Borehole Geophysics Applied to Bedrock Hydrogeological Evaluations

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

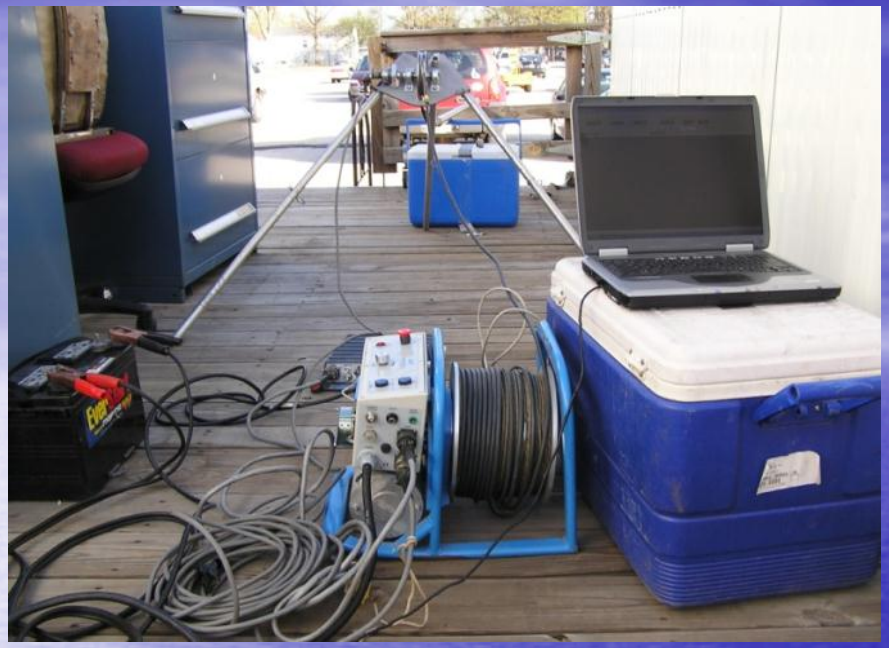
Borehole Geophysical Tools:

Hydrogeologic Bedrock Groundwater Assessments

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

Oil and Gas Well Abandonments

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




USGS

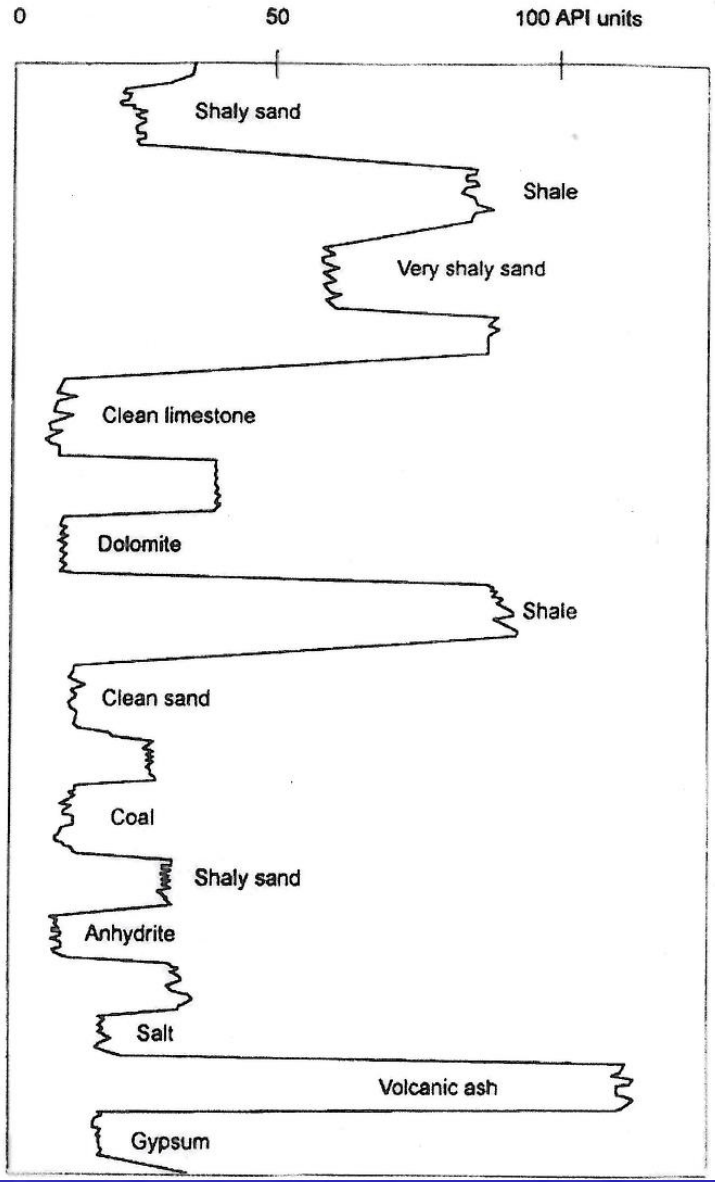
Natural Gamma Logging

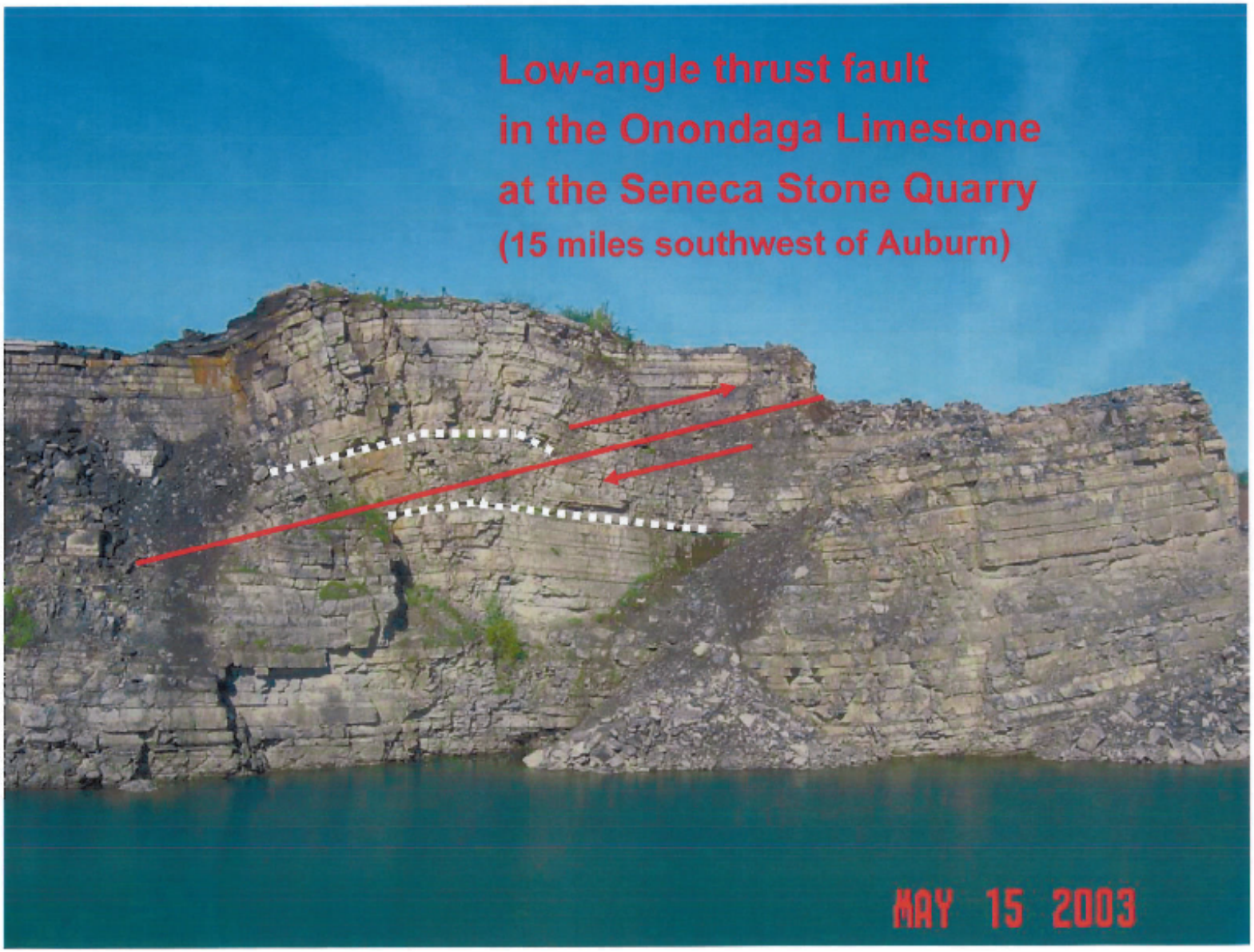
Gamma logging is useful in evaluating stratigraphic sequences and for borehole to borehole correlation.

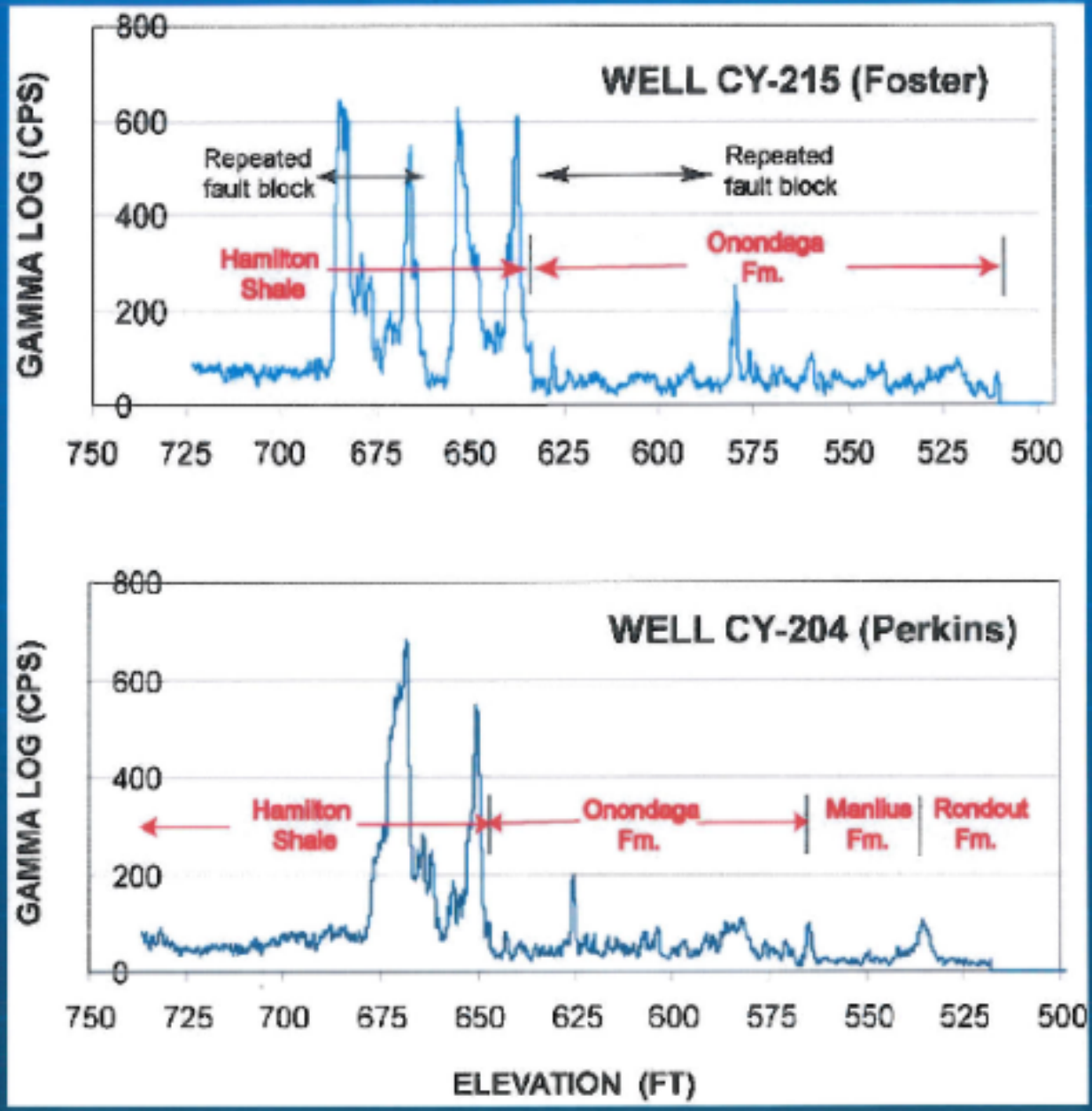
Can be used in open or cased boreholes.

GR Log

General GR Response

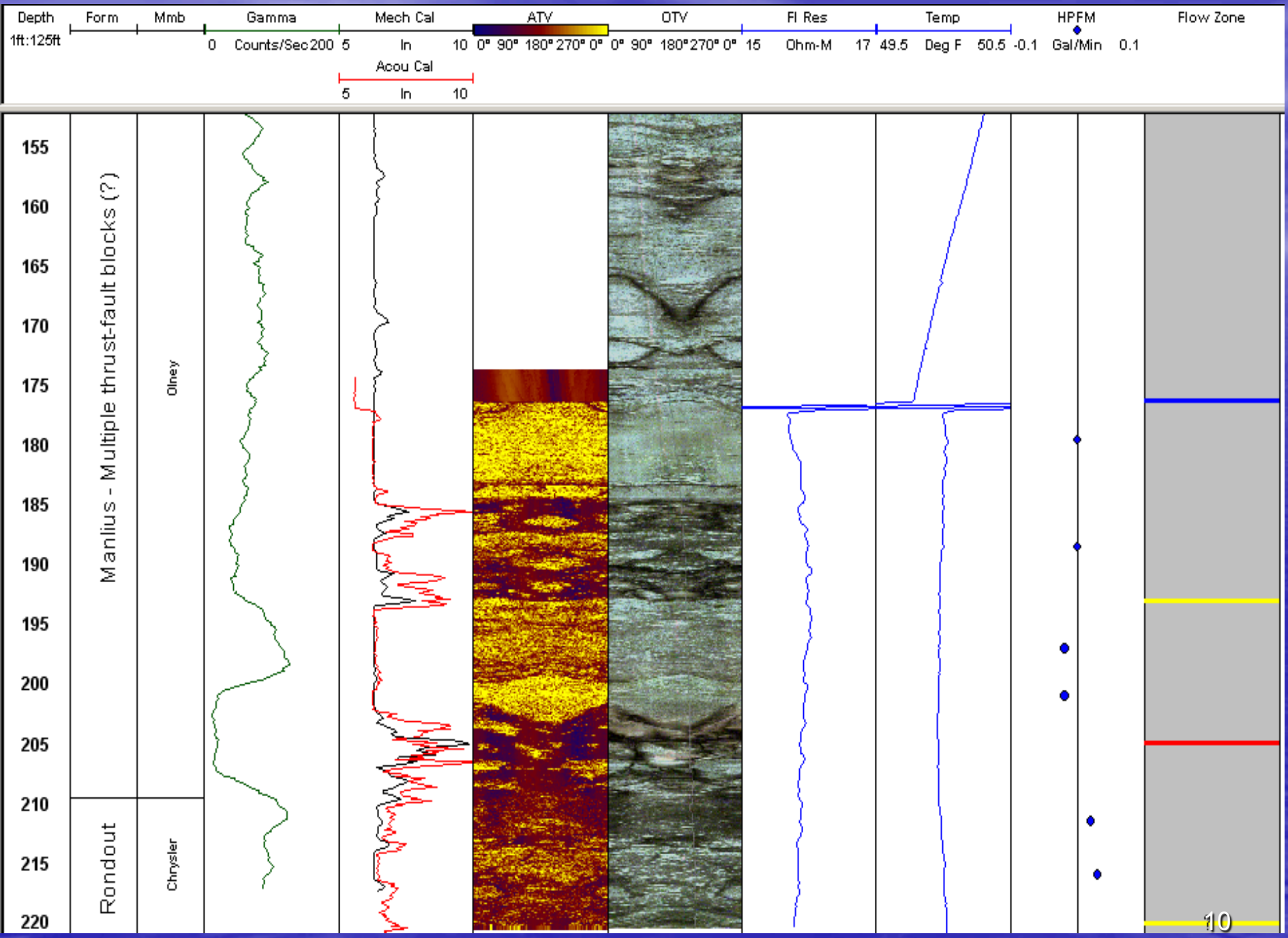



Low-angle thrust fault
in the Onondaga Limestone
at the Seneca Stone Quarry
(15 miles southwest of Auburn)
MAY 15 2003


WELL CY-215 (Foster)
GAMMA LOG (CPS)
800
600
400
200
0
Repeated fault block
Repeated fault block
Hamilton Shale
Onondaga Fm.
750 725 700 675 650 625 600 575 550 525 500
WELL CY-204 (Perkins)
GAMMA LOG (CPS)
800
600
400
200
0
Hamilton Shale
Onondaga Fm.
Manlius Fm.
Rondout Fm.
750 725 700 675 650 625 600 575 550 525 500
ELEVATION (FT)

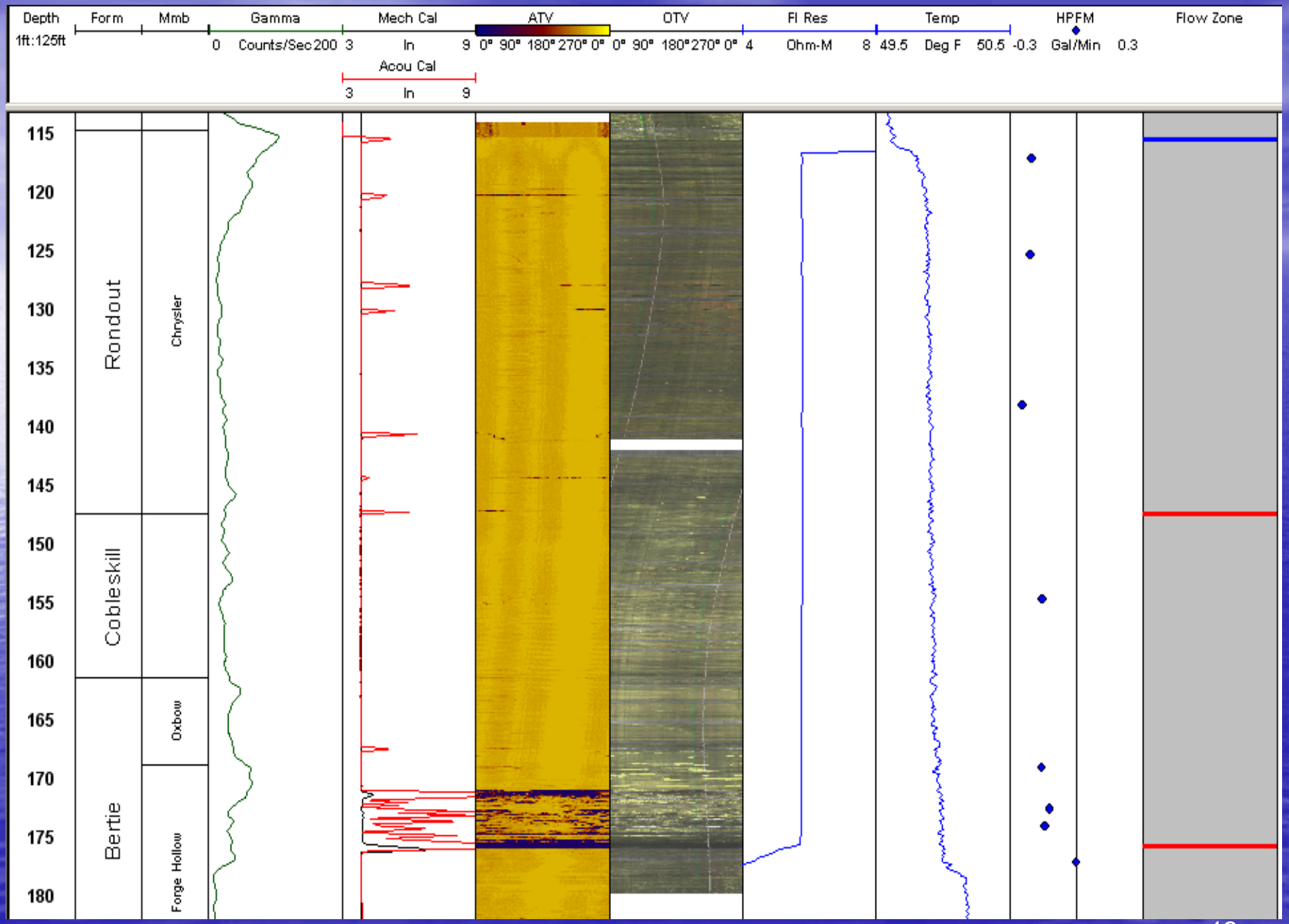
Caliper Logging

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


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 (?)
Olney
Rondout
Chrysler
10

Temperature Logging

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

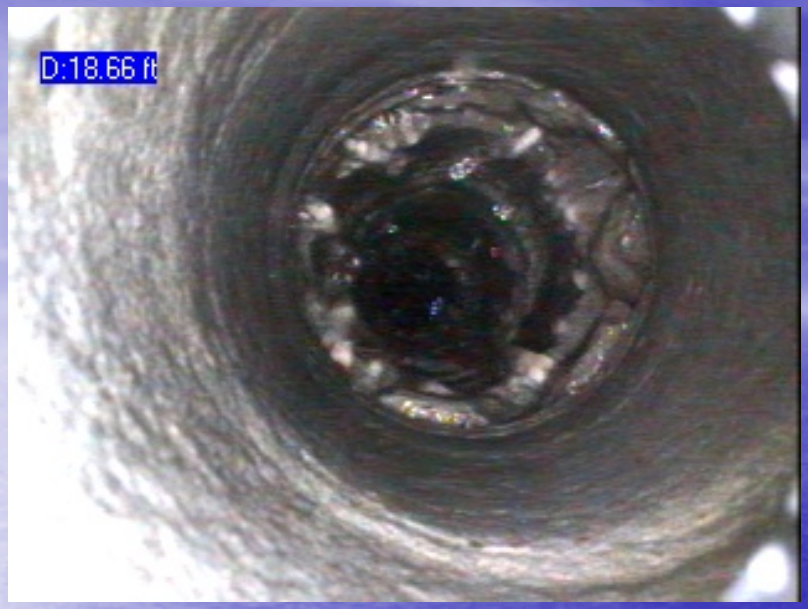

Depth
1ft:125ft
Form
Mmb
Gamma
0 Counts/Sec 200
Mech Cal
3 In 9
Acou Cal
3 In 9
ATV
0° 90° 180° 270° 0°
OTV
0° 90° 180° 270° 0°
Fl Res
4 Ohm-M 8
Temp
49.5 Deg F 50.5
HPFM
-0.3 Gal/Min 0.3
Flow Zone
115
120
125
130
135
140
145
150
155
160
165
170
175
180
Rondout
Cobleskill
Bertie
Chrysler
Oxbow
Forge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

Borehole Video Logging

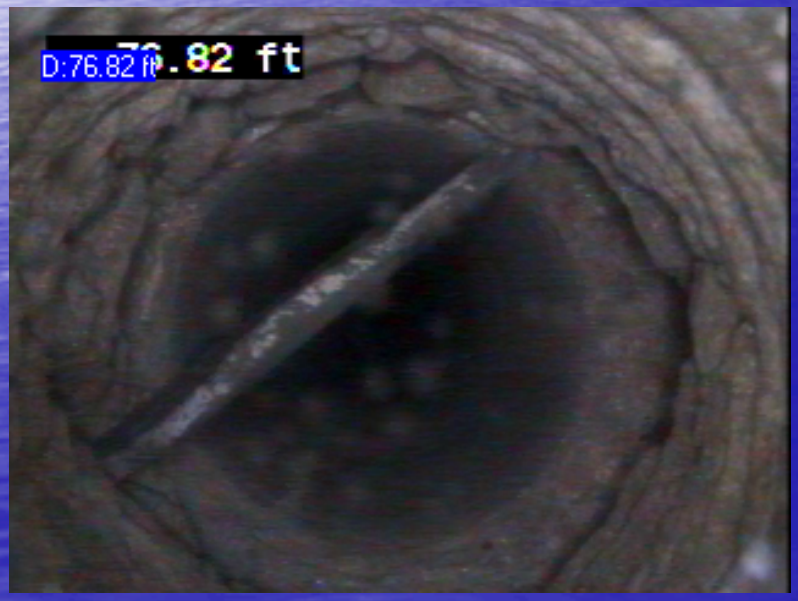
Borehole video logging provides a visual picture of borehole conditions.

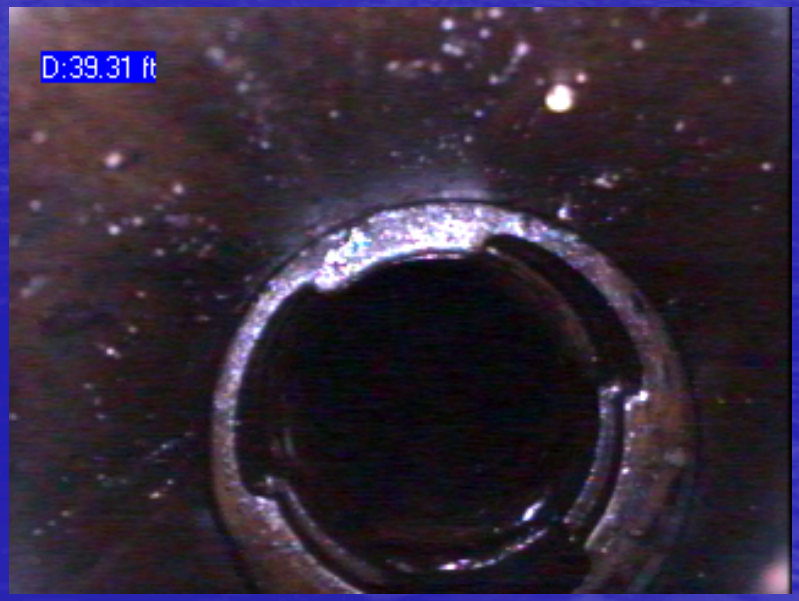
Useful in identifying fractures, voids, cascading water, well/boring blockage and other downhole trouble shooting.

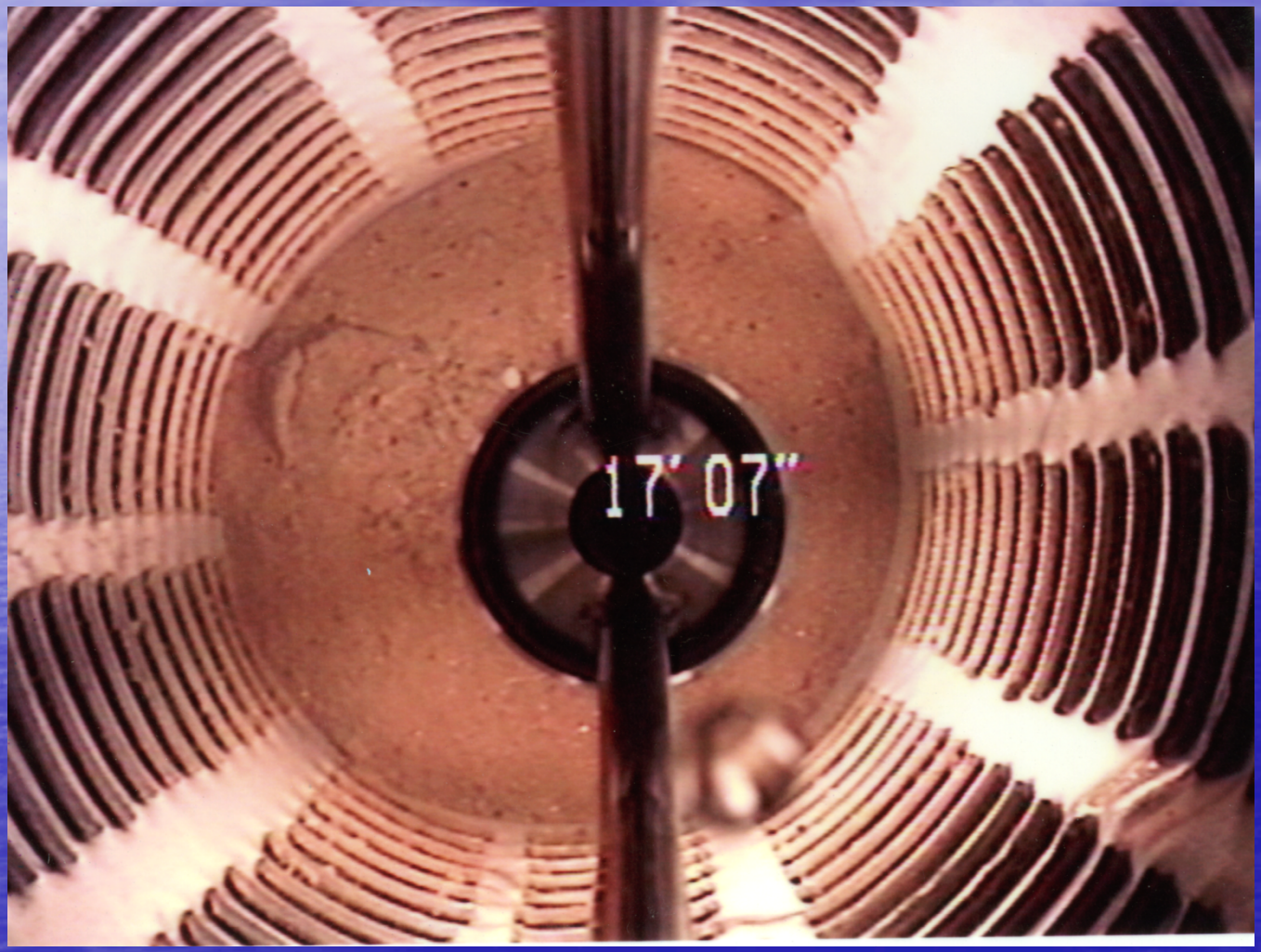

Nature Coast
SPECIAL


D:18.66 ft


D:114.80 ft


D:76.82 ft


D:39.31 ft


17' 07"

Challenges in Fractured Rock Aquifers:

Borehole Video

- Borehole video logging conducted by U.S. EPA Environmental Response Team
- **Cascading groundwater observed entering boreholes above static well water levels**
- Air hammer drilled borehole

Challenges in Fractured Rock Aquifers:

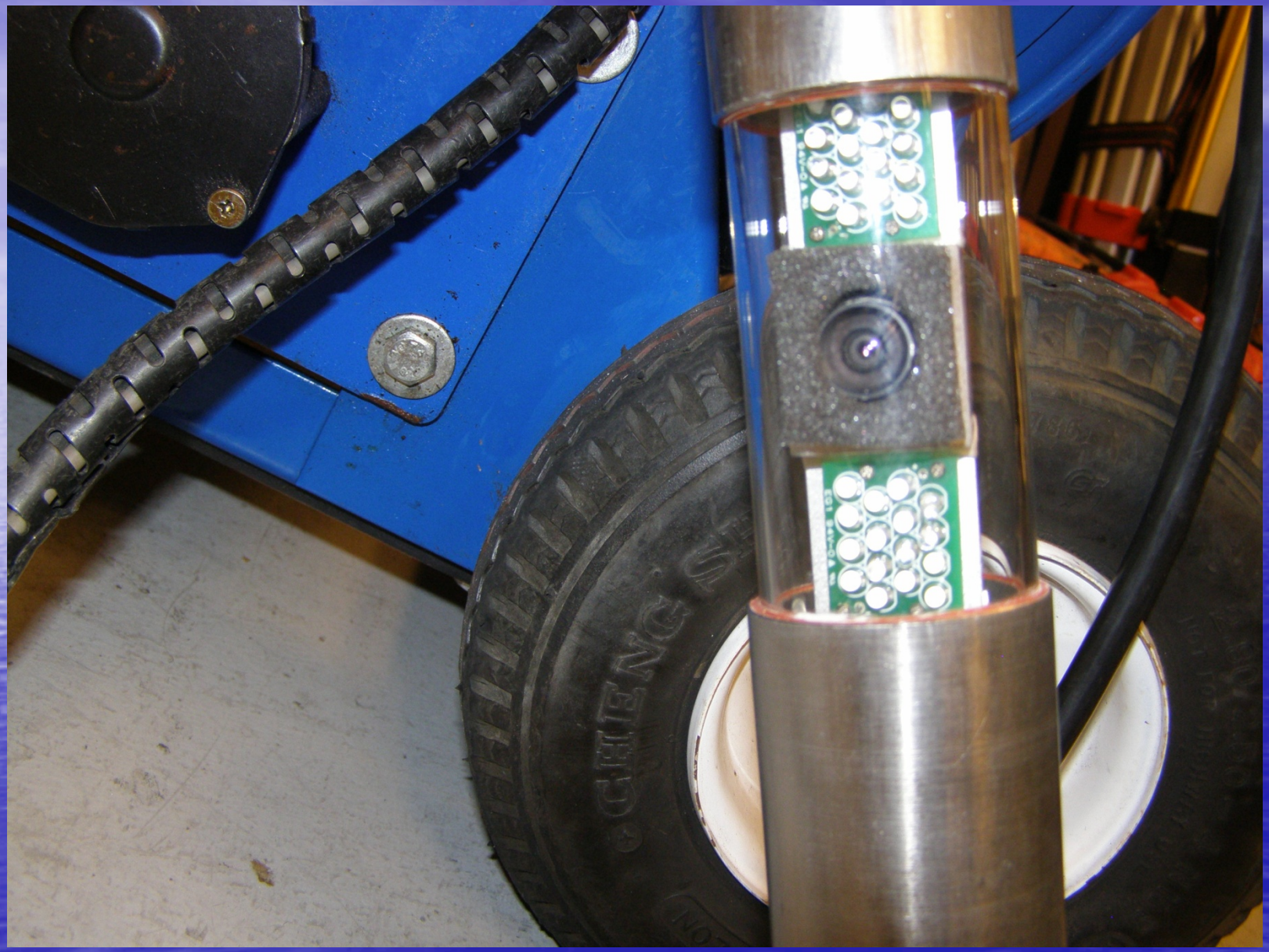
Borehole Video

- Borehole video logging conducted by U.S. EPA Environmental Response Team
- **Cascading groundwater observed entering boreholes above static well water levels**
- Cored borehole

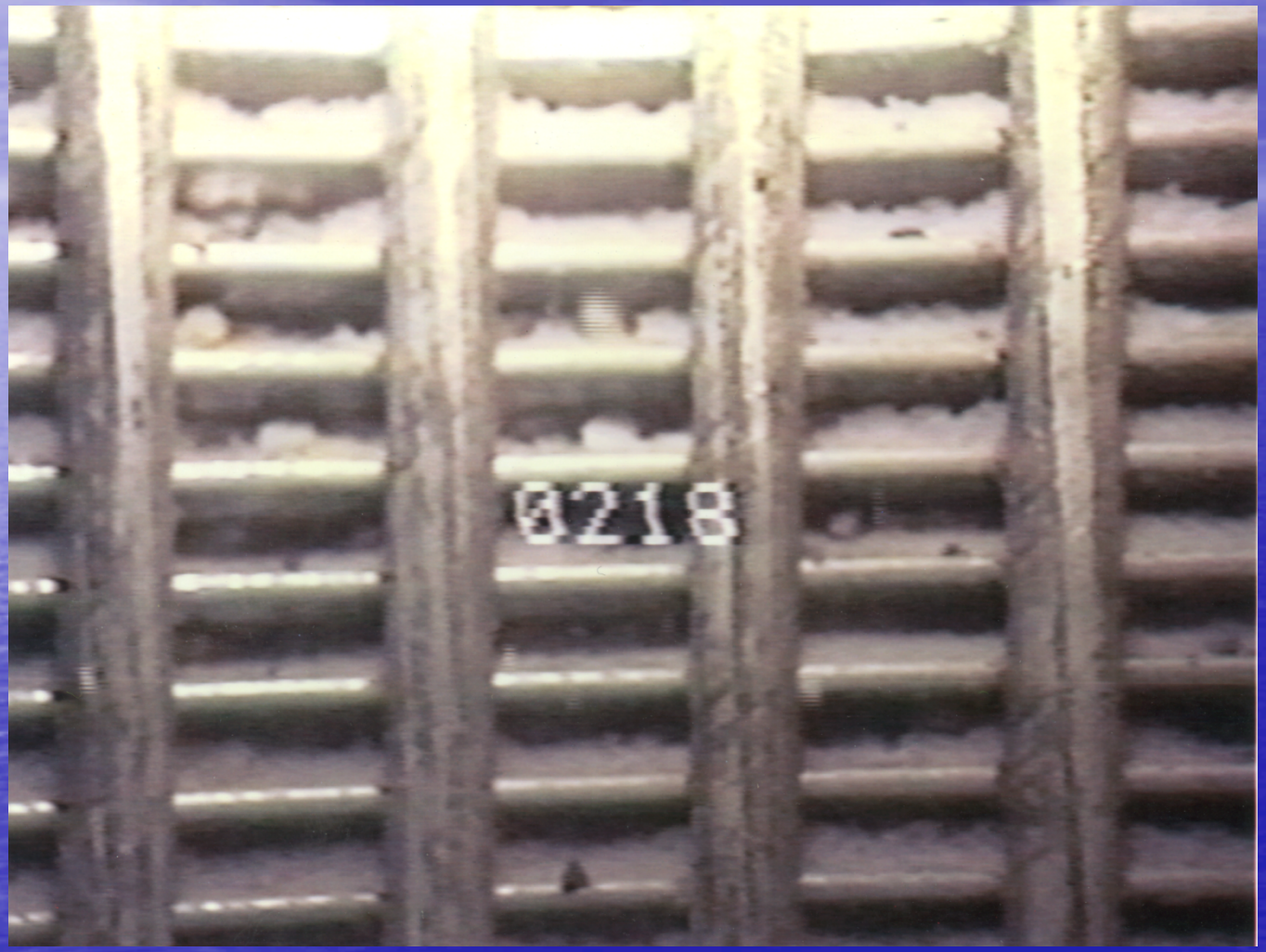
Challenges in Fractured Rock Aquifers:

Borehole Video

- Borehole video logging conducted by U.S. EPA Environmental Response Team
- **Solution void**

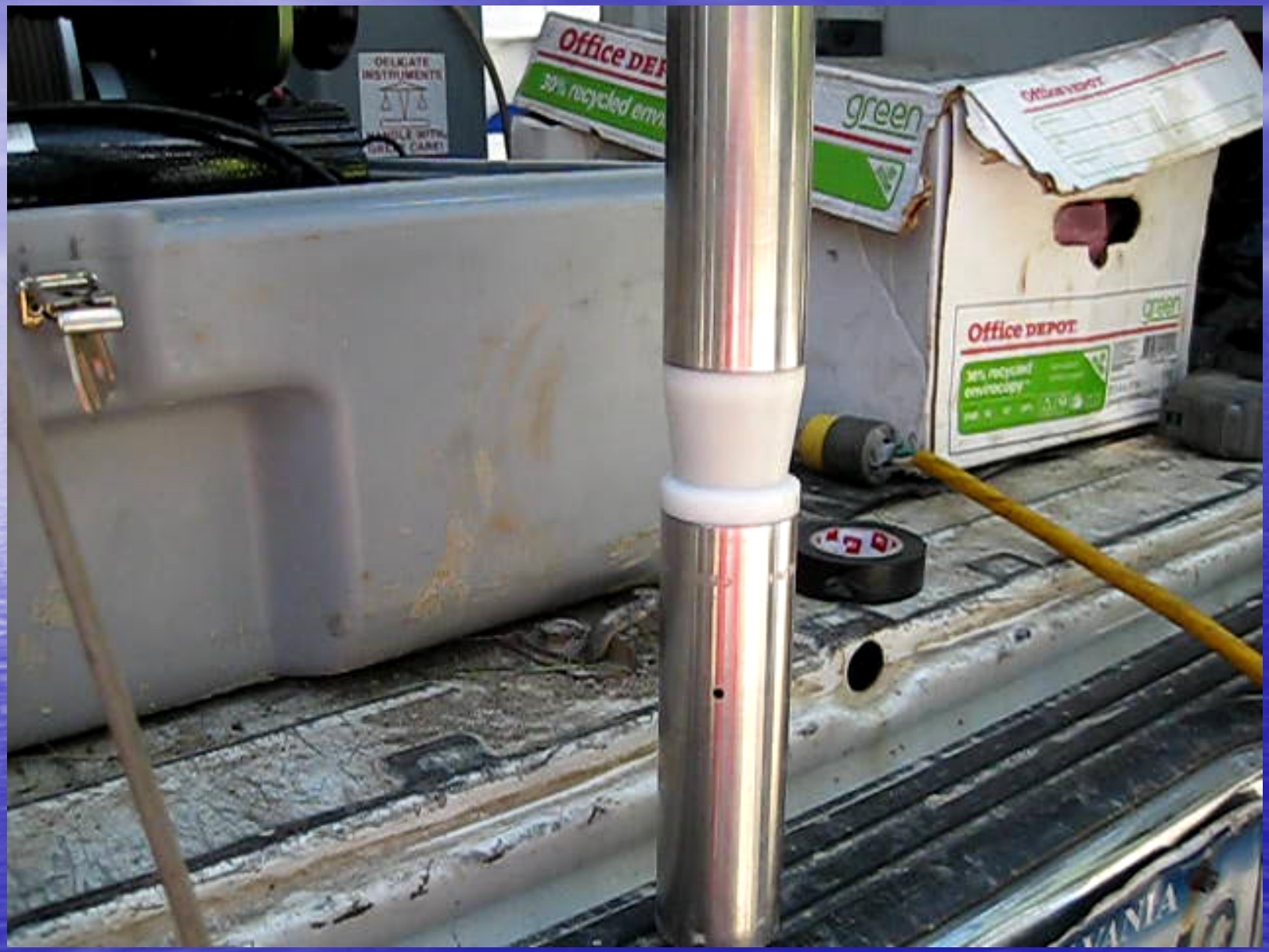

CHENG SH

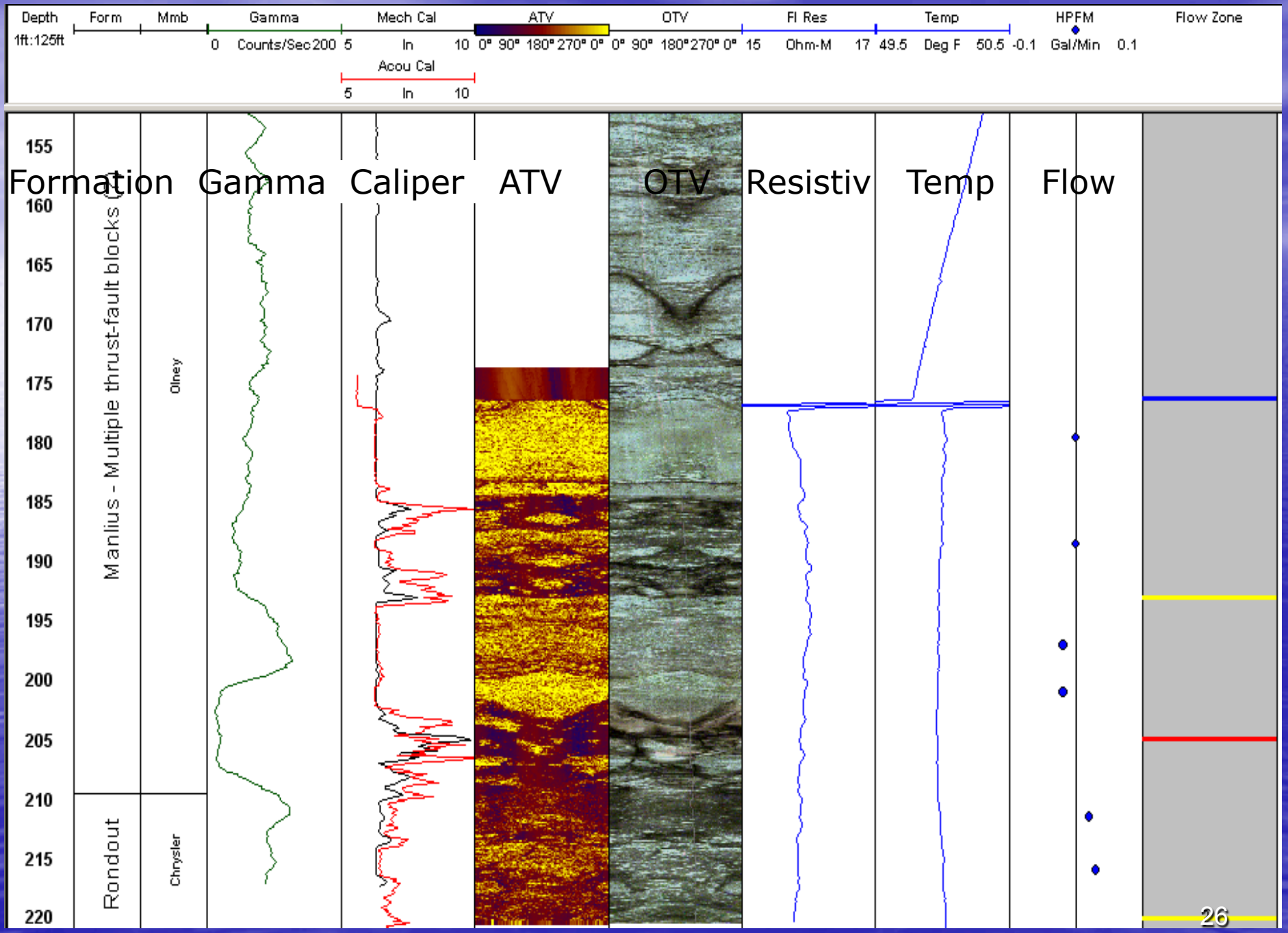

Nature Coast Envir
SPECIAL TO
Provided by the Southwest Florida Water Management District


0218

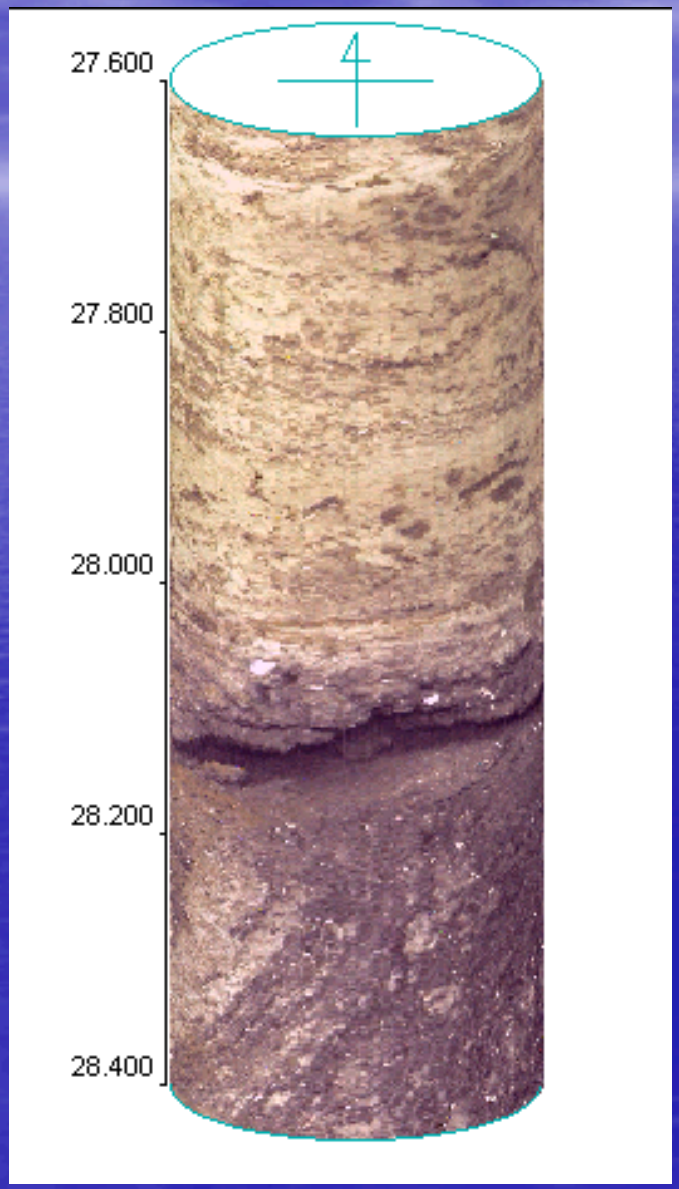
Optical and Acoustical Televiewer Logging

- 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.


Office DEPOT
green
Office DEPOT
green


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
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

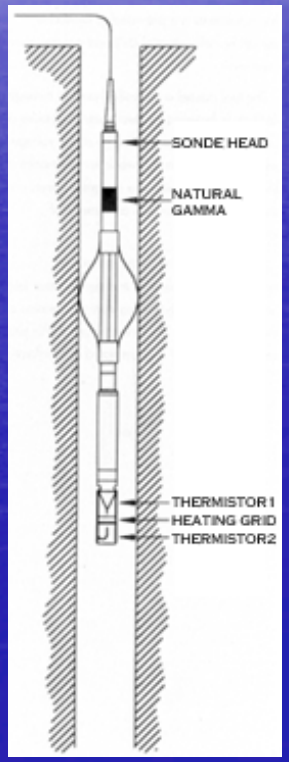
Virtual Core Using Optical Televiewer Data

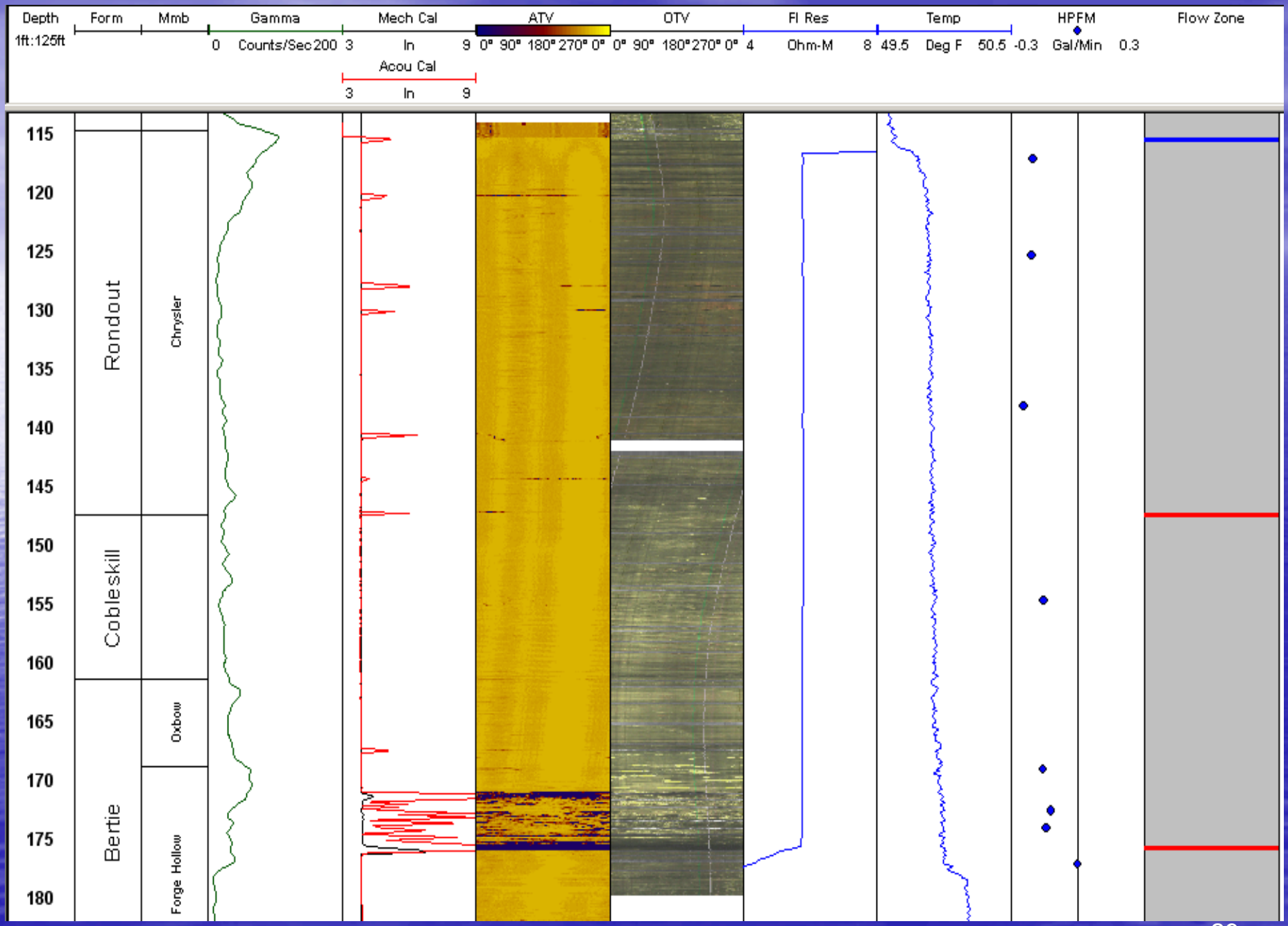


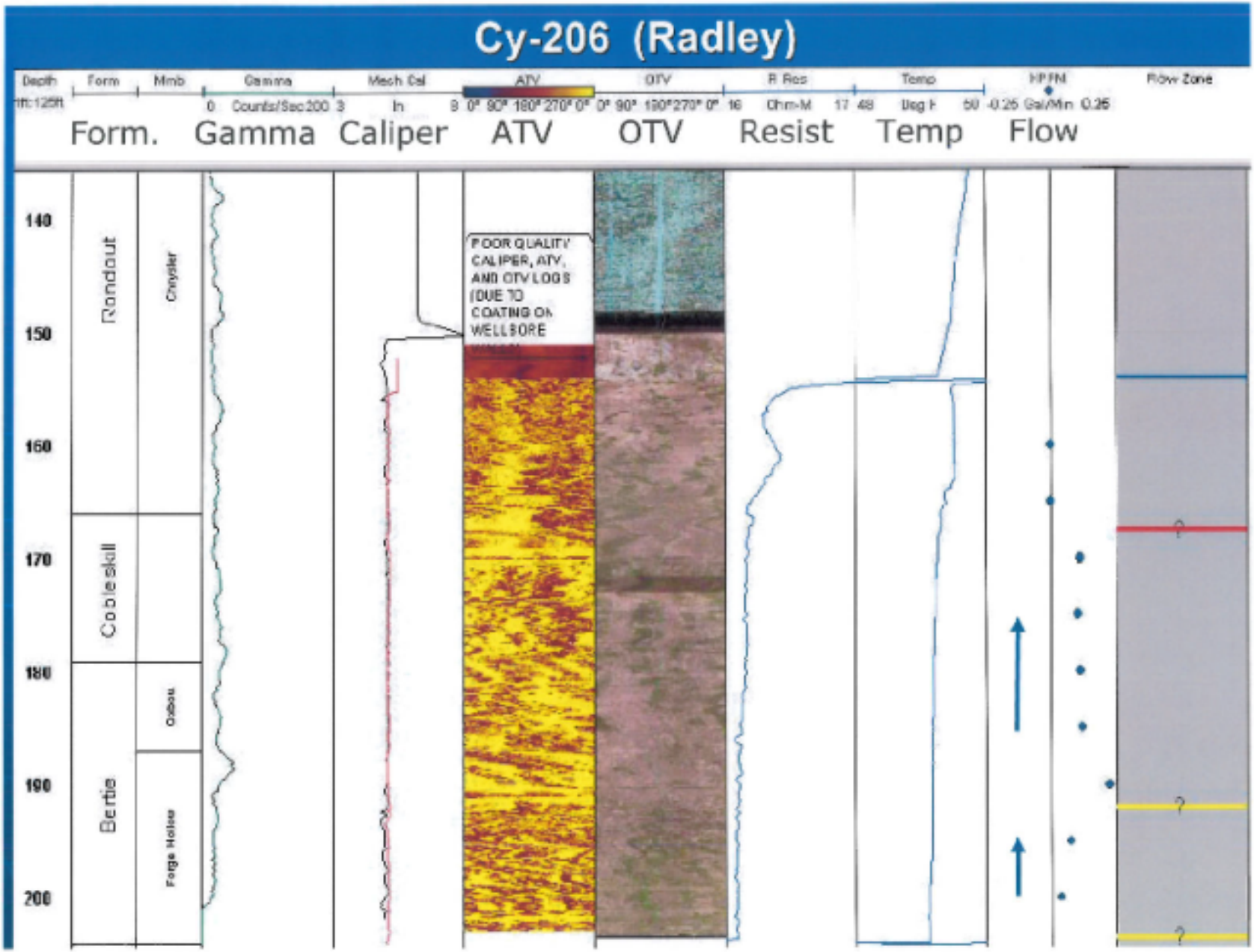
Heat-Pulse Flowmeter Logging

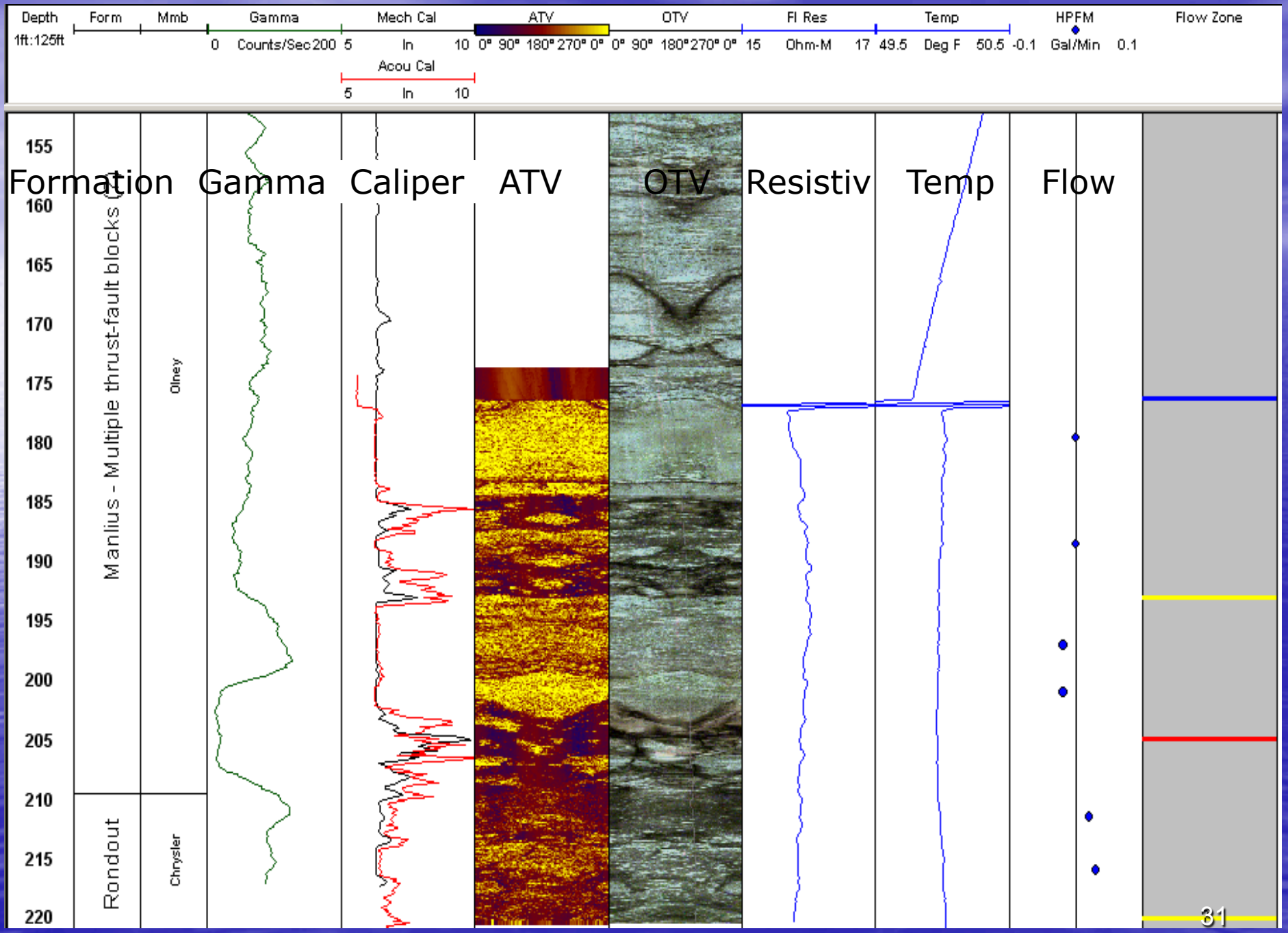
Heat-pulse Flowmeter logging is used to measure vertical flow within a well at discrete vertical intervals (> 0.1 gpm).

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



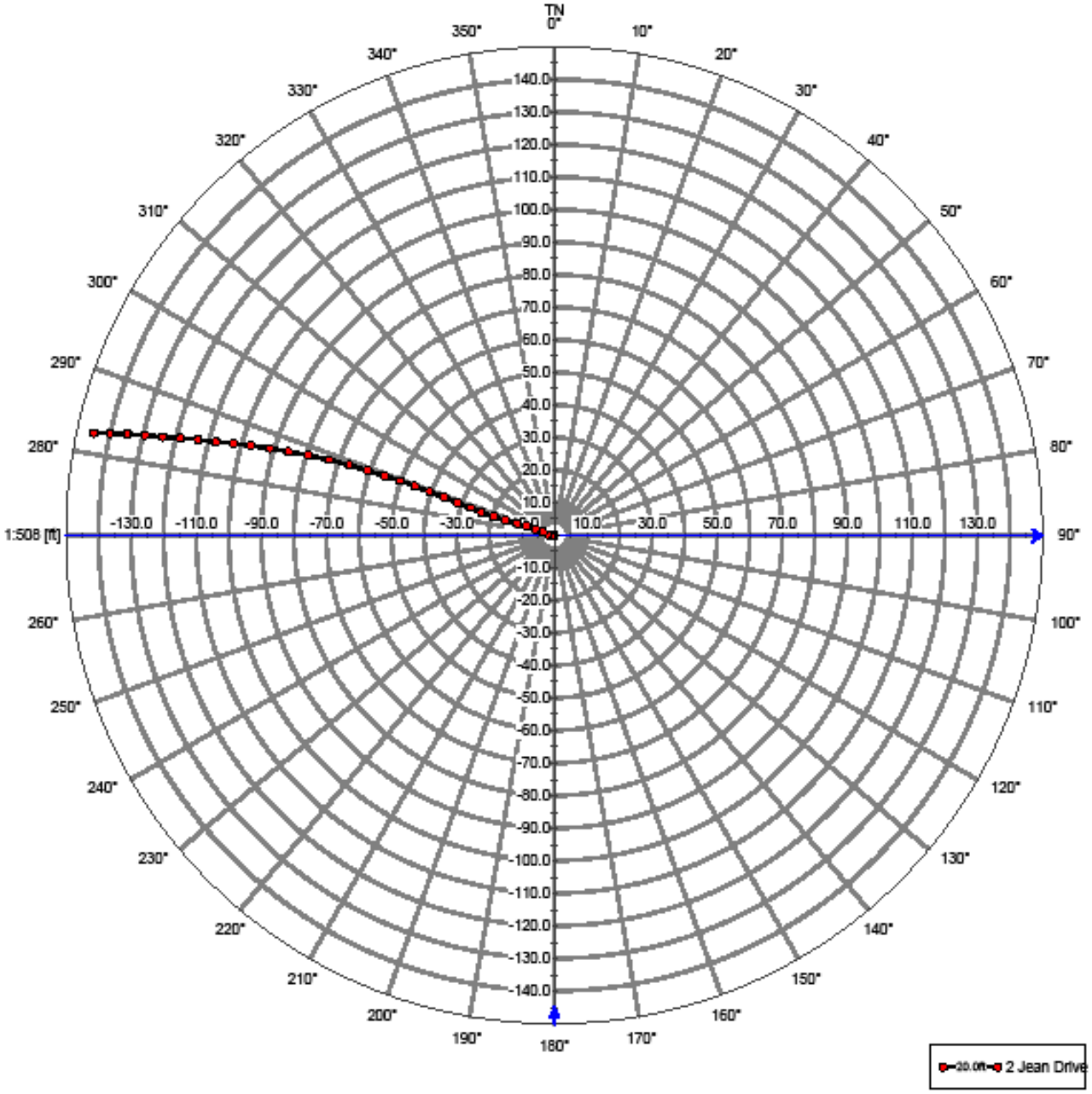

Depth
1ft:125ft
Form
Mmb
Gamma
0 Counts/Sec 200
Mech Cal
3 In 9
Acou Cal
3 In 9
ATV
0° 90° 180° 270° 0°
OTV
0° 90° 180° 270° 0°
Fl Res
4 Ohm-M 8
Temp
49.5 Deg F 50.5
HPFM
-0.3 Gal/Min 0.3
Flow Zone
115
120
125
130
135
140
145
150
155
160
165
170
175
180
Rondout
Cobleskill
Bertie
Chrysler
Oxbow
Forge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

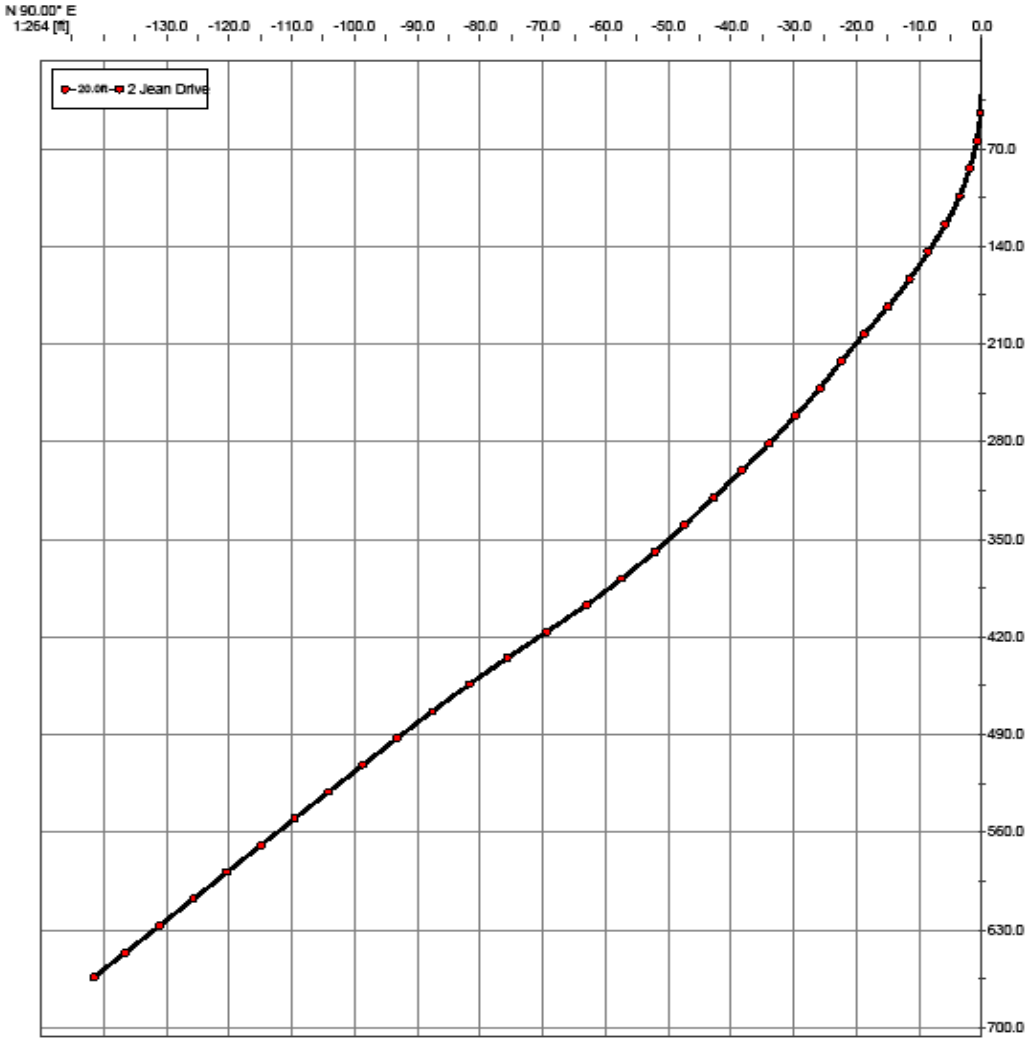

Cy-206 (Radley)
Depth
Form
Mmb
Gamma
Mech Cal
ATV
OTV
R Res
Temp
HP/M
Flow Zone
Form.
Gamma
Caliper
ATV
OTV
Resist
Temp
Flow
140
150
160
170
180
190
200
Randolt
Cobleskill
Berlie
Chrysler
Osbou
Forge Hollow
POOR QUALITY CALIPER, ATV, AND OTV LOGS (DUE TO COATING ON WELLBORE


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
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

Borehole Deviation Logging

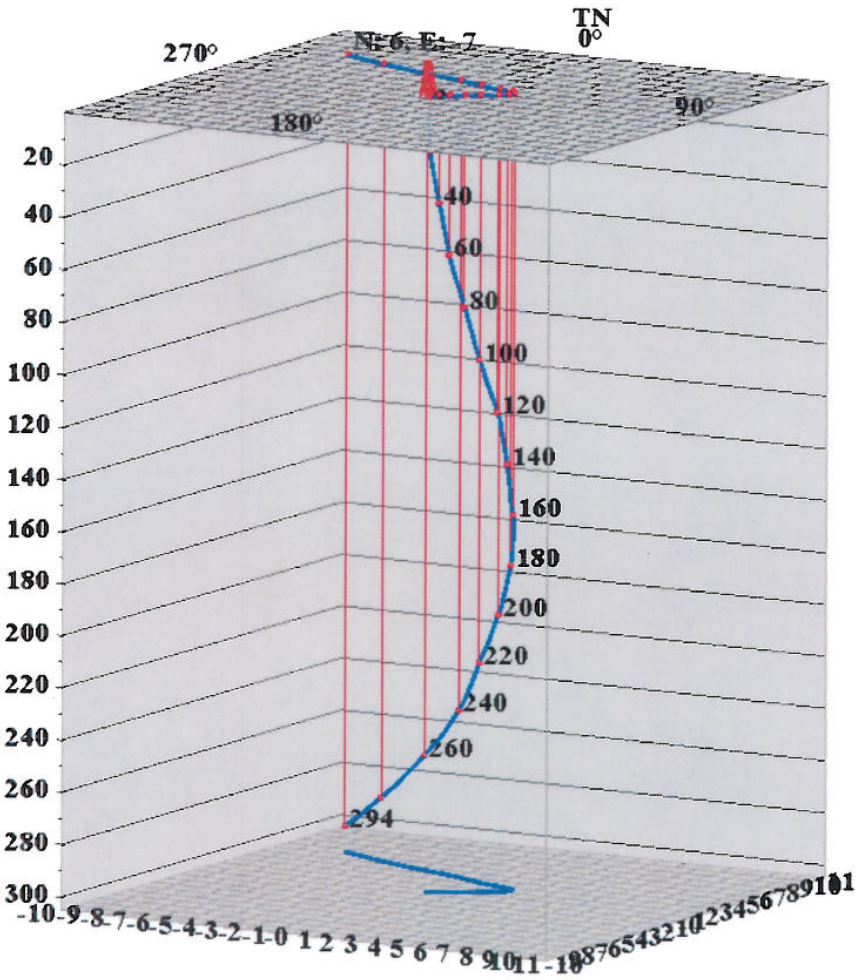
- Useful to determine borehole deviation
- Useful to evaluate whether packer assemblies can be utilized downhole


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°
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
-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]
20.0ft
2 Jean Drive



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

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

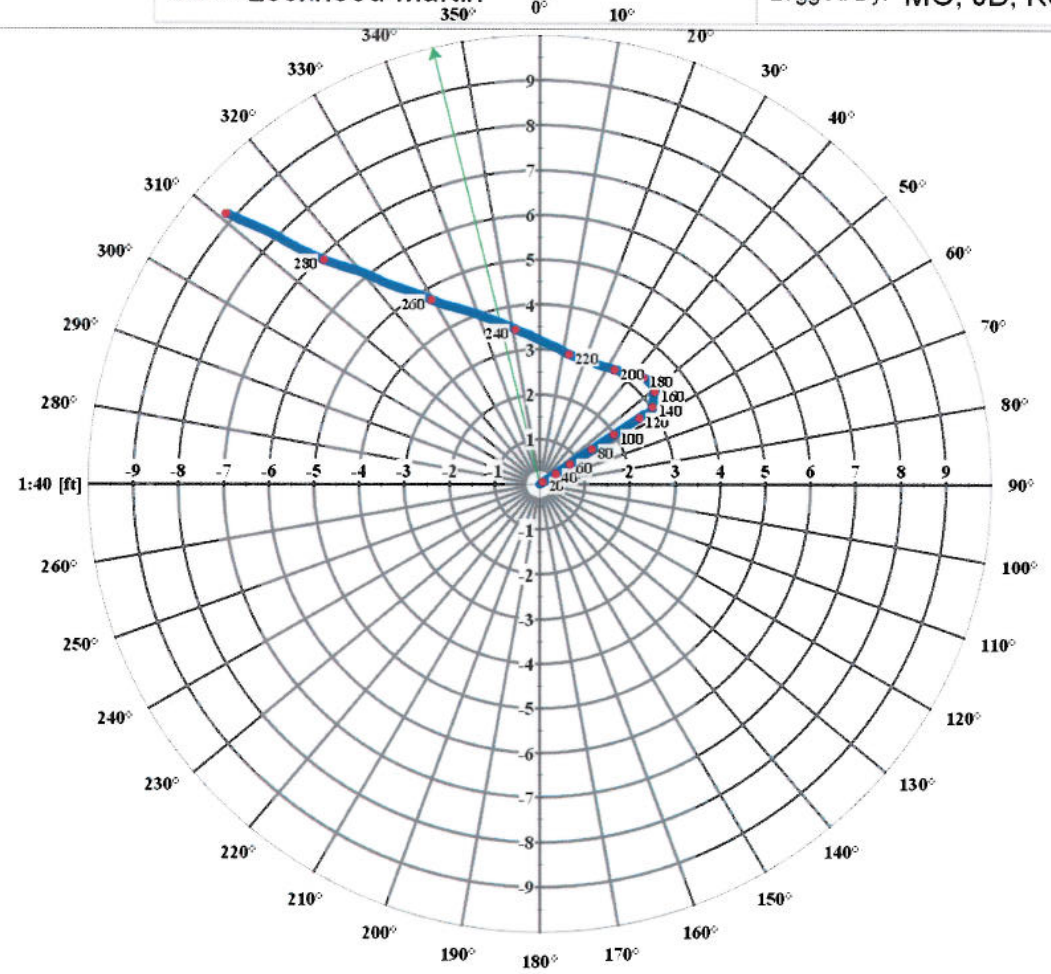


Hager GeoScience Inc.

Geophysical Logging Record:

Bull's Eye Deviation Plot

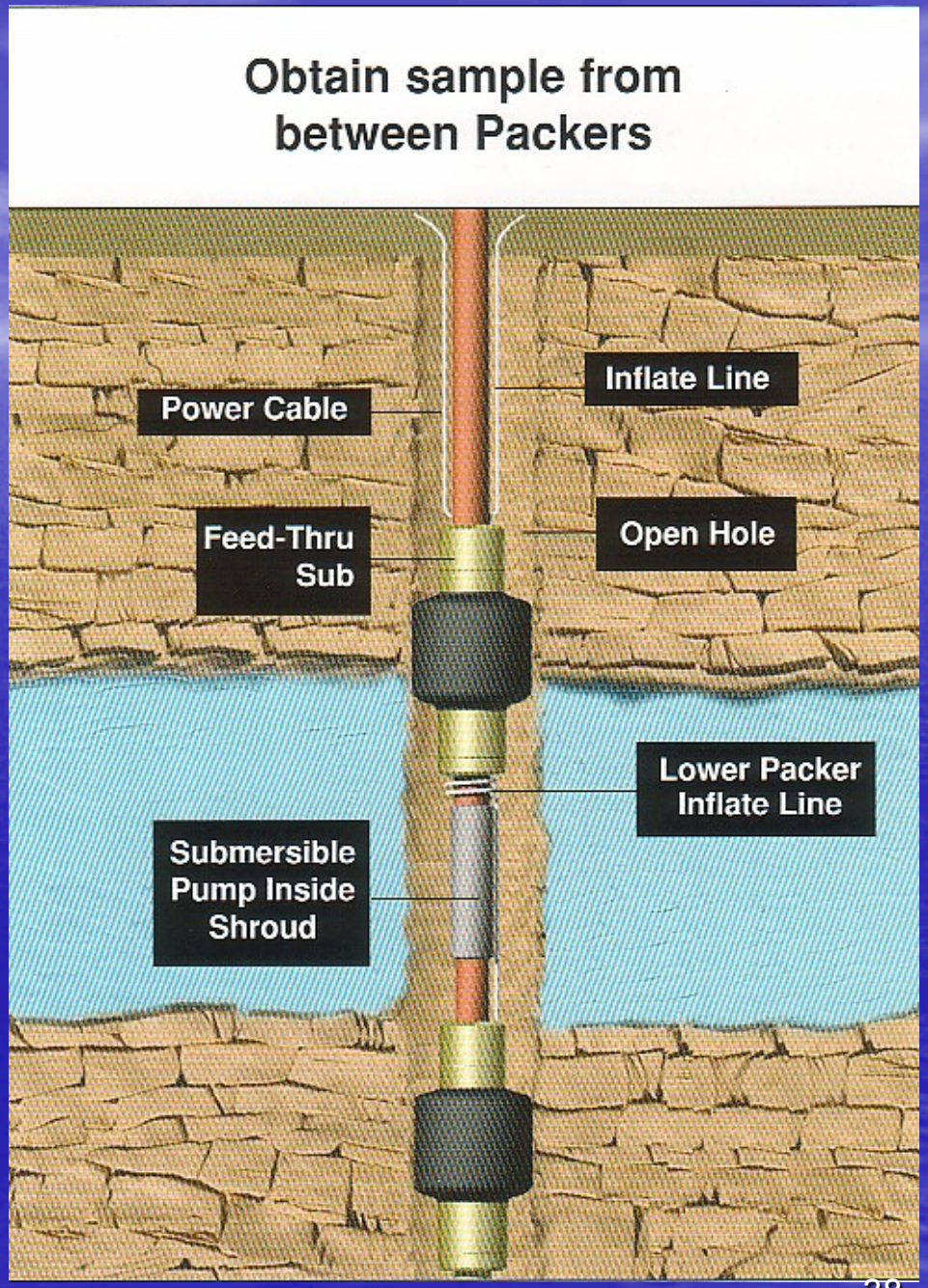
Site: Dewey Landfill	Boring #: MW-3
Location: Nassau, NY	Date Logged: 8-16-11
Client: Lockheed-Martin	Logged By: MC, JB, KS



Borehole Geophysical Data - Uses

- Packer Test Design
- Discrete-zone Multi-level Assembly Design
- Groundwater Sampling Strategy (Discussed in Case Studies)

Groundwater Straddle Packer Testing



Discrete-zone Multi-level Assembly Design

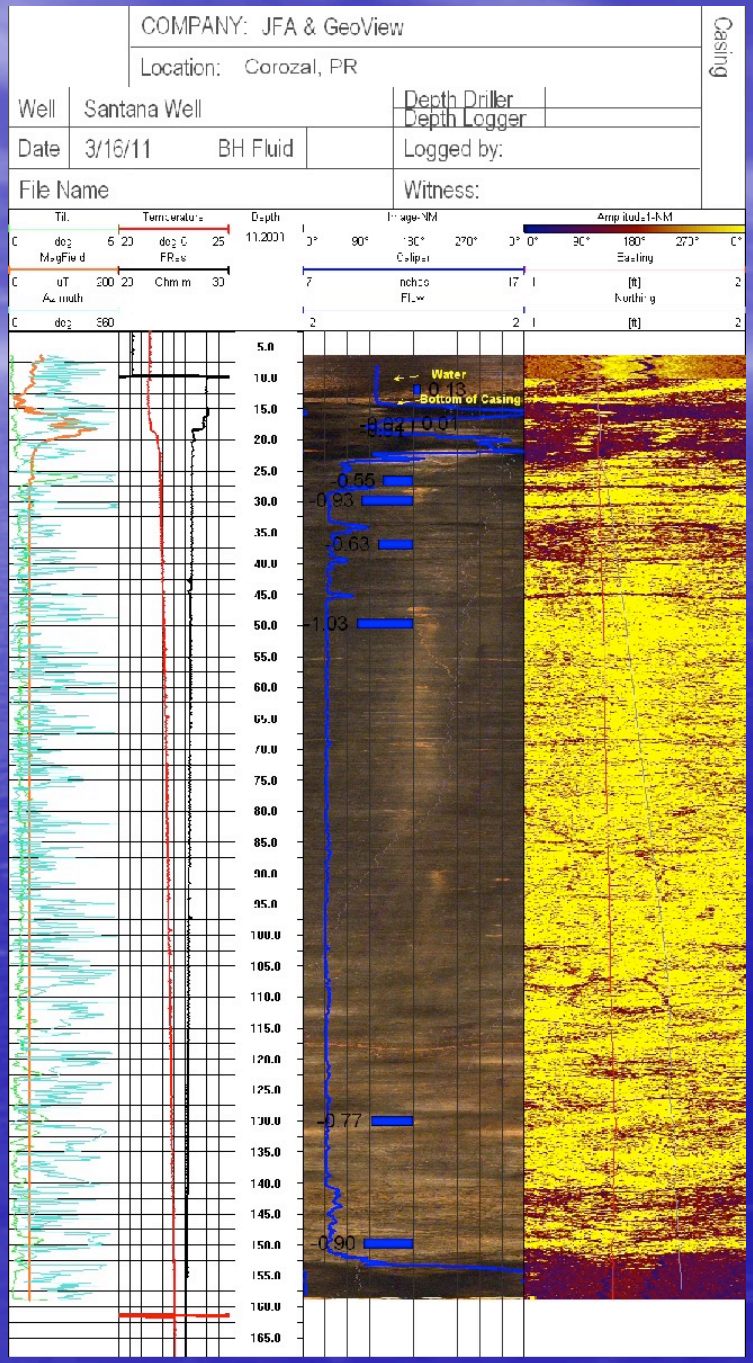
(Westbay, Flute, Solinist, etc.)

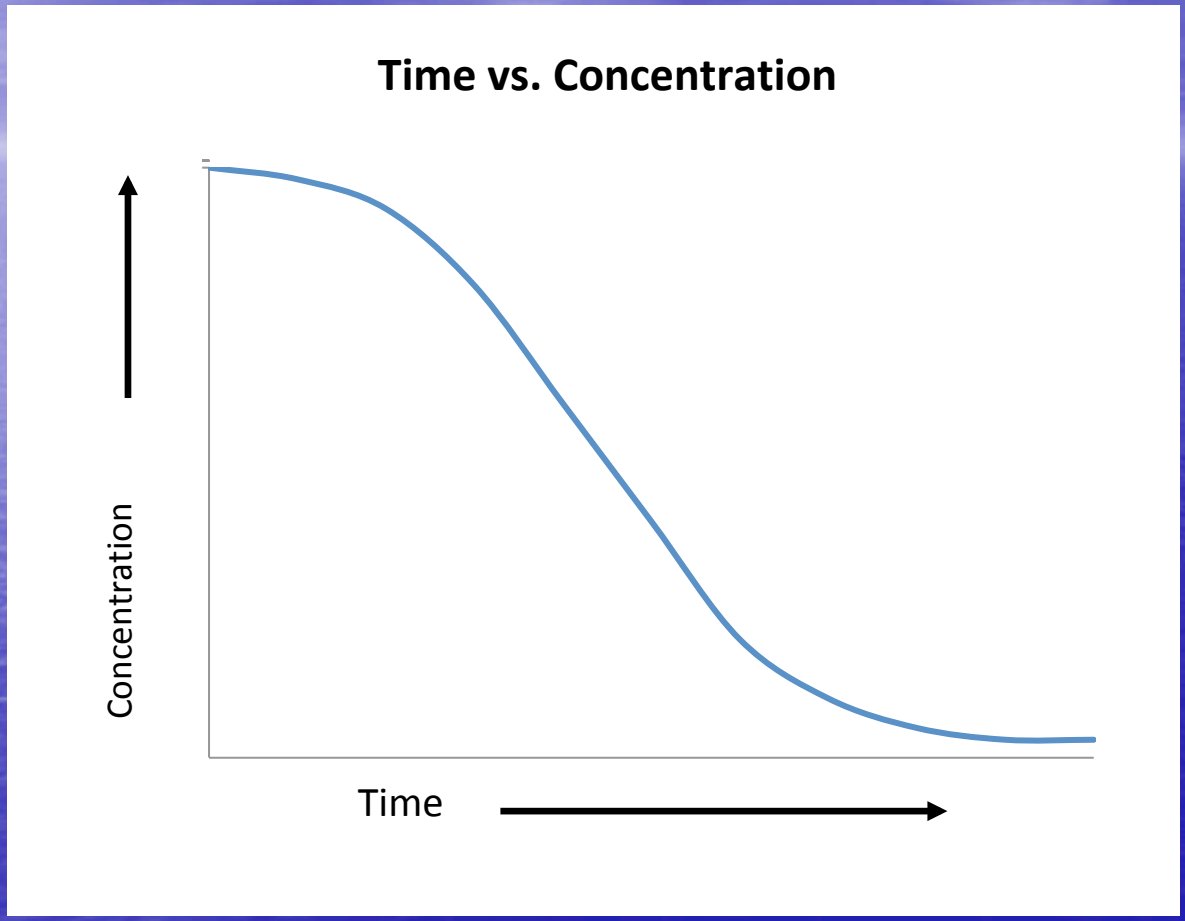

POWEREX

Case Study

Santana Community Production Well

Corozal, Puerto Rico


COMPANY: JFA & GeoView
Location: Corozal, PR
Casing
Well Santana Well
Depth Driller
Depth Logger
Date 3/16/11 BH Fluid
Logged by:
File Name
Witness:
Water
Bottom of Casing
-0.13
-0.84
-0.01
-0.55
-0.93
-0.63
-1.03
-0.77
-0.90

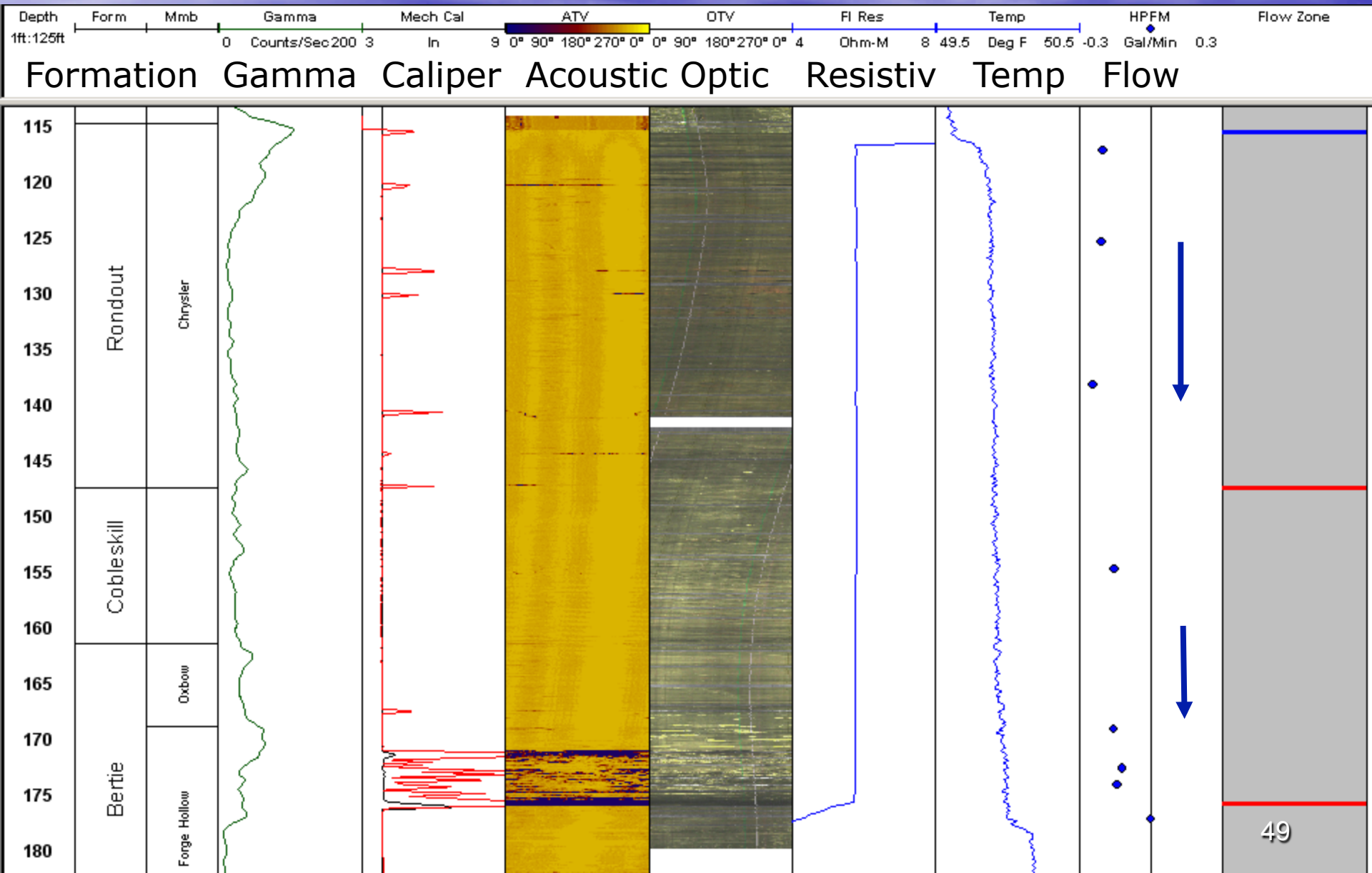

Time vs. Concentration
Concentration
Time

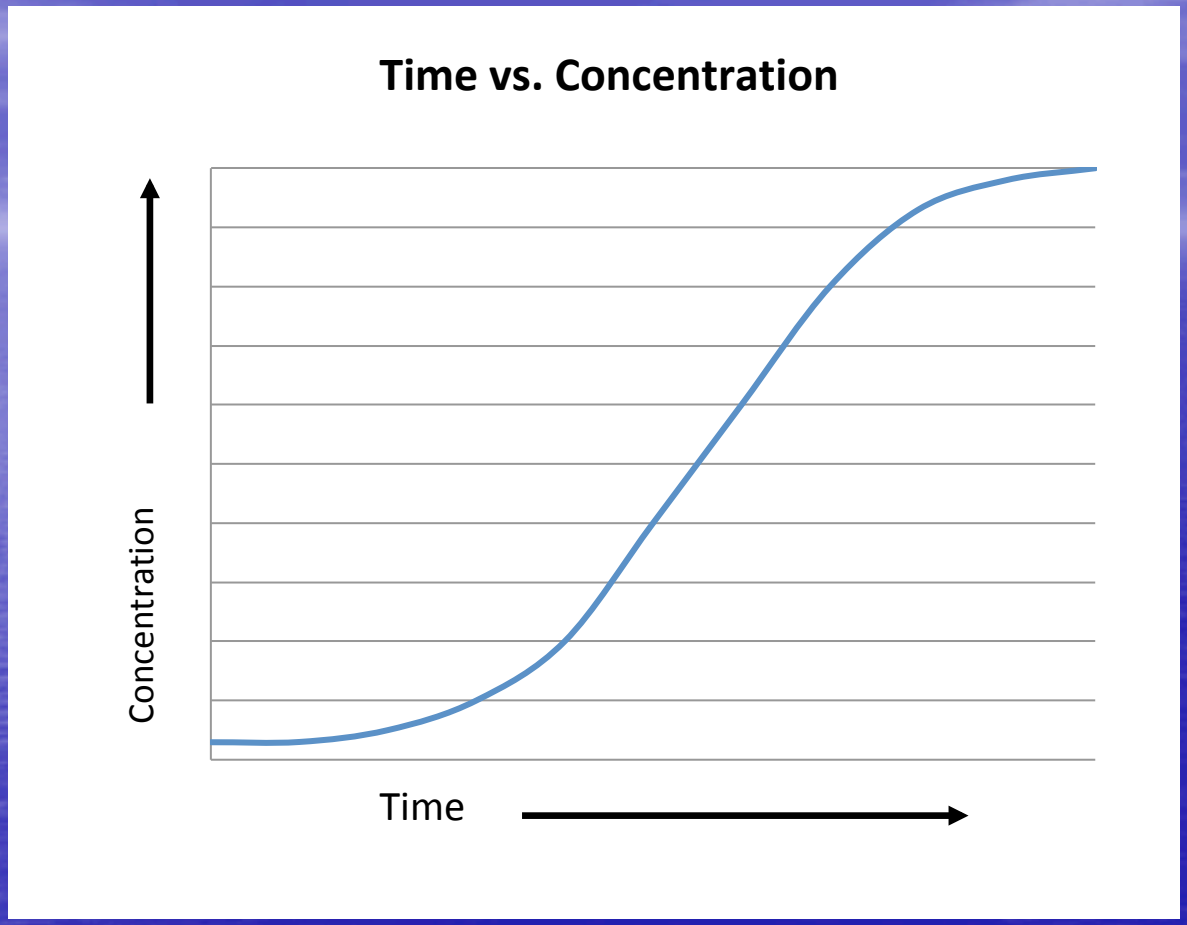
Case Study

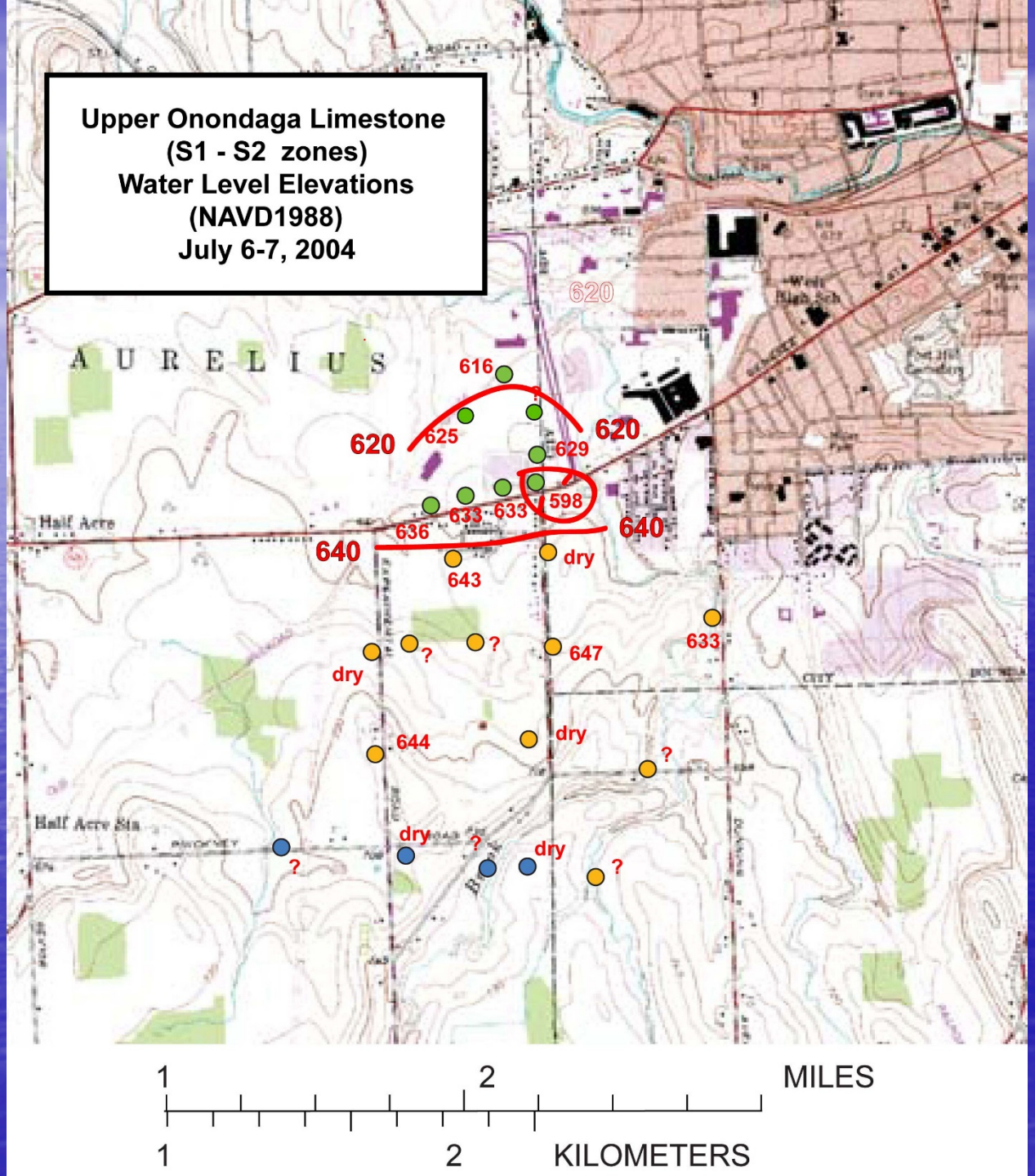
Cayuga County Groundwater Contamination Site

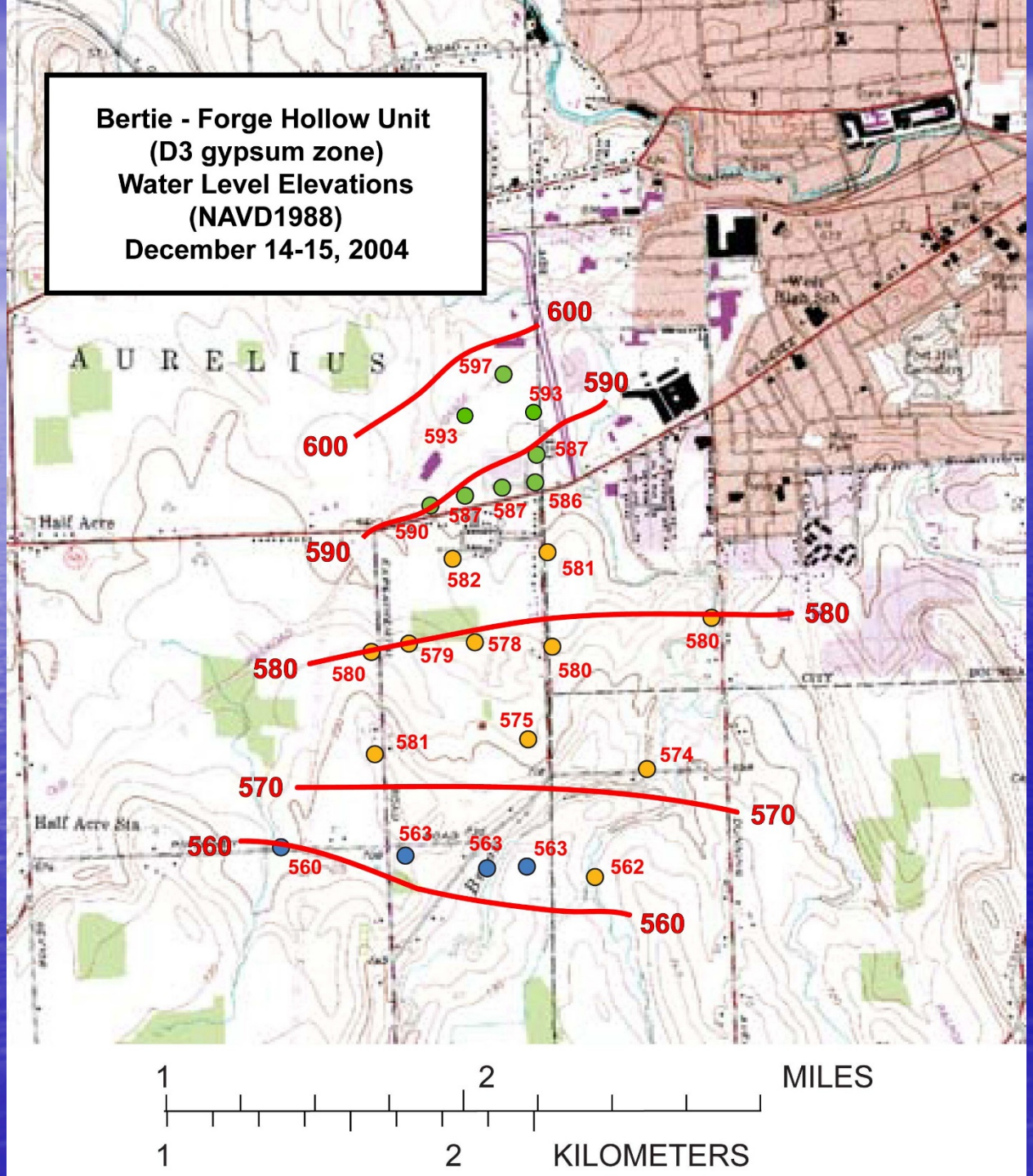
Cayuga County, New York

Geophysical, Stratigraphic, and Flow-Zone Logs
EPA-1



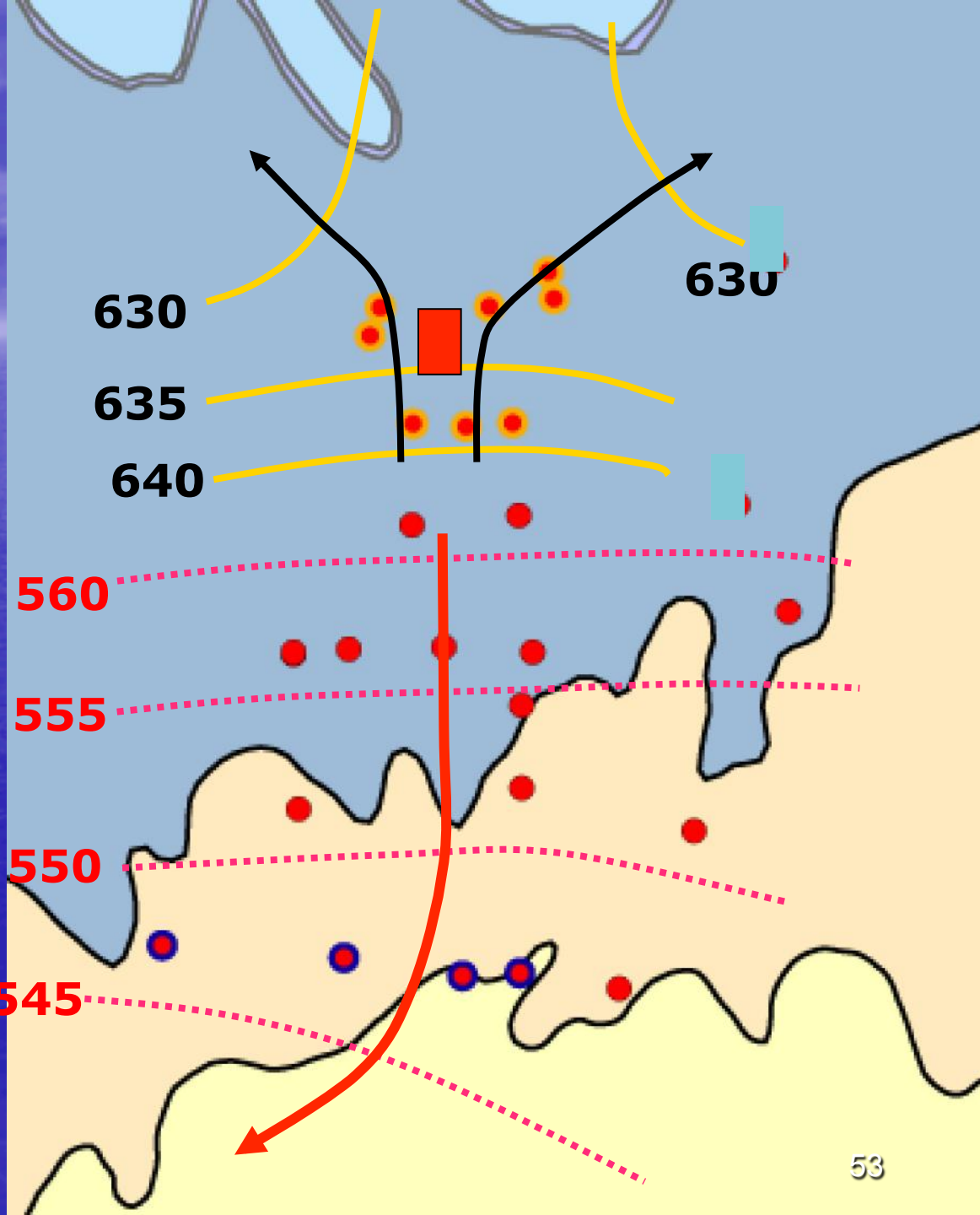

Time vs. Concentration
Concentration
Time


Upper Onondaga Limestone
(S1 - S2 zones)
Water Level Elevations
(NAVD1988)
July 6-7, 2004
AURELIUS
Half Acre
Half Acre Sta
620
640
616
625
629
598
633
636
643
dry
647
644
1
2
MILES
KILOMETERS


Bertie - Forge Hollow Unit
(D3 gypsum zone)
Water Level Elevations
(NAVD1988)
December 14-15, 2004
AURELIUS
Half Acre
600
597
593
590
593
587
600
586
587
587
590
590
582
581
580
580
579
578
580
580
580
575
581
574
570
570
Half Acre Sta
560
563
563
563
562
560
1
2
MILES
1
2
KILOMETERS

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

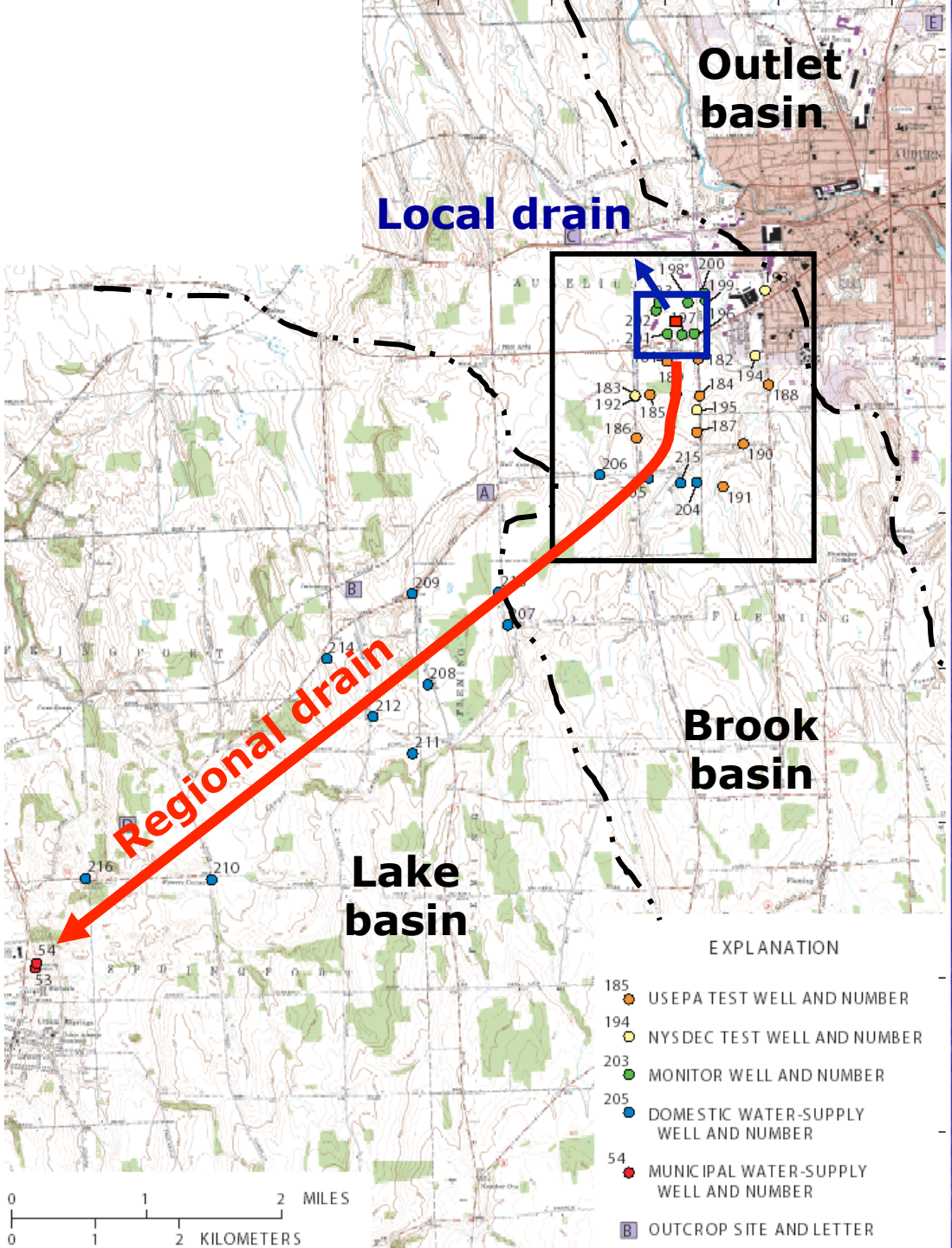


Regional Discharge

- U.S. EPA Dive Team locates groundwater discharge into a small bay in Cayuga Lake near Union Springs where the Forge Hollow Member of the Bertie Formation outcrops
- The location was an old gypsum mine site

Local and Regional Flow Paths

High likelihood that the Bertie Formation is a regional ground-water drain that allows movement of water (and contaminants?) toward southwestward discharge points



Hydrogeologic Appraisal of a Fractured-Rock Ground-Water Contamination Site -- A Discrete-zone Approach

by

David A. Eckhardt, USGS, Ithaca, NY

John H. Williams, USGS, Troy, NY

and

Donald T. Bussey, USEPA, Las Vegas, NV

U. S. Geological Survey

In cooperation with
U. S. Environmental Protection Agency

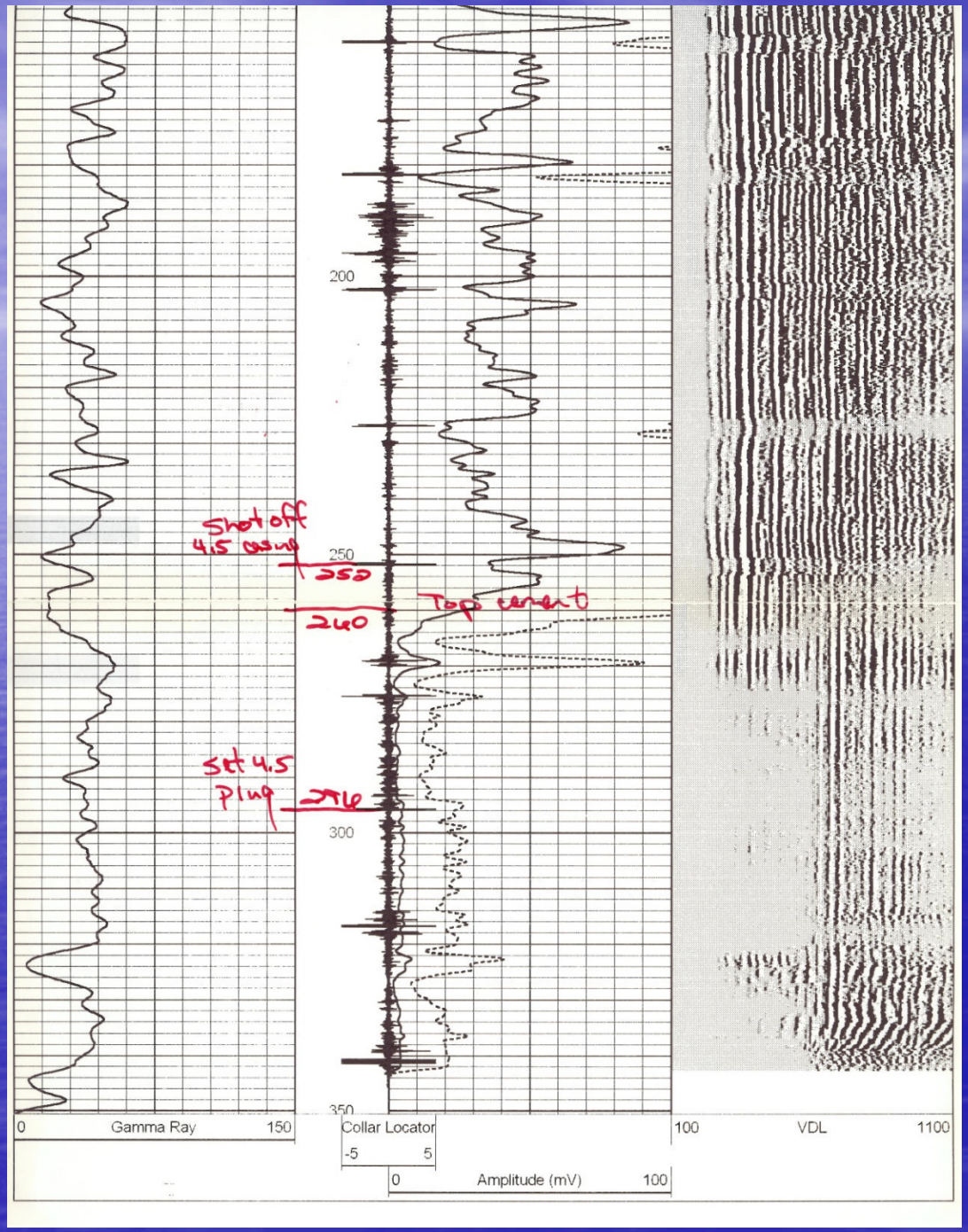
Oil & Gas Well Abandonment Applications
Casing Collar Locator and Cement Bond Logging

Used in the oil and gas industry during borehole abandonment.

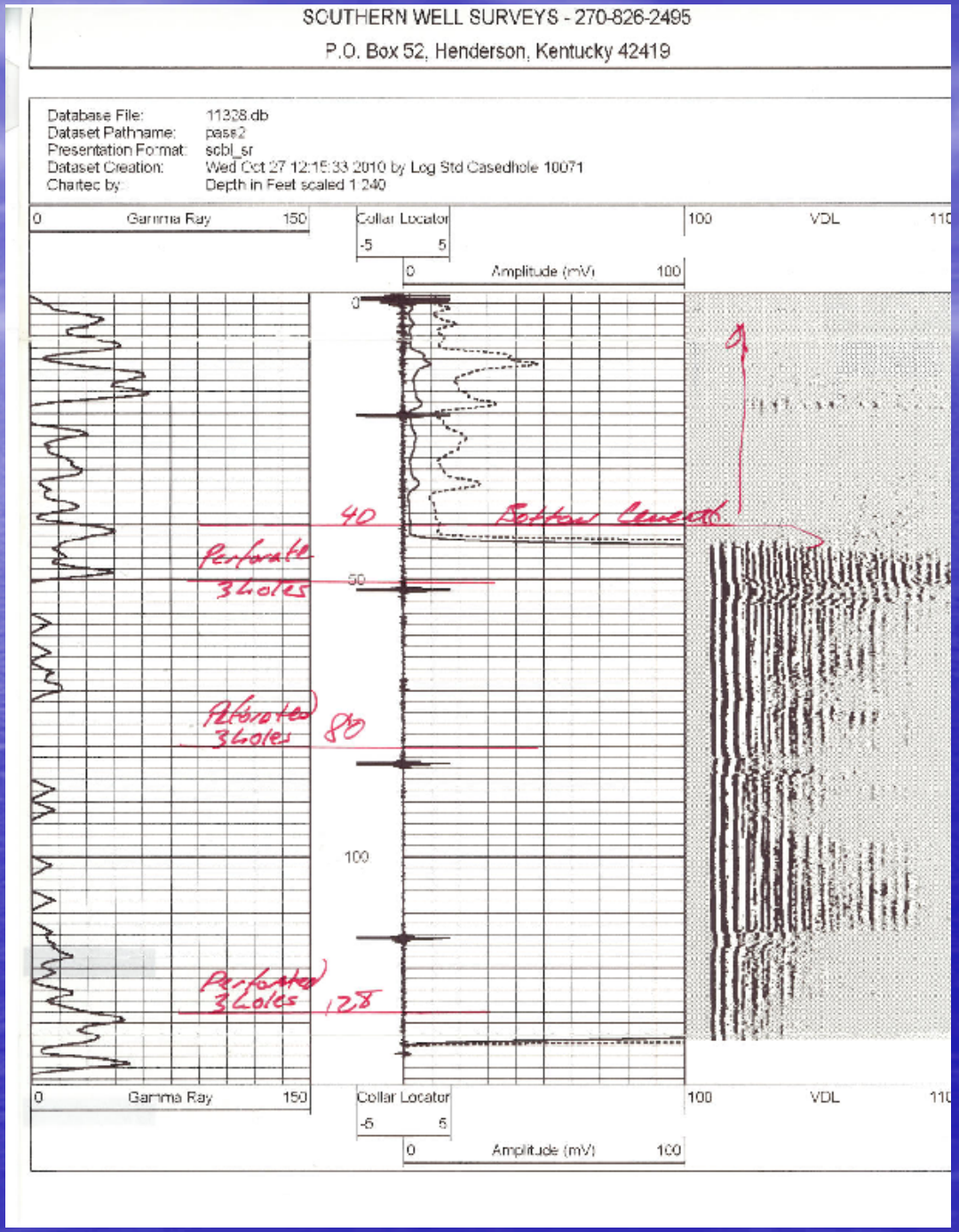
Casing Collar logs (magnetic) used to identify casing collars for targeting during casing shoot offs.

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.


200
250
300
350
Shot off
4.5 casing
250
240
Top cement
Set 4.5
plug
236
0
Gamma Ray
150
Collar Locator
-5
5
0
Amplitude (mV)
100
100
VDL
1100


CAUTION CAUTION CAUTION


SOUTHERN WELL SURVEYS - 270-826-2495
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 10071
Chartec by: Depth in Feet scaled 1:240
0 Gamma Ray 150
Collar Locator
-5 5
0 Amplitude (mV) 100
100 VDL 110
40
Bottom Casing
Perforated
3 holes
50
Perforated
3 holes
80
100
Perforated
3 holes
128
0 Gamma Ray 150
Collar Locator
-5 5
0 Amplitude (mV) 100
100 VDL 110


CAUTION
CAUTION

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

1. *ERTVideo.org*,

2. Click on *Videos*,

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

To view a streaming video of this presentation, or to obtain slides in PowerPoint format (Borehole Geophysics Applied to Bedrock Hydrogeological Evaluations) go to:

1. *http://www.clu-in.org/conf/tio/ERTPBoreholeGeophysics_092914/*,

2. Click on *View archive online* (for streaming video), or

3. *Download slides in PowerPoint format*.

Conclusion

Know Your Borehole !

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

Don Bussey, CPG-08847

USEPA-ERT/Las Vegas

bussey.don@epa.gov