

NEWMOA Webinar Geophysical Evaluation of Bedrock Drinking Water Wells Understanding the Science

Jeffrey Reid, P.G. – Vice President/Senior Geophysicist
Robert Garfield, P.G. – Vice President/Senior Borehole Geophysicist

Hager-Richter Geoscience, Inc.
www.hager-richter.com
February 10, 2016

Salem, NH – Tel. 603.893.9944
Fords, NJ – Tel. 732.661.0555

HAGER-RICHTER
GEOSCIENCE, INC.

Outline of Presentation

- ▶ Introduction
- ▶ Surface Geophysical Methods
- ▶ Borehole Geophysical Methods
- ▶ Case Study

HAGER-RICHTER
GEOSCIENCE, INC.



Surface Geophysics

HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

- ▶ Very Low Frequency EM (VLF-EM)
- ▶ Terrain Conductivity EM (EM34)
- ▶ Electrical Resistivity Imaging (ERI)
- ▶ Seismic Reflection

HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

- ▶ VLF-EM
 - Passive geophysical method
 - Good for reconnaissance survey
 - Depth of investigation 0-150 ft
 - Determine strike of water-bearing bedrock fractures (near-vertical features)
 - Confirm results from fracture trace analysis
 - Poor at determining dip angle and direction
 - Fractures must be “near vertical” and generally aligned with an active VLF transmitter site

HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

- ▶ VLF-EM - Transmitter Locations



HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

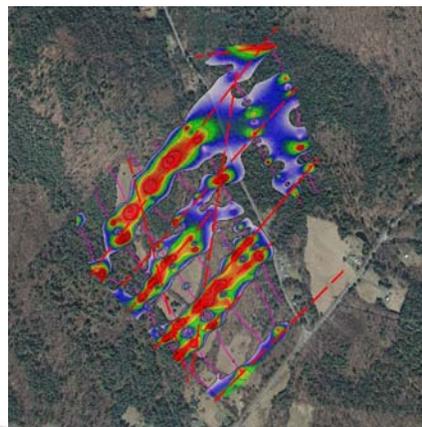
- ▶ VLF-EM – Equipment



HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

- ▶ VLF-EM – Typical Results



HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

- ▶ Terrain Conductivity EM34
 - Active geophysical method
 - Good for reconnaissance survey
 - Depth of investigation 0–100 ft
 - Ability to located bedrock fractures based on increased electrical conductivity
 - Confirm results from fracture trace analysis
 - Poor at determining dip angle and direction
 - Fractures/fracture zones must be “near vertical” and relatively large to be detected

HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

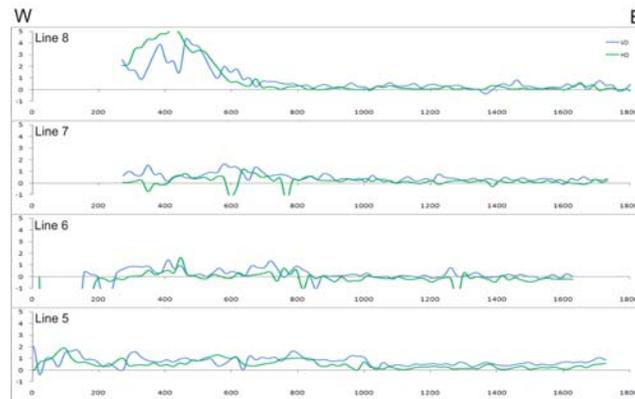
- ▶ Terrain Conductivity EM34 – Equipment



HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

► Terrain Conductivity EM34 – Typical Results



HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

► ERI

- Active geophysical method
- Good for detailed surveying
- Depth of investigation 0–200 ft
- Determine strike of water-bearing bedrock fractures
- Confirm results from fracture trace analysis or other geophysical surveys
- Good at determining apparent dip angle
- Fractures/fracture zones must be at least $\frac{1}{2}$ the electrode spacing in width to be detected

HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

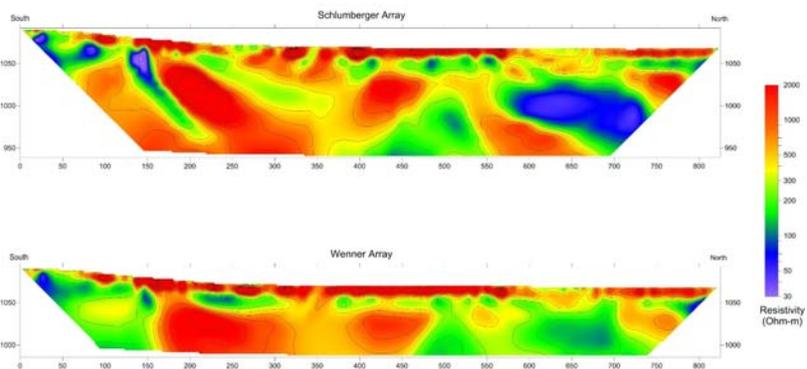
► ERI - Equipment



HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

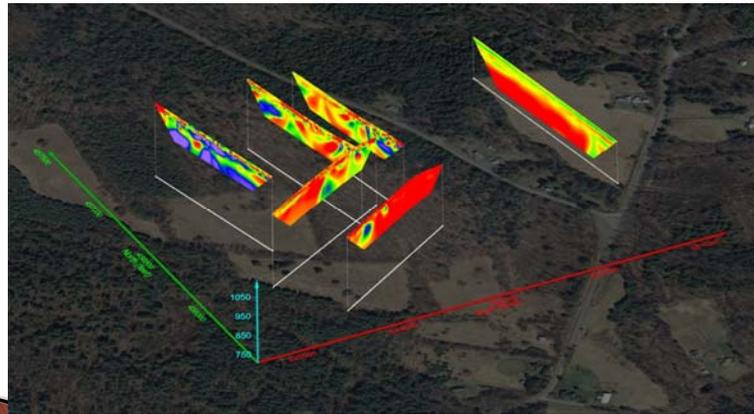
► ERI - Typical Results as Profiles



HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

- ▶ ERI – Typical Results as Prospective Views



HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

- ▶ Seismic Reflection
 - Active geophysical method
 - Good for focused surveys
 - Determines apparent strike and dip of bedrock structures
 - Works well in sedimentary environments, more difficult in metamorphic environments with significant structure
 - Poor at determining true dip angle
 - Will only detect larger regional type features such as fracture zones/faults

HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

- ▶ Seismic Reflection – Equipment



HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

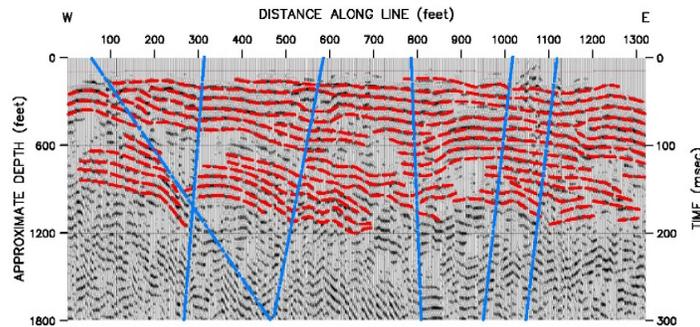
- ▶ Seismic Reflection – Equipment



HAGER-RICHTER
GEOSCIENCE, INC.

Surface Geophysical Methods For Bedrock Fracture Characterization

- ▶ Seismic Reflection – Typical Results as Profile



B. SEISMIC REFLECTION PROFILE WITH INTERPRETATION

HAGER-RICHTER
GEOSCIENCE, INC.



Borehole Geophysical Logging

HAGER-RICHTER
GEOSCIENCE, INC.

Borehole Geophysical Logging For Bedrock Fracture Characterization

- ▶ Standard Logging
 - Caliper
 - Natural Gamma Ray
 - Electrical (Normal Resistivity, SP, SPR)
 - EM Induction
- ▶ Flow Logging
 - Flow Meter (HPFM & Spinner)
 - Fluid Temperature & Fluid Conductivity/Resistivity
- ▶ Image Logging
 - Optical Televiwer (OTV) & Acoustic Televiwer (ATV)

HAGER-RICHTER
GEOSCIENCE, INC.

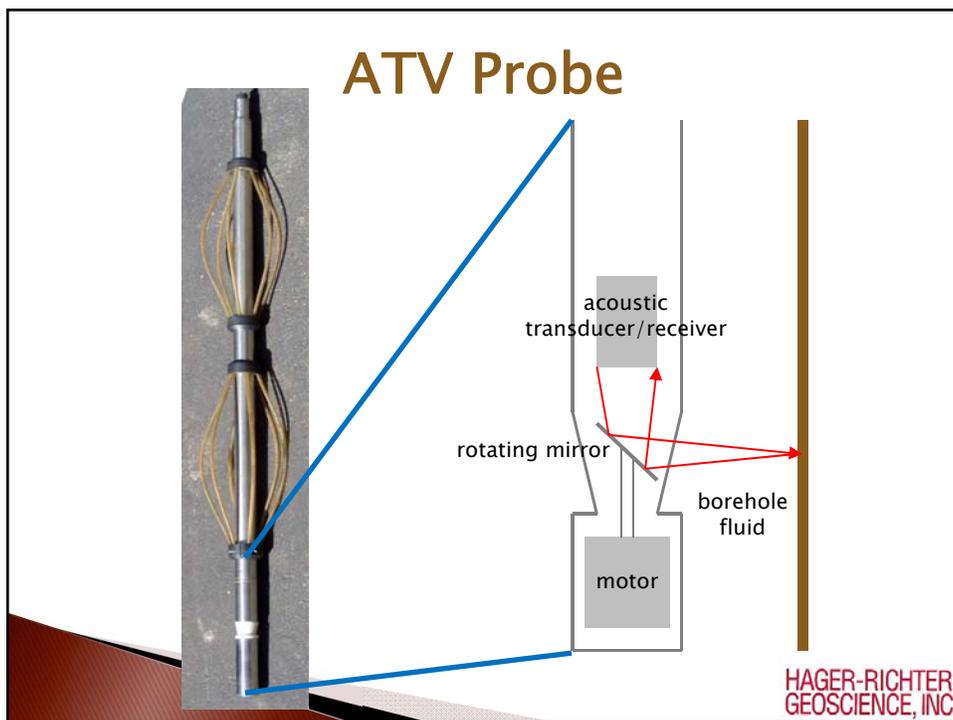
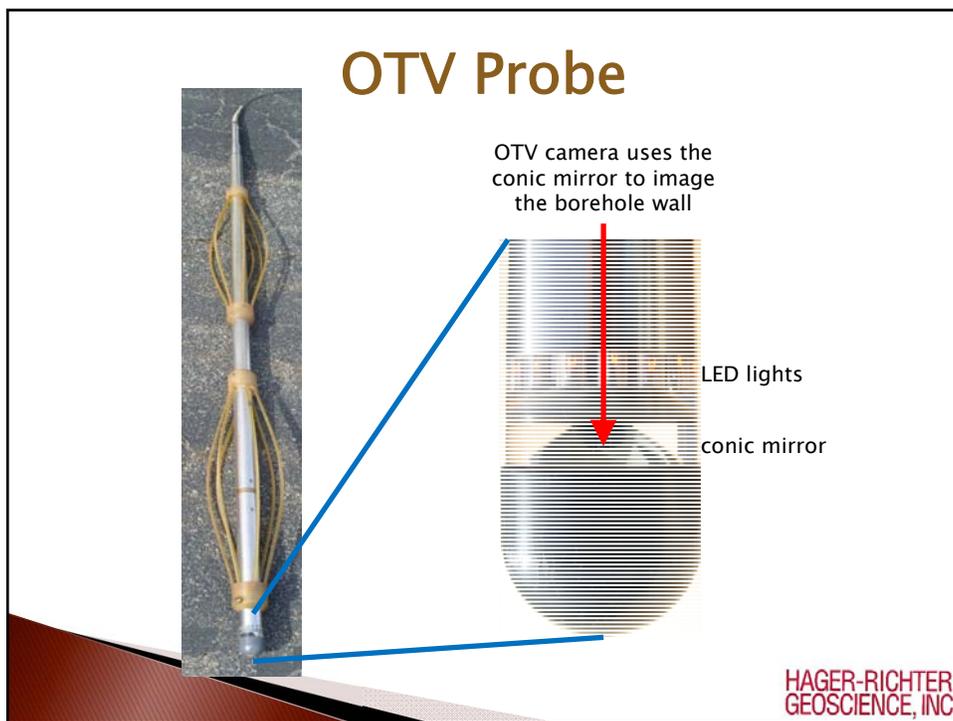
Borehole Geophysical Logging For Bedrock Fracture Characterization

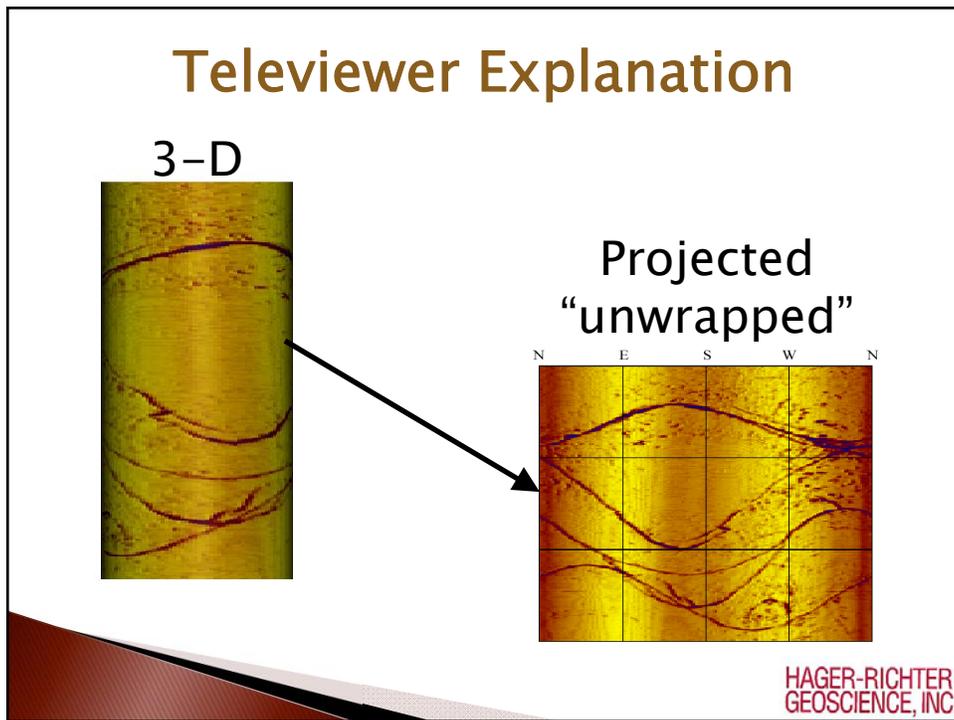
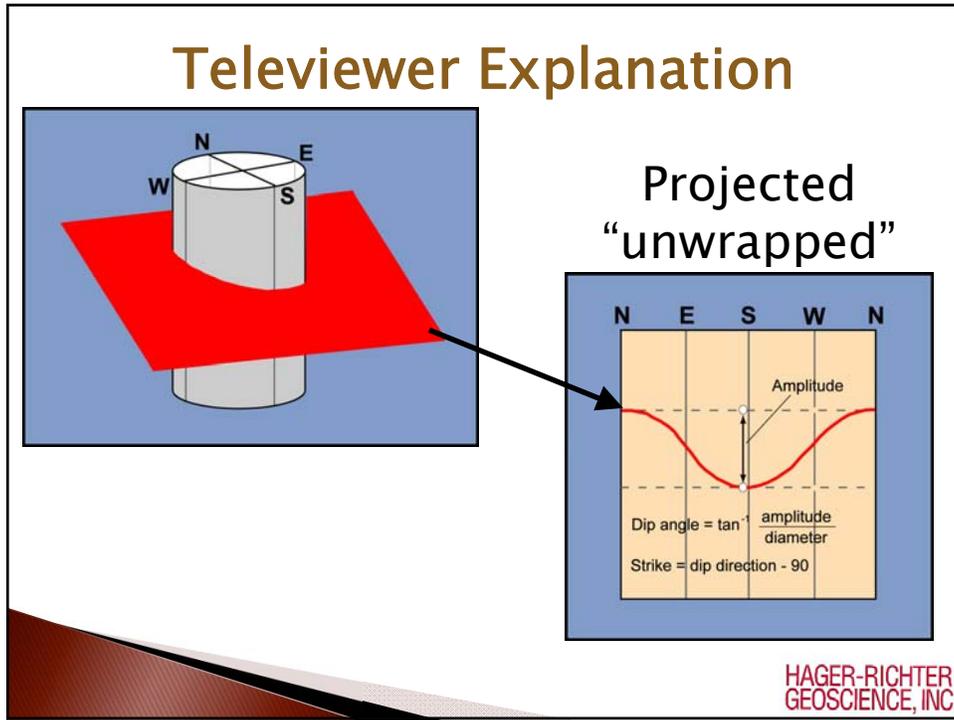
- ▶ Fracture Detection
 - Depth & Orientation of Bedrock Fractures
 - Fracture Aperture
- ▶ Flow Conditions
- ▶ Lithologic Variation
- ▶ Borehole Deviation

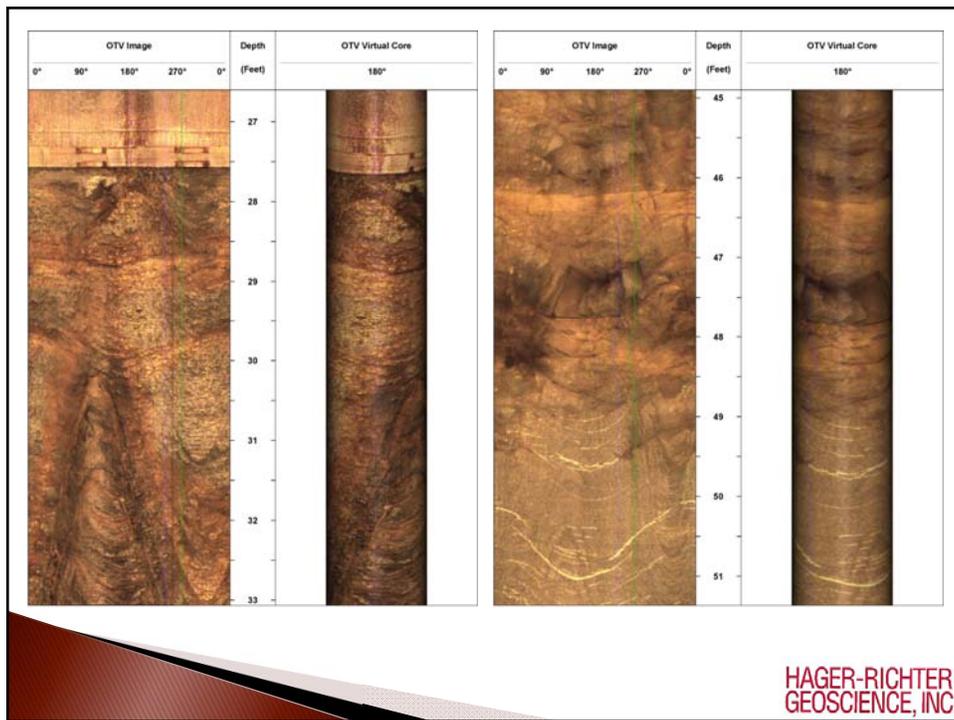
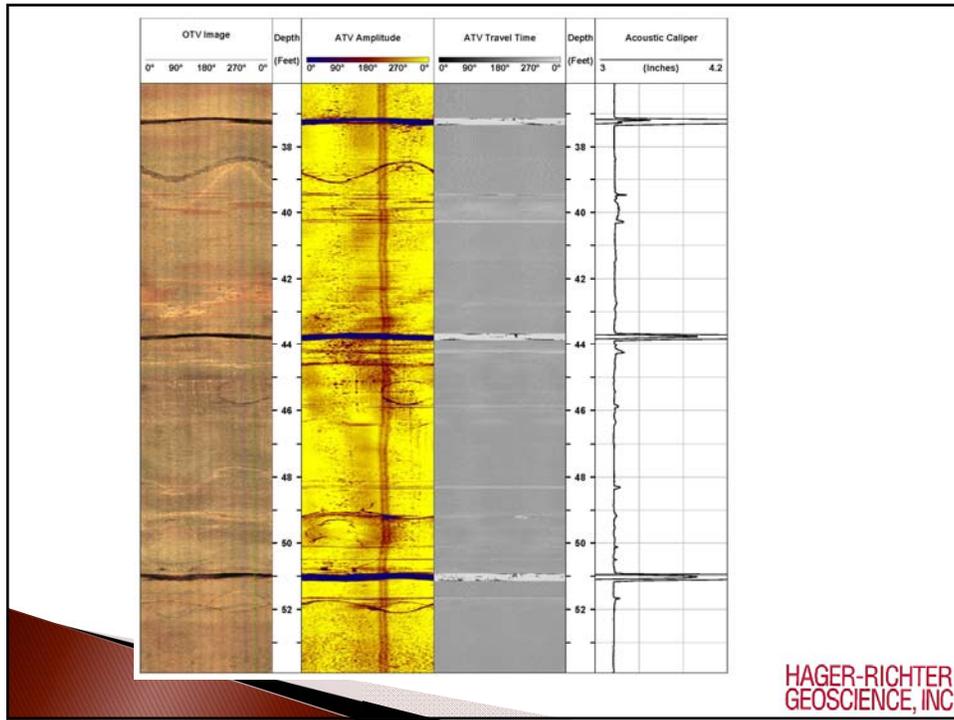
HAGER-RICHTER
GEOSCIENCE, INC.

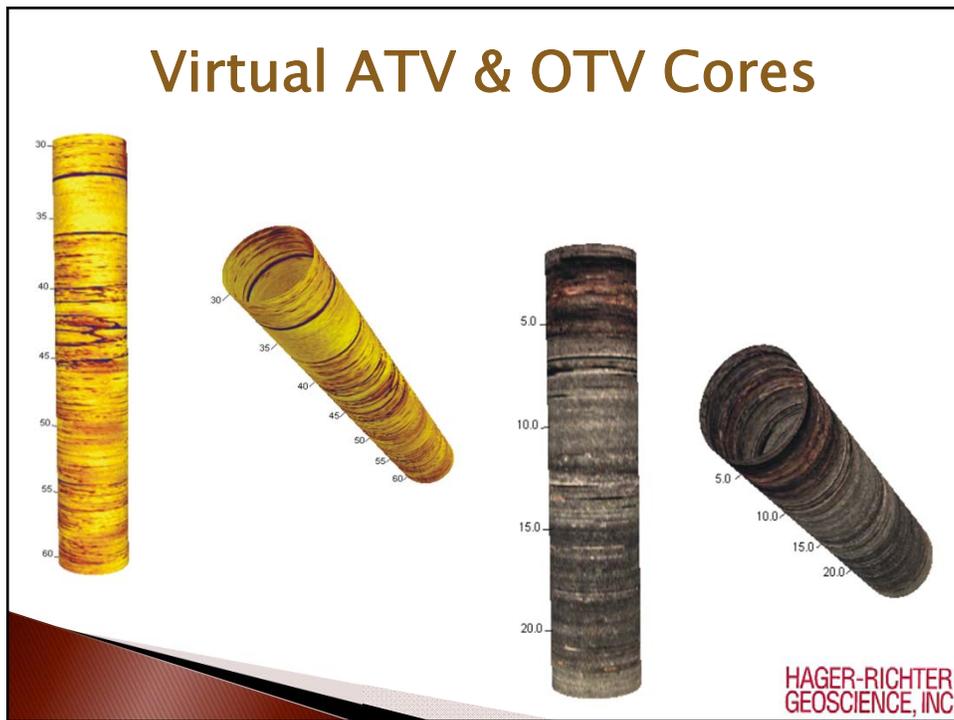
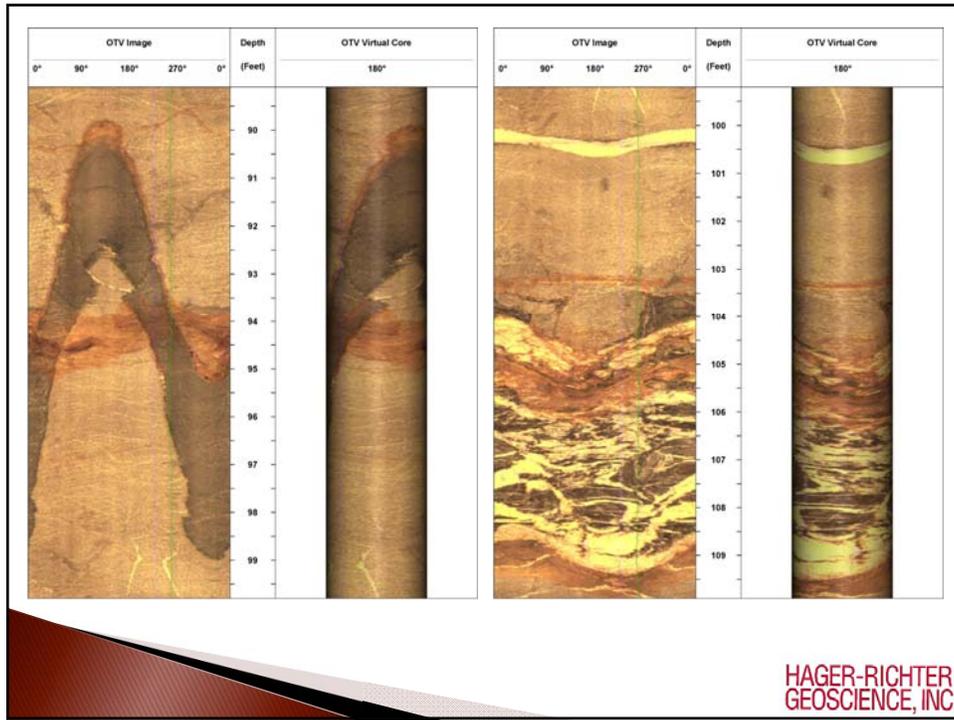


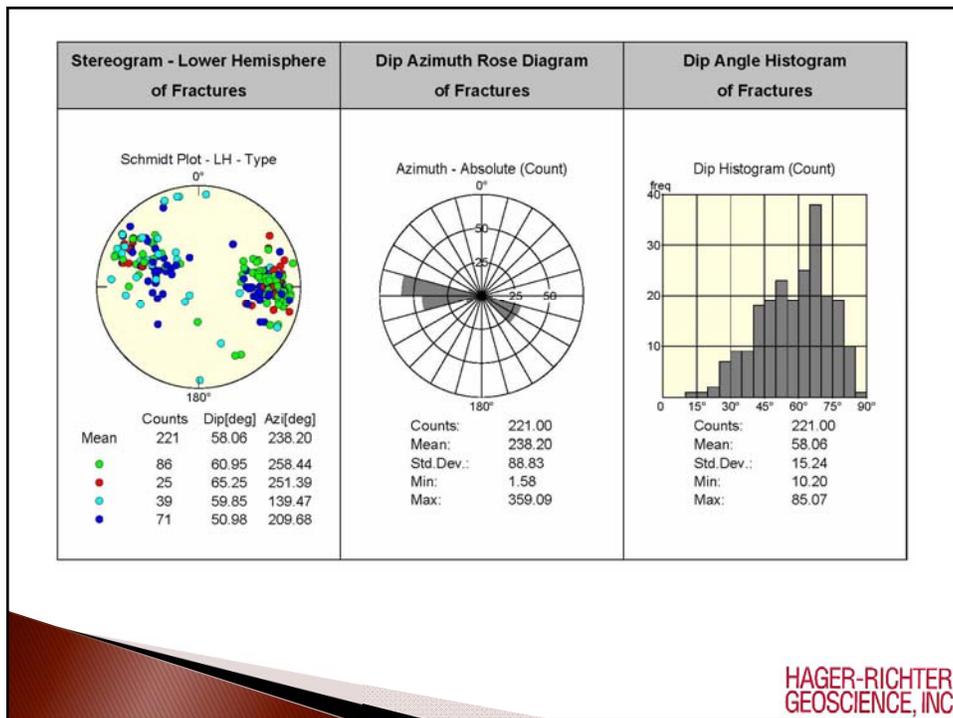
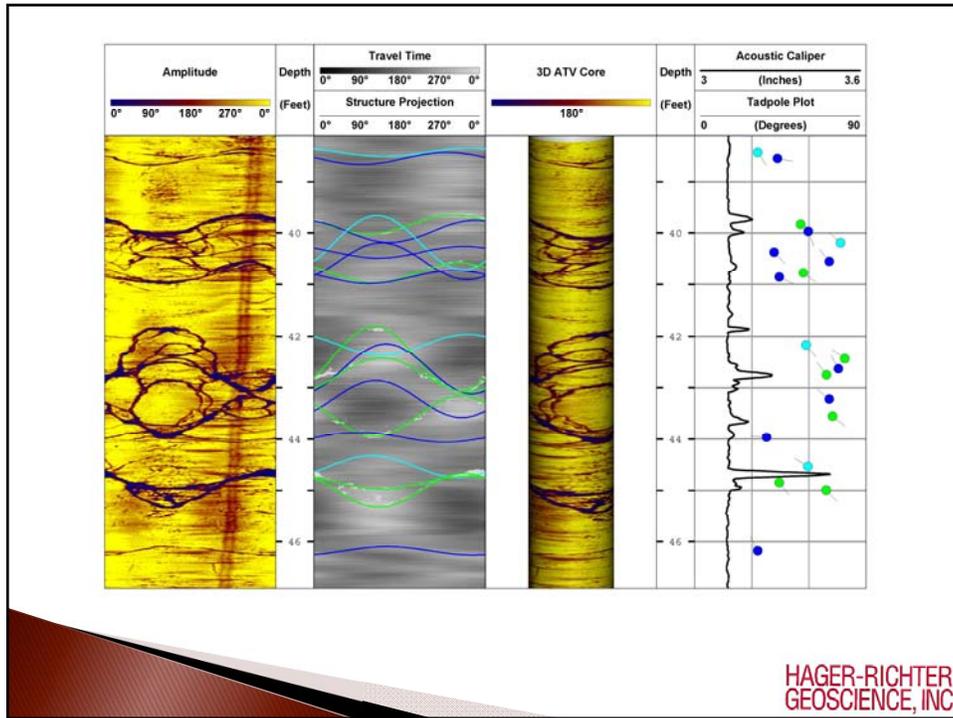


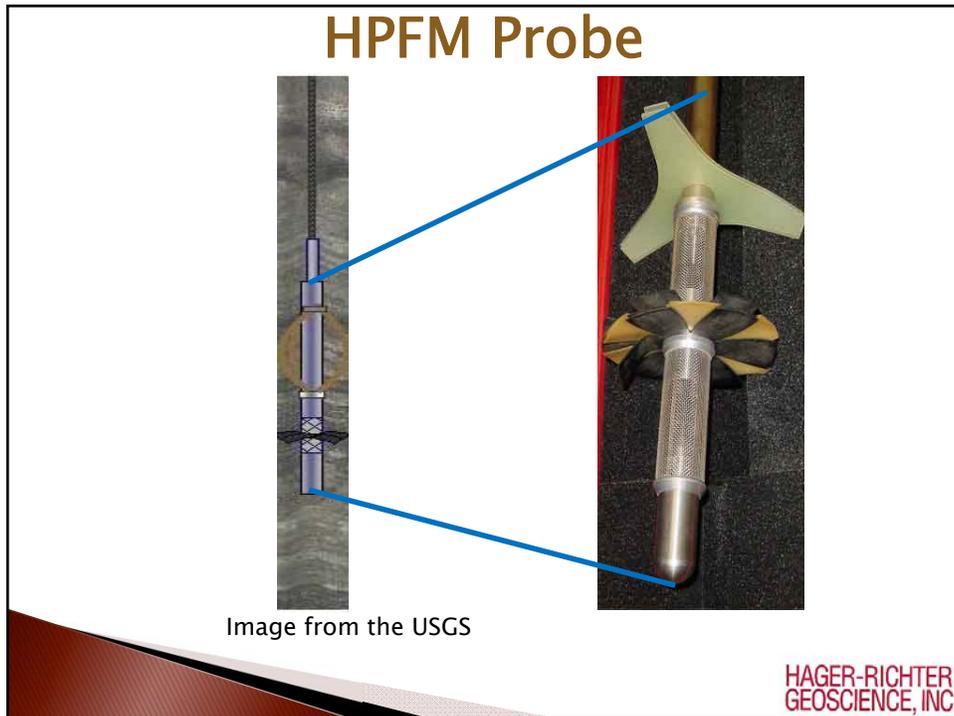
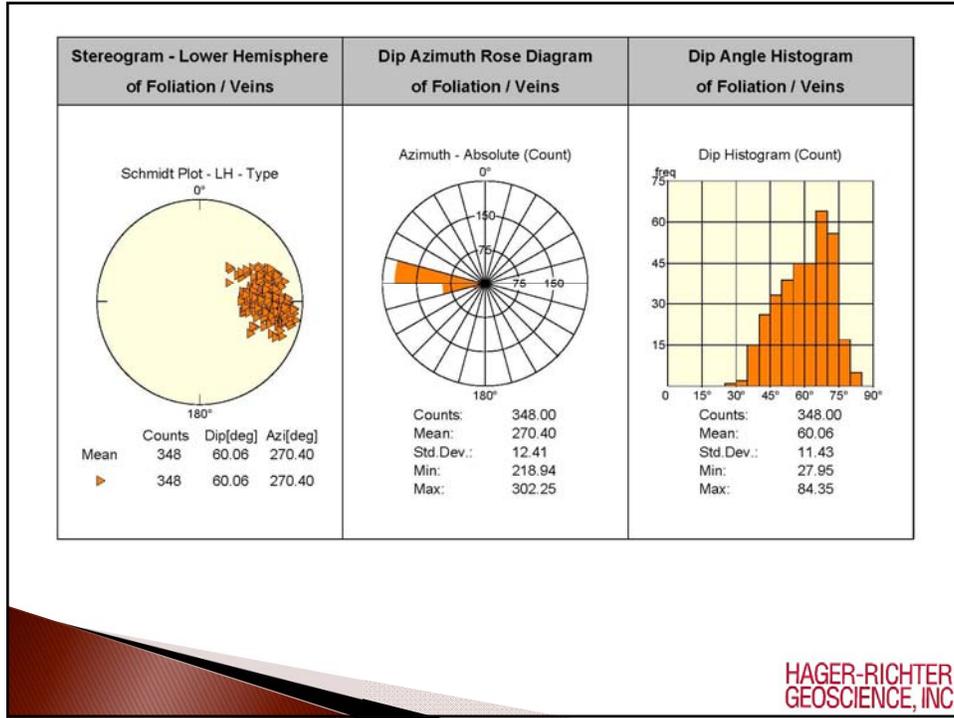


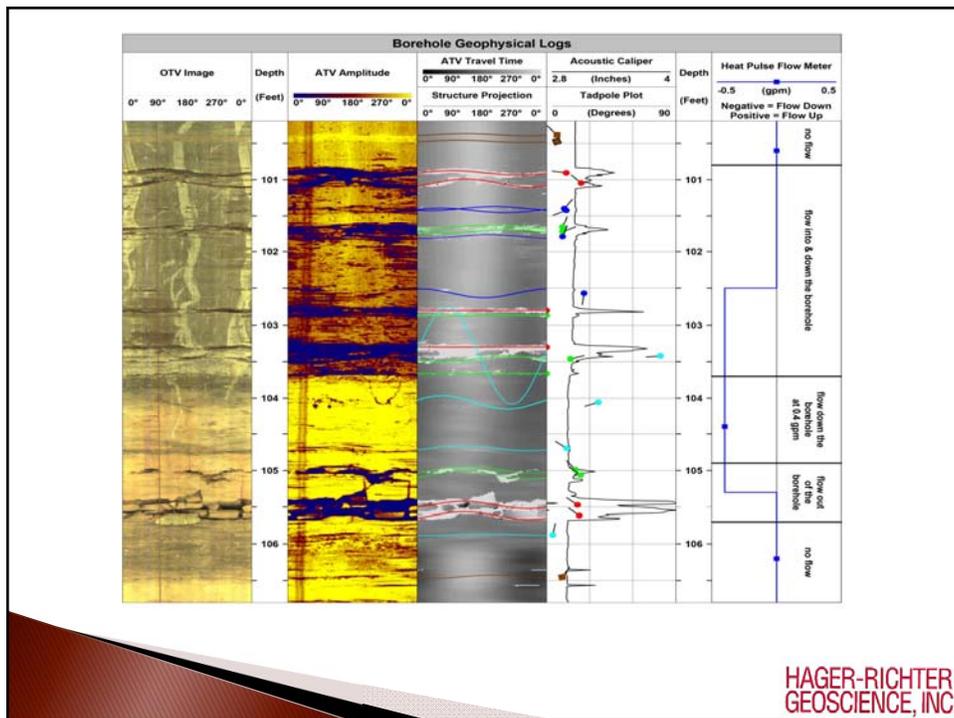
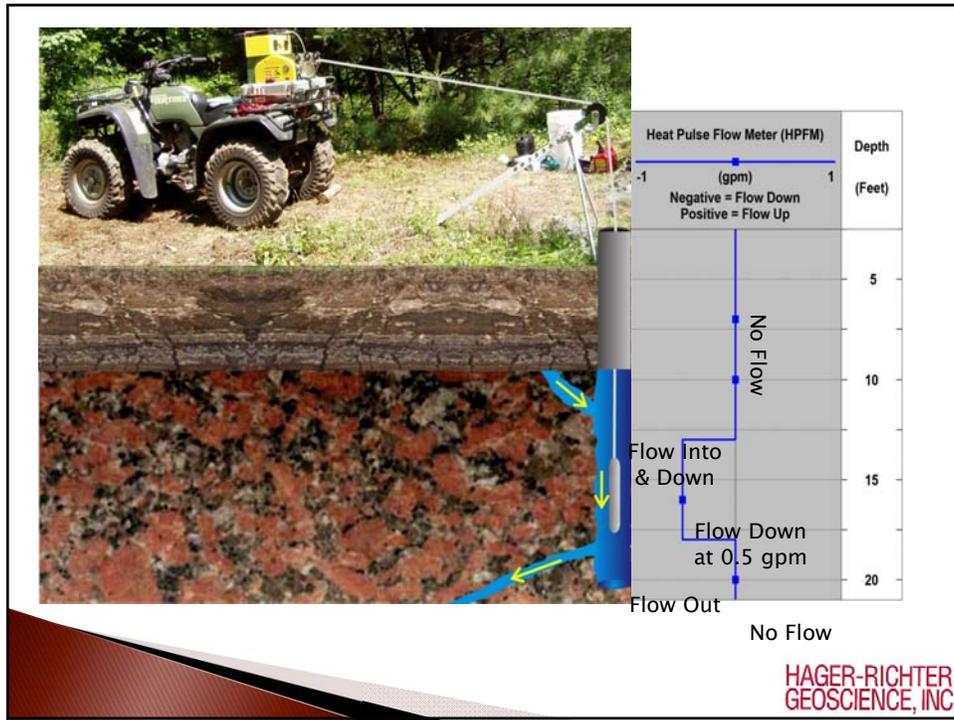


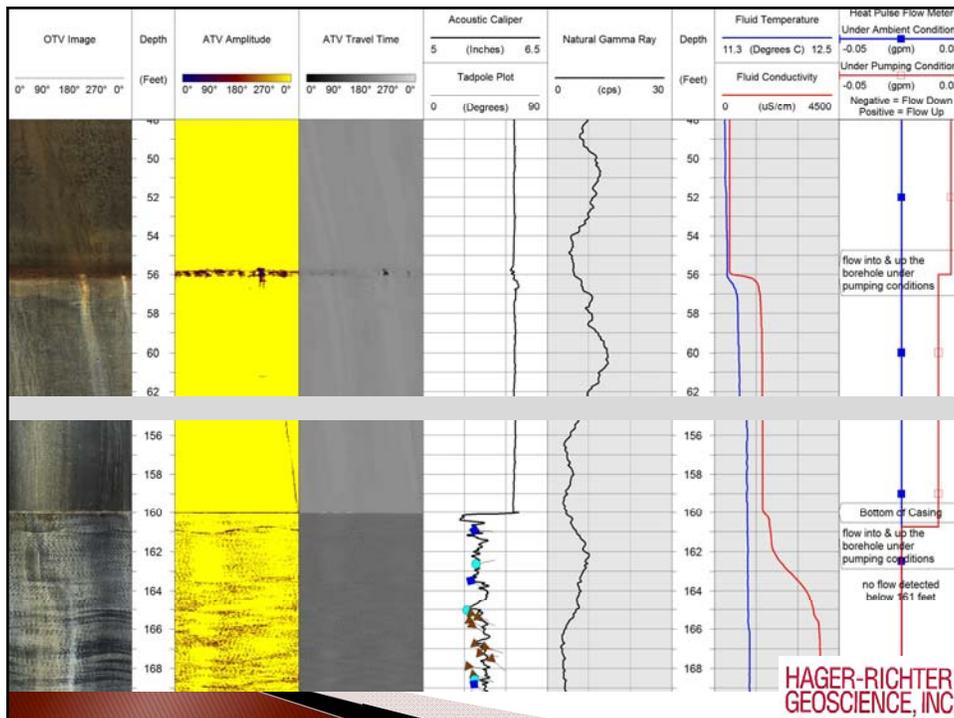
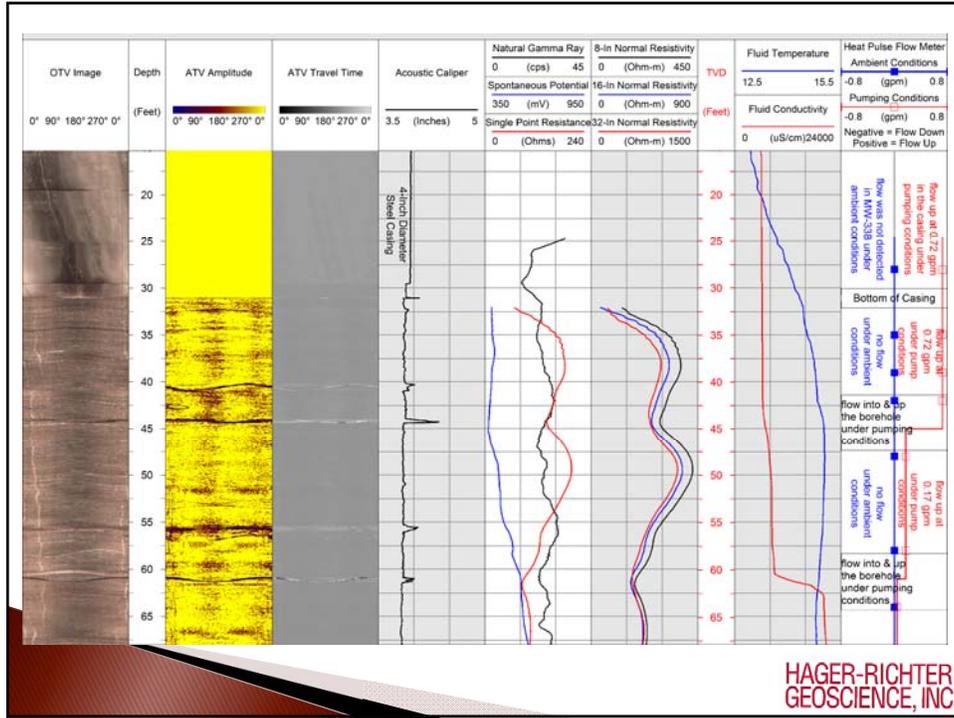


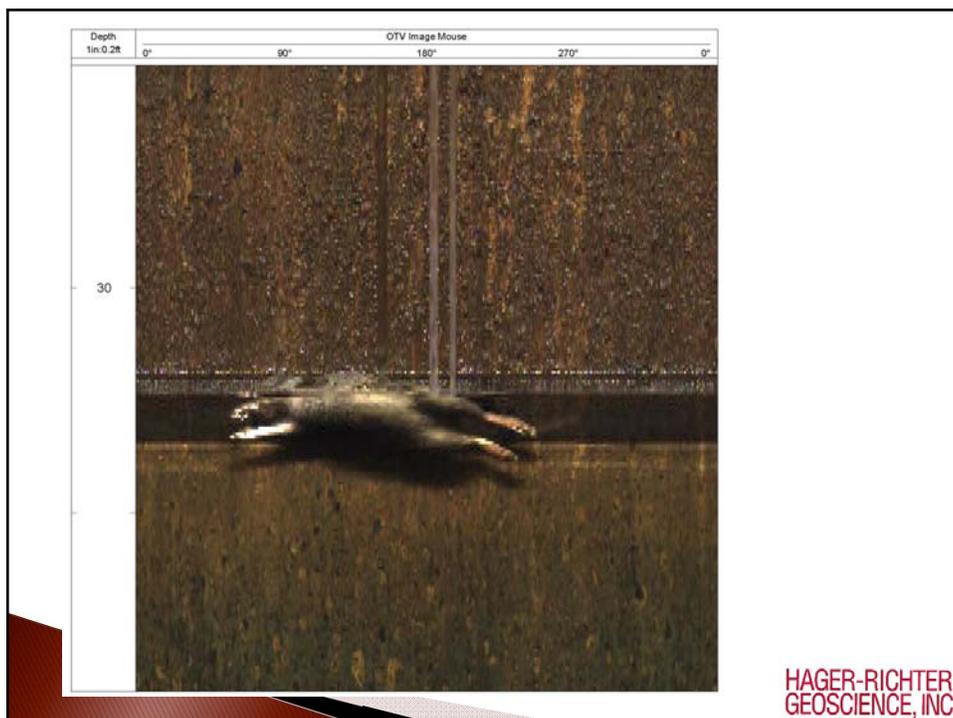
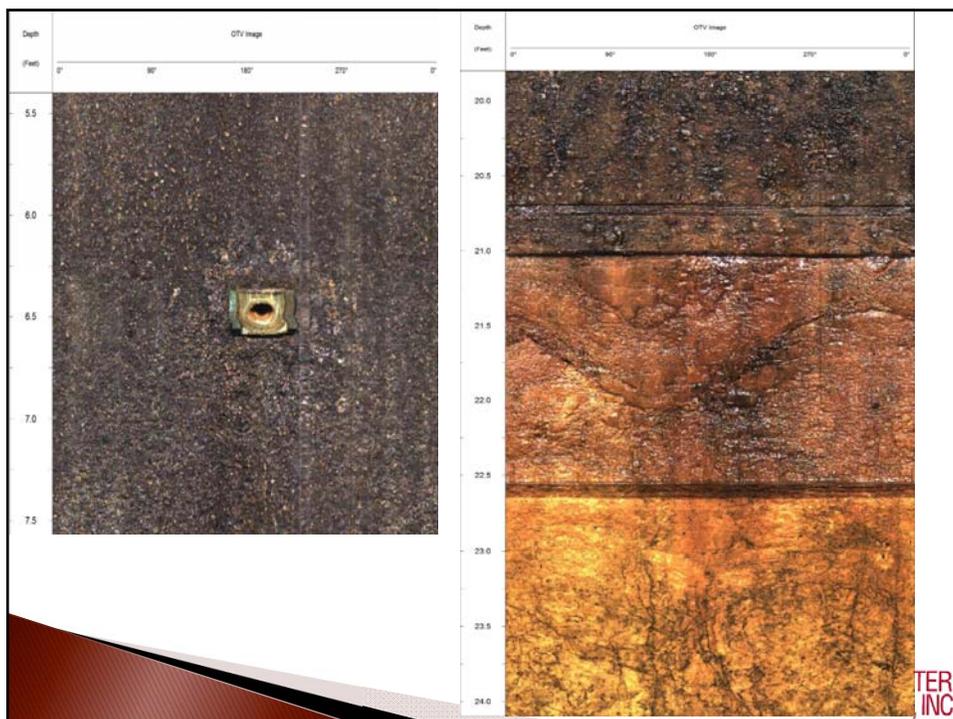


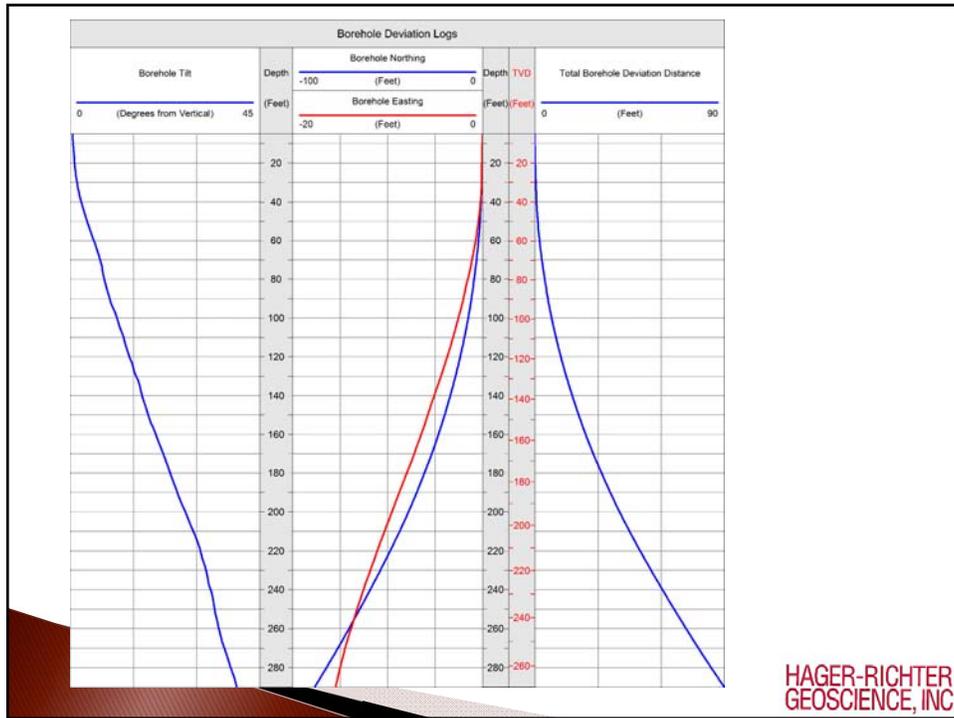












NEWMOA Webinar Geophysical Evaluation of Bedrock Drinking Water Wells Understanding the Science

Dorothy Richter, P.G. – Dorothy.Richter@Hager-Richter.com

Jeffrey Reid, P.G. – Jeff.Reid@Hager-Richter.com

Robert Garfield, P.G. – Rob@Hager-Richter.com

Hager-Richter Geoscience, Inc.

www.hager-richter.com

February 10, 2016

Salem, NH – Tel. 603.893.9944

Fords, NJ – Tel. 732.661.0555

HAGER-RICHTER
GEOSCIENCE, INC.