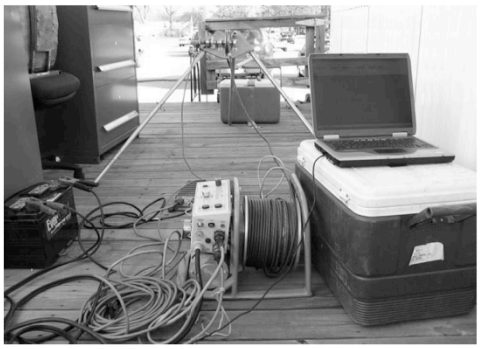
Borehole Geophysics Applied to Bedrock Hydrogeologic Evaluations



Don Bussey, CPG-08847
USEPA/ERT – Las Vegas, Nevada
bussey.don@epa.gov

1

Borehole Geophysical Tools:

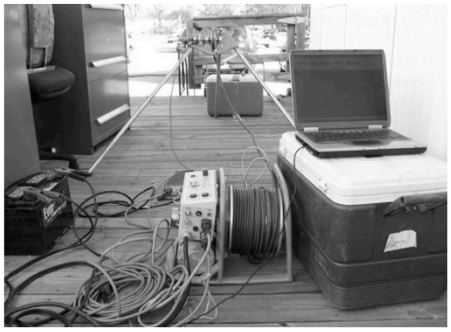
Hydrogeologic Bedrock Groundwater Assessments

- Natural Gamma
- Temperature
- Caliper
- Conductivity/Resistivity
- Borehole Video
- Heat-Pulse Flowmeter
- Optical and Acoustical Televiewer
- Borehole Deviation

Oil and Gas Well Abandonments

- Casing Collar Locator (Magnetic)
- Cement Bond (Acoustic)

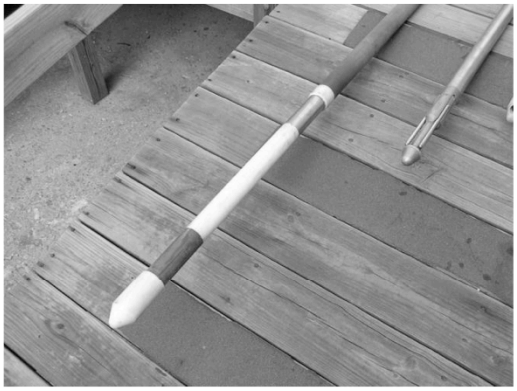
2



3

4

Natural Gamma Logging

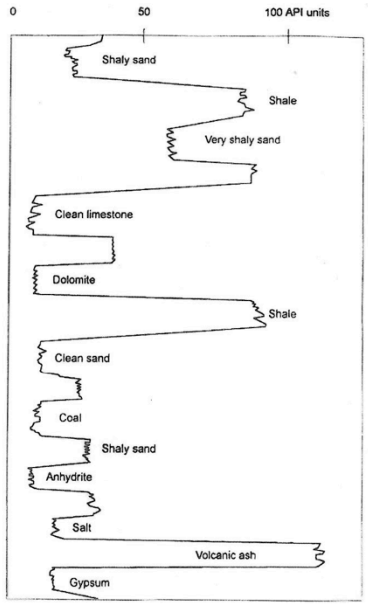


- Gamma logging is useful in evaluating stratigraphic sequences and for borehole to borehole correlation.
- Can be used in open or cased boreholes.

5

GR Log

General GR Response



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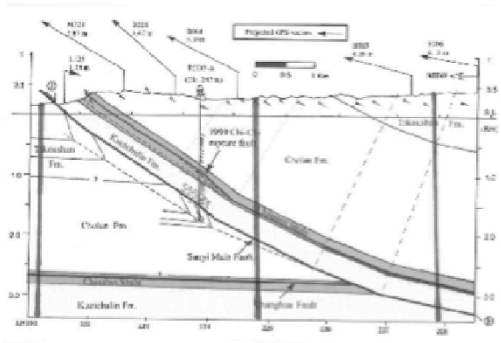
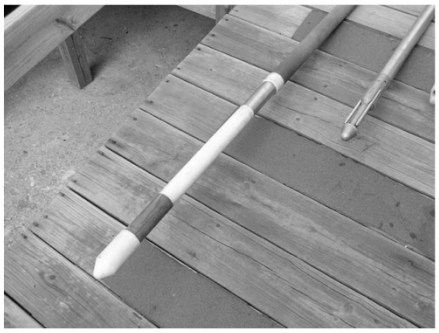

Chaoshan Fm.
Kanchalin Fm.
Chelungpu Fault
Chaoshan Fm.
Chelungpu Fault
Kanchalin Fm.

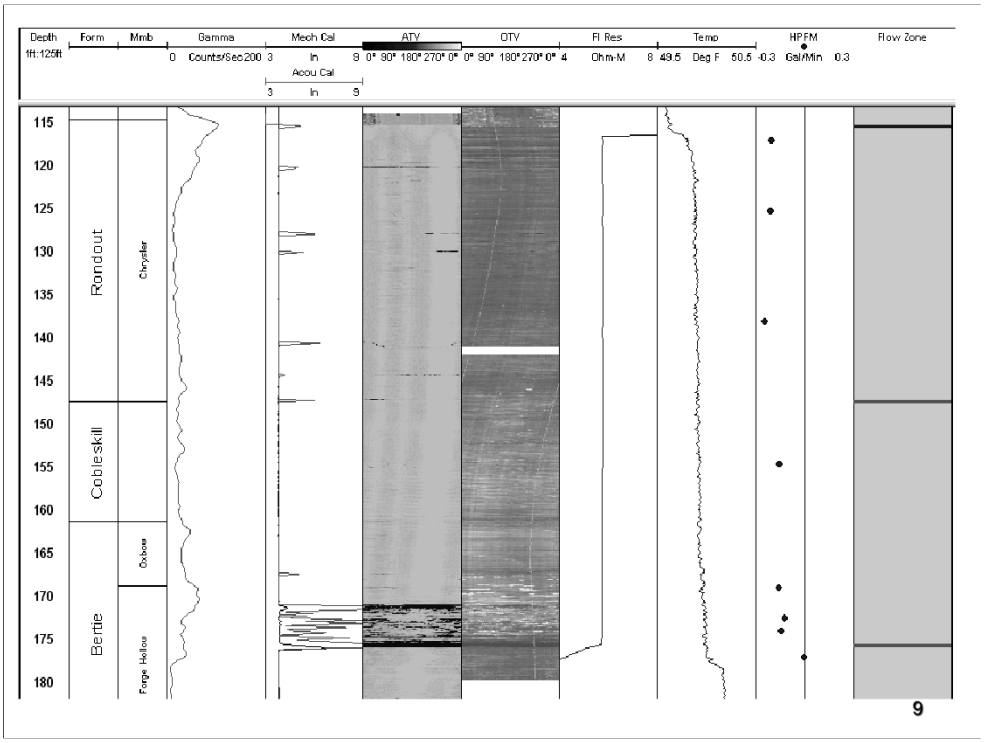
7

Temperature Logging



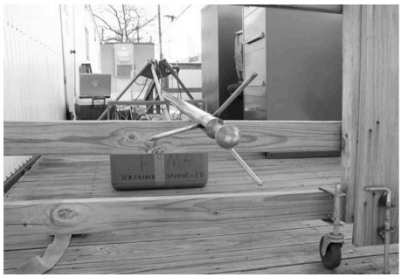
Temperature logging can aid in detection of groundwater flow in or out of a borehole.

8


Depth
1ft:125ft
Form
Mmb
Gamma
0 Counts/Sec 200
Mech Cal
3 In 9
Accu Cal
3 In 9
ATV
0° 90° 180° 270° 0°
OTV
0° 90° 180° 270° 0°
Fl Res
4 Ohm-M 8
Temp
49.5 Deg F 50.5
HPFM
-0.3 Gal/Min 0.3
Flow Zone
115
120
125
130
135
140
145
150
155
160
165
170
175
180
Rondout
Cobleskill
Bertie
Chrysler
Oxbow
Forge Hollow
9

Caliper Logging

Caliper logging measures borehole diameter, useful in detecting fractures or voids in **open-hole bedrock** boreholes.



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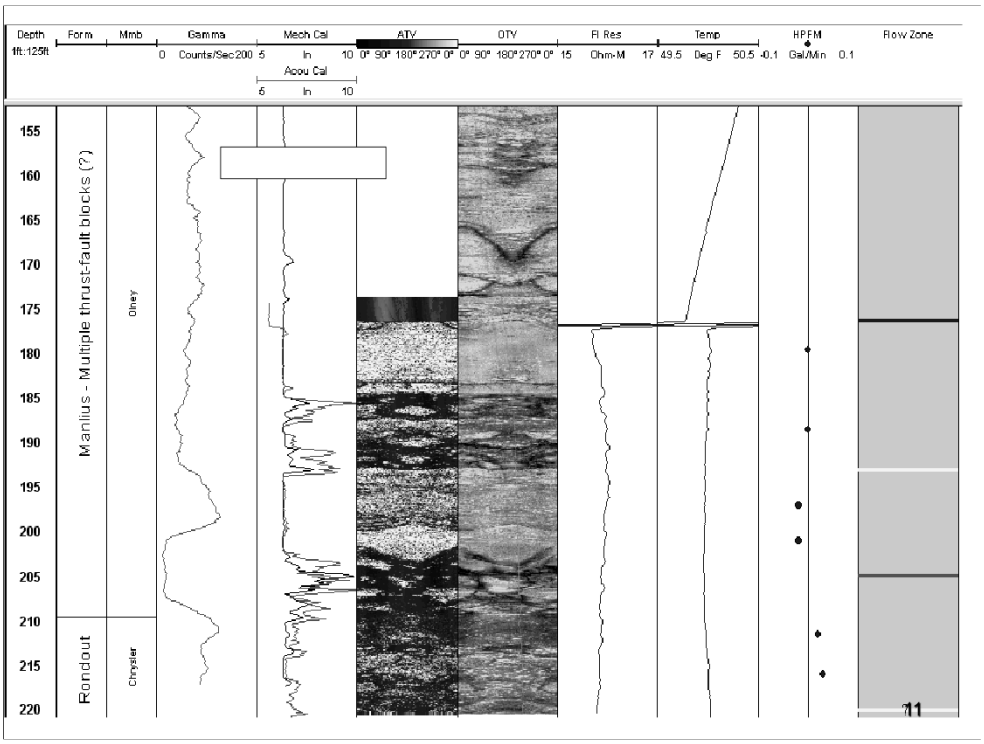
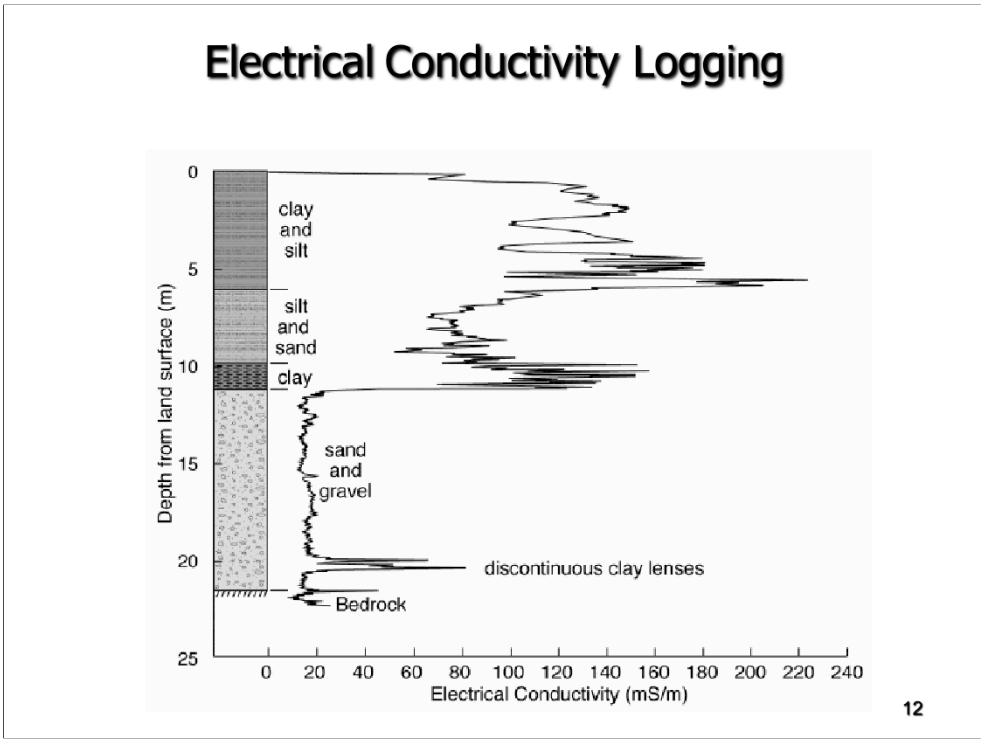

Depth
1ft:125ft
Form
Mmb
Gamma
0 Counts/Sec 200
Mech Cal
5 In 10
Acou Cal
5 In 10
ATV
0° 90° 180° 270° 0°
OTV
0° 90° 180° 270° 0°
Fl Res
15 Ohm-M 17
Temp
49.5 Deg F 50.5
HPFM
-0.1 Gal/Min 0.1
Flow Zone
155
160
165
170
175
180
185
190
195
200
205
210
215
220
Manlius - Multiple thrust-fault blocks (?)
Rondout
Olney
Chrysler
11

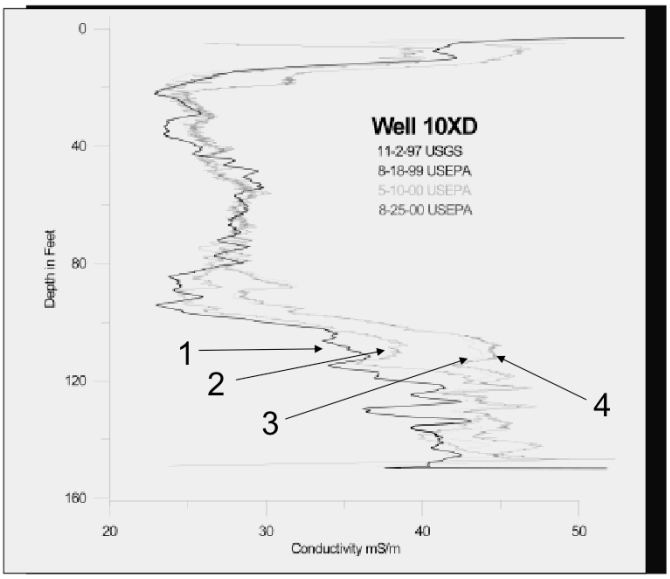


Once again we are mentioning water, and water is a big "drain" on GPR signals.

Dielectric permittivity is the ability to store & transmit energy where conductivity is the abillity to conduct currentAs conductivity increases, the penetration depth also decreases. This is because the electromagnetic energy is more quickly dissipated into heat, causing a loss in signal strength at depth

Conductivity of materials (the ability to transmit energy – differs from RDP in that it is incapable of storing energy)

Conductivity Case Study



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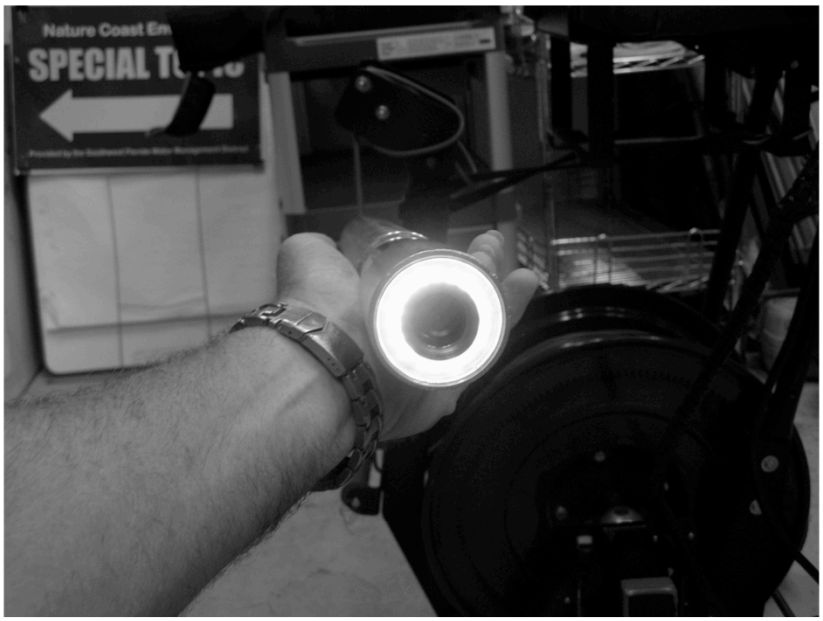
Borehole Video Logging

Borehole video logging provides a visual picture of borehole conditions.

Useful in identifying fractures, voids, cascading water, well/boring blockage and other downhole trouble shooting.

14



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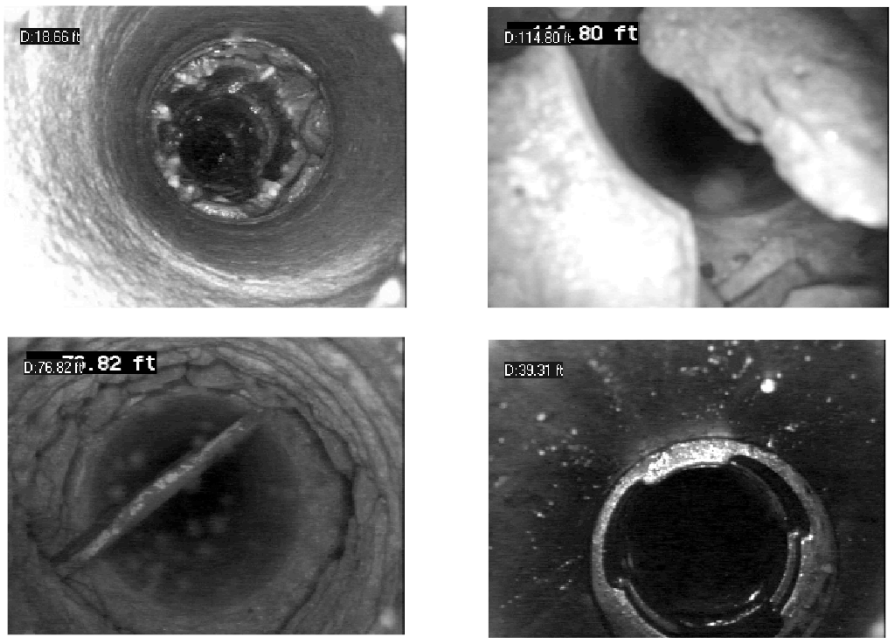
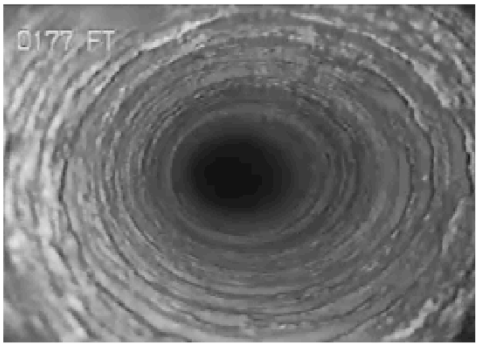
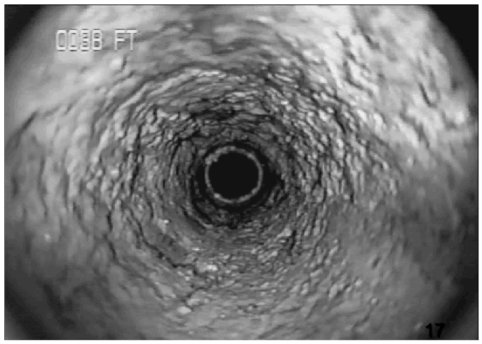


16

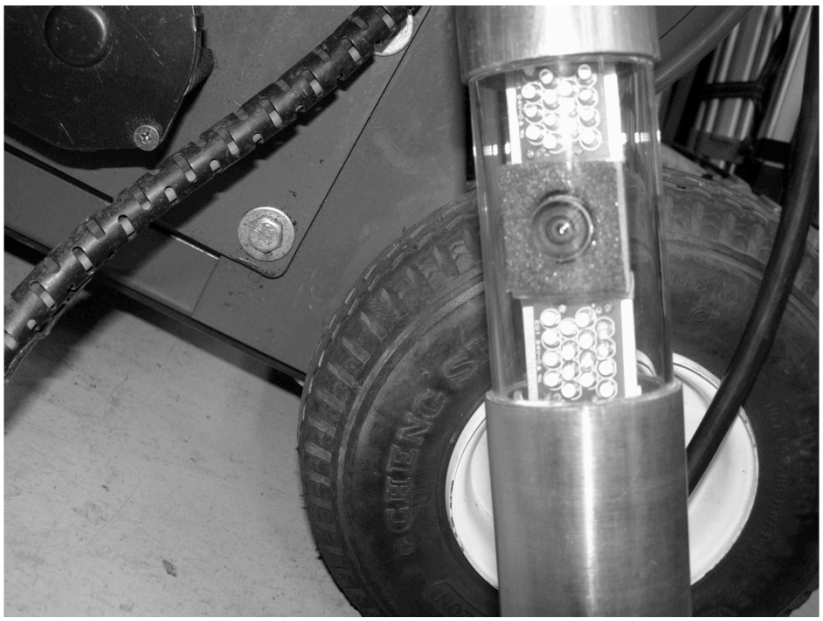

0177 FT


0338 FT

Borehole Video

18

This is a video of a borehole video camera going down a open rock well. There are several instances of water coming into the well from the side, most of them are just dribbles of water. At the end of the video water is shooting out of the right side of the hole wall. Notice the difference between this and the optical televiewer.



19

20

Optical and Acoustical Televiewer Logging

- Televiewer logging presents a 360-degree acoustical or optical digital borehole representation.
- Useful in evaluating fractures, bedding, and voids.
- Strike and dip of fractures can also be calculated.

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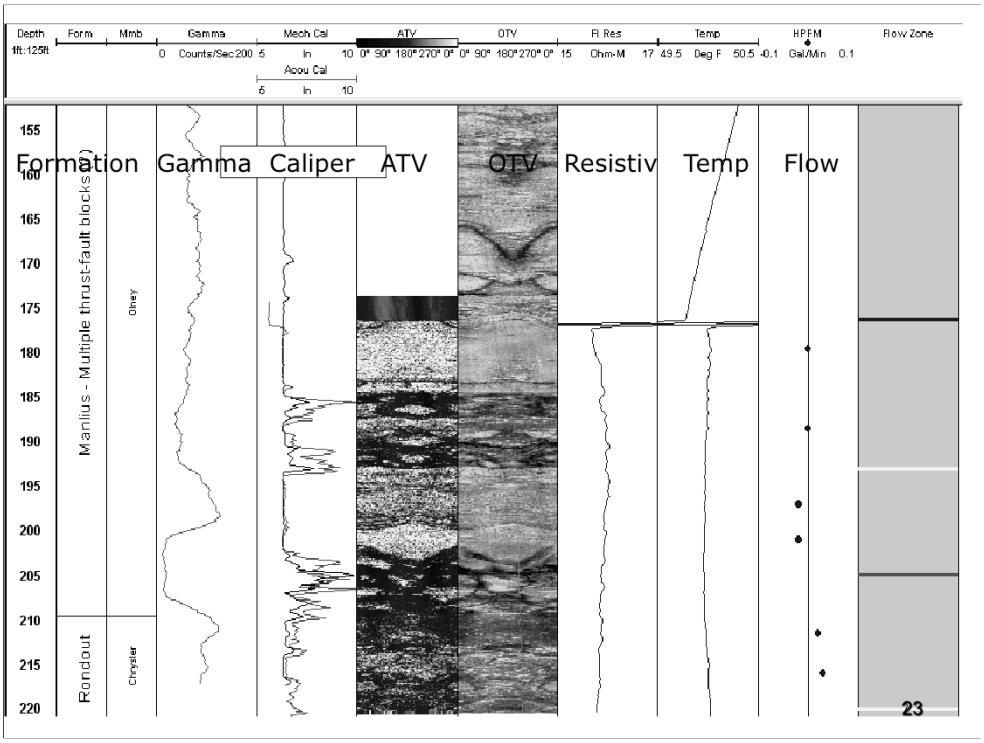
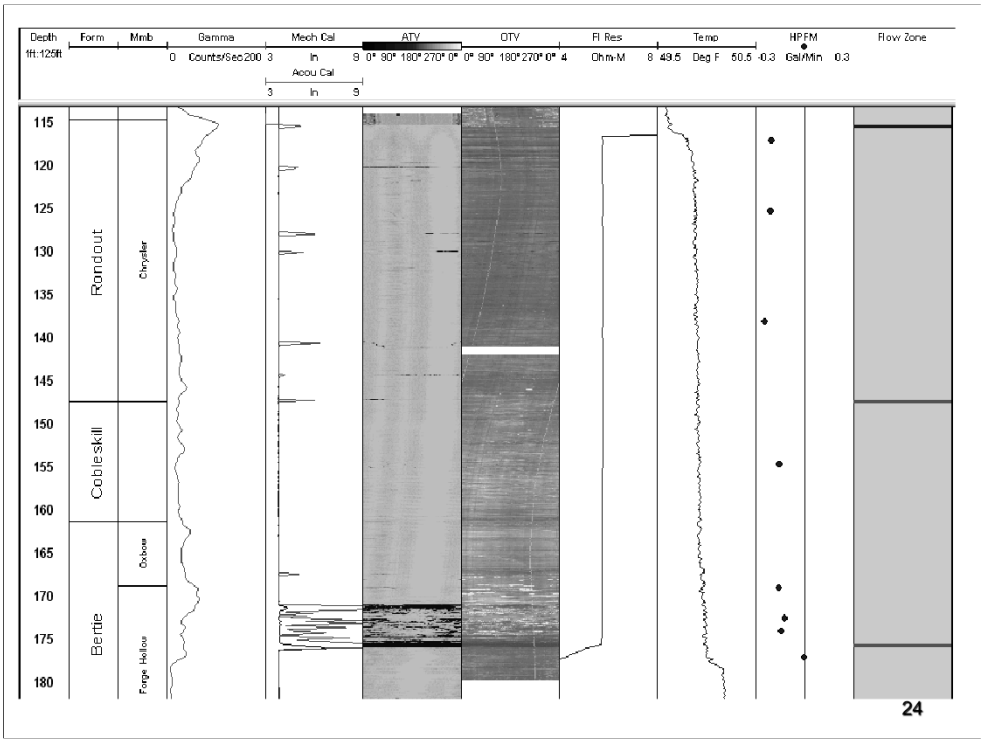
22

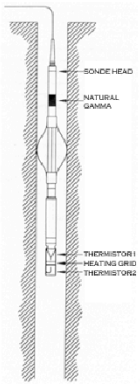

Depth
Form
Mmb
Gamma
Mech Cal
ATV
OTV
Fl Res
Temp
HPFM
Flow Zone
1ft:125ft
0 Counts/Sec 200
5 In 10
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
15 Ohm-M 17
49.5 Deg F 50.5
-0.1 Gal/Min 0.1
Acou Cal
5 In 10
Formation
Gamma
Caliper
ATV
OTV
Resistiv
Temp
Flow
155
160
165
170
175
180
185
190
195
200
205
210
215
220
Manlius - Multiple thrust-fault blocks (?)
Olney
Rondout
Chrysler
23

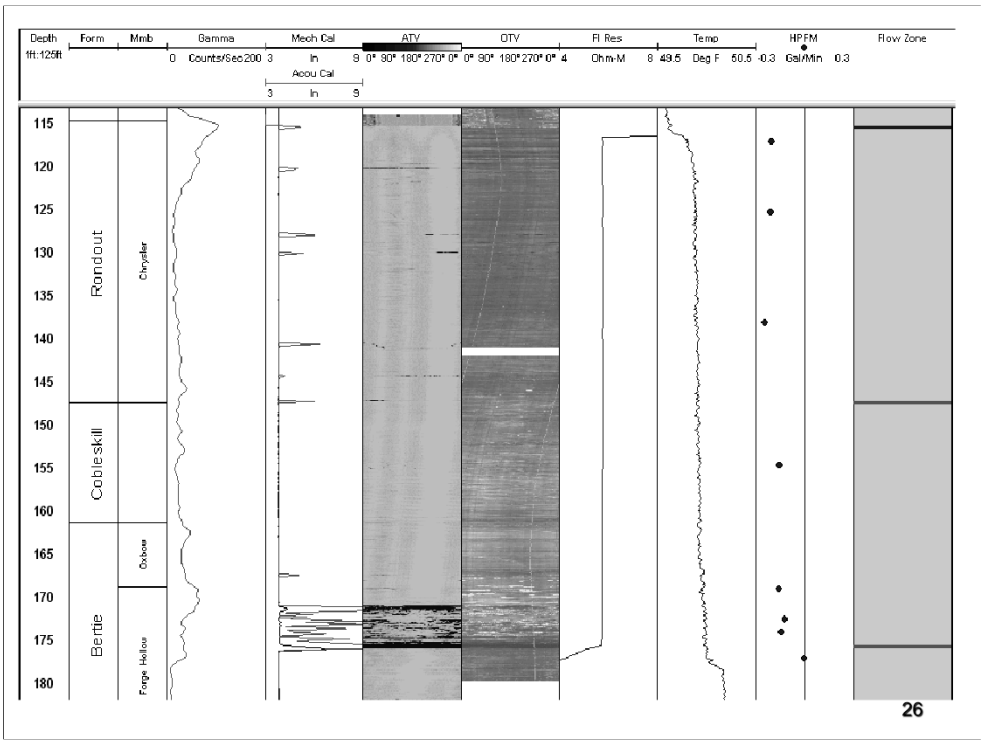

Depth
1ft:125ft
Form
Mmb
Gamma
0 Counts/Sec 200
Mech Cal
3 In 9
Accu Cal
3 In 9
ATV
0° 90° 180° 270° 0°
OTV
0° 90° 180° 270° 0°
Fl Res
4 Ohm-M 8
Temp
49.5 Deg F 50.5
HPFM
-0.3 Gal/Min 0.3
Flow Zone
115
120
125
130
135
140
145
150
155
160
165
170
175
180
Rondout
Cobleskill
Bertie
Chrysler
Oxbow
Forge Hollow
24

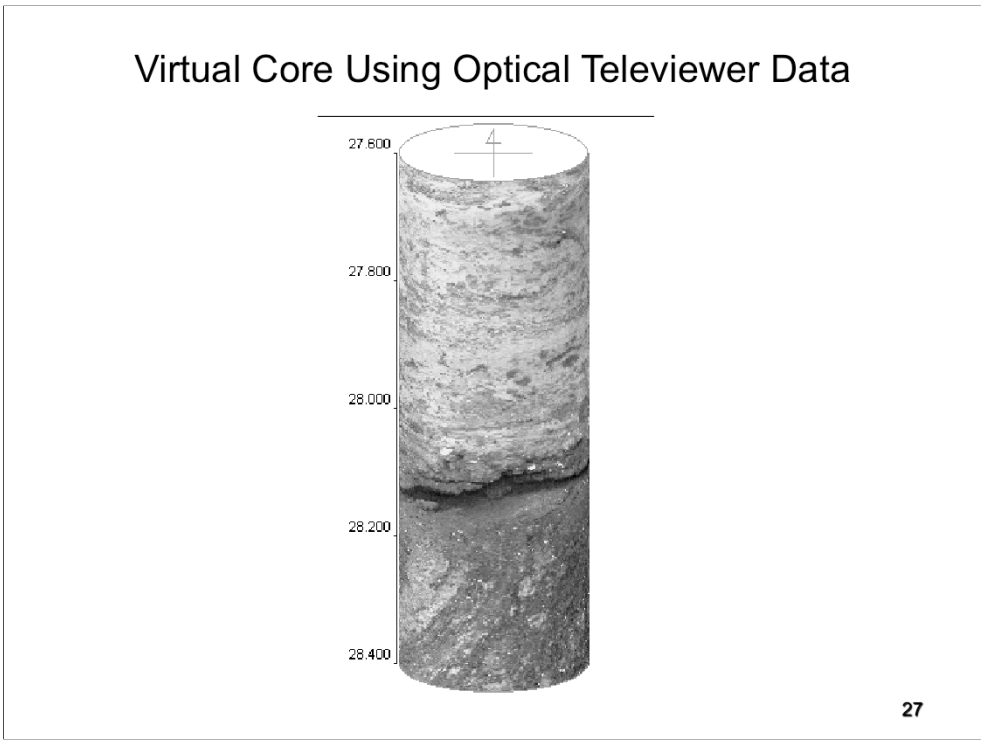
Heat-Pulse Flowmeter Logging

Heat-pulse Flowmeter logging is used to measure vertical flow within a well at discrete vertical intervals (> 0.1 gpm).

Useful in determining depths where water may be entering or leaving a borehole.




Depth
1ft:125ft
Form
Mmb
Gamma
0 Counts/Sec 200
Mech Cal
3 In 9
Accu Cal
3 In 9
ATV
OTV
0° 90° 180° 270° 0°
Fl Res
4 Ohm-M 8
Temp
49.5 Deg F 50.5
HPFM
-0.3 Gal/Min 0.3
Flow Zone
115
120
125
130
135
140
145
150
155
160
165
170
175
180
Rondout
Cobleskill
Bertie
Chrysler
Oxbow
Forge Hollow
26

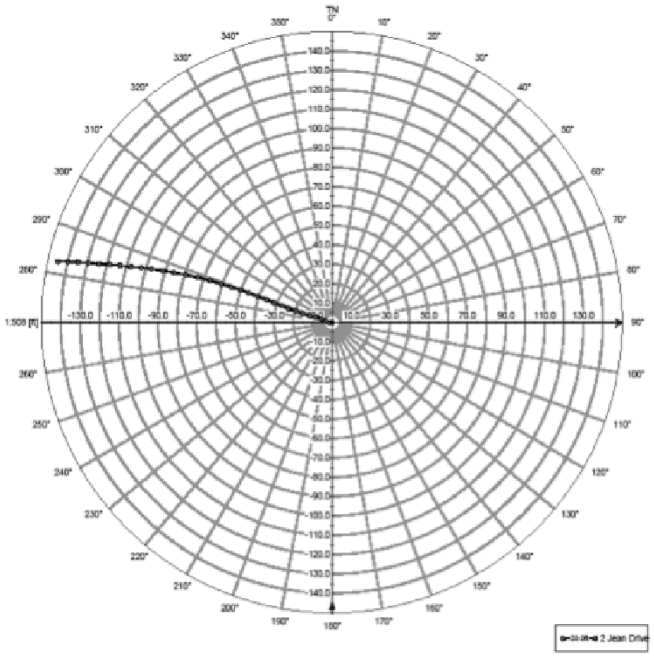


This is a video from an Optical televiewer in an open rock borehole. While it looks like a core it is actually a video of the walls of the hole. What you are seeing is actually the inside of the hole as the televiewer rotates.

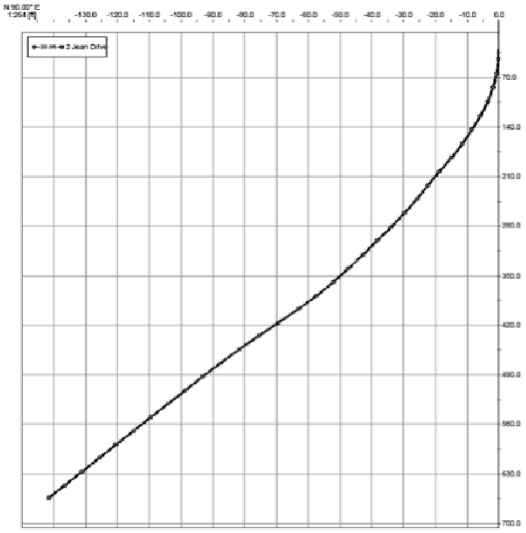
Borehole Deviation Logging

- Useful to determine borehole deviation
- Useful to evaluate whether packer assemblies can be utilized downhole

28


TN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
-130.0
-110.0
-90.0
-70.0
-50.0
-30.0
10.0
30.0
50.0
70.0
90.0
110.0
130.0
1.508 [ft]
2 Jean Drive

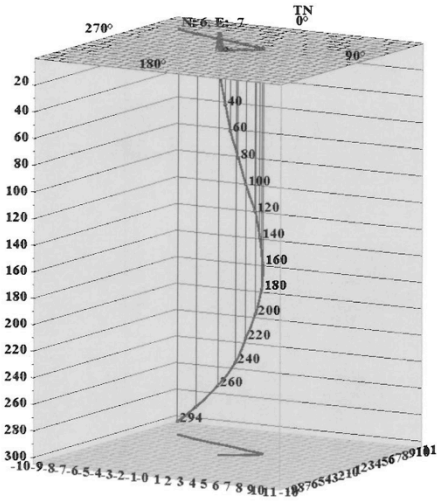
29



Well Depth >700 feet
Well Base Elev. Difference
650 feet
Deviation 143 feet
0.215 ft/ft

30

Hager GeoScience Inc.	Geophysical Logging Record: *3D Deviation Plot*
Site: Dewey Landfill	Boring #: MW-
Location: Nassau, NY	Date Logged: 8- -11
Client: Lockheed-Martin	Logged By: MC, JB, KS



31

Hager GeoScience Inc.	Geophysical Logging Record: ***Bull's Eye Deviation Plot***
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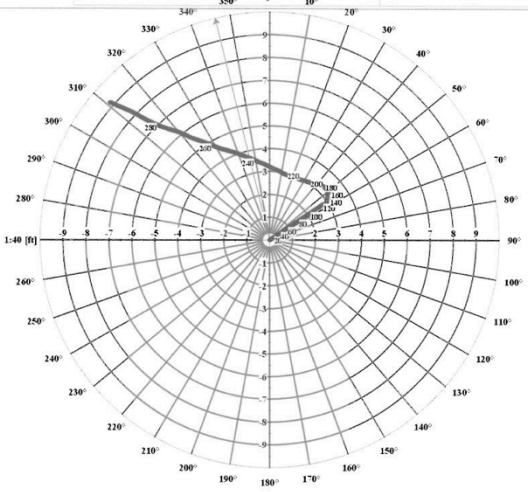
Location: Nassau, NY	Date Logged: 8-16-11
Client: Lockheed-Martin	Logged By: MC, JB, KS



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Borehole Geophysical Data - Uses

- Packer Test Design
- Discrete-zone Multi-level Assembly Design (Westbay, Flute, Solinist , etc.)
- Groundwater Sampling Strategy (Discussed in Case Studies)

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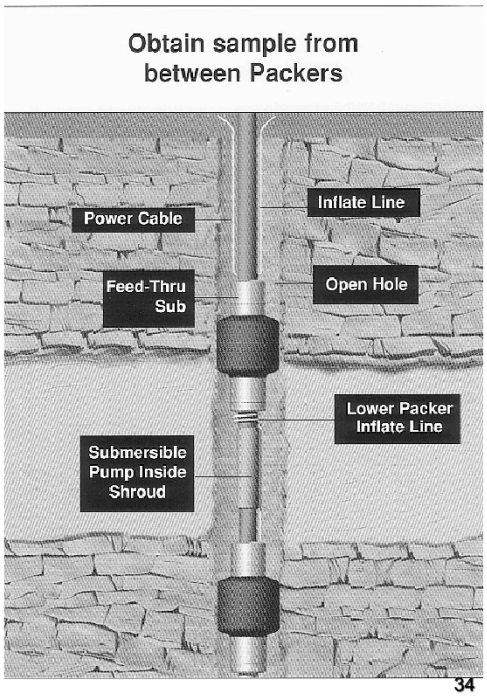
Groundwater Straddle Packer Testing



34

Discrete-zone Multi-level Assembly Design

35


36

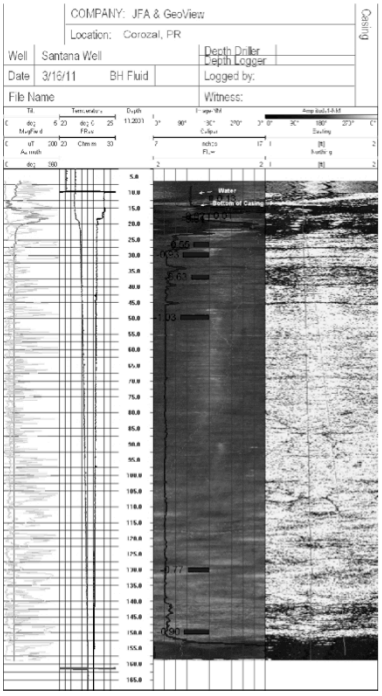
37

Case Study

Santana Community Production Well

Corozal, Puerto Rico

38


COMPANY: JFA & GeoView
Location: Corozal, PR
Well Santana Well
Depth Driller
Depth Logger
Date 3/16/11 BH Fluid
Logged by:
File Name
Witness:
Casing
Water
Bottom of Casing

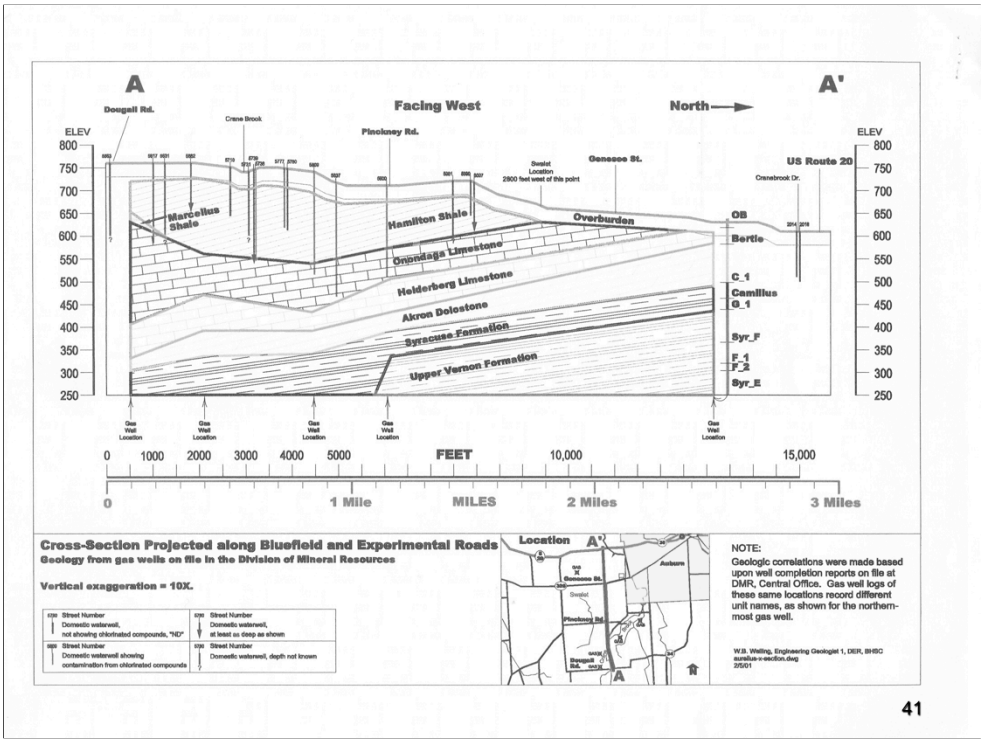
39

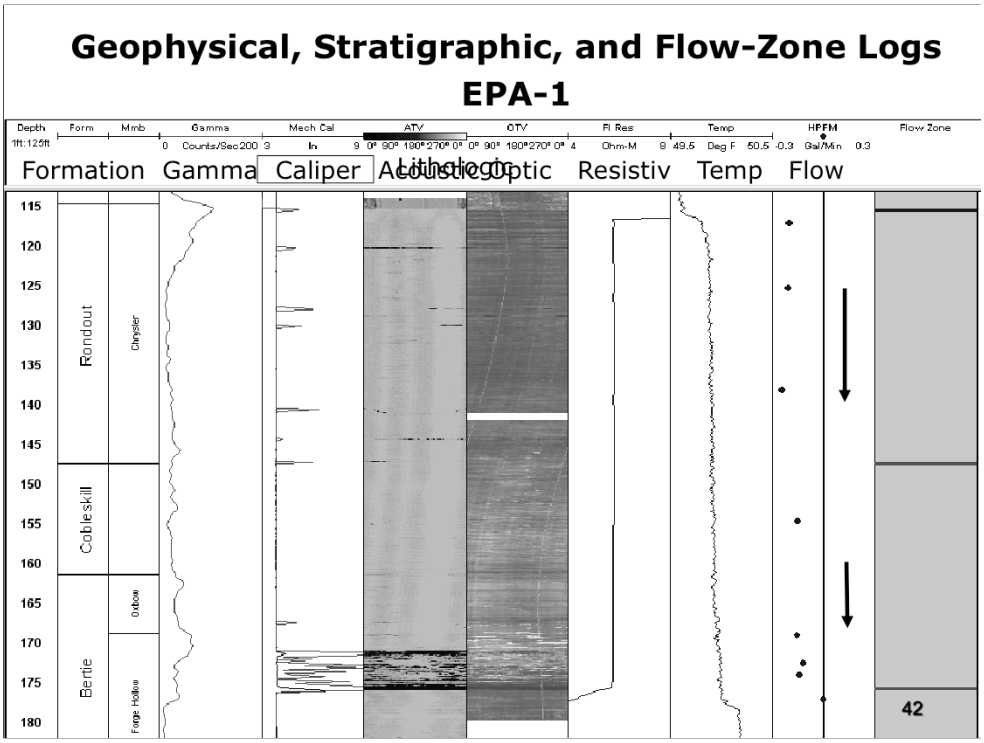
Case Study

Cayuga County Groundwater Contamination Site

Cayuga County, New York

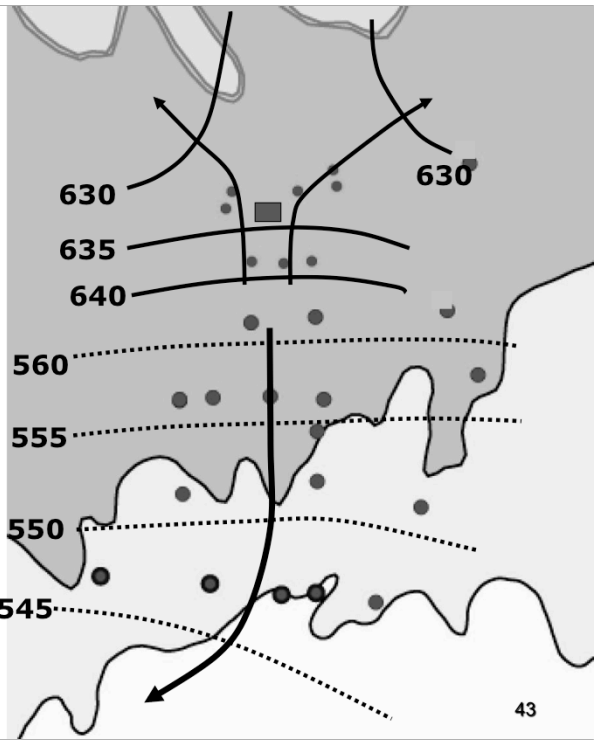
40


A
A'
Facing West
North
Dougall Rd.
Crane Brook
Pinckney Rd.
Genesee St.
Swartz Location 2800 feet west of this point
US Route 20
Cranebrook Dr.
ELEV
800
750
700
650
600
550
500
450
400
350
300
250
Marcellus Shale
Hamilton Shale
Onondaga Limestone
Helderberg Limestone
Akron Dolostone
Syracuse Formation
Upper Vernon Formation
Overburden
OB
Bertie
C_1
Camillus
G_1
Syr_F
F_1
F_2
Syr_E
Gas Well Location
0
1000
2000
3000
4000
5000
FEET
10,000
15,000
0
1 Mile
MILES
2 Miles
3 Miles
Cross-Section Projected along Bluefield and Experimental Roads
Geology from gas wells on file in the Division of Mineral Resources
Vertical exaggeration = 10X.
Street Number
Domestic waterwell, not showing chlorinated compounds, "ND"
Street Number
Domestic waterwell showing contamination from chlorinated compounds
Street Number
Domestic waterwell, at least as deep as shown
Street Number
Domestic waterwell, depth not known
Location
Auburn
Swartz
Pinckney Rd
Dougall Rd.
NOTE:
Geologic correlations were made based upon well completion reports on file at DMR, Central Office. Gas well logs of these same locations record different unit names, as shown for the northern-most gas well.
W.B. Welling, Engineering Geologist 1, DER, BHSC
auralus-x-section.dwg
2/5/01
41


Geophysical, Stratigraphic, and Flow-Zone Logs
EPA-1
Depth
1ft:125ft
Form
Mmb
Gamma
0 Counts/Sec 200
Mech Cal
3 In 9
ATV
0° 90° 180° 270° 0°
OTV
0° 90° 180° 270° 0°
Fl Res
4 Ohm-M 8
Temp
49.5 Deg F 50.5
HPFM
-0.3 Gal/Min 0.3
Flow Zone
Formation
Gamma
Caliper
Lithology
Acoustic
Optic
Resistiv
Temp
Flow
115
120
125
130
135
140
145
150
155
160
165
170
175
180
Rondout
Cobleskill
Bertie
Chrysler
Ovlbow
Forge Hollow
42

Ground water at the monitor wells in the Onondaga Limestone flows NW *and* NE

Ground water at the EPA test wells in the Bertie Fm. flows South *then* SW



Oil & Gas Well Abandonment Applications
Casing Collar Locator and Cement Bond Logging

Used in the oil and gas industry during borehole abandonment.

Casing Collar logs (magnetic) used to identify casing collars for targeting during casing shoot offs.

Cement Bond logs (acoustic) identify presence of cement behind logged casing – useful during casing perforating.

Cement Bond logs also utilized in Underground Injection well evaluation.

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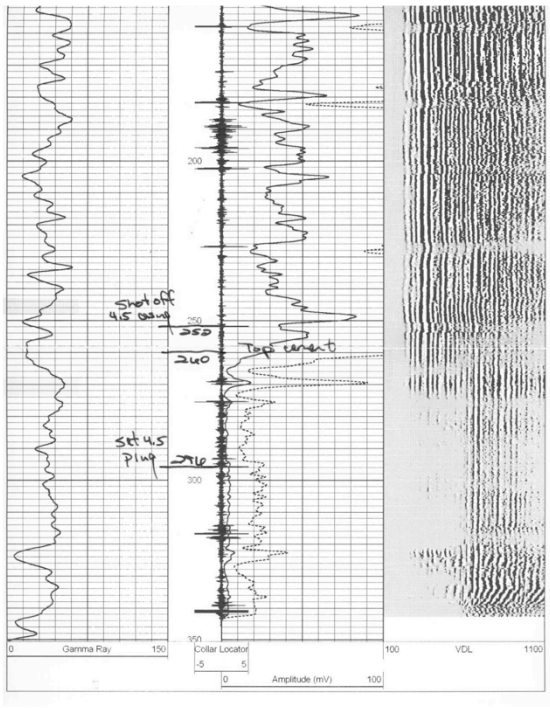
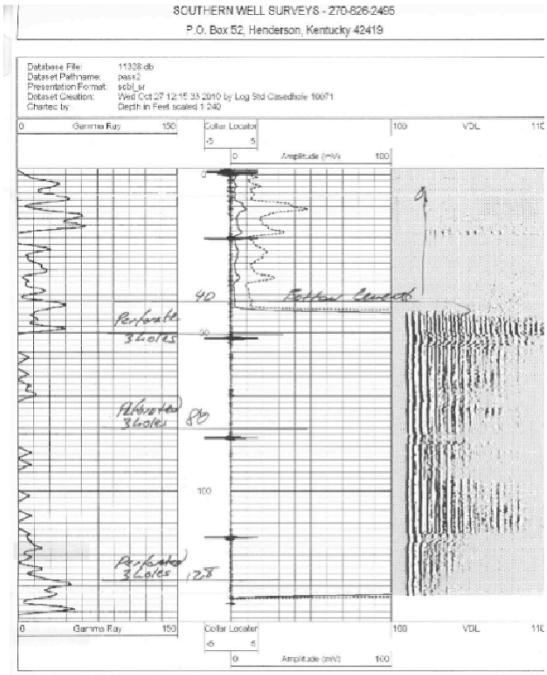

Shot off
4.5 @ 240
250
350
240
Top cement
Set 4.5
Plug
300
350
0
Gamma Ray
150
Collar Locator
-5
5
0
Amplitude (mV)
100
100
VDL
1100

45

46


SOUTHERN WELL SURVEYS - 270-826-2465
P.O. Box 52, Henderson, Kentucky 42419
Database File: 11328.db
Dataset Pathname: pass2
Presentation Format: scbl_sr
Dataset Creation: Wed Oct 27 12:15:33 2010 by Log Std Casedhole 1007f1
Charted by: Depth in Feet scaled 1:240
Gamma Ray
Collar Locator
Amplitude (mV)
VDL
Perforated Shots
Perforated Shots
Perforated Shots
Bottom Cement

47

48

For more information on borehole geophysical log applications in abandoning oil and gas wells, go to:

1. *ERTVideo.org*,

2. click on *Videos*,

3. and go to the *Kentucky Oil Wells Plugging* page for a streaming video.

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Conclusion

Know Your Borehole !

Borehole Geophysics can help Understanding Geology, Hydrogeology, and Chemistry in Bedrock Geologic Settings

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