Surface & Borehole Geophysical Methods for Environmental Investigations

LIAPG and NYSCPG Joint Event
November 8, 2018

Robert Garfield, P.G.
Owner/Principal Borehole Geophysicist

Hager-Richter Geoscience, Inc.
www.hager-richter.com

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Presentation Outline

- **Benefits of Geophysics**
- Surface Geophysical Methods
- Borehole Geophysical Logging Methods
- Questions

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Benefits of Geophysics for Environmental Investigations

- Many Methods are Non-Invasive & Can Be an Important Tool in Your Site Characterization Toolbox
- Characterize Larger Areas than Borings & Test Pits, Target Future Borings & Test Pits, Provide Additional Information
- Relatively Inexpensive Considering Value of Information Provided
- Less Uncertainty in Subsurface Characterization & Groundwater Flow Models

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- Benefits of Geophysics
- **Surface Geophysical Methods**
- Borehole Geophysical Logging Methods
- Questions

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Surface Geophysical Methods

- **Ground Penetrating Radar (GPR)**
- **Electromagnetic (EM) Induction**
- **Precision Utility Locating (PUL)**
- Electrical Resistivity
- Seismic Refraction

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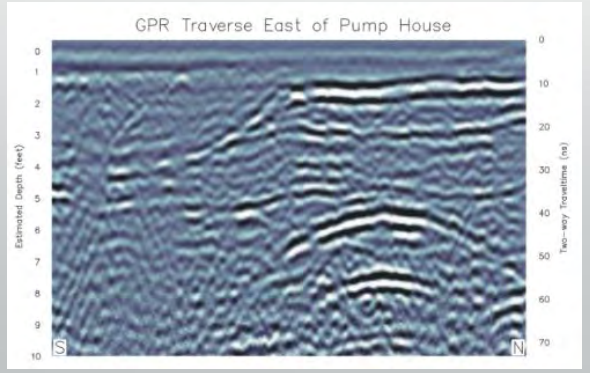
Ground Penetrating Radar (GPR)

- Presence, ID, & Location of Subsurface Objects
  - Metallic & Non-Metallic Objects
- Nature of Shallow Geologic Layers
- Depth of Shallow Bedrock
- Thickness of Concrete & Pavement



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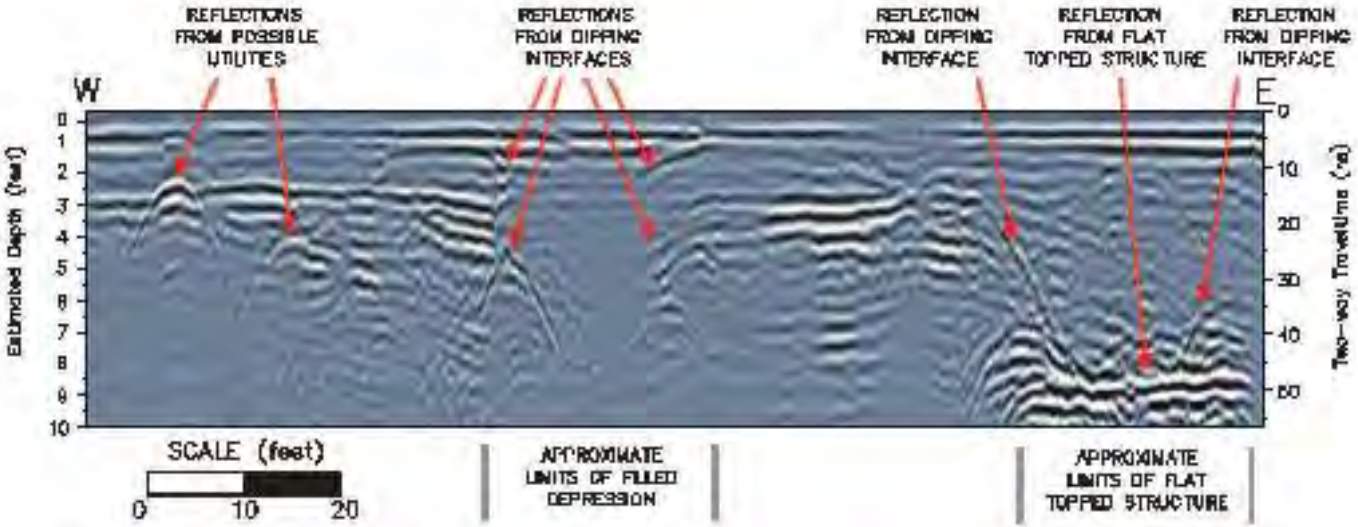

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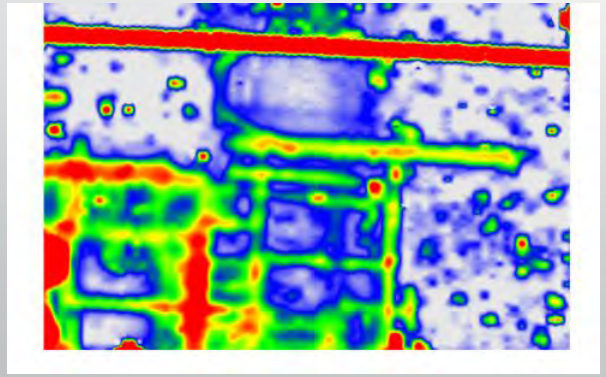
Electromagnetic (EM) Induction

- Presence & Location of Subsurface Objects
  - Especially Metallic Objects
- Changes in Soil Properties
  - Landfill Delineation



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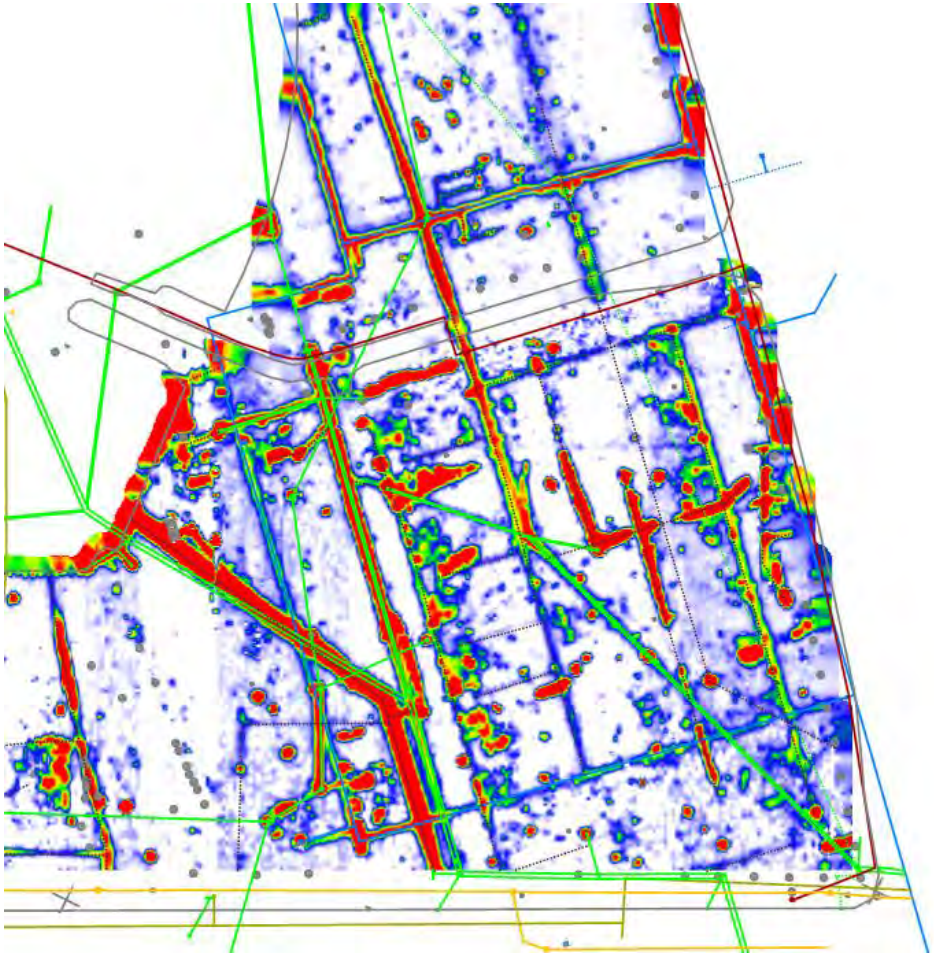

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Precision Utility Locating (PUL)

- Detect Live Electric
- Detect Utilities by Inducing Signal Along Conductive Conduits or Tracer Wire
- PVC & Concrete Pipes Can be Detected by Snaking the Utility

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Surface Geophysical Methods

- Ground Penetrating Radar (GPR)
- Electromagnetic (EM) Induction
- Magnetics
- Precision Utility Locating (PUL)
- **Electrical Resistivity**
- Seismic Refraction

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Electrical Resistivity

- Characteristics of Shallow Geologic Layers
  - Peat, Clay, Sand, Silt, & Till
  - Voids, Caves, Karst
- Depth of Shallow Bedrock
- Depth of Water Table
- Location of Tunnels & Other Manmade Structures

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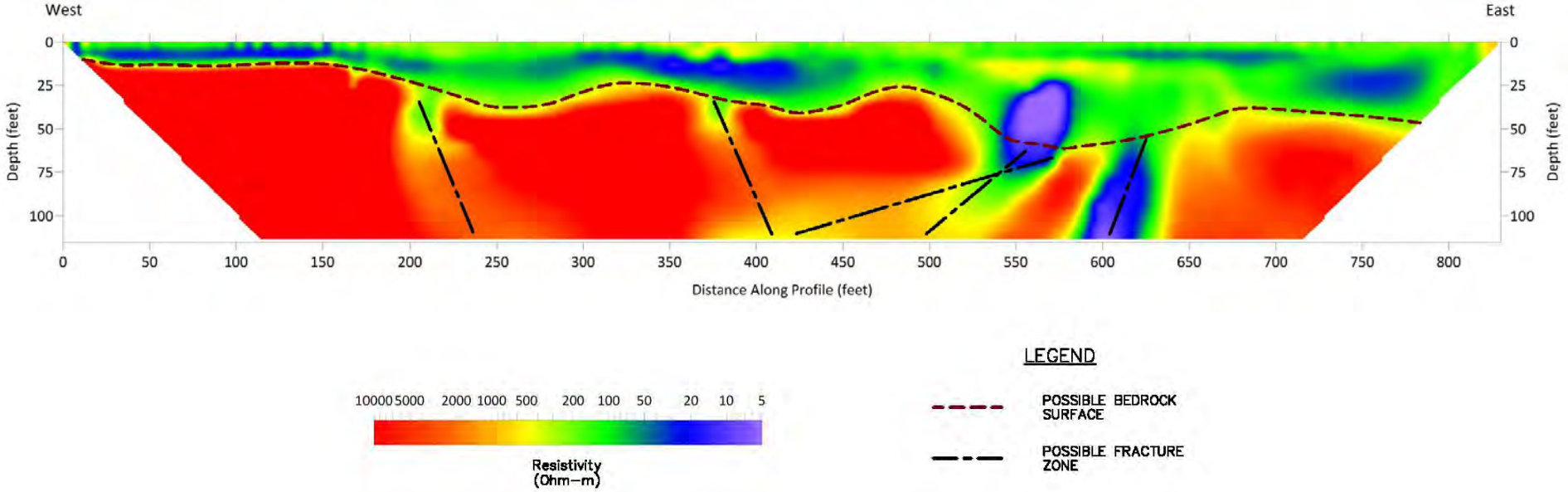

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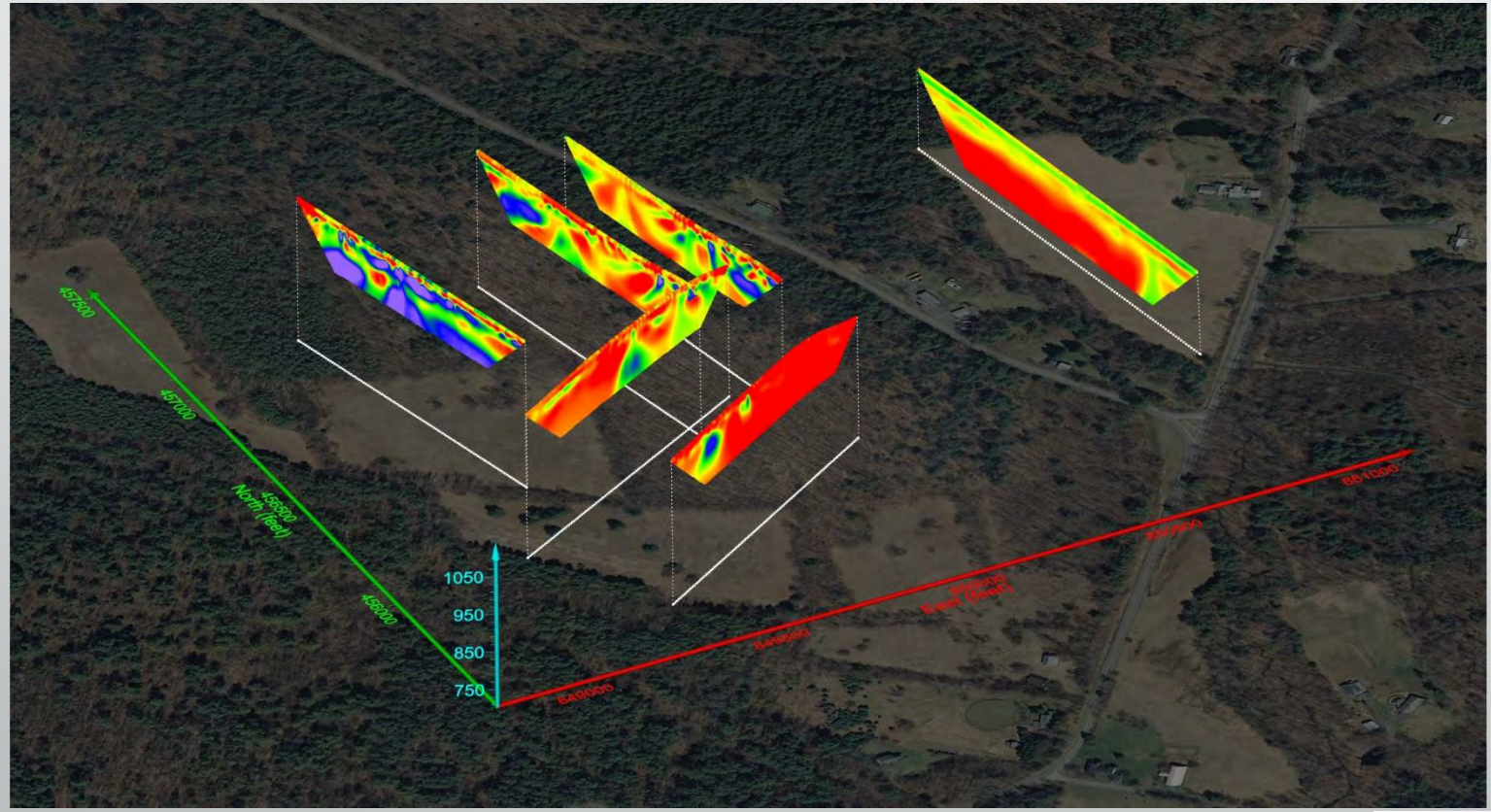

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Surface Geophysical Methods

- Ground Penetrating Radar (GPR)
- Electromagnetic (EM) Induction
- Magnetics
- Precision Utility Locating (PUL)
- Electrical Resistivity
- **Seismic Refraction**

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Seismic Refraction

- Depth & Configuration of Bedrock
- Velocity of Bedrock – Rippability
- Depth of Overburden Layer Interfaces
- Velocity of Overburden
- Depth of Water Table
- Uses an Active Source

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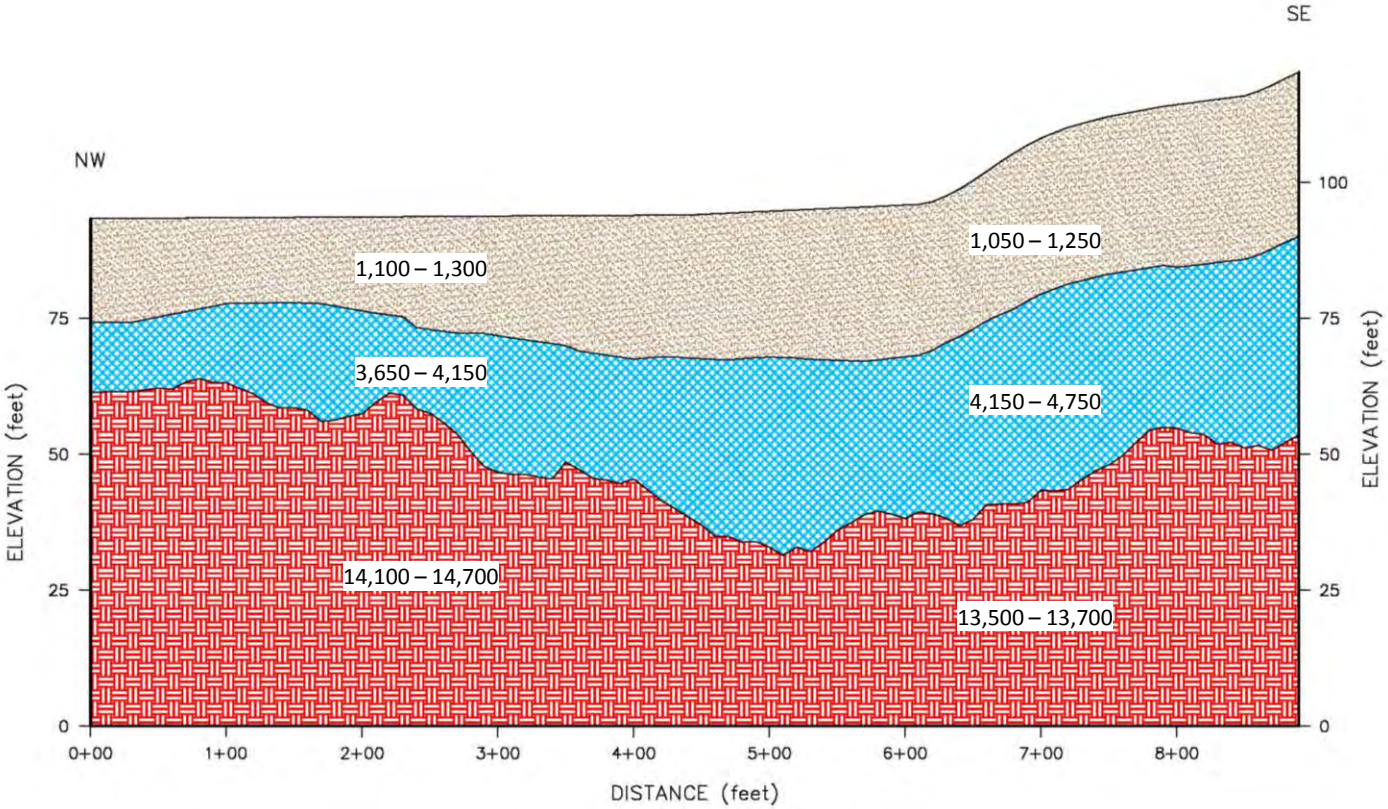

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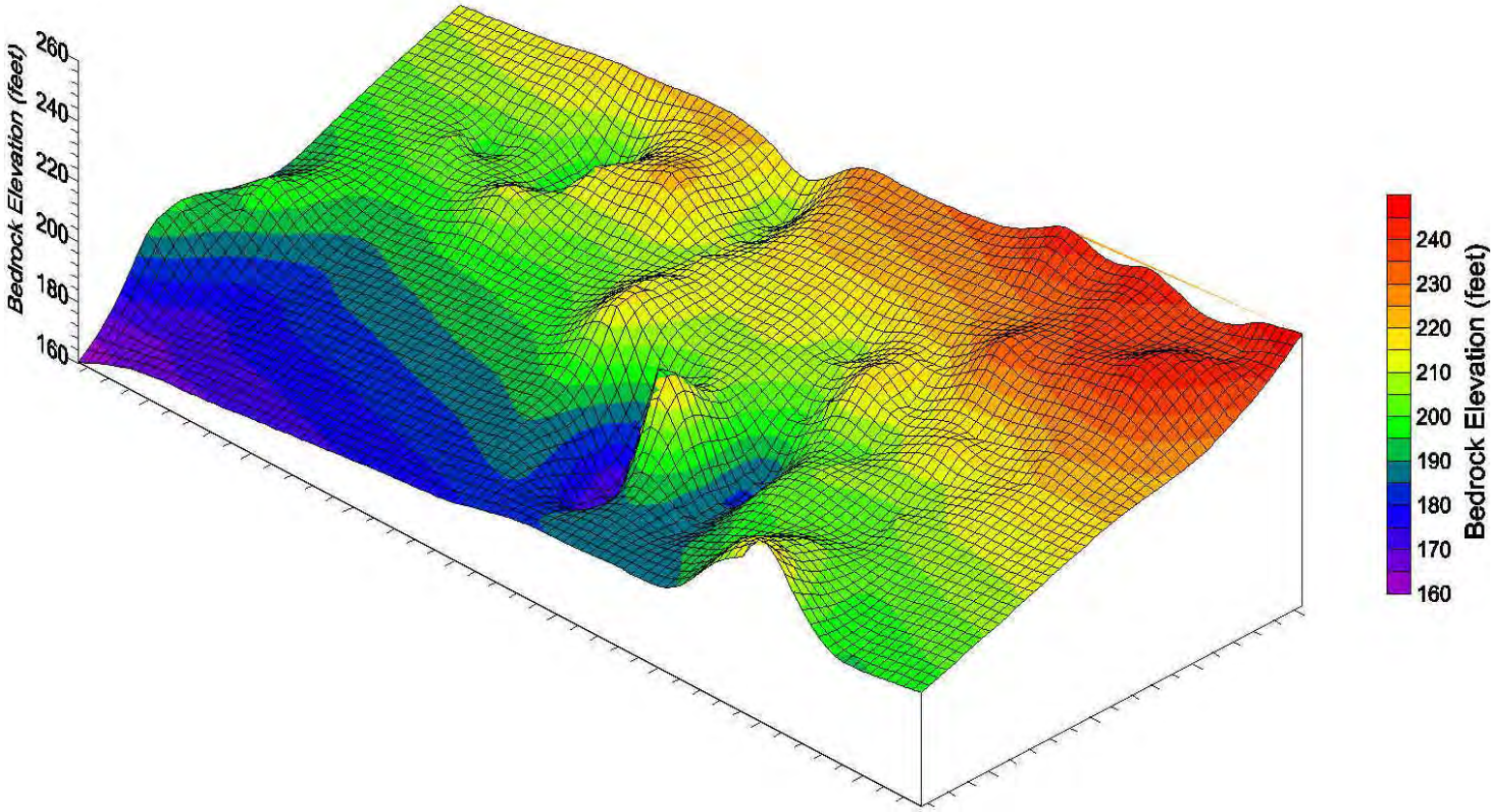

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Borehole Geophysical Logging

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Borehole Geophysical Logging Setup

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Borehole Geophysical Logging Van & Setup

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Borehole Geophysical Logging Methods

- Standard Logging
  - Caliper
  - Natural Gamma Ray
  - Electrical (Normal Resistivity, SP, SPR)
  - EM Induction & Magnetic Field
- Flow Logging
  - Fluid Properties (Temp, Cond/Res, + Others Fluid Parameters)
  - Flow Meters (HPFM & Spinner)
- Image Logging
  - Optical Televiewer (OTV) & Acoustic Televiewer (ATV)
  - Borehole Video
- Deviation Logging

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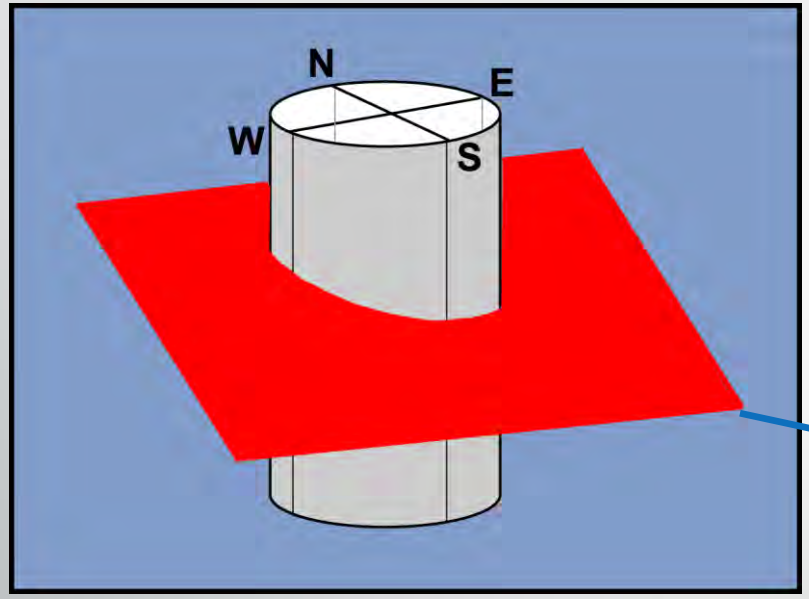
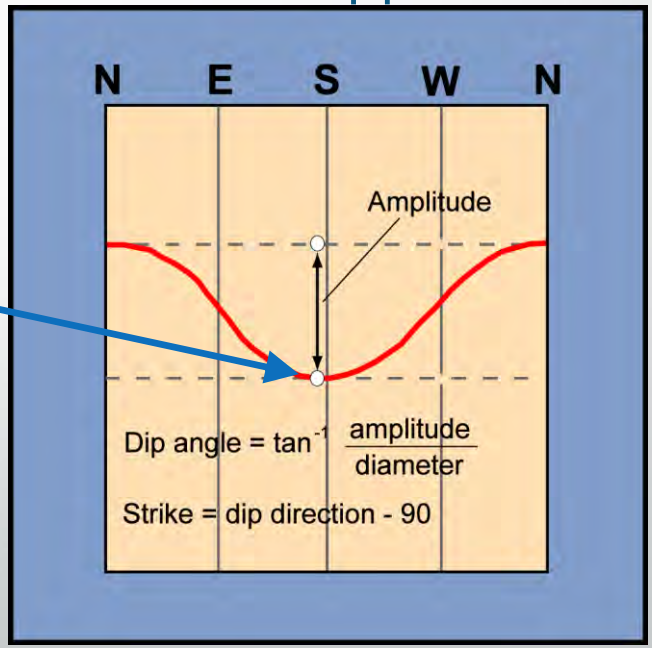
Borehole Televiewer Explanation



Projected
"unwrapped"



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Borehole Televiewer Explanation

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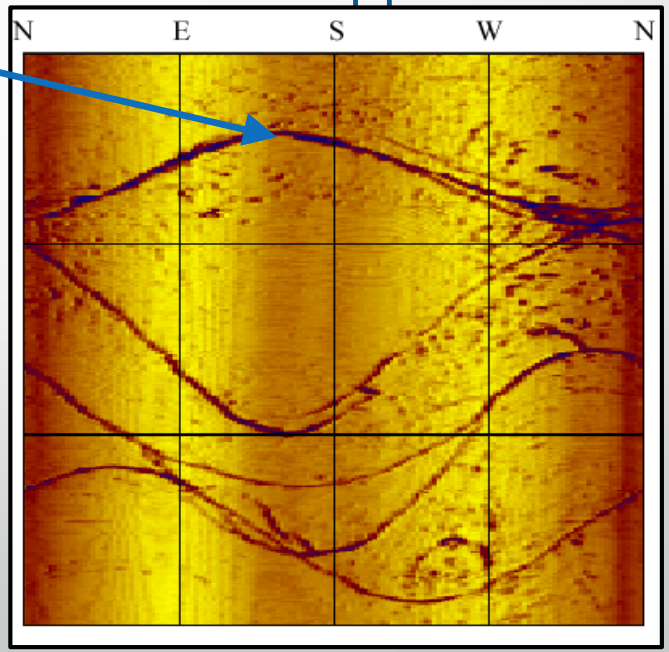
"unwrapped"



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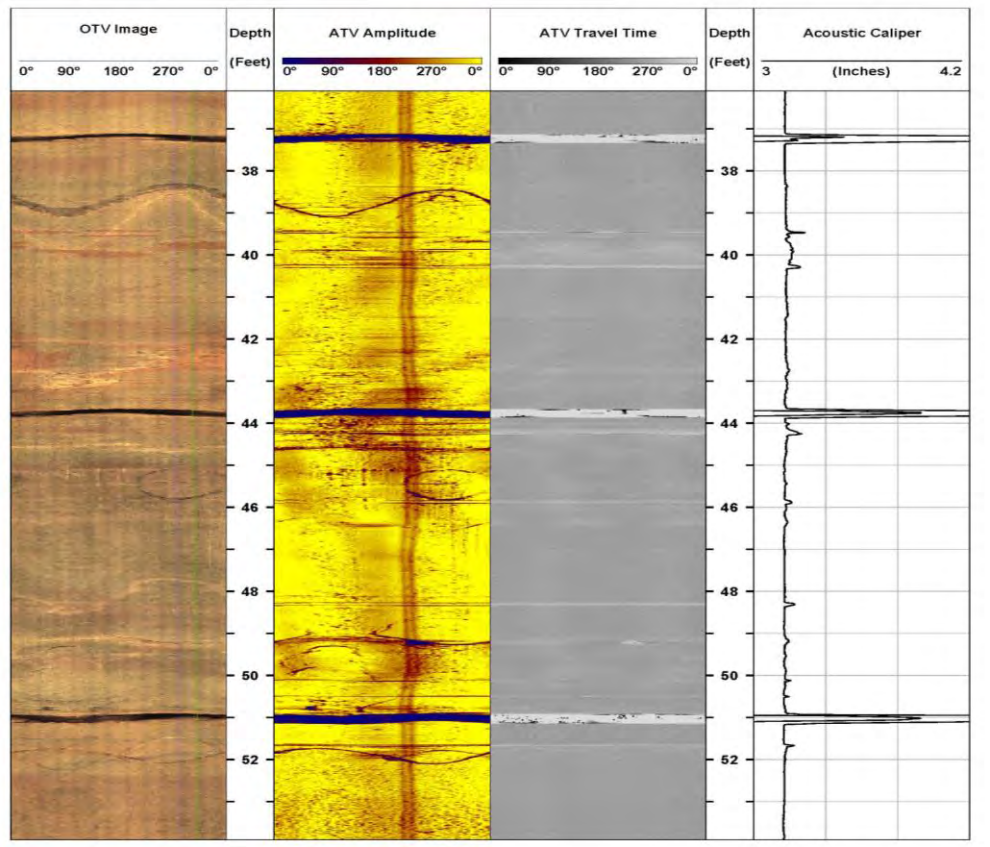
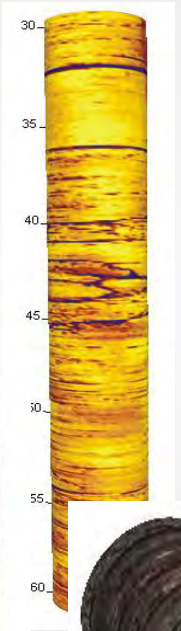
Borehole Televiewer Images





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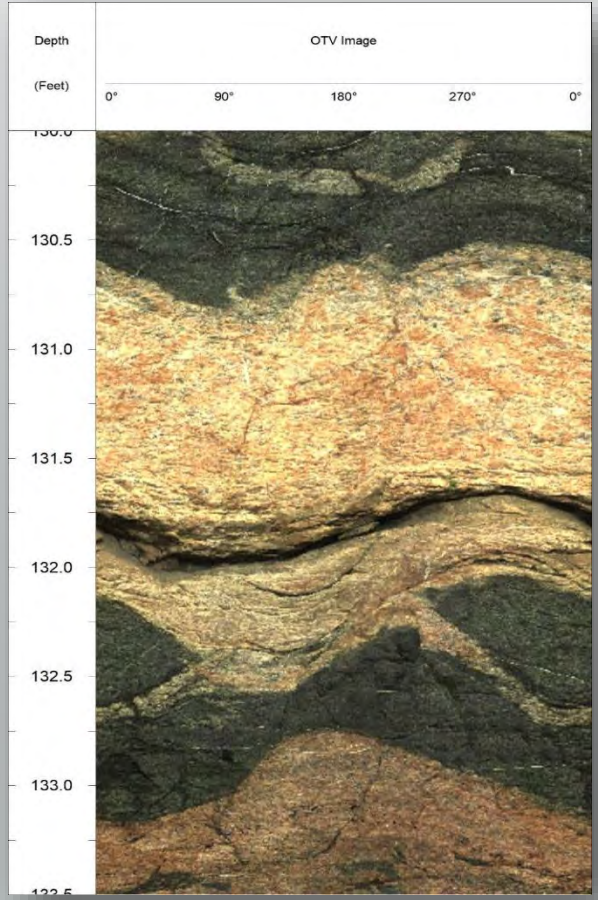
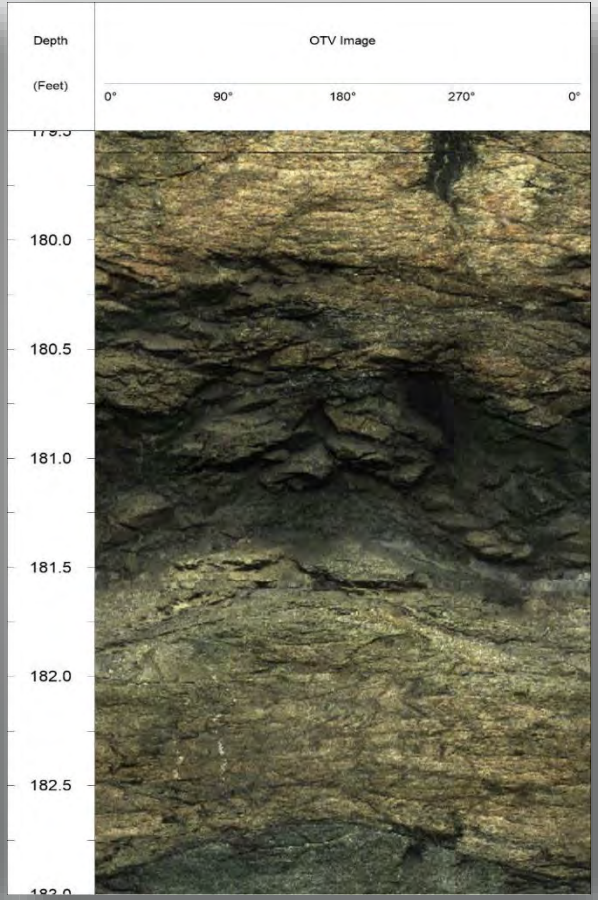
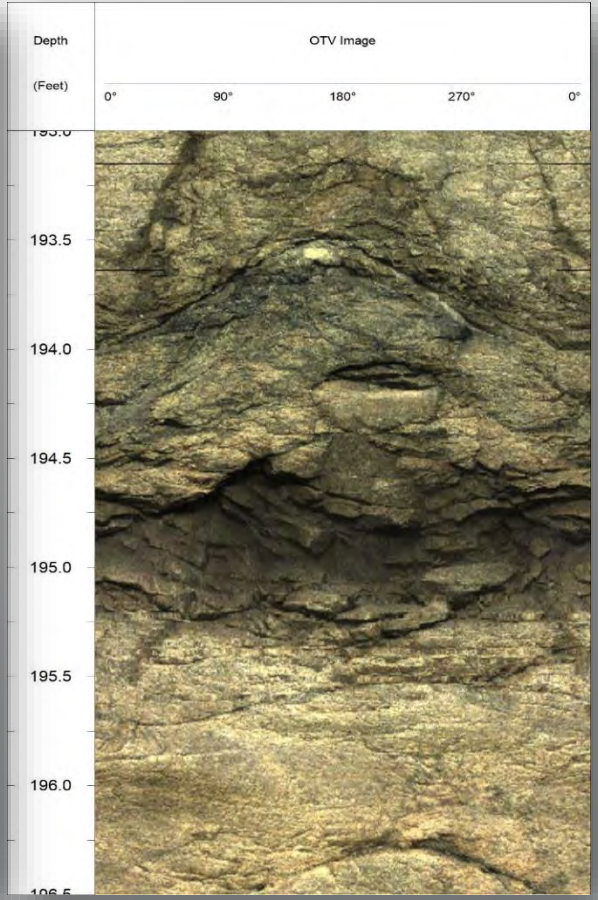
Optical Televiewer (OTV) Images







STRUCTURE LEGEND

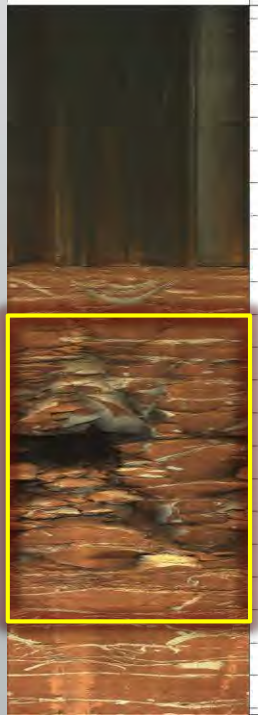
Fracture Rank 1

OTV Image

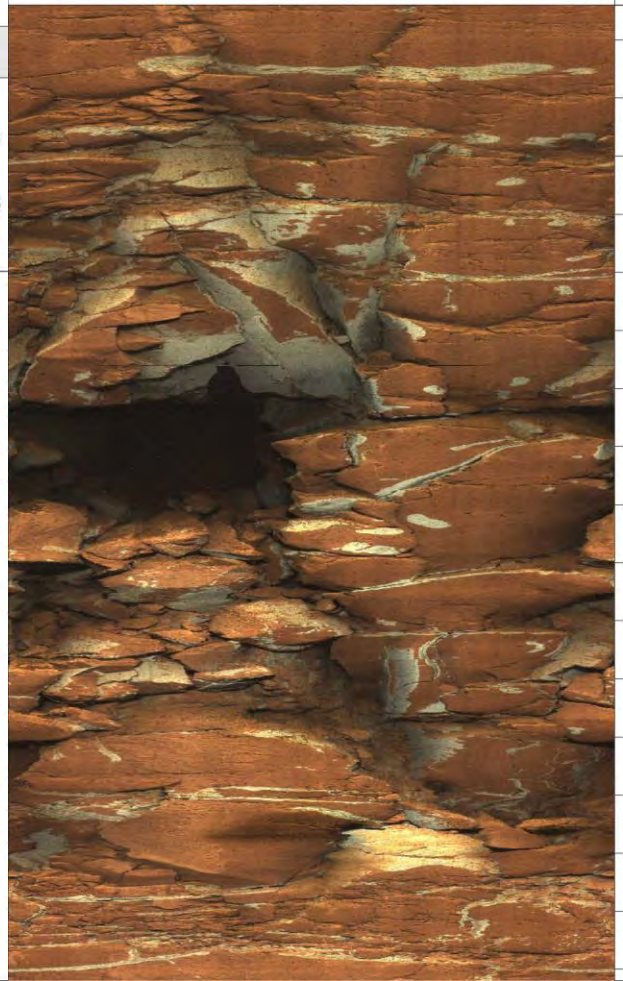
0° 90° 180° 270° 0°

Depth

(Feet)



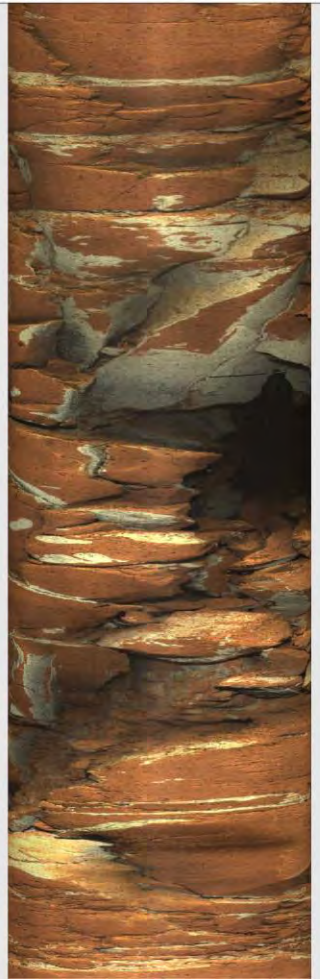
34 36 38 40 42 44 46 48 50 52 54

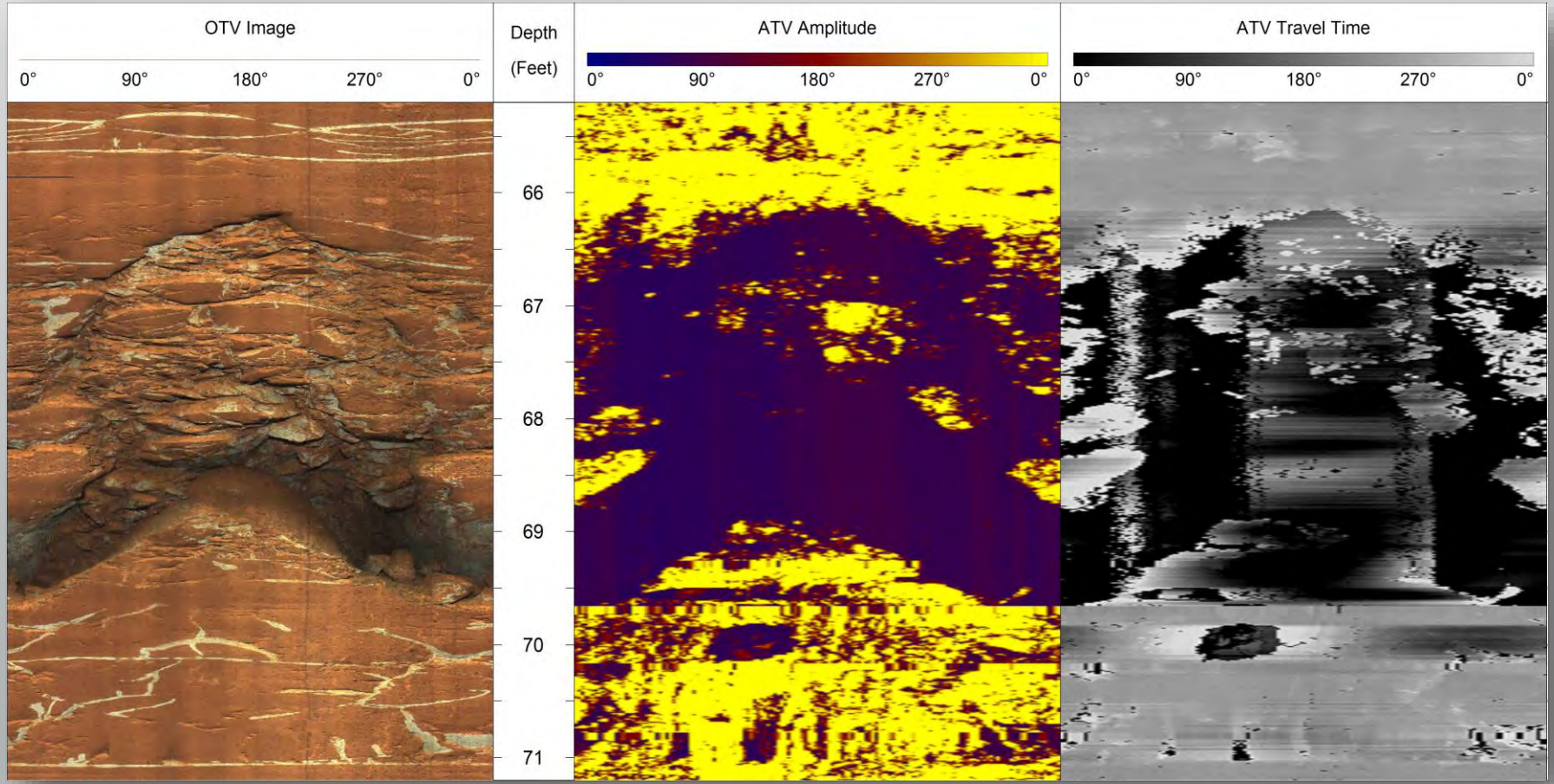


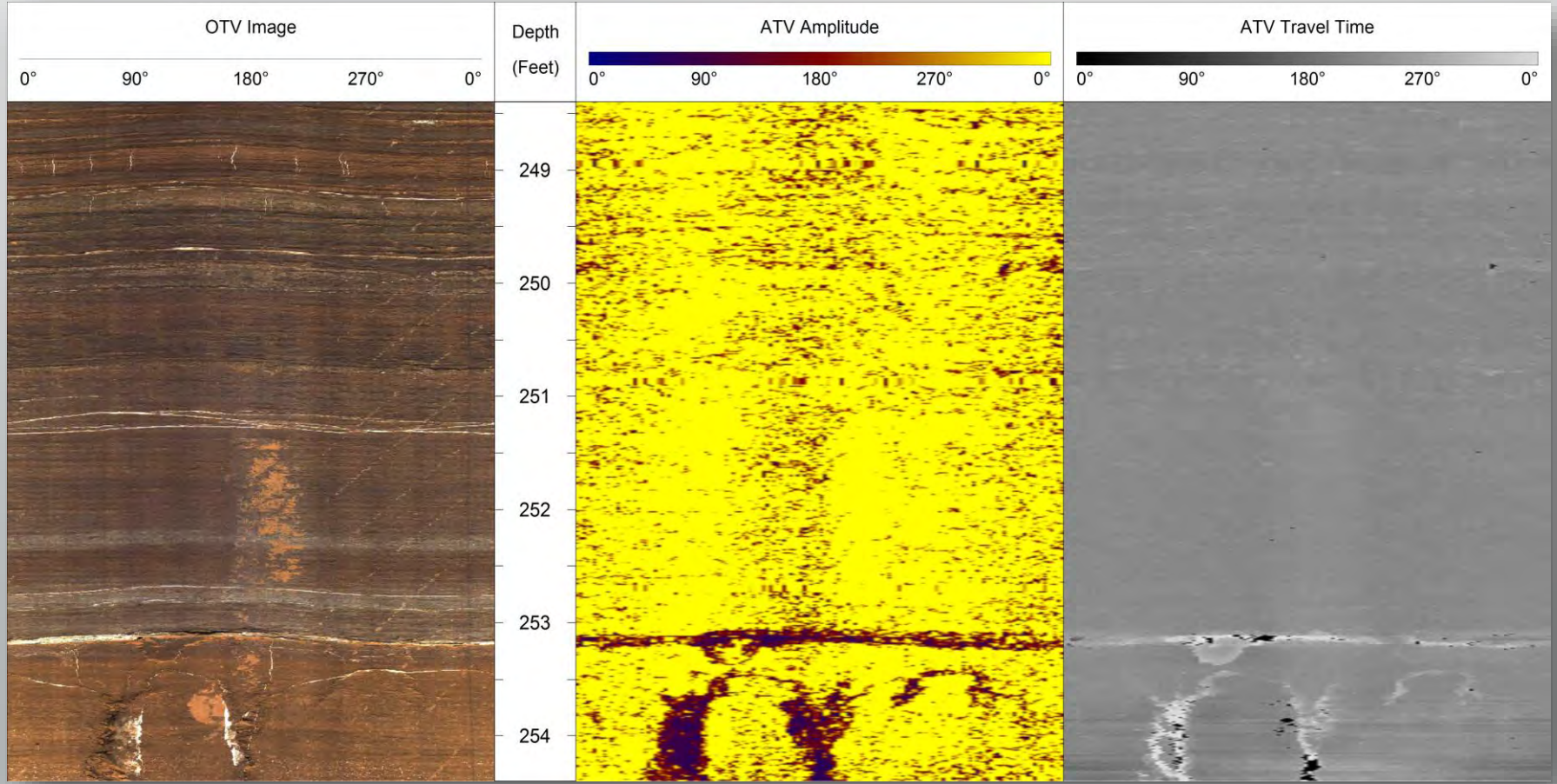
43 44 45 46 47 48 49 50

OTV Virtual Core

180°





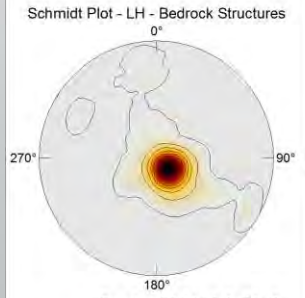


Bedrock Structure Statistics Plots

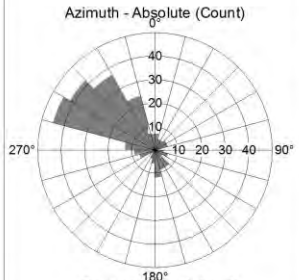
STRUCTURE LEGEND

Fracture Rank 1 | Fracture Rank 2 | Fracture Rank 3 | Bedding

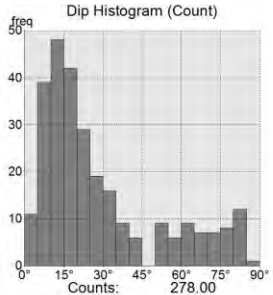
Stereogram - Lower Hemisphere of Bedrock Fractures	Dip Azimuth Rose Diagram of Bedrock Fractures	Dip Angle Histogram of Bedrock Fractures	Stereogram - Lower Hemisphere of Bedding	Dip Azimuth Rose Diagram of Bedding	Dip Angle Histogram of Bedding



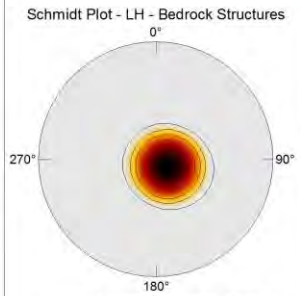
	Counts	Dip[deg]	Azi[deg]
Mean	278	11.64	310.70
	101	13.47	303.84
	147	11.24	315.69
	30	7.99	309.51



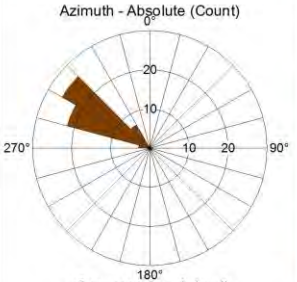
Components:	Azimuth
Counts:	278.00
Mean (3D):	310.70
Min:	0.09
Max:	357.62



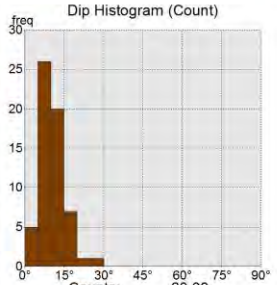
Counts:	278.00
Mean (3D):	11.64
Min:	0.90
Max:	87.66



	Counts	Dip[deg]	Azi[deg]
Mean	60	9.79	301.81
▸	60	9.79	301.81



Components:	Azimuth
Counts:	60.00
Mean (3D):	301.81
Min:	13.31
Max:	327.75



Counts:	60.00
Mean (3D):	9.79
Min:	1.85
Max:	25.23

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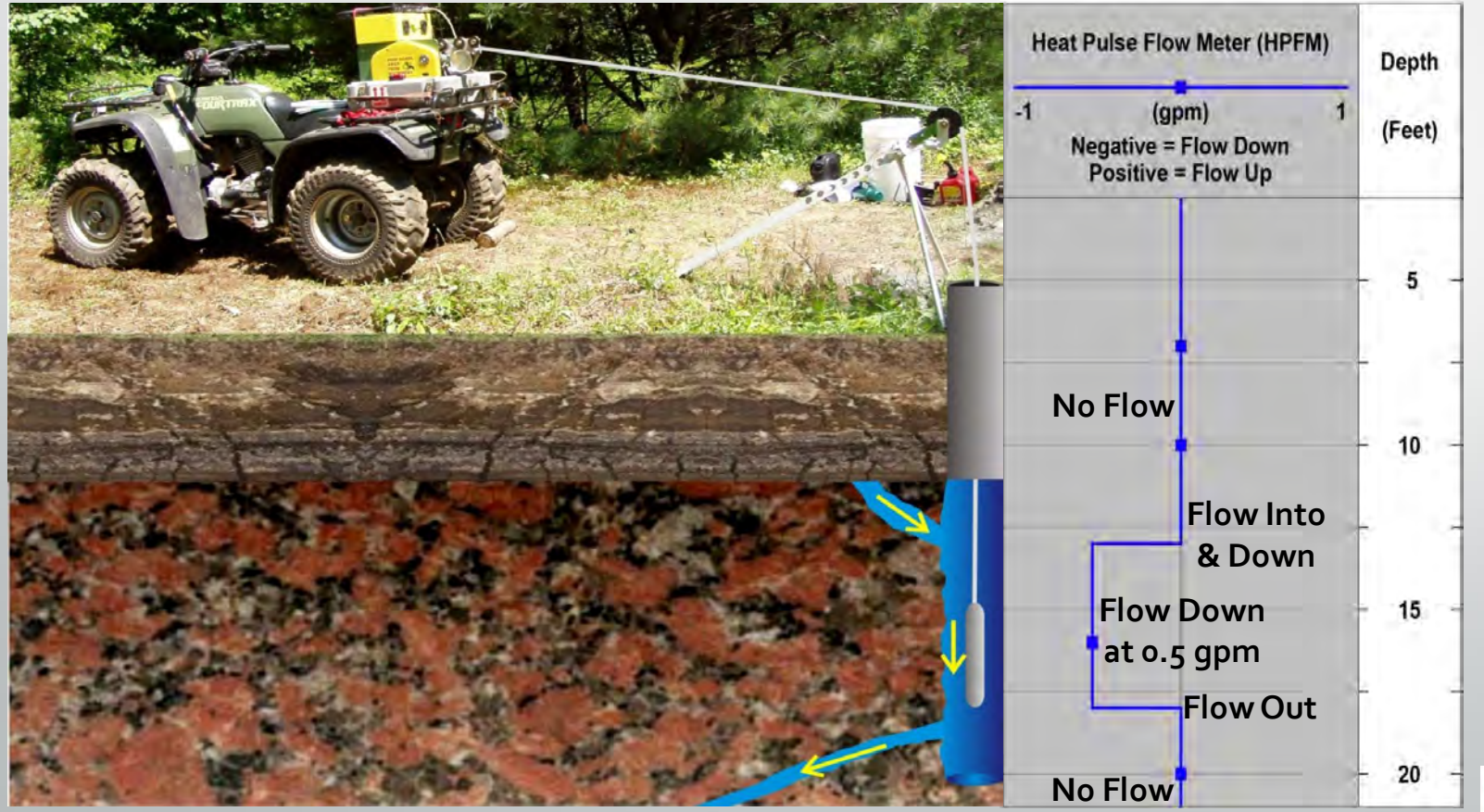
Heat Pulse Flow Meter



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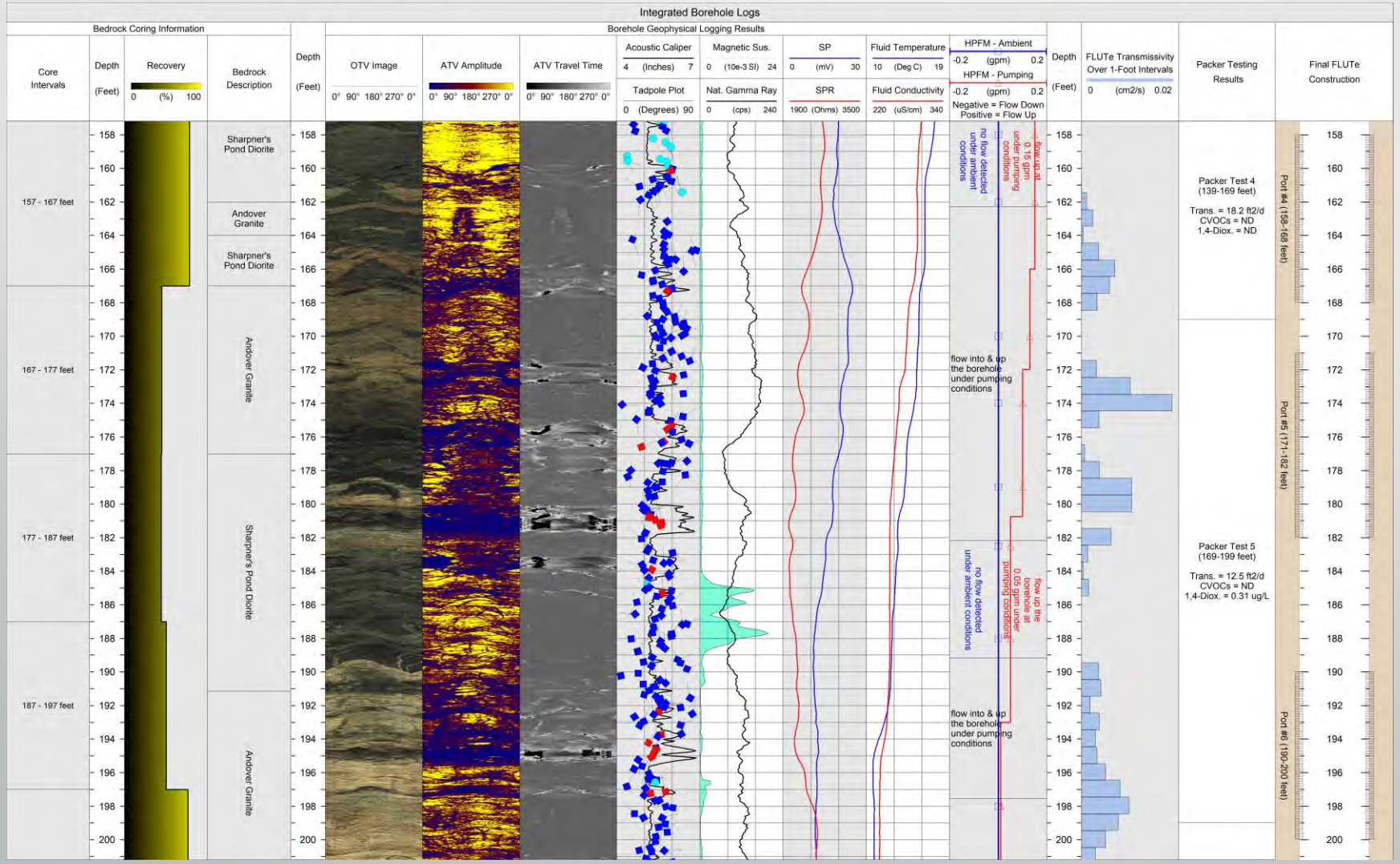
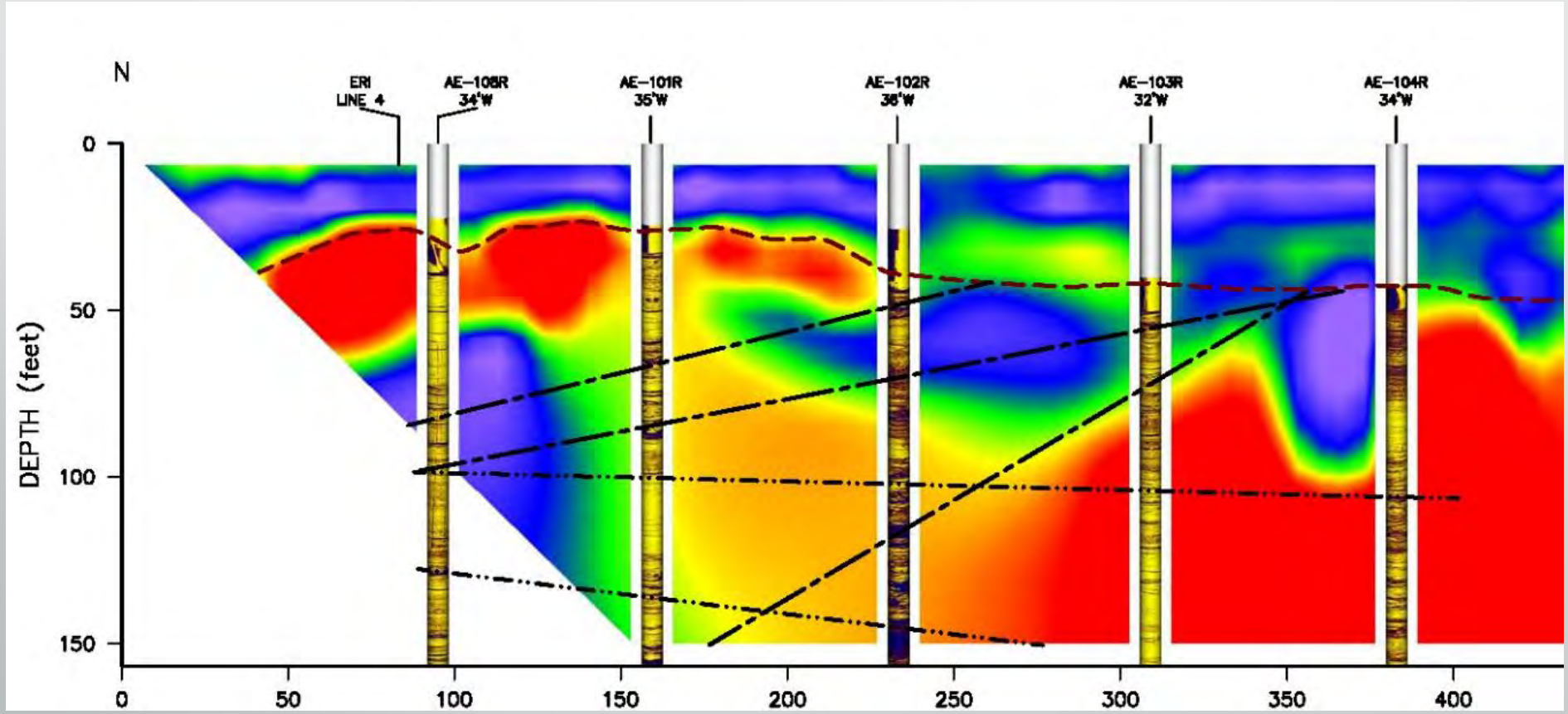

Integrated Borehole Logs
Bedrock Coring Information
Borehole Geophysical Logging Results
Core Intervals
Depth (Feet)
Recovery
0 (%) 100
Bedrock Description
Depth (Feet)
OTV Image
0° 90° 180° 270° 0°
ATV Amplitude
0° 90° 180° 270° 0°
ATV Travel Time
0° 90° 180° 270° 0°
Acoustic Caliper
4 (Inches) 7
Tadpole Plot
0 (Degrees) 90
Magnetic Sus.
0 (10e-3 SI) 24
Nat. Gamma Ray
0 (cps) 240
SP
0 (mV) 30
SPR
1900 (Ohms) 3500
Fluid Temperature
10 (Deg C) 19
Fluid Conductivity
220 (uS/cm) 340
HPFM - Ambient
-0.2 (gpm) 0.2
HPFM - Pumping
-0.2 (gpm) 0.2
Negative = Flow Down
Positive = Flow Up
Depth (Feet)
FLUTe Transmissivity Over 1-Foot Intervals
0 (cm2/s) 0.02
Packer Testing Results
Final FLUTe Construction
157 - 167 feet
167 - 177 feet
177 - 187 feet
187 - 197 feet
Sharpner's Pond Diorite
Andover Granite
Sharpner's Pond Diorite
Andover Granite
Sharpner's Pond Diorite
Andover Granite
no flow detected under ambient conditions
flow up at 0.15 gpm under pumping conditions
flow into & up the borehole under pumping conditions
no flow detected under ambient conditions
flow up the borehole at 0.05 gpm under pumping conditions
flow into & up the borehole under pumping conditions
Packer Test 4 (139-169 feet)
Trans. = 18.2 ft2/d
CVOCs = ND
1,4-Diox. = ND
Packer Test 5 (169-199 feet)
Trans. = 12.5 ft2/d
CVOCs = ND
1,4-Diox. = 0.31 ug/L
Port #4 (158-168 feet)
Port #5 (171-182 feet)
Port #6 (190-200 feet)



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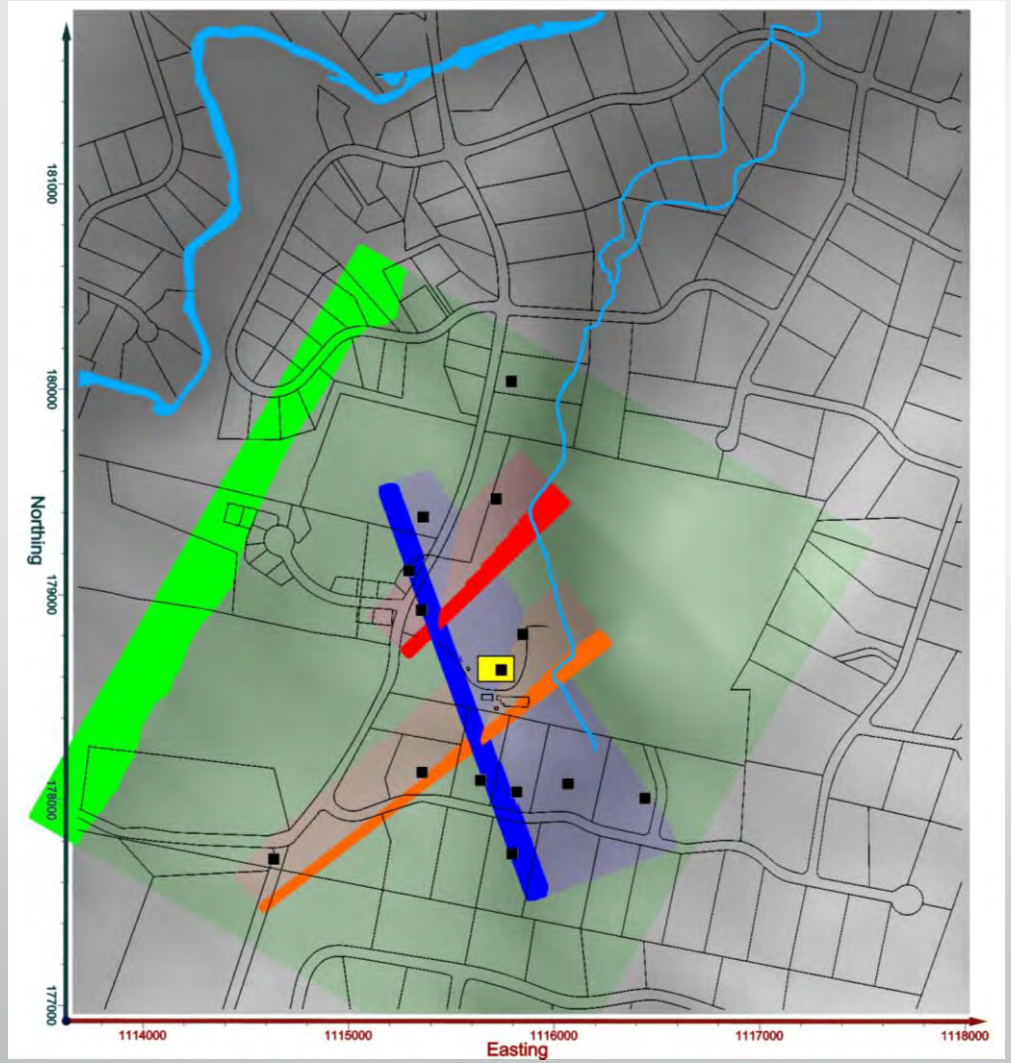

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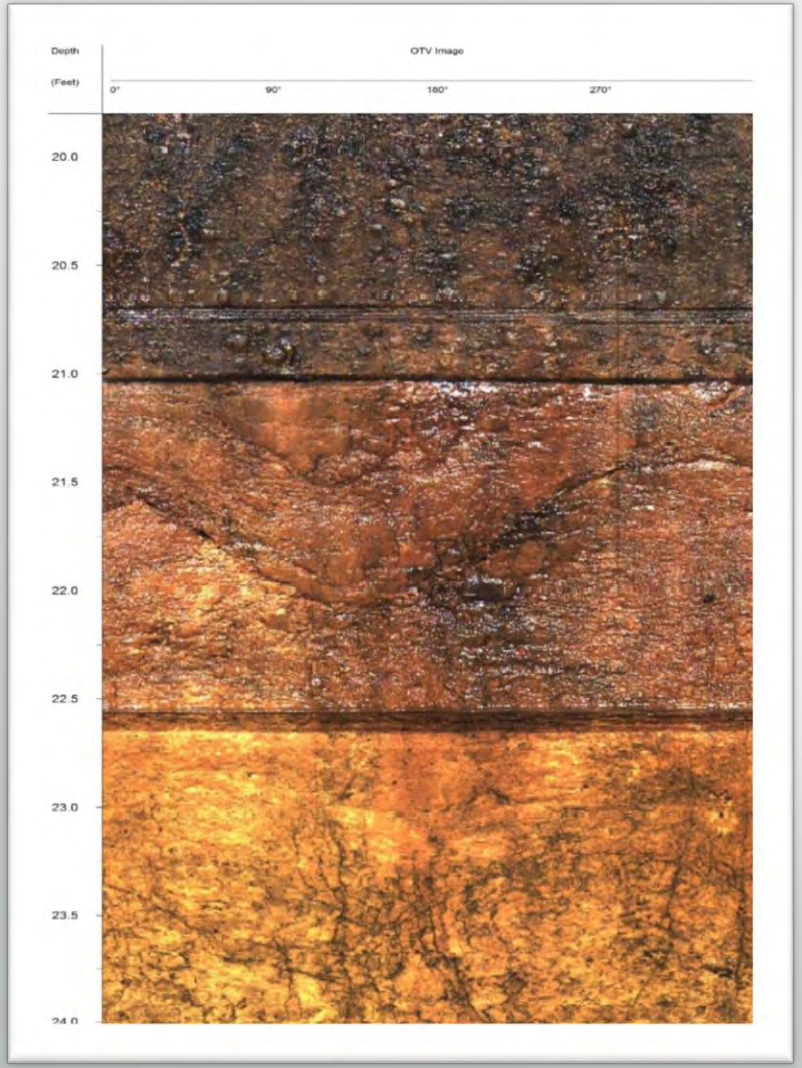

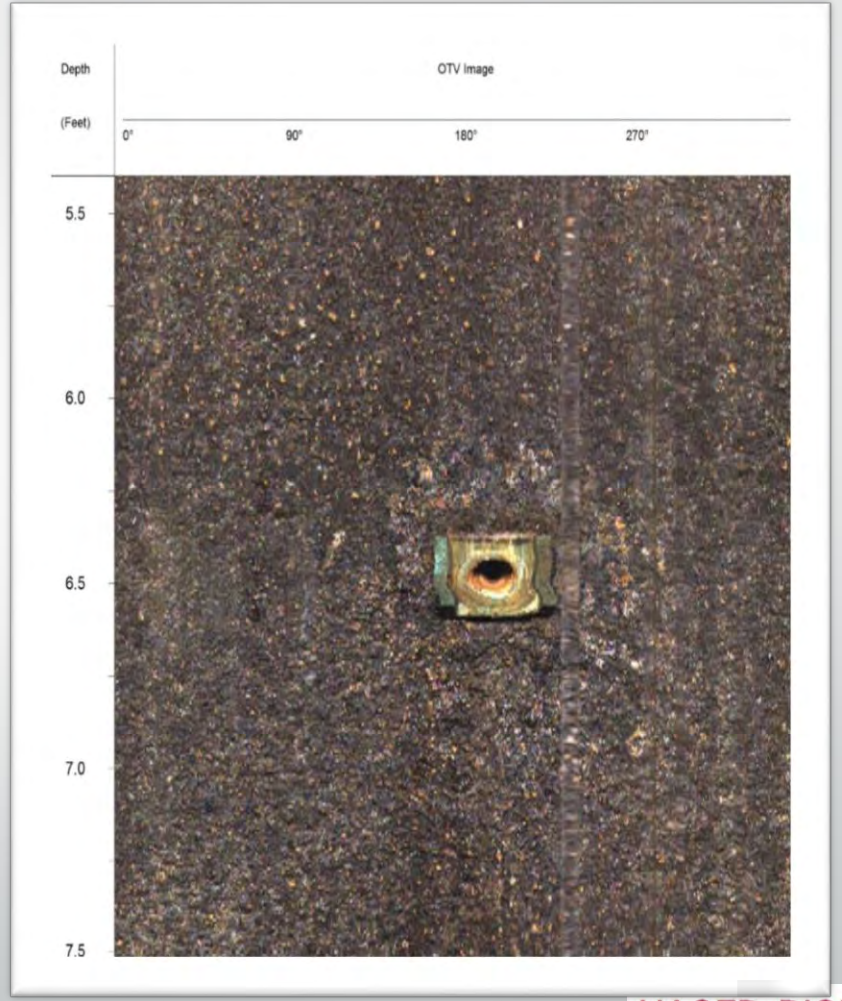

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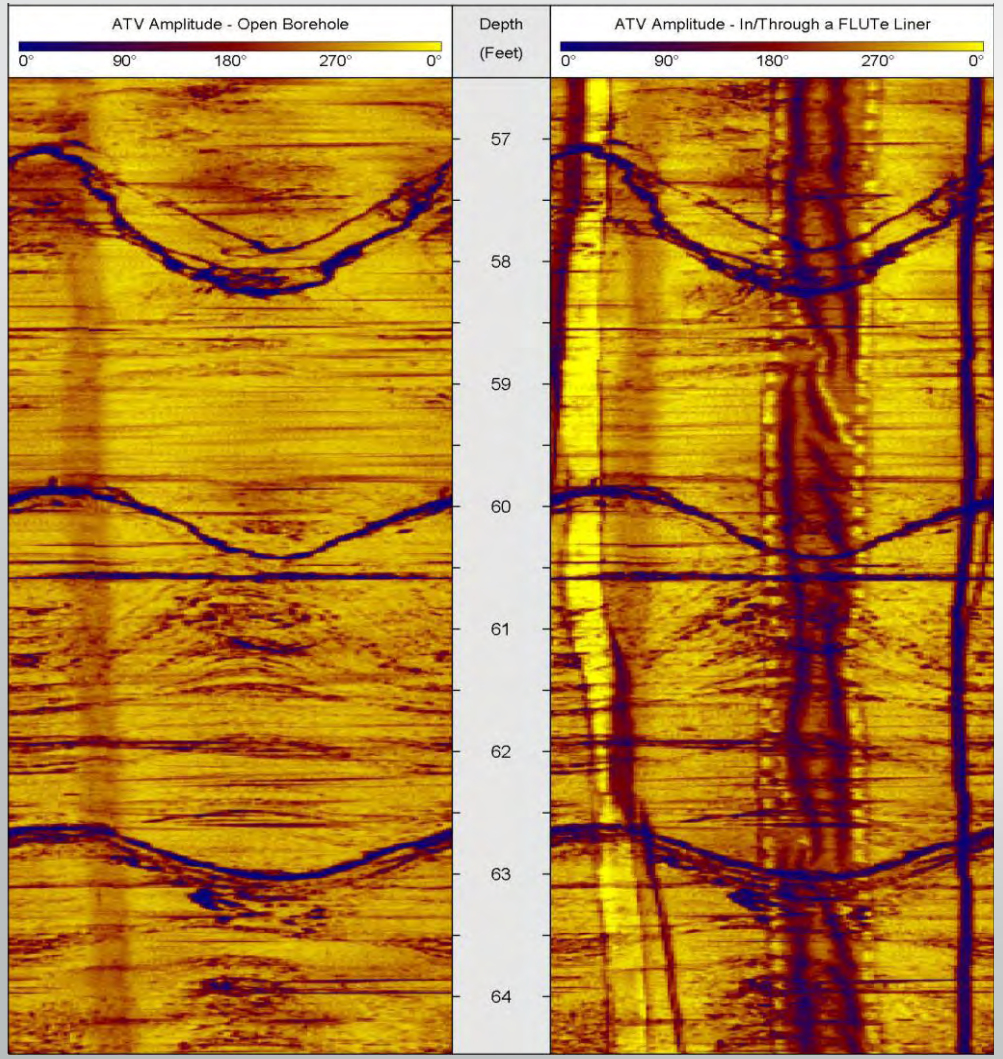

ATV Through a FLUTe Liner

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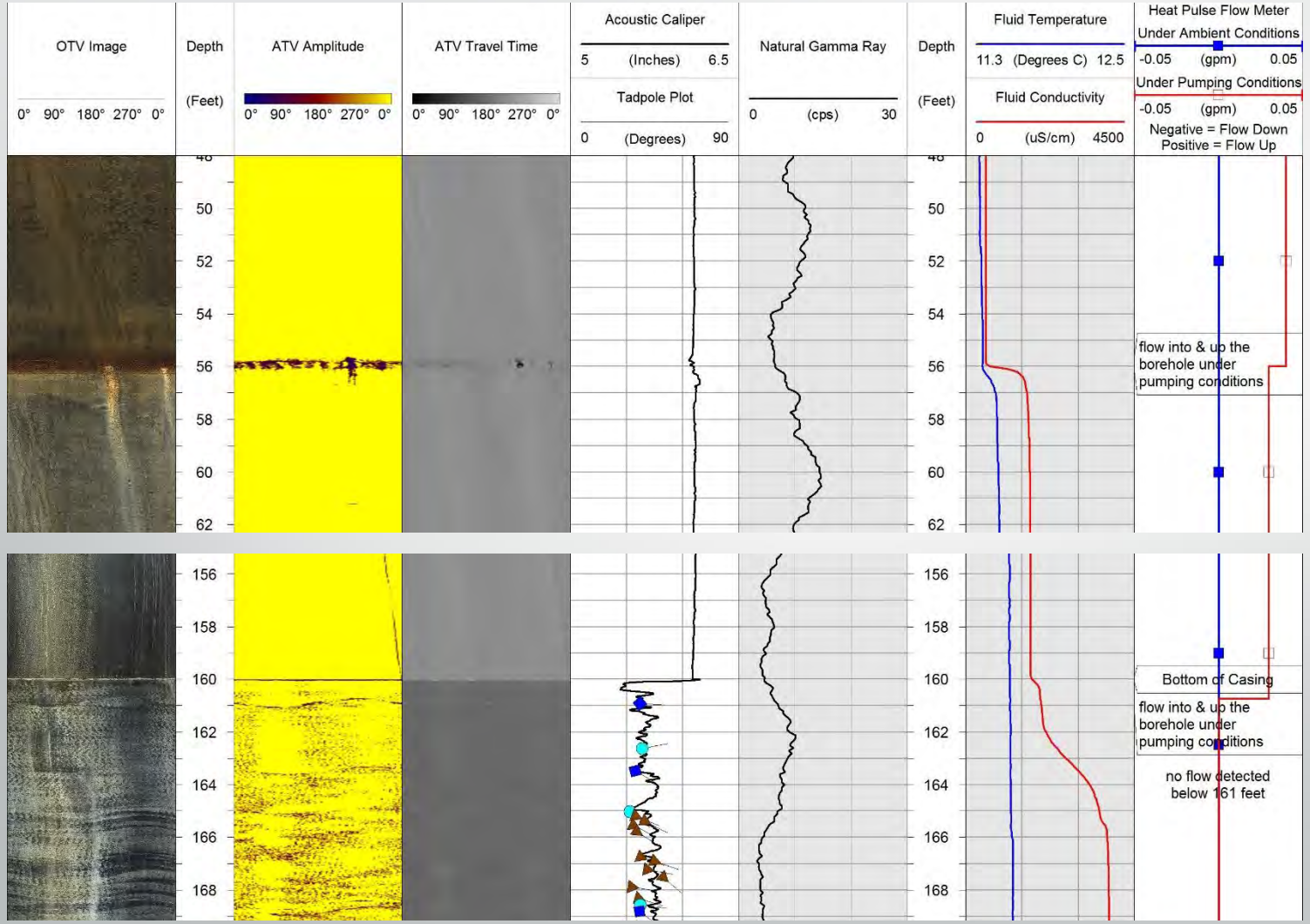

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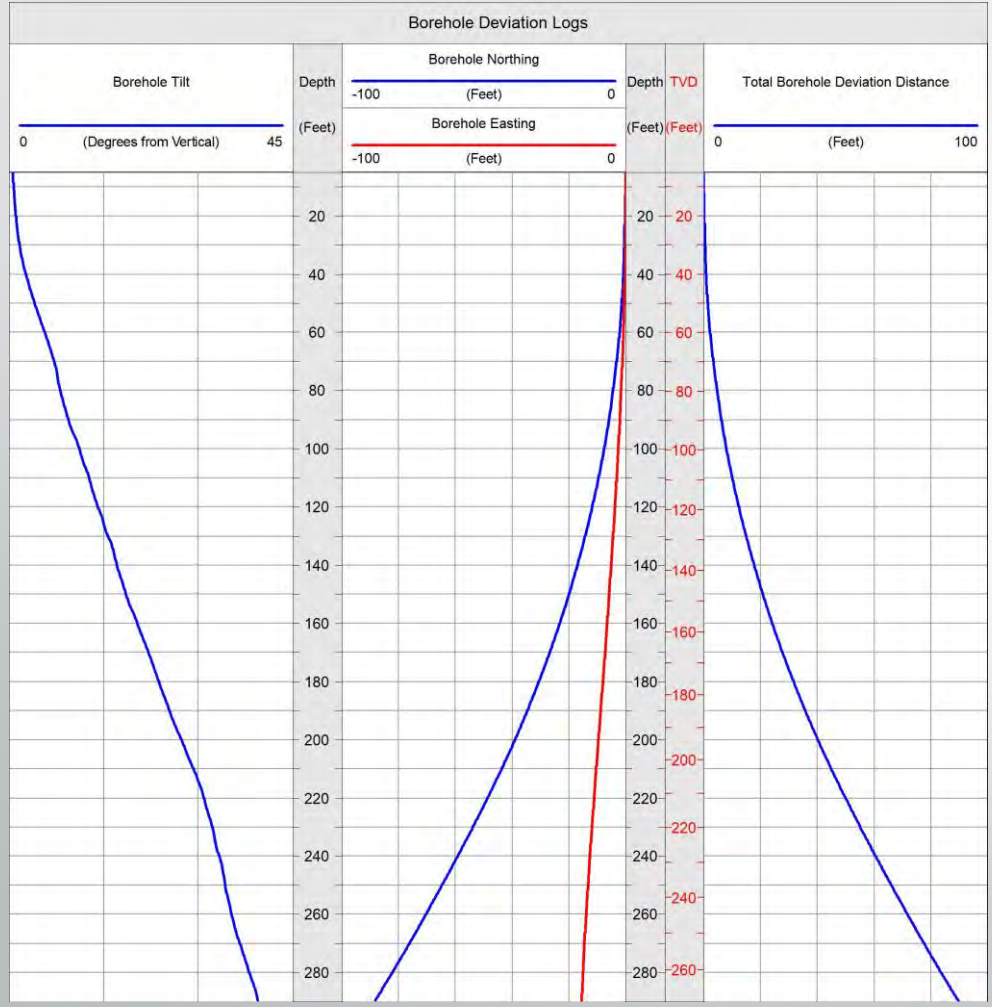

- Deviation at 20 feet
  - Tilt = 1°
  - Drift = 0.2 feet SSW
  - TVD = 20.0 feet - no vertical loss
- Deviation at 160 feet
  - Tilt = 20°
  - Drift = 24.1 feet SSW
  - TVD = 157.3 feet
- Deviation at 290 feet
  - Tilt = 40°
  - Drift = 89.7 feet SSW
  - TVD = 268.6 feet

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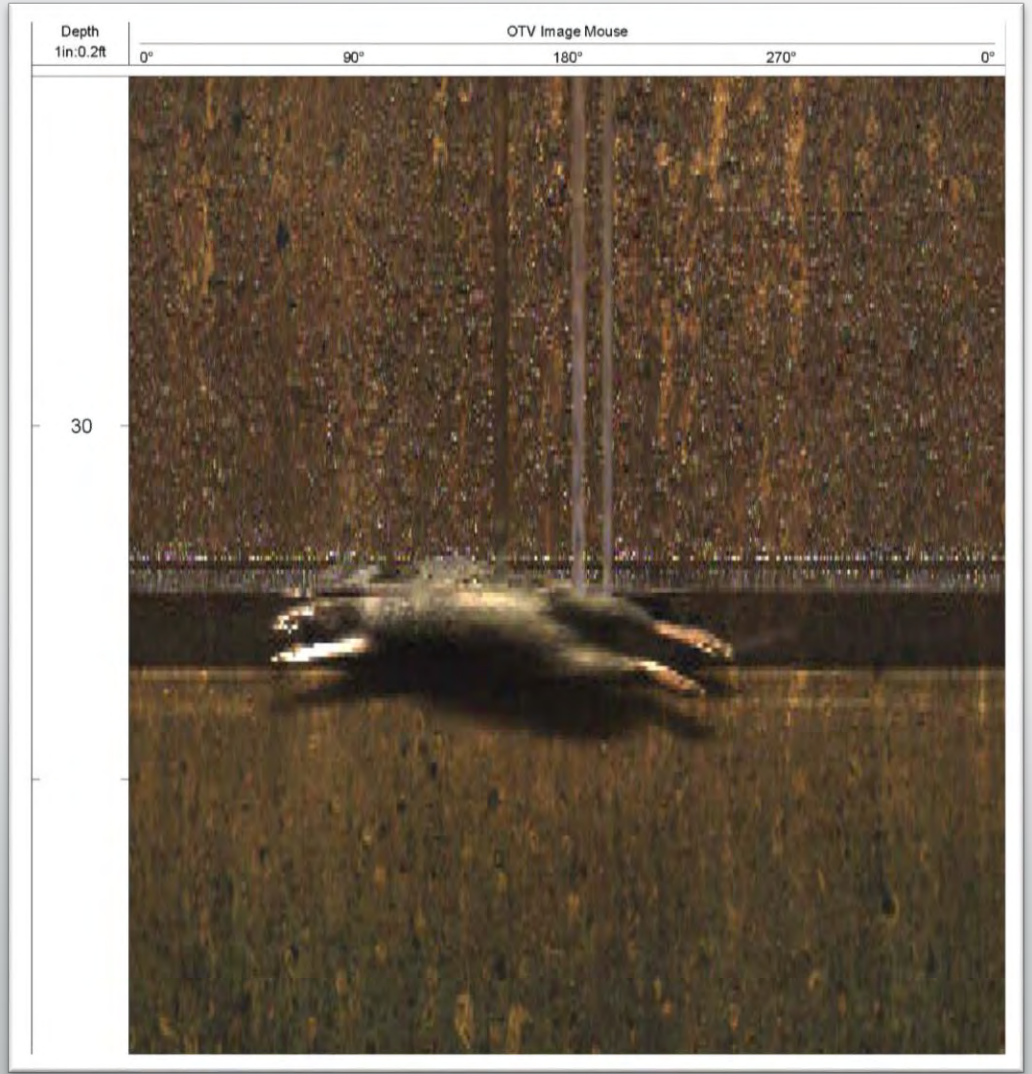

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