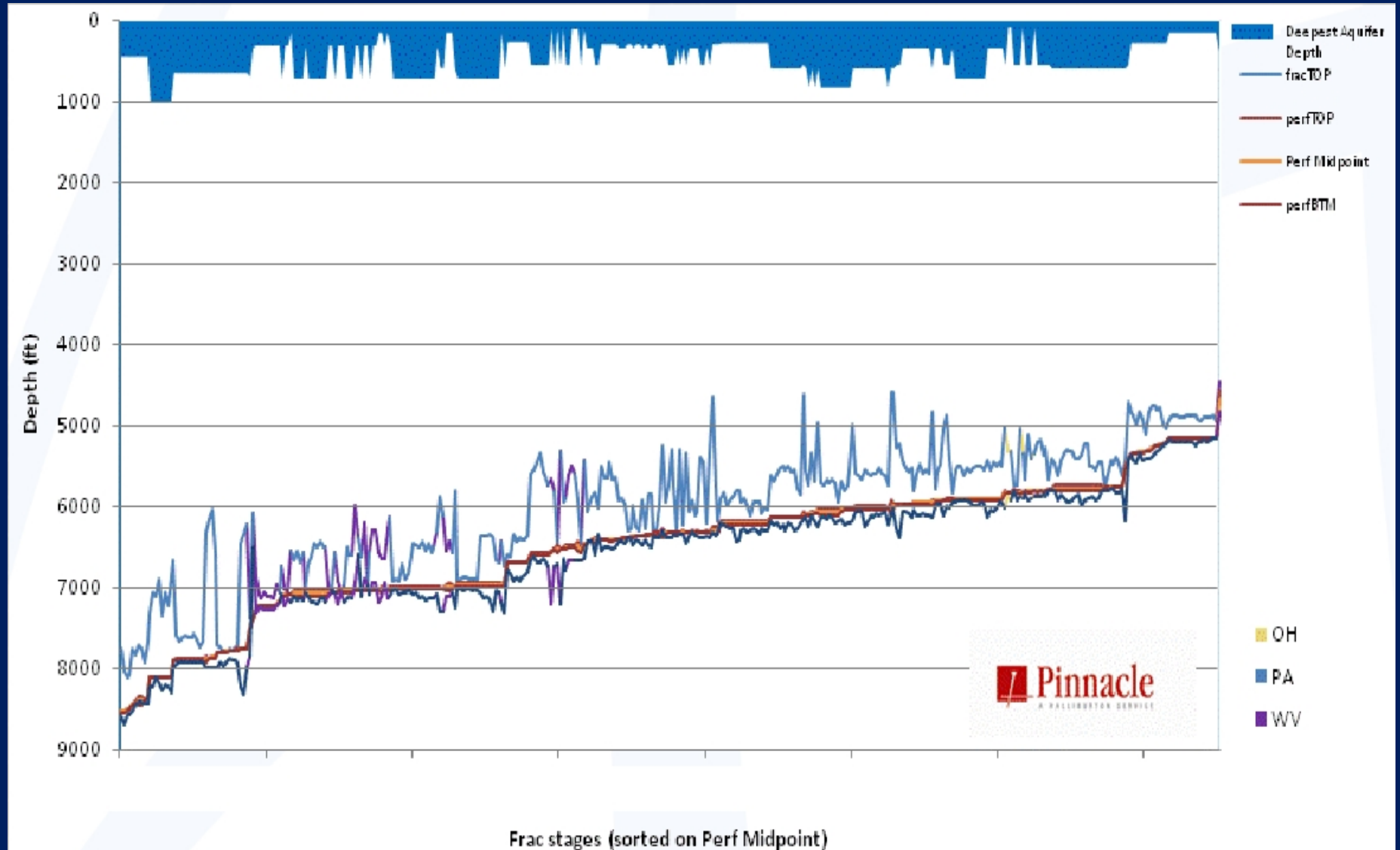
# Pressure Data from Water Well



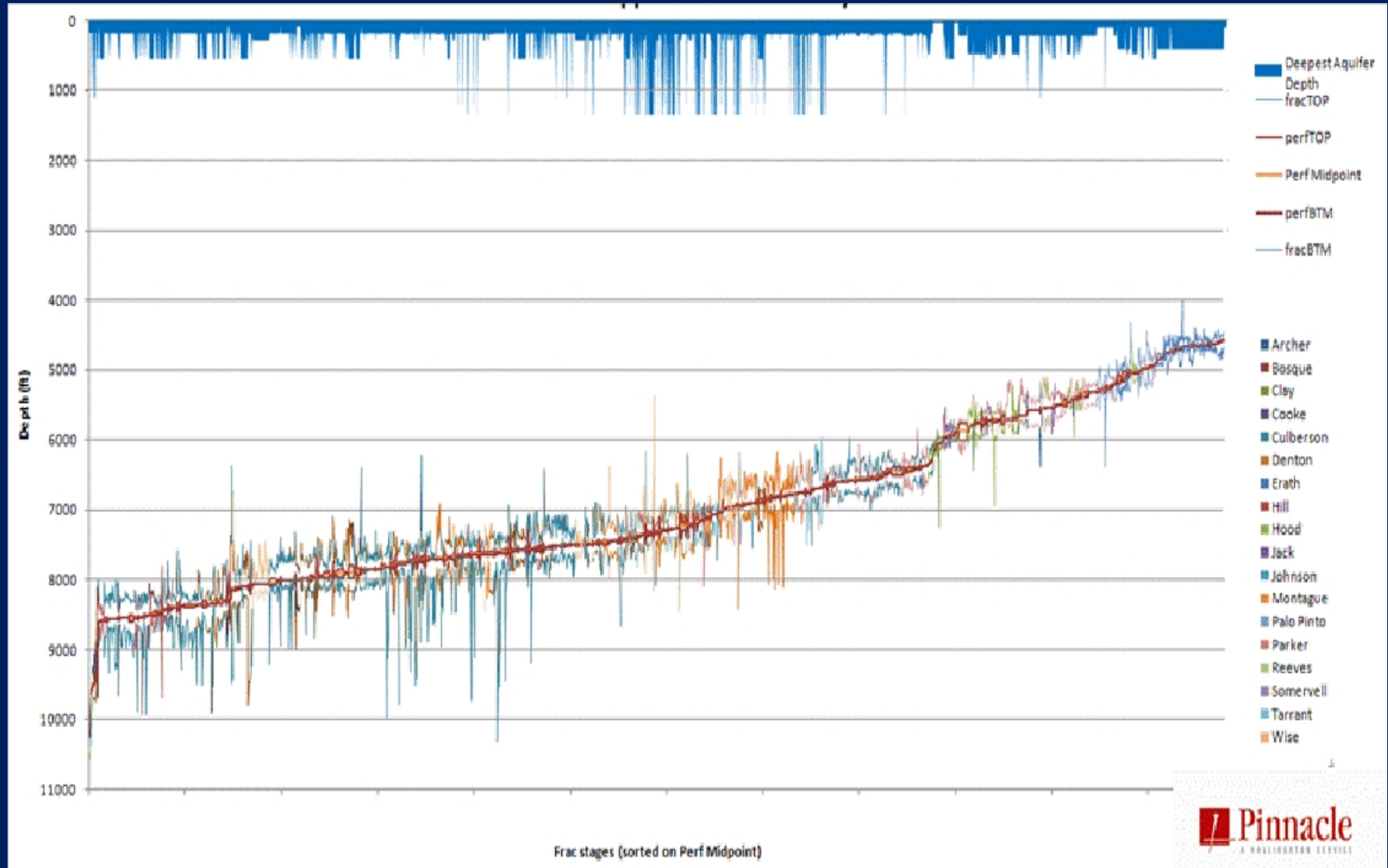
# Data on Frac Geometry

- Microseismic records the location of the mini-earthquakes generated by frac creation
- Microseismic not routinely run on frac jobs
- Data presented by industry based on relatively few data points
- Fractures may extend a max of 2,000' above or below perfs (usually only a few 100')
- Fractures 3,000' + below deepest aquifer

# Marcellus Shale Microseismic Cross Section



# Barnett Shale Microseismic Cross Section

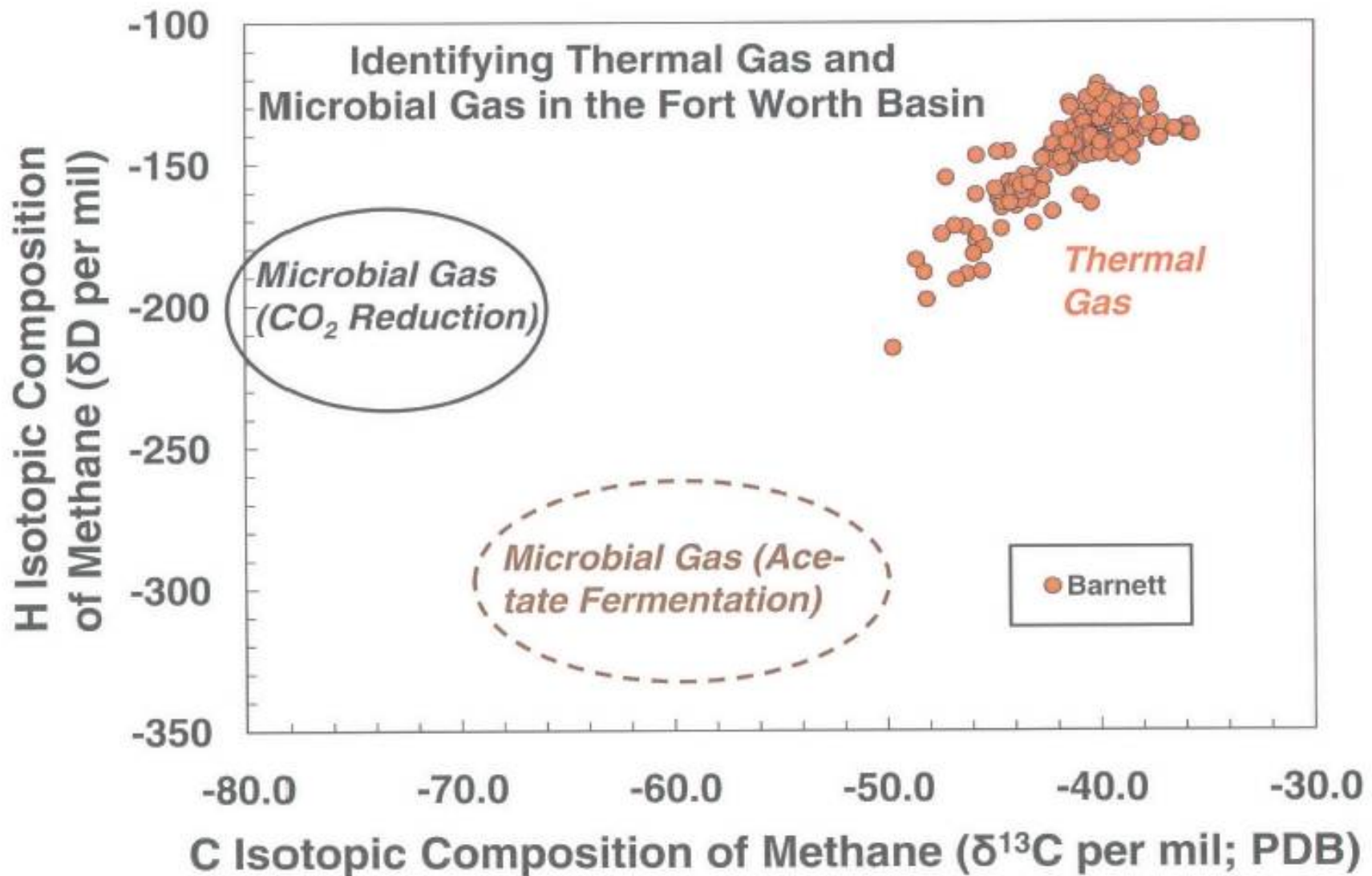


# Natural Gas Composition

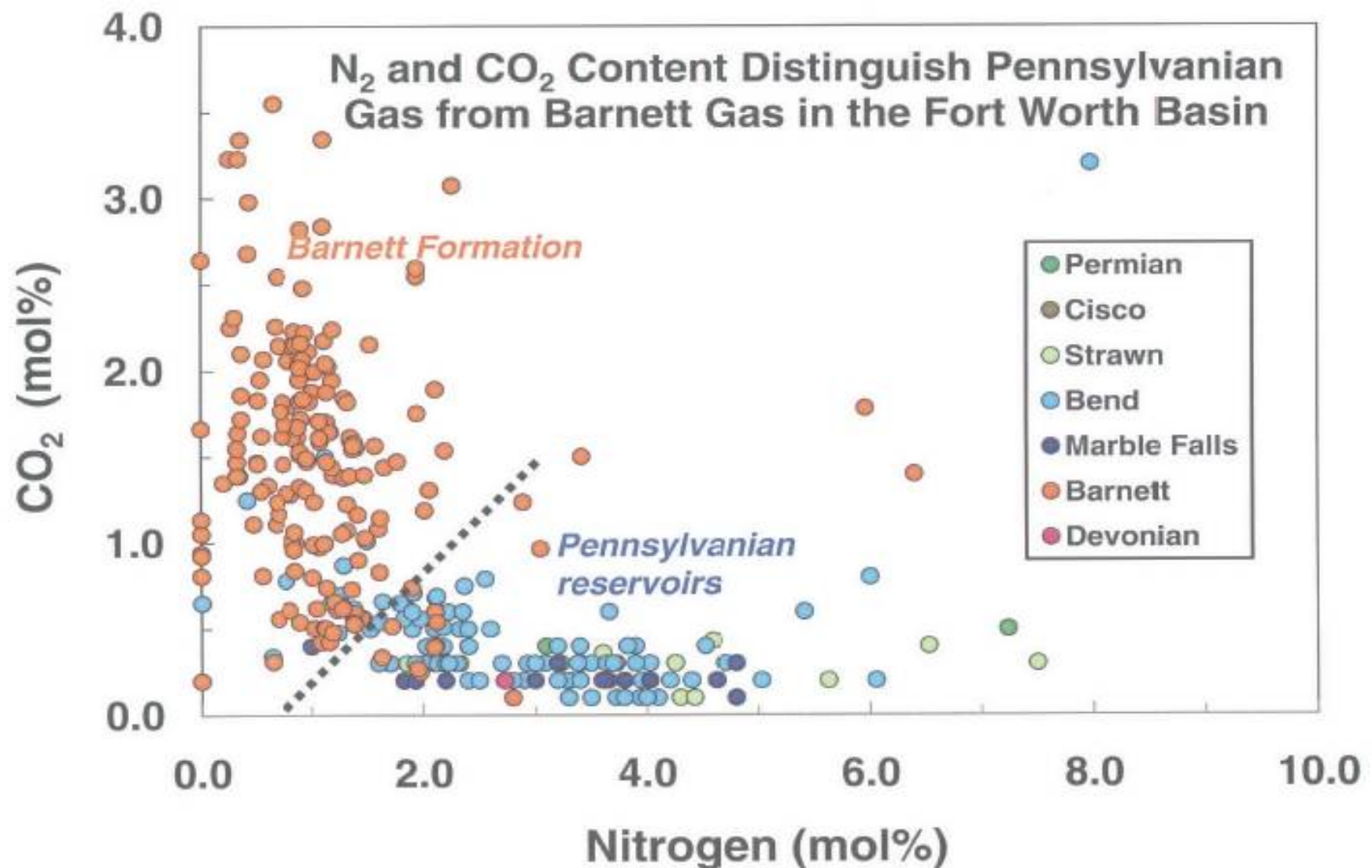
- Methane –  $\text{CH}_4$  – natural gas
  - Microbial gas
  - Thermal gas
  - Carbon & hydrogen isotopic composition
- Heavier gases
- $\text{N}_2$  and  $\text{CO}_2$  content



# Natural Gas Composition



# Natural Gas Composition



# Condensate Composition

- Gas well condensate composed of:
  - TPH (total petroleum hydrocarbons) mainly gasoline range organics
  - BTEX (benzene, toluene, ethylbenzene, xylenes) – marker constituents
  - VOC (volatile organic compounds)
  - PAH (polycyclic aromatic hydrocarbons)

# Water Composition (dissolved constituents)

- TPH - gas, diesel, & oil range organics
- BTEX – benzene, toluene, ethylbenzene, xylenes
- VOC – volatile organic compounds
- PAH – polycyclic aromatic hydrocarbons
- TPH, BTEX, VOC, & PAH not normally present in water well water

# Water Composition (dissolved constituents)

- Methane – CH<sub>4</sub> – natural gas
  - Lab analysis for methane & other gases
  - Flame ionization detector with carbon filter
  - Methane meter
  - Explosimeter
  - Light it?
  - Methane not normally present in high concentrations in water well water

# Water Composition

## (dissolved constituents)

- Minerals & salts – naturally occurring
- TDS (total dissolved solids) & chlorides measure dissolved minerals & salts in water
- TDS – total dissolved solids
  - Water wells (500 – 1,800 ppm)
  - Gas wells (typically > 20,000 ppm)
- Chlorides
  - Water wells (20 - 500 ppm)
  - Gas wells (typically > 20,000 ppm)

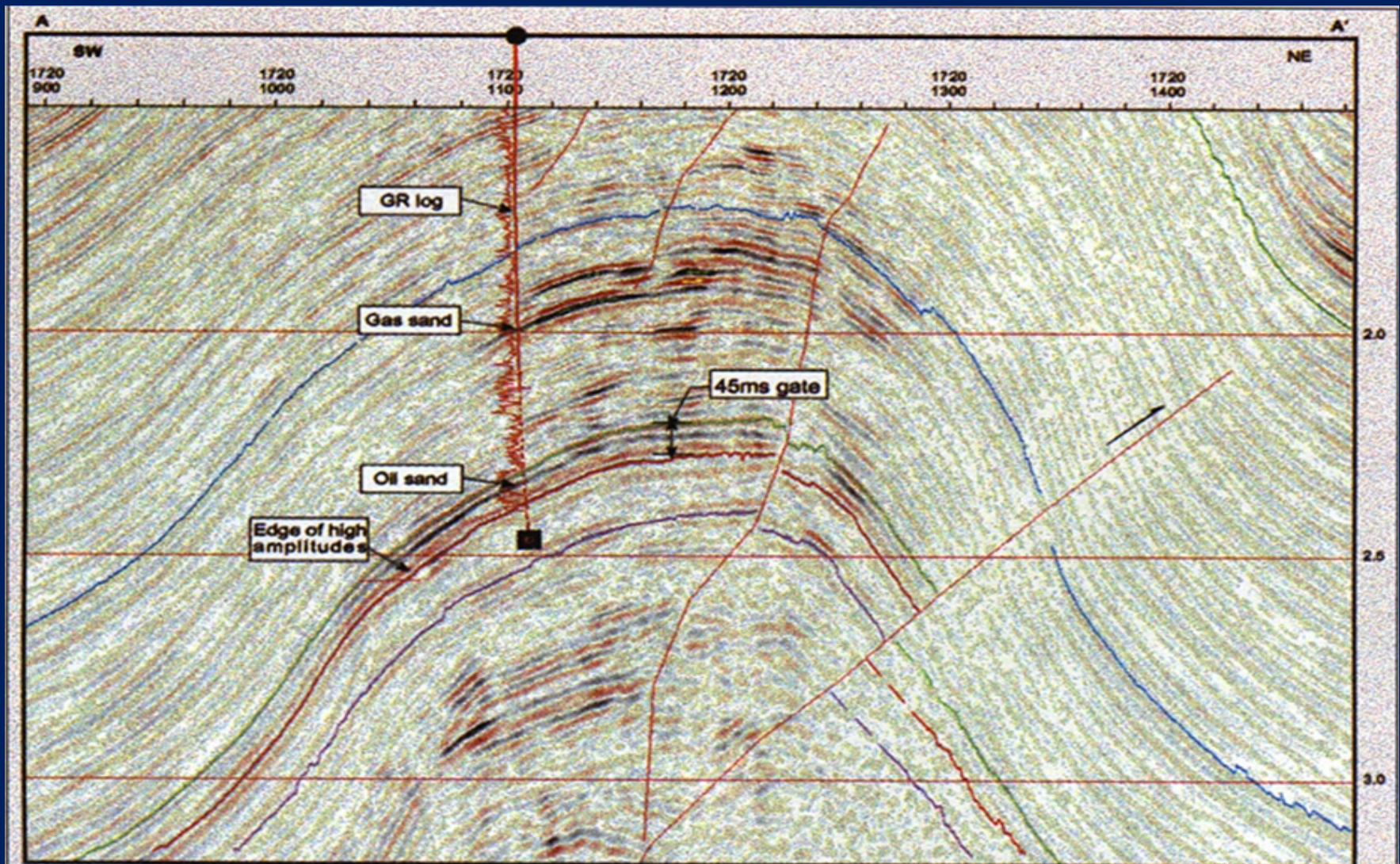
# Seismic Data

- Seismic or sound waves used to image the subsurface
- Analogous to sonograms
- Gas accumulations give a “bright spot” amplitude anomaly
- 3D seismic is available over most oilfields





# Seismic “Bright Spots”



# Seismic Data (Potential Problems)

- Timing of data acquisition relative to gas accumulation
- Seismic data focus may not yield useable data in shallow subsurface
- Zone of gas accumulation too thin for seismic resolution
- “Bright spot” not a unique solution for gas

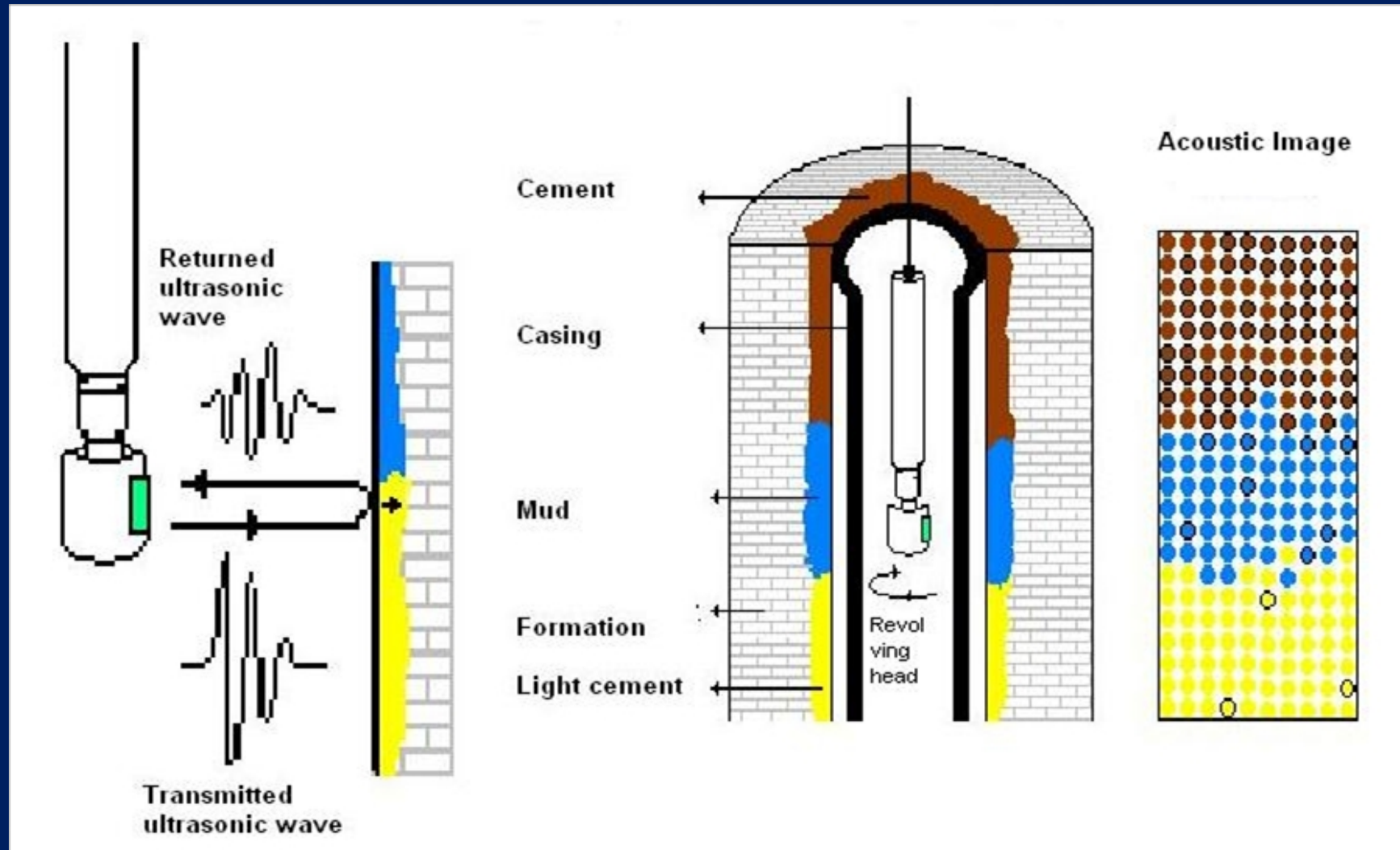


# Cement Bond Logs

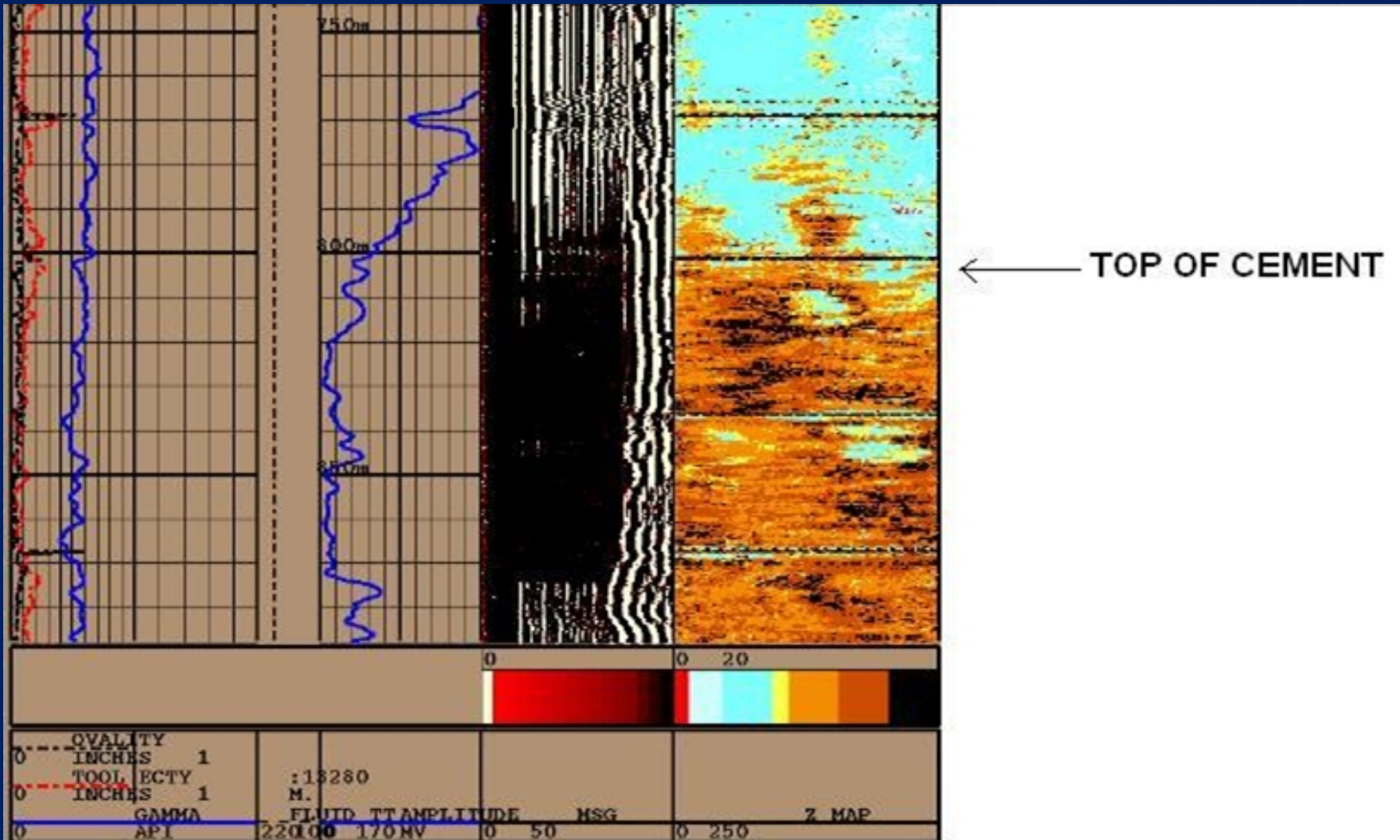
- Acoustic (sonic) device utilizes sound waves to image
- Analogous to sonograms
- Free pipe returns a much greater amplitude signal than cemented pipe
- Amplitude display
- VDL (variable density log) display



# Principles of the Cement Bond Log



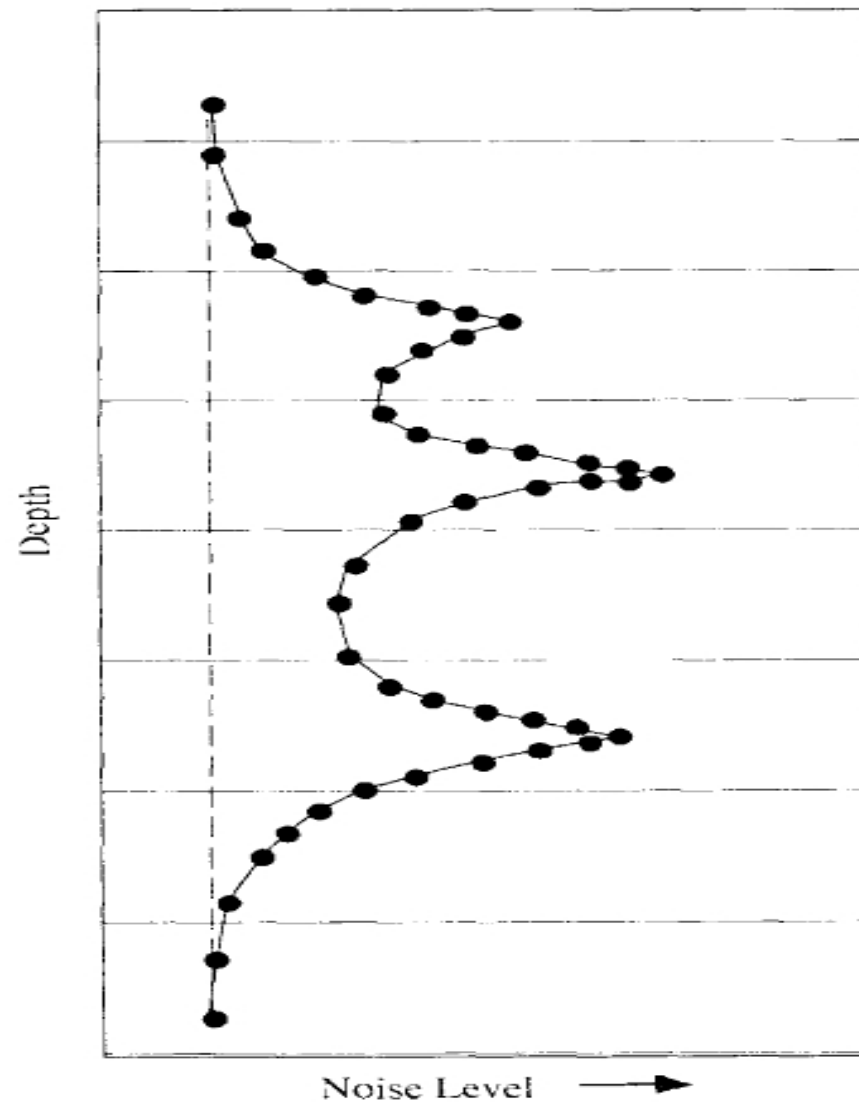
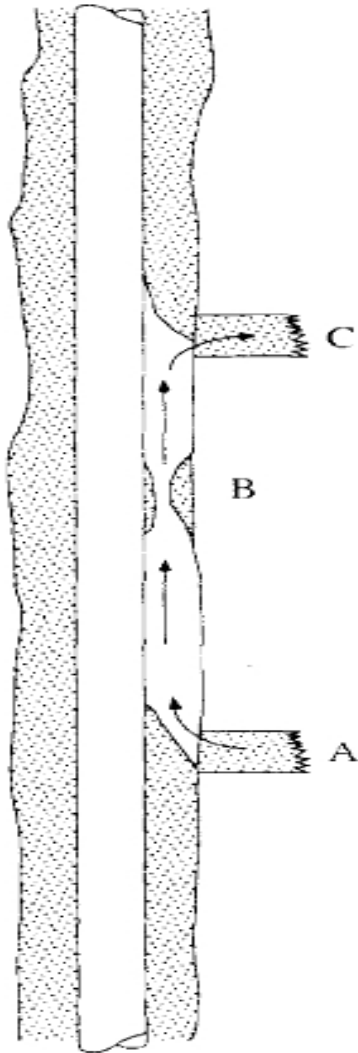
# Cement Bond Log Presentation



## Noise Logs (Sound Surveys)

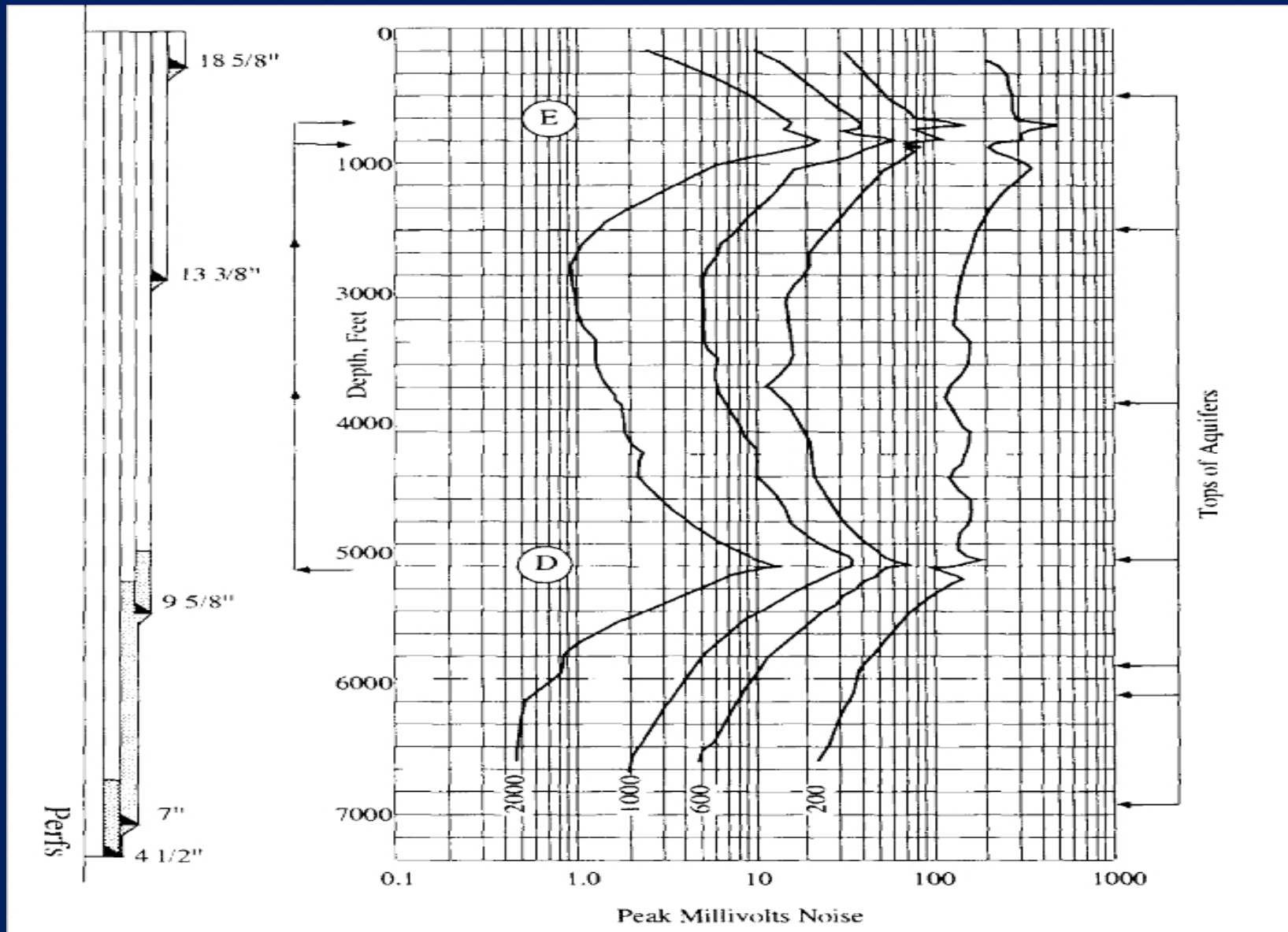
- Sensor is an underwater microphone (hydrophone)
- Will detect flow within wellbore or behind pipe
- Turbulent fluid flow
- Gas expansion
- Disturbance of gas/liquid interface

# Noise Logs (Sound Surveys)





# Noise Logs (Sound Surveys)



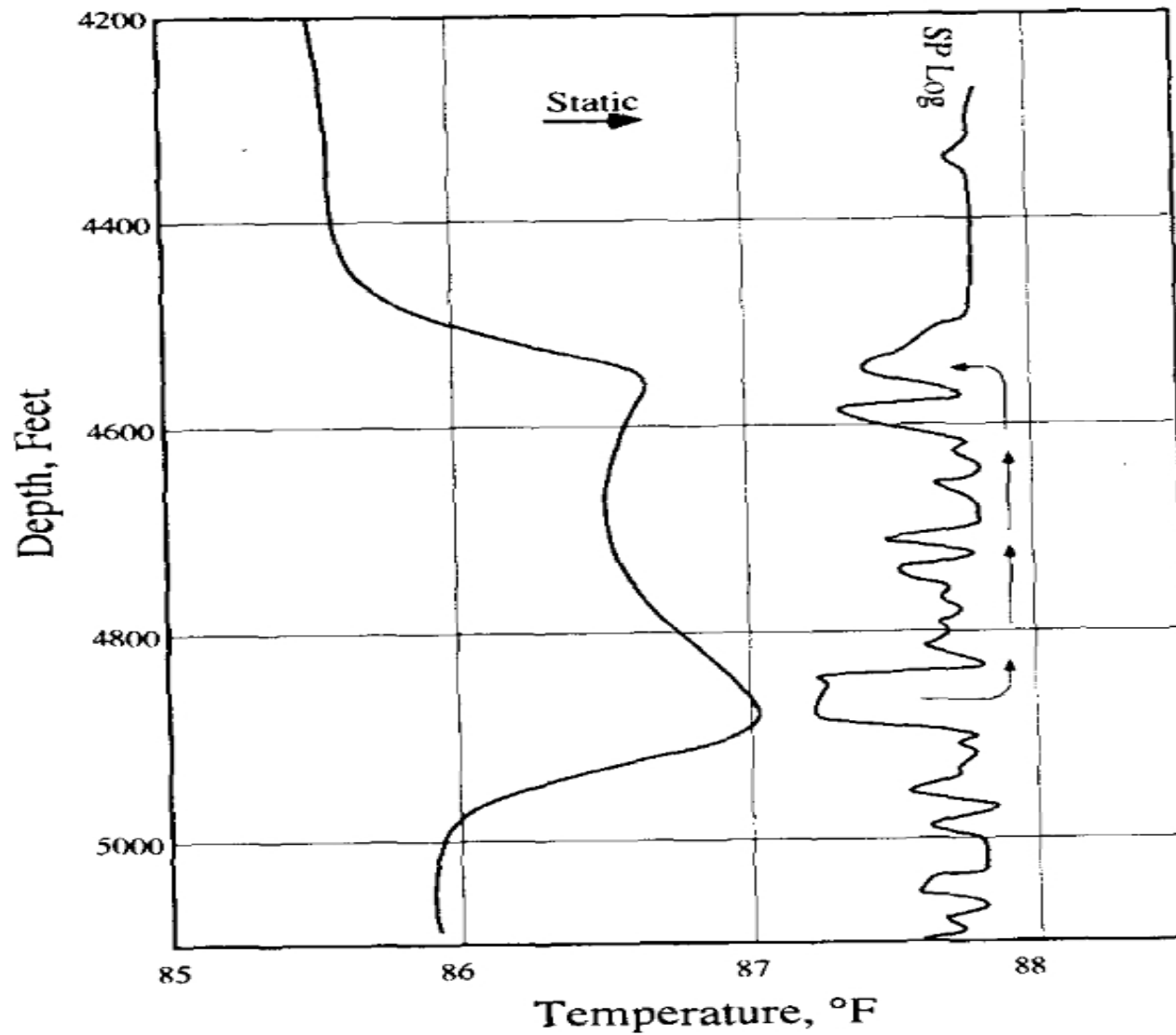
# Temperature Logs

- Temperature increases with depth – normal geothermal gradient
- Anomalies created by fluids or gas entering wellbore or annulus or exiting into formation
- Identify zones producing or taking fluid
- Evaluating cement jobs
- Evaluating frac jobs

# Temperature Logs

- EPA Underground Injection Control (UIC) program approves temperature logs to demonstrate well mechanical integrity –  
“no significant fluid movement into an underground source of drinking water through vertical channels adjacent to the injection wellbore”.

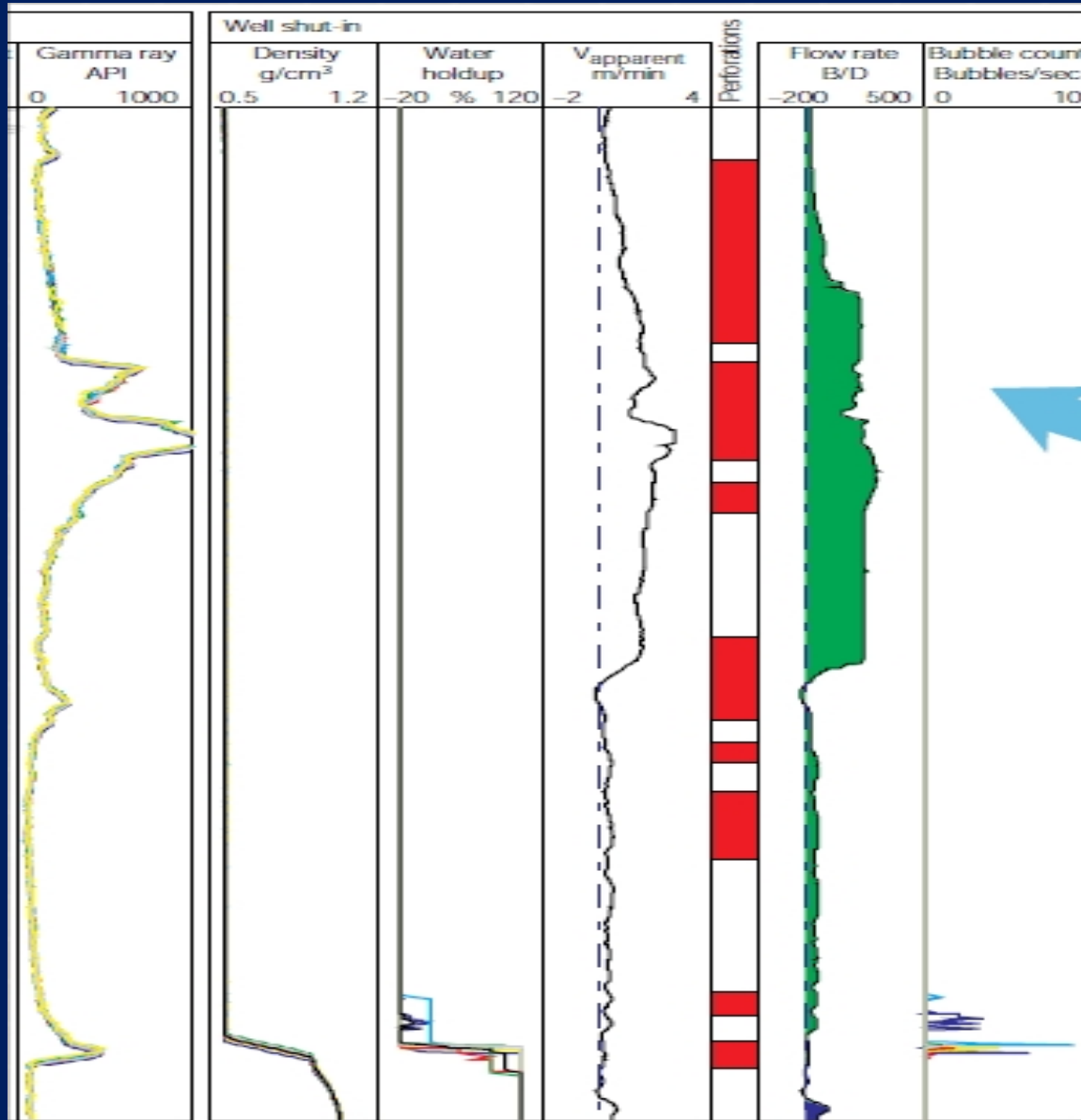
# Temperature Logs



# Gamma Ray Logs

- Measures natural gamma ray emissions from the formation
- Shales – high gamma ray emissions
- Sands, limestones – low gamma ray emissions
- Migration of fluids within & adjacent to the wellbore deposits radioactive salts & zones of migration often marked by high gamma ray emissions

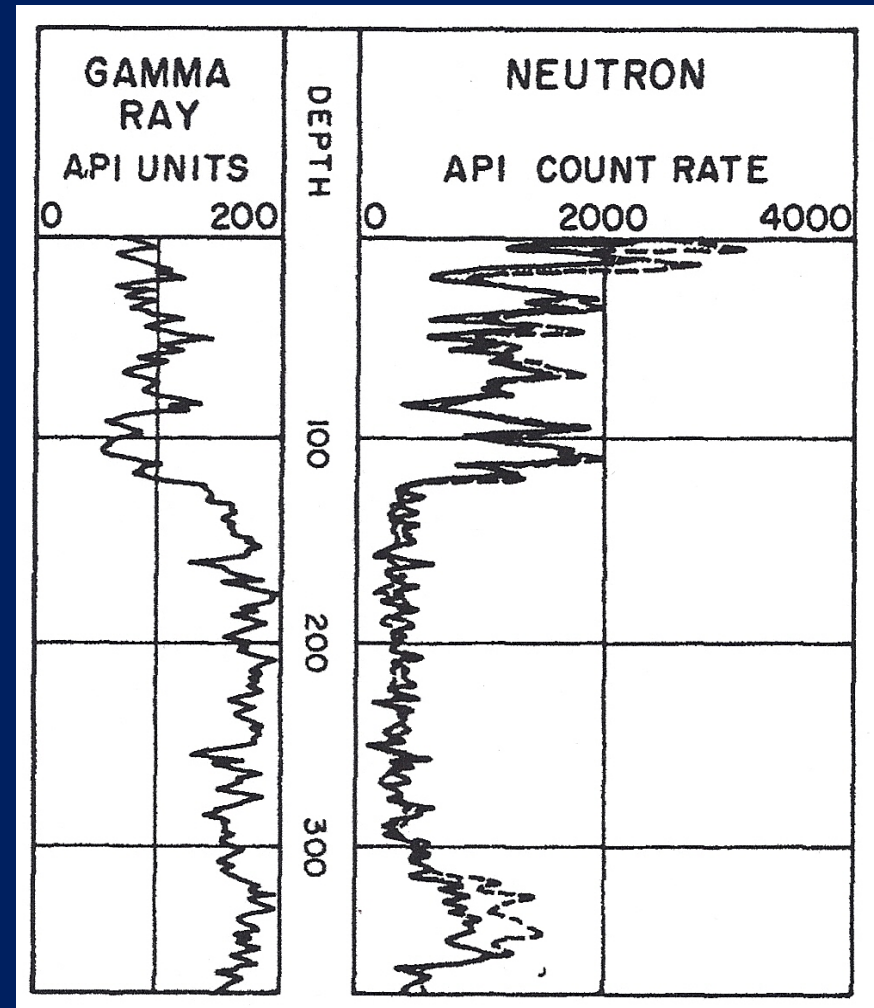
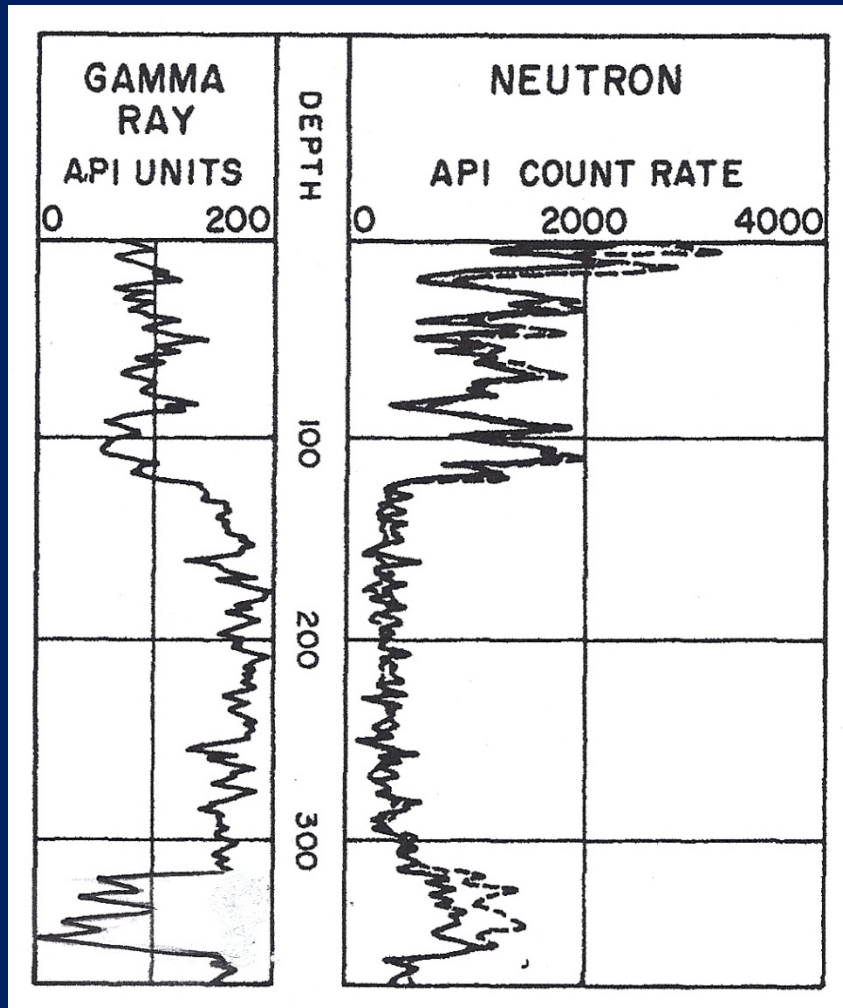
# Gamma Ray Logs



# Gamma Ray/Neutron Logs

2000

2010





# Radioactive Tracers

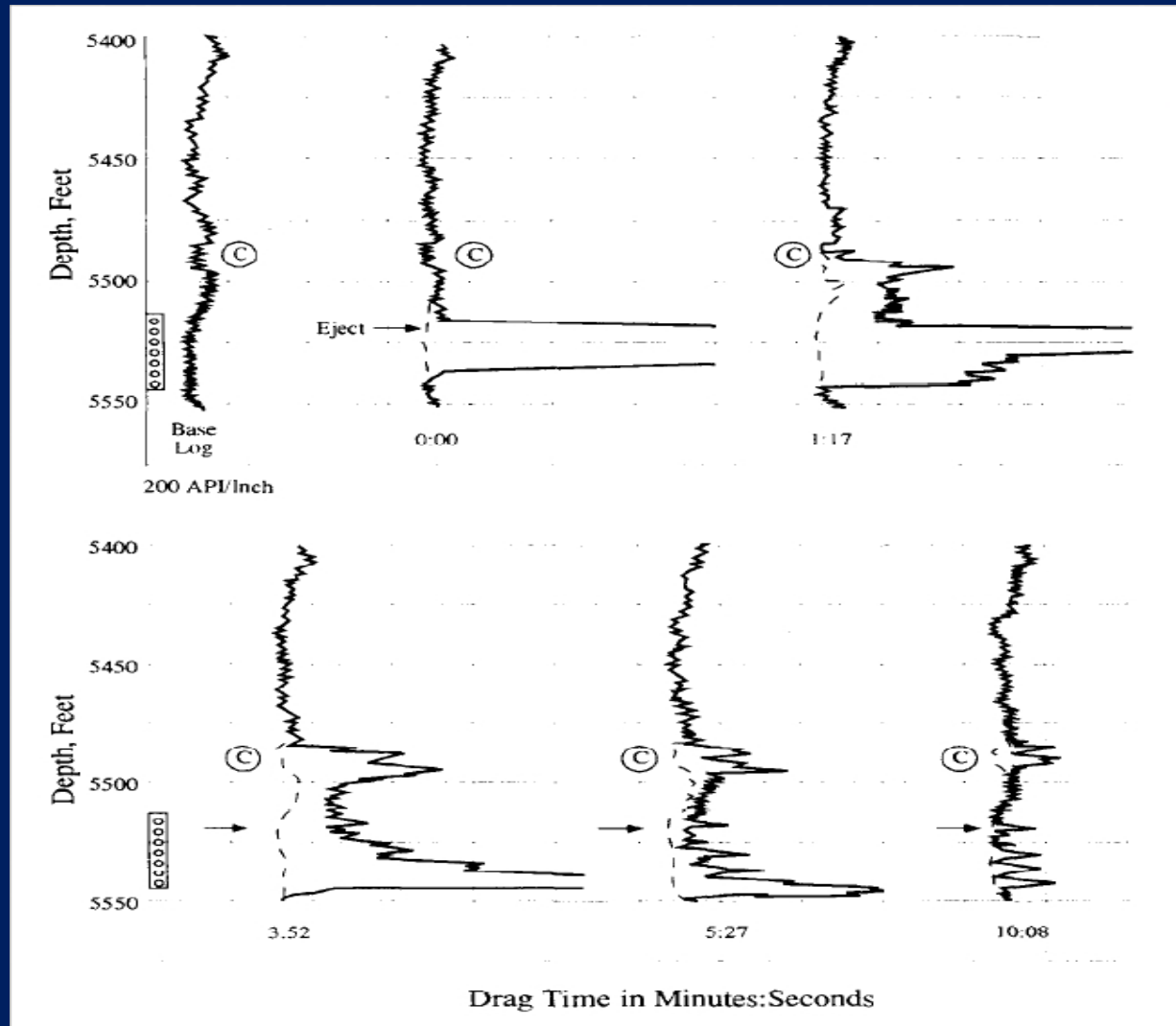
- Tracer is a radioactive isotope that is soluble in gas, oil, and water (iodine; half life 8.1 days)
- Gamma radiation emitted by the tracer is detected by a gamma ray tool
- Gamma radiation penetrates steel, PVC pipe, cement, & formation
- 90% of gamma radiation recorded originates within 1 foot of the detector

# Radioactive Tracers

- Tool can inject tracer and record gamma emissions simultaneously
- Fluid movement & velocity & volume can be monitored within a well, behind casing, & between wells

# Radioactive Tracers

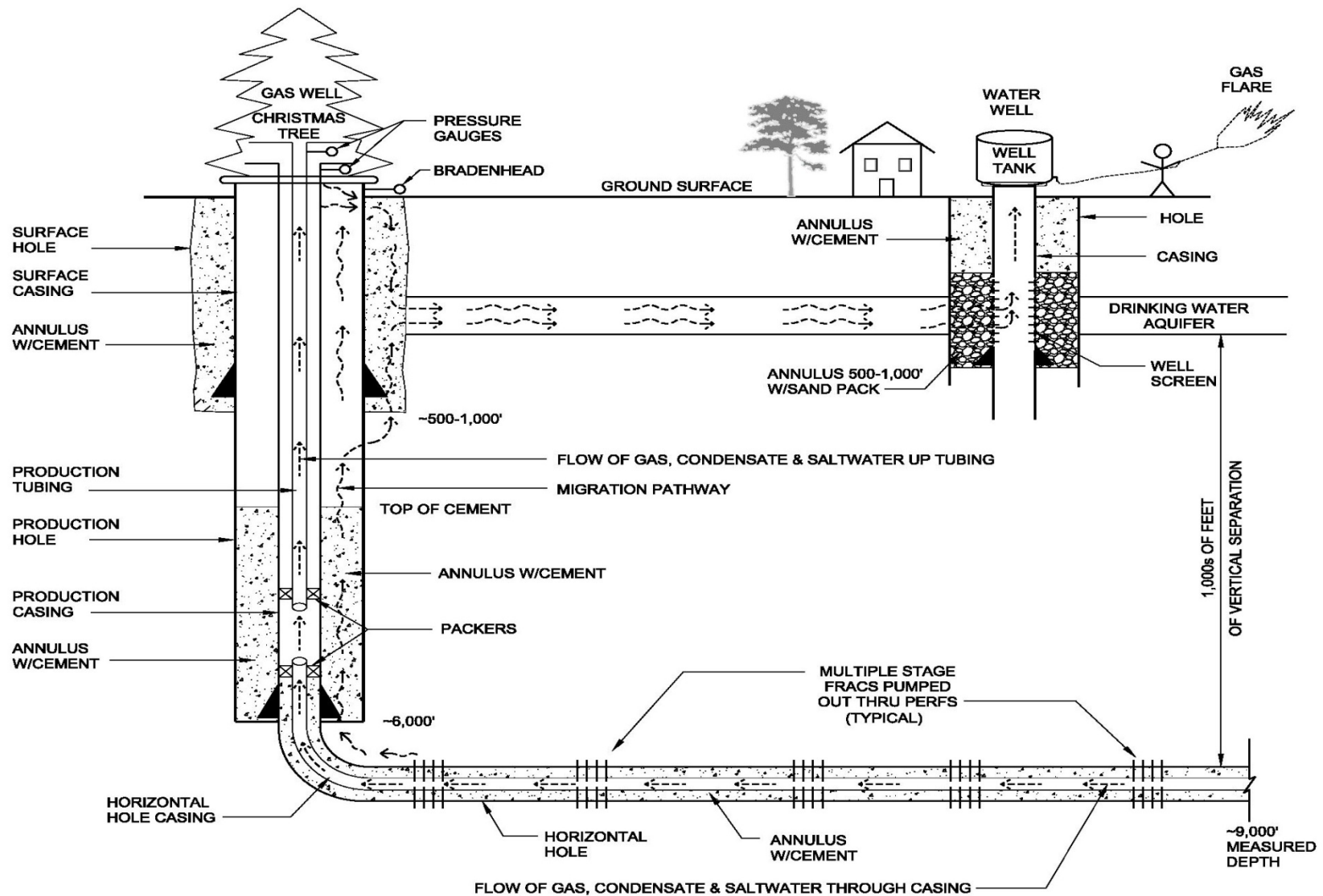
(Well on injection into perfs; 5-log runs presented on separate logs; flow behind casing into Sand C)



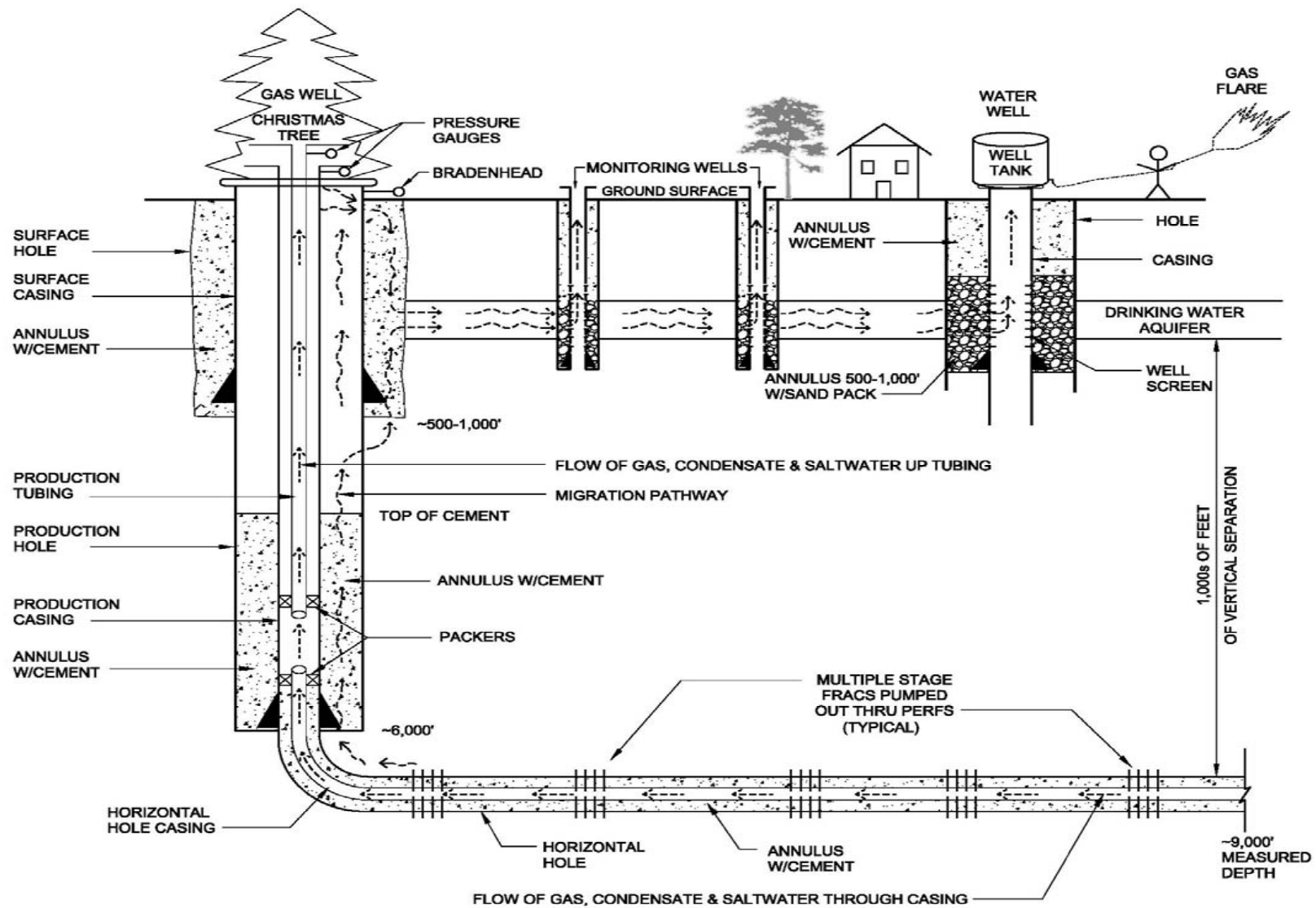
# Pressure Interference Tests

- Downhole pressure gauge installed in the water well
- Pressure wave created in gas well by producing well & shutting it in intermittently
- Pressure changes recorded in water well
- Cross contamination requires hydraulic connection between gas well & water well

# Pressure Interference Tests



# Installation of Monitoring Wells



# Summary

- 18 different investigative tools – can we solve the contamination problem??
- Choose the most time effective tools
- Choose the most cost effective tools
- Choose the tools that will support our case
- Find the “truth”



“And ye shall know the truth and the truth shall make you free.”

- Oil companies – “it has never been proven that an oil or gas well has contaminated an aquifer.”
- Environmentalists – “every oil and gas well has contaminated all our aquifers.”

# GAS WELL/WATER WELL SUBSURFACE CONTAMINATION

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