Optical and Acoustic Televiewer Logging in Competent and Unstable Rock

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Borehole Logging System

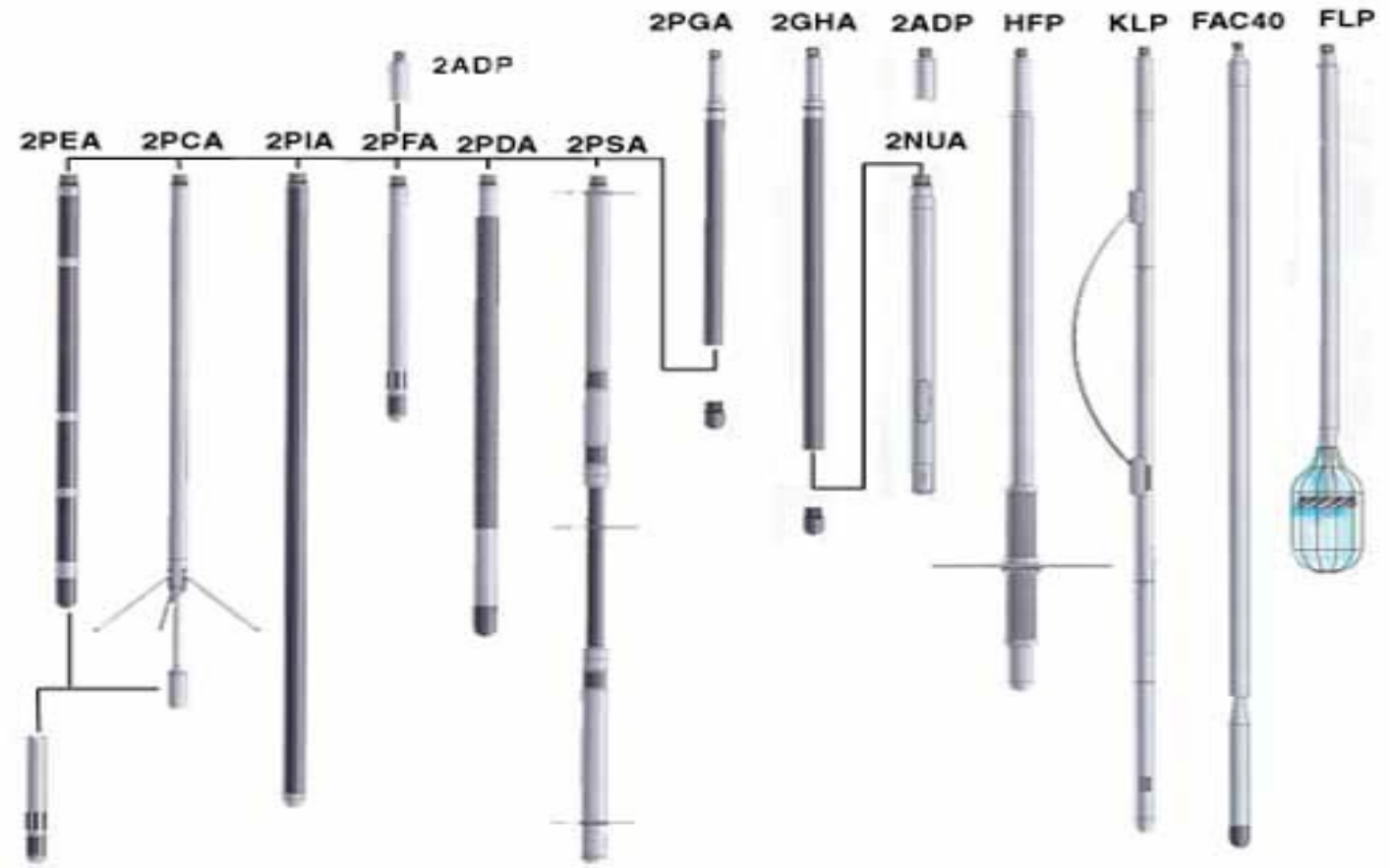
Logging cable carries signals to and from the downhole tool

Logging Control Console

Winch and Cable

Data Storage, Processing and Visualization

Borehole Logging System – Downhole Tools



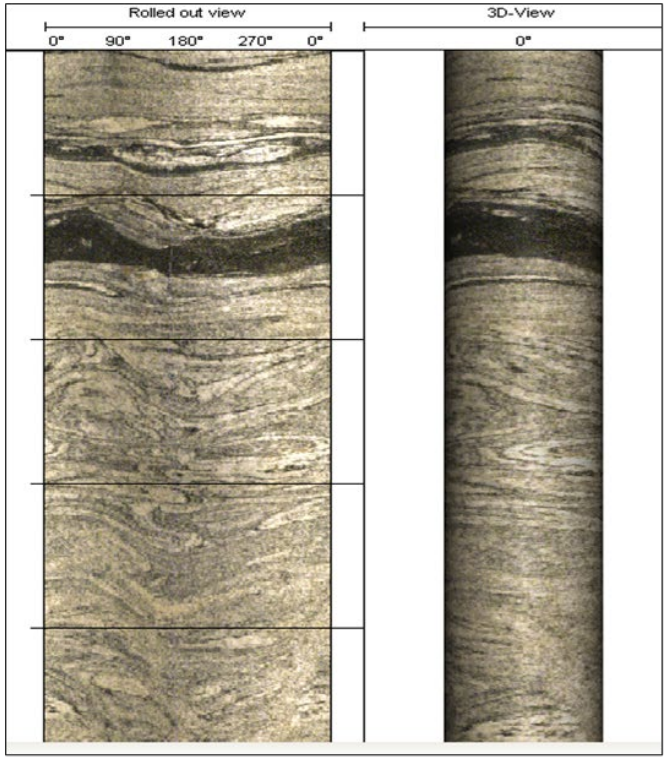
- Slimline downhole probes are approximately 40mm diameter
- Minimum borehole diameter is between 2-3 inches depending on tool selection and test

The Most Common Tools for Mapping and Evaluating Fractures in Open Holes

- Caliper
- Optical and Acoustic Televiewer
- Fluid Temperature and Conductivity
- Single Point Resistance and Spontaneous Potential
- Flowmeter

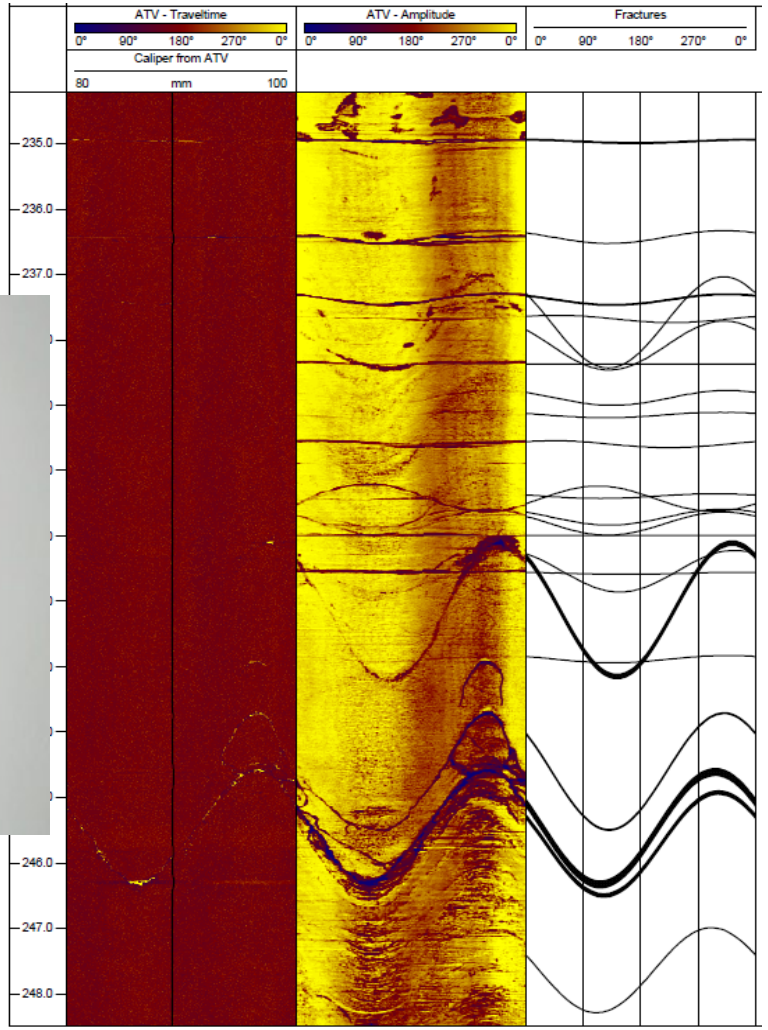
Televiewer Logs: Optical Televiewer

- **Optical Televiewer**
  - Theory:
    - High Resolution fisheye lens creates a magnetically oriented, 360 degree image of the borehole wall.
  - Uses:
    - Structural Analysis, Core Sample Correlation, Fracture Mapping, Bedding and Foliation
  - Borehole Conditions:
    - Uncased, Dry or Fluid Filled
  - Limitations:
    - Requires air or visually clear water, tool must be centralized



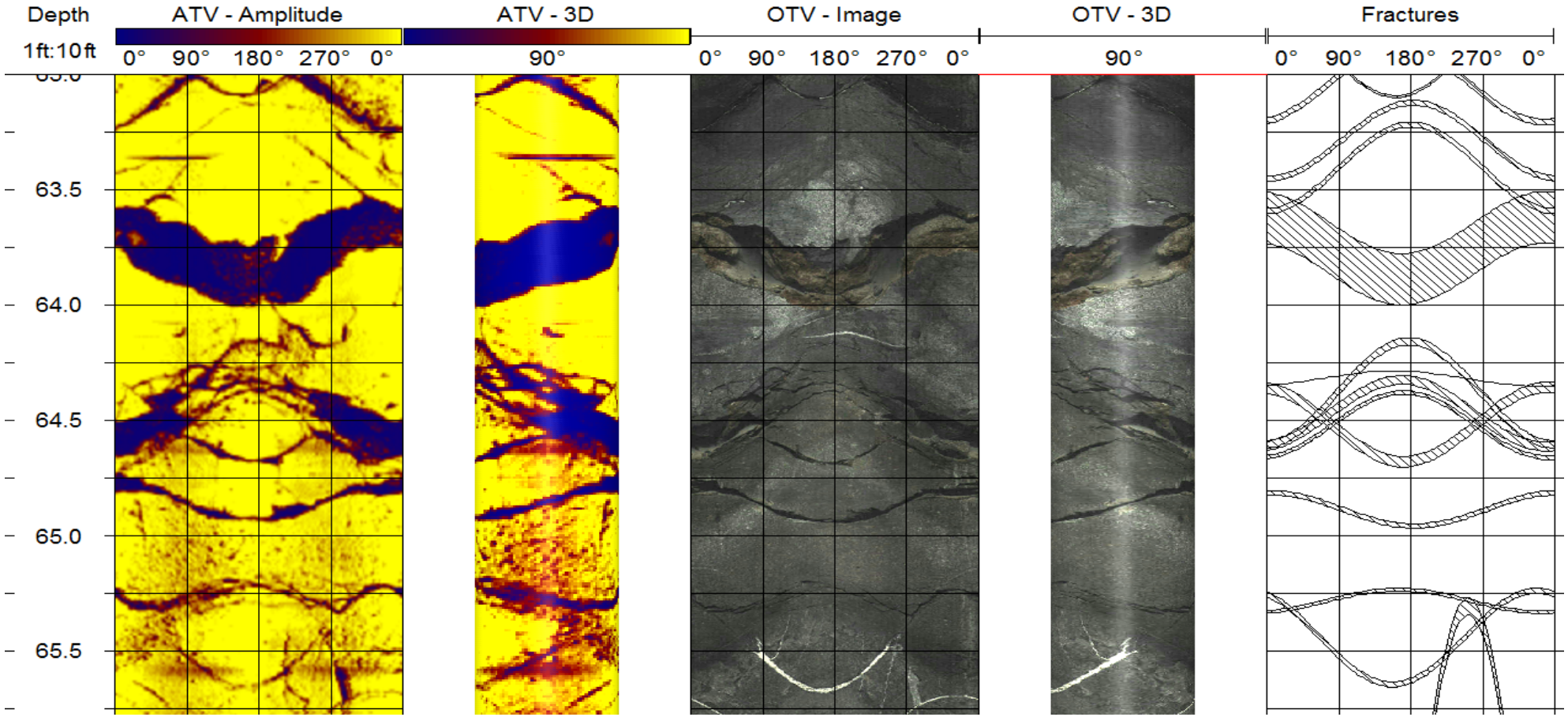
Televiewer Logs: Acoustic Televiewer

- **Acoustic Televiewer**
  - Theory:
    - Transducer generates and measures ultrasonic (~1MHz) waves as they reflect off the borehole wall. A rotating mirror directs the wave in incremental directions around the borehole . Travel times and amplitudes are measured for each reflection.
  - Uses:
    - Fracture Mapping, breakouts, borehole dimension
  - Borehole Conditions:
    - Fluid filled, Preferably uncased (behind PVC casing mode available with some models)
  - Limitations:
    - Must be centralized, data quality reduced in large diameter holes.



Televiewer Logging

Optical and Acoustic Televiewer Data



The initial orientation of identified planar features is relative to the axis of the borehole. Features are then reoriented to true space by correcting for borehole deviation and magnetic declination

Televiewer Logging – Orientation Corrections

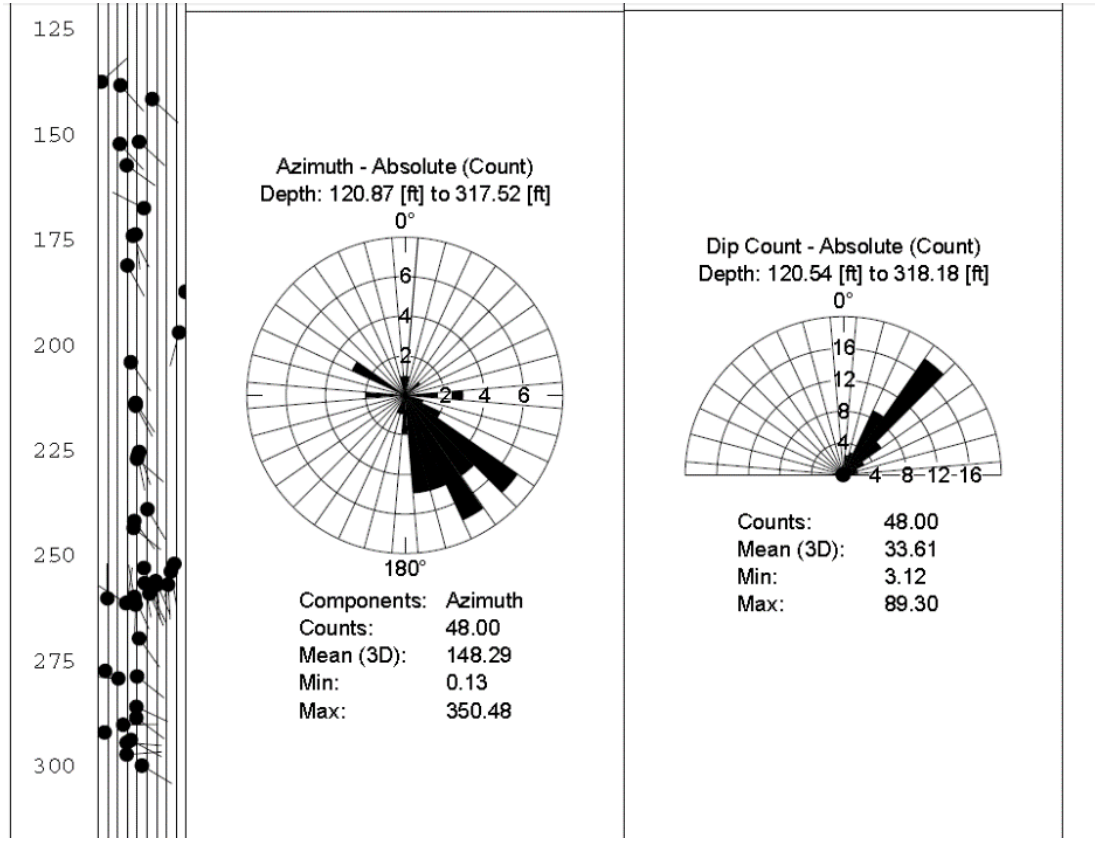
Borehole deviation: Use Built in sensors (for non-magnetic environment):
Orientation: 3 axis magnetometer, 3 accelerometers

Or:
Run gyroscopic based borehole deviation log separately and post-process

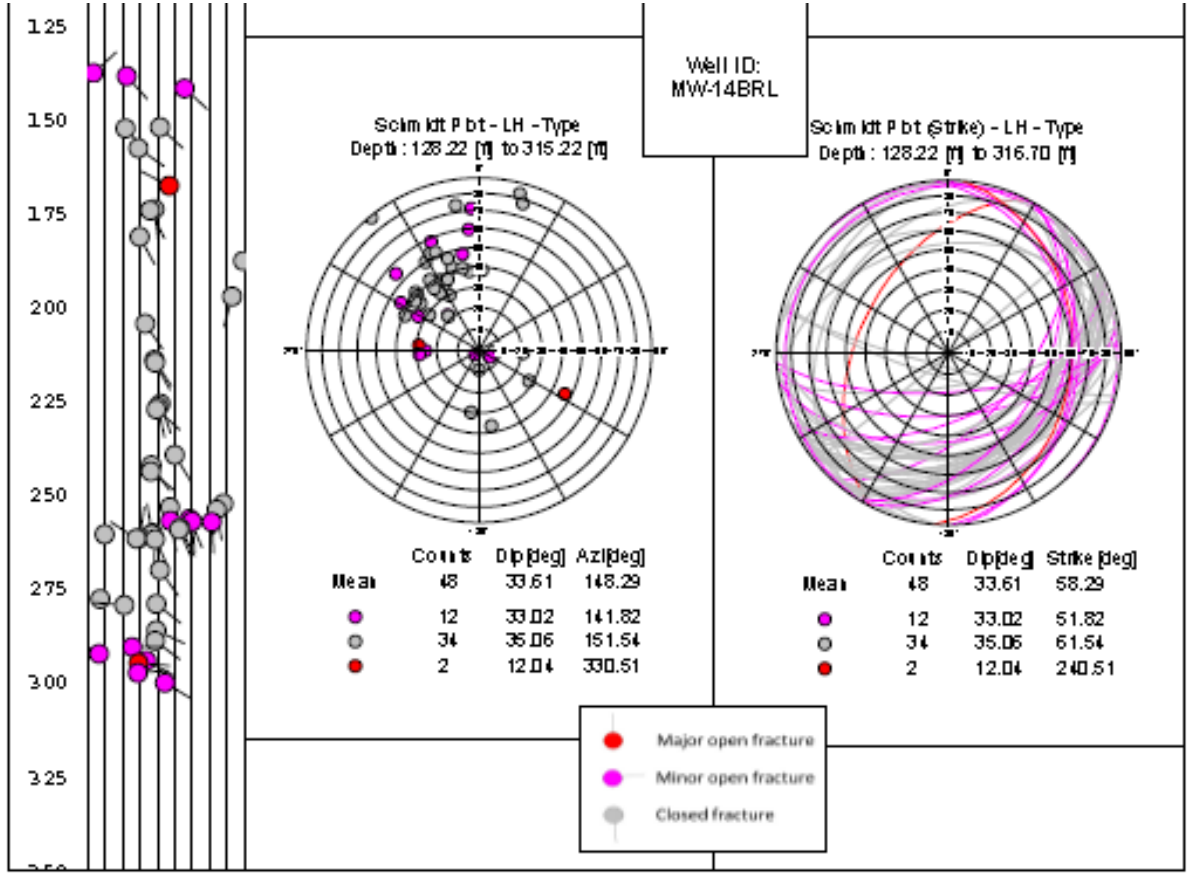
Magnetic to geographic north: World magnetic model (NOAA Web-site)
https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml

Data Interpretations – Fracture Orientation

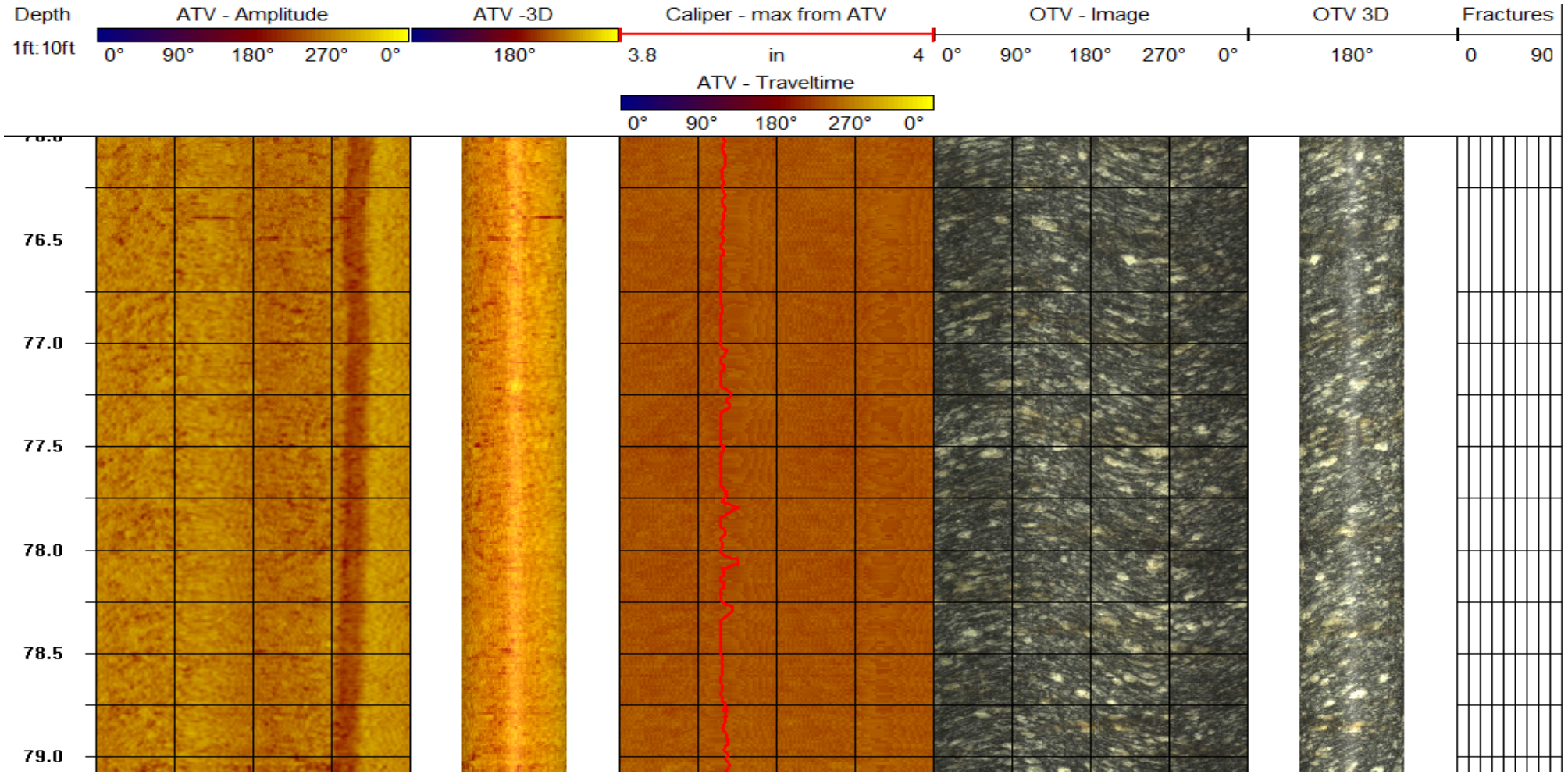
Rose diagrams



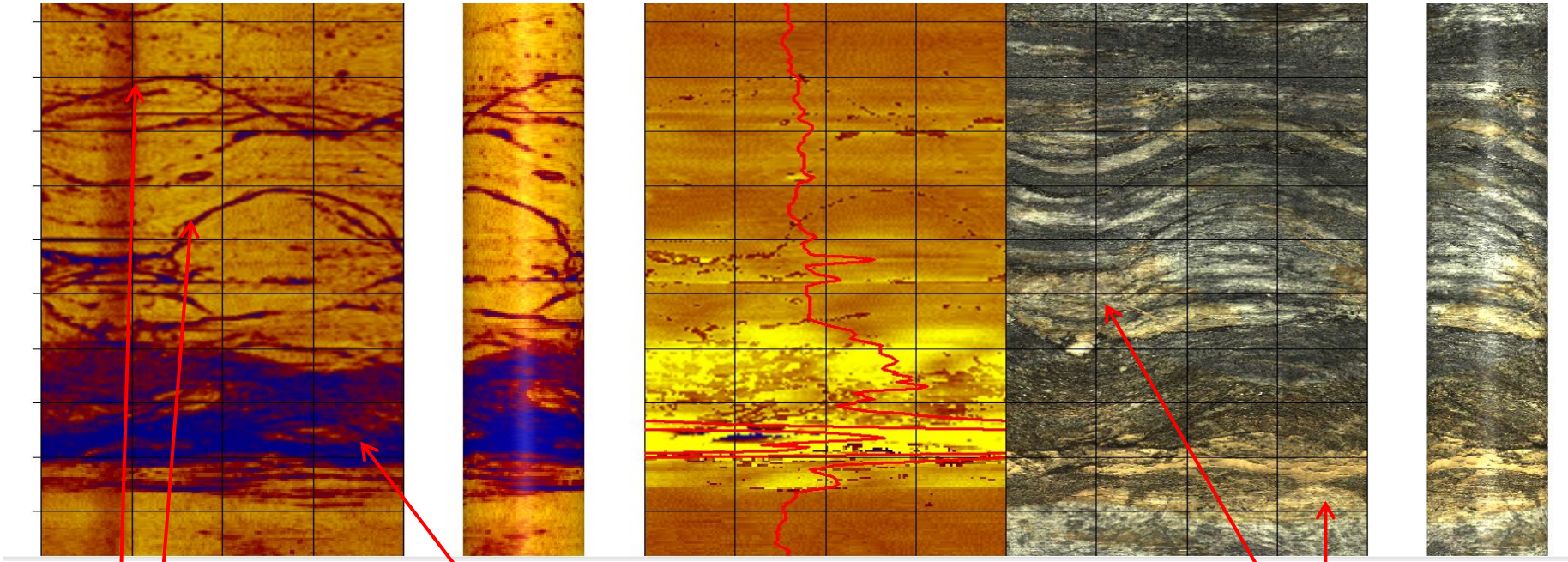
Schmidt Stereonets



Fracture-Free Rock Section



Fractured Rock Section



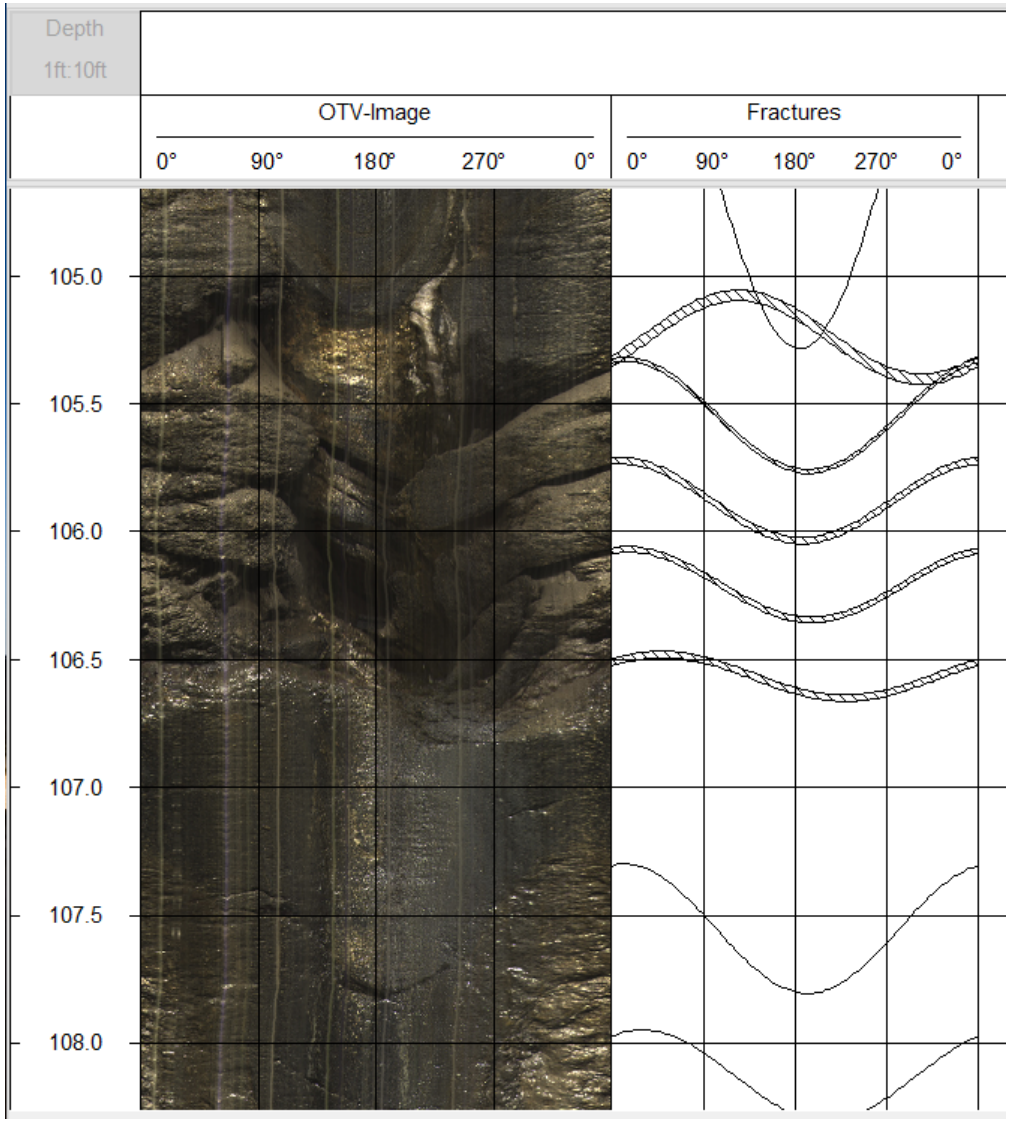
Smaller fractures
2-3 mm wide

Major fracture
10-15 mm wide

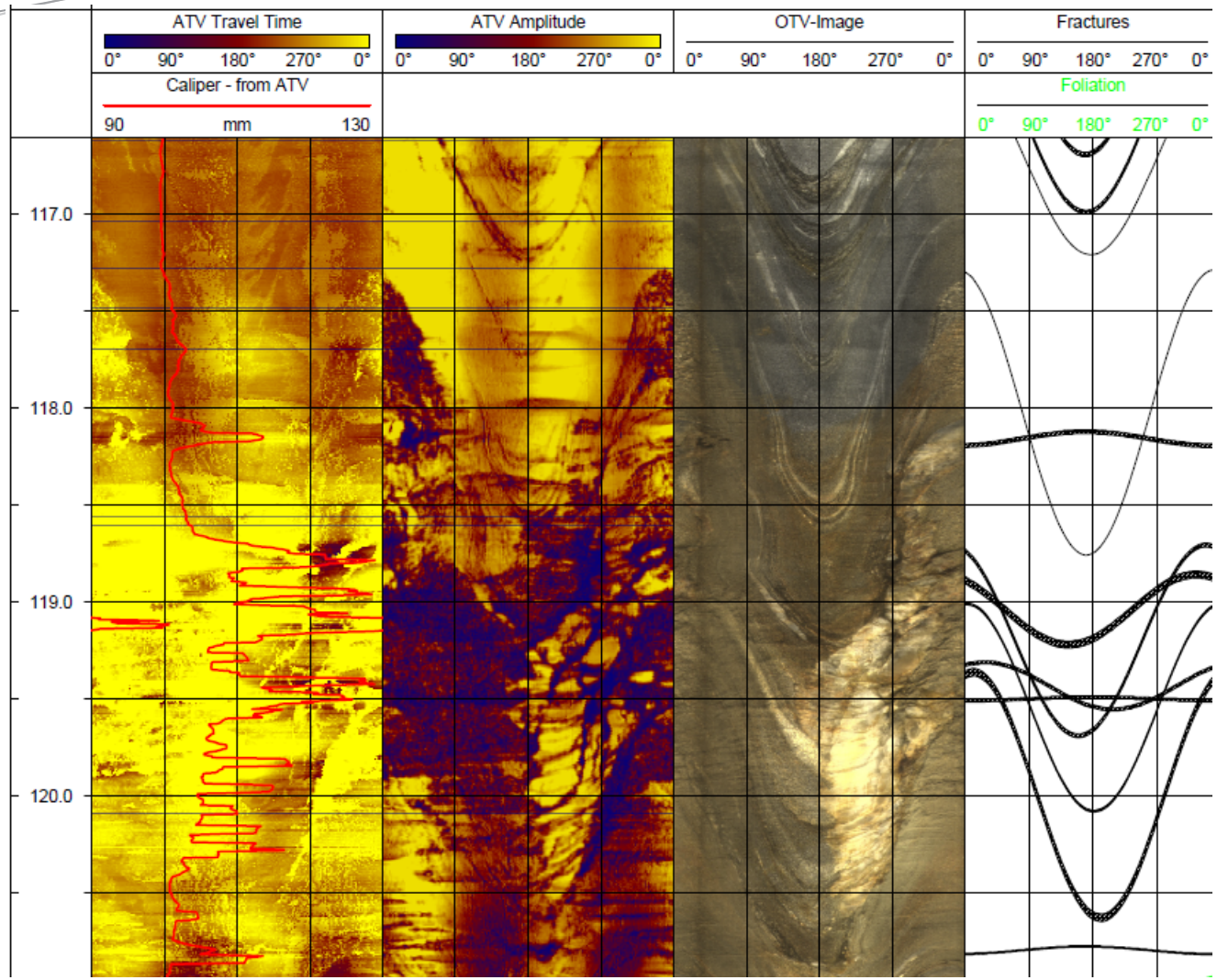
Yellow discoloration
(from water producing fractures)

NC-88 Widening and Realignment
West Jefferson, North Carolina

- Section through mountainous areas with significant rock cut slopes
- Roadside geologic mapping was conducted to assess rock type and discontinuities
- Televiewer logging was added to enhance roadside mapping observations closer to the proposed alignment
- Angle bore was oriented to intercept high-angle joint sets and to pin down the persistence/spacing of high-angle joint sets truncating planar and wedge features related to foliations in the amphibolite / schistose gneiss rock mass

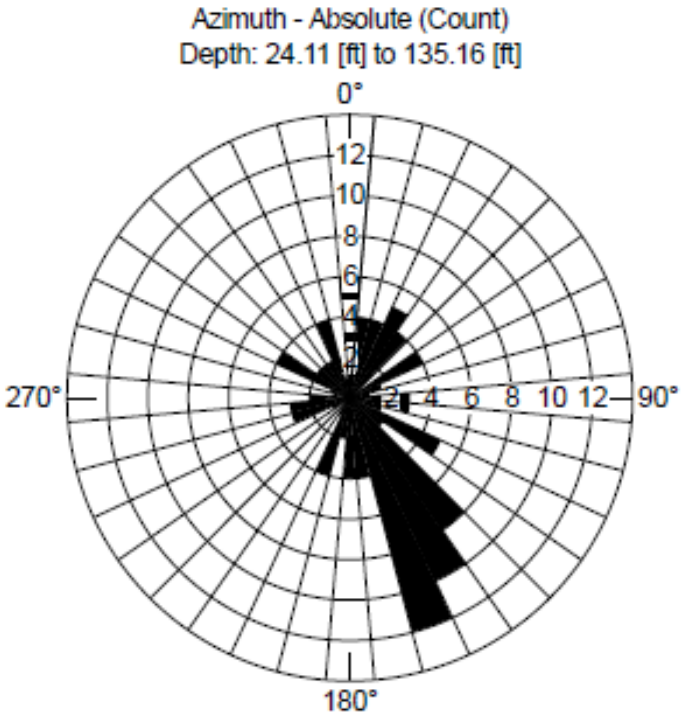


Above the water table - OTV Data and Interpretations

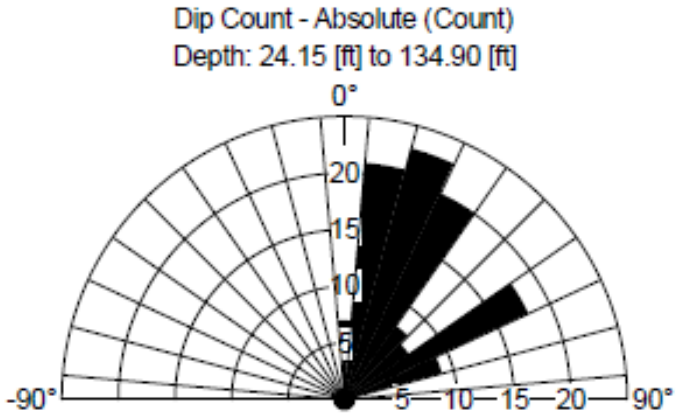


Below the water table - ATV and OTV Data and Interpretations

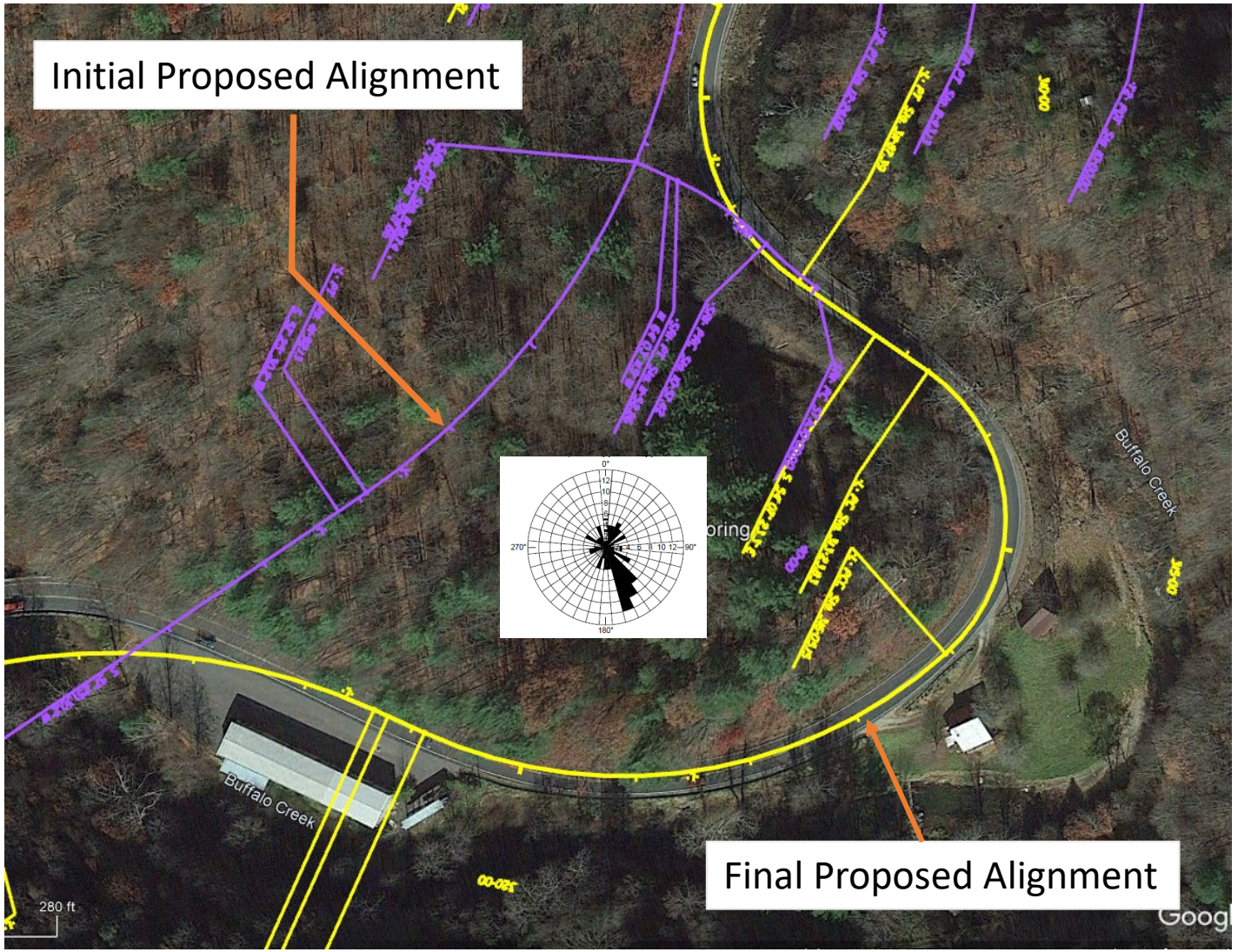
Rose Diagrams. Fracture orientation corrected for borehole deviation and magnetic declination



Components:	Azimuth
Counts:	115.00
Mean (3D):	129.51
Min:	0.85
Max:	357.10

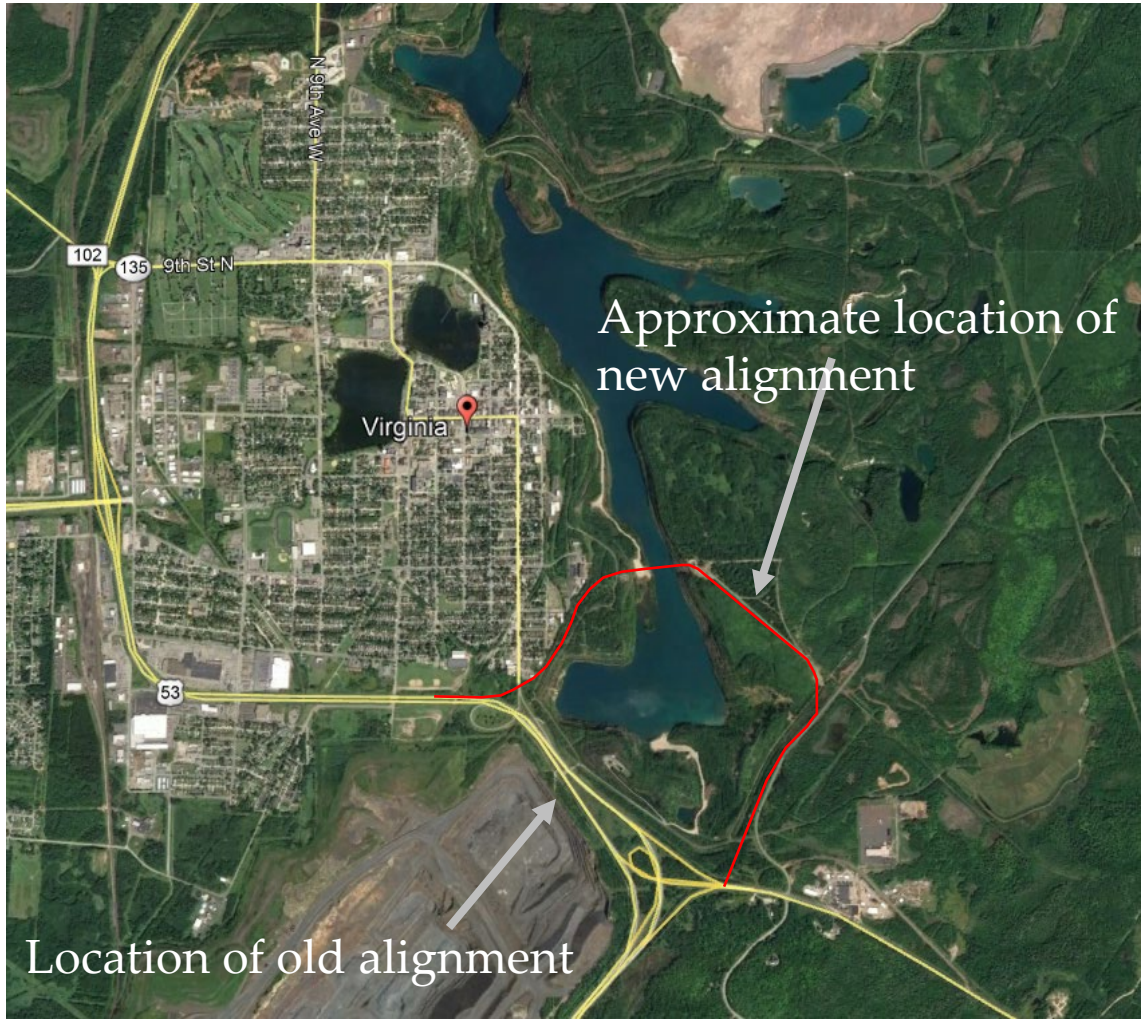


Counts:	115.00
Mean (3D):	11.19
Min:	0.69
Max:	87.36


Initial Proposed Alignment
Buffalo Creek
Buffalo Creek
280 ft
Final Proposed Alignment

Proposed New Bridge for the TH 53 Relocation, Virginia, Minnesota

- MnDOT built the past TH 53 alignment in 1960 on land owned by iron mining interests.
- In 2010, the mining interests notified MnDOT that the road would need to be moved.
- MnDOT and the mining company agreed to a 2017 date for the road move.

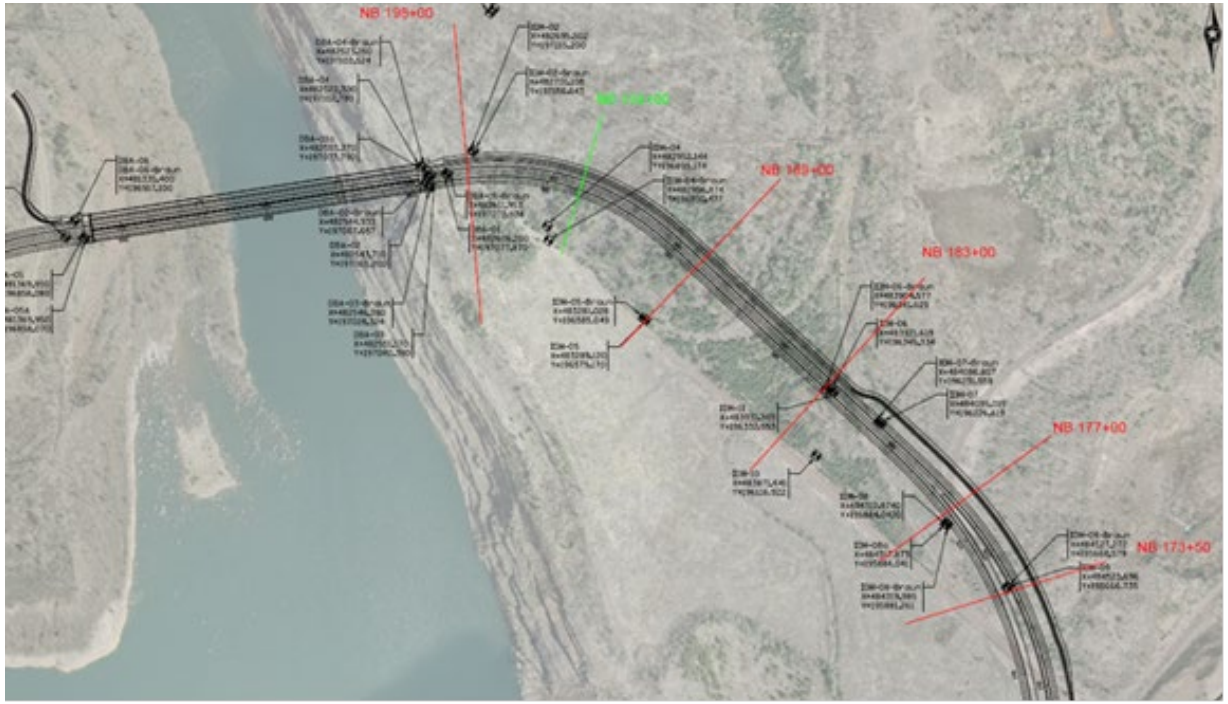


Project Site

Google Earth 2015

Google Earth 2022

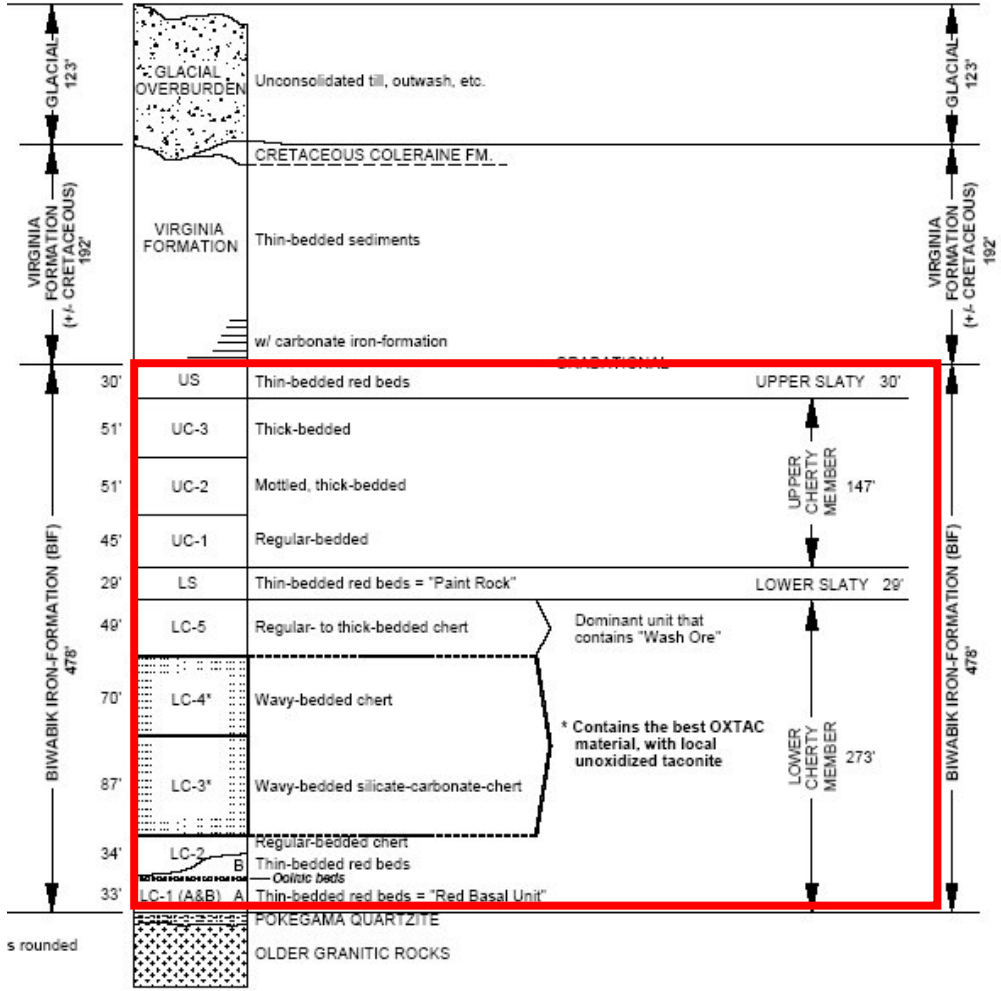
Bridge Concept



Construct new, shorter, tall bridge trough inactive mining area, further north of current TH 53 alignment.

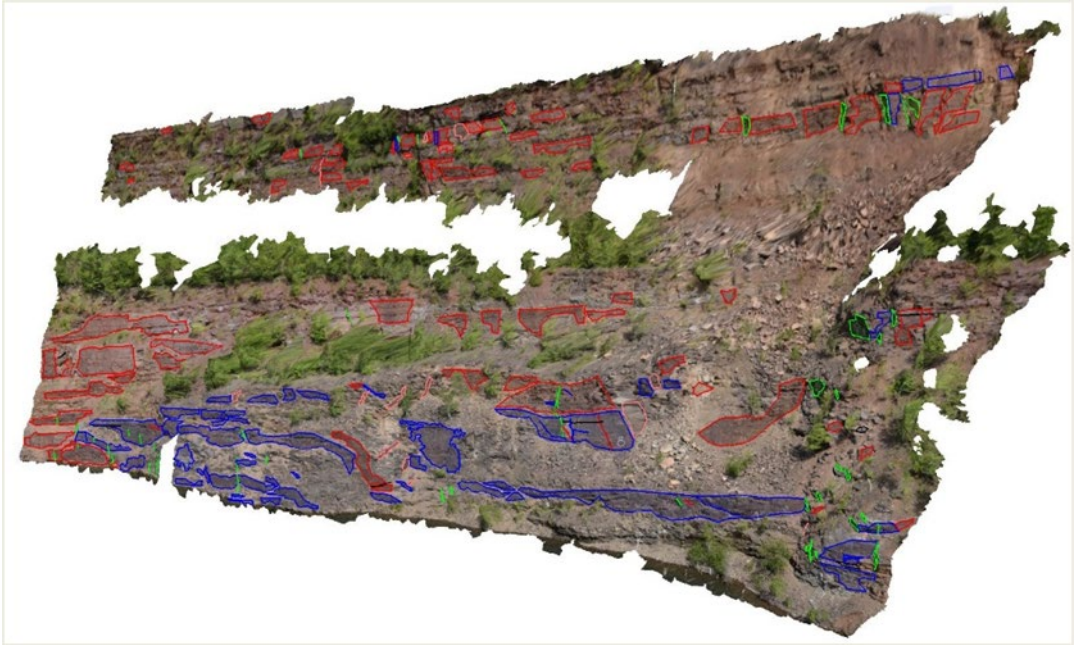
Geology Overview

- Rock slopes are located in the Biwabik Iron Formation



Field Program

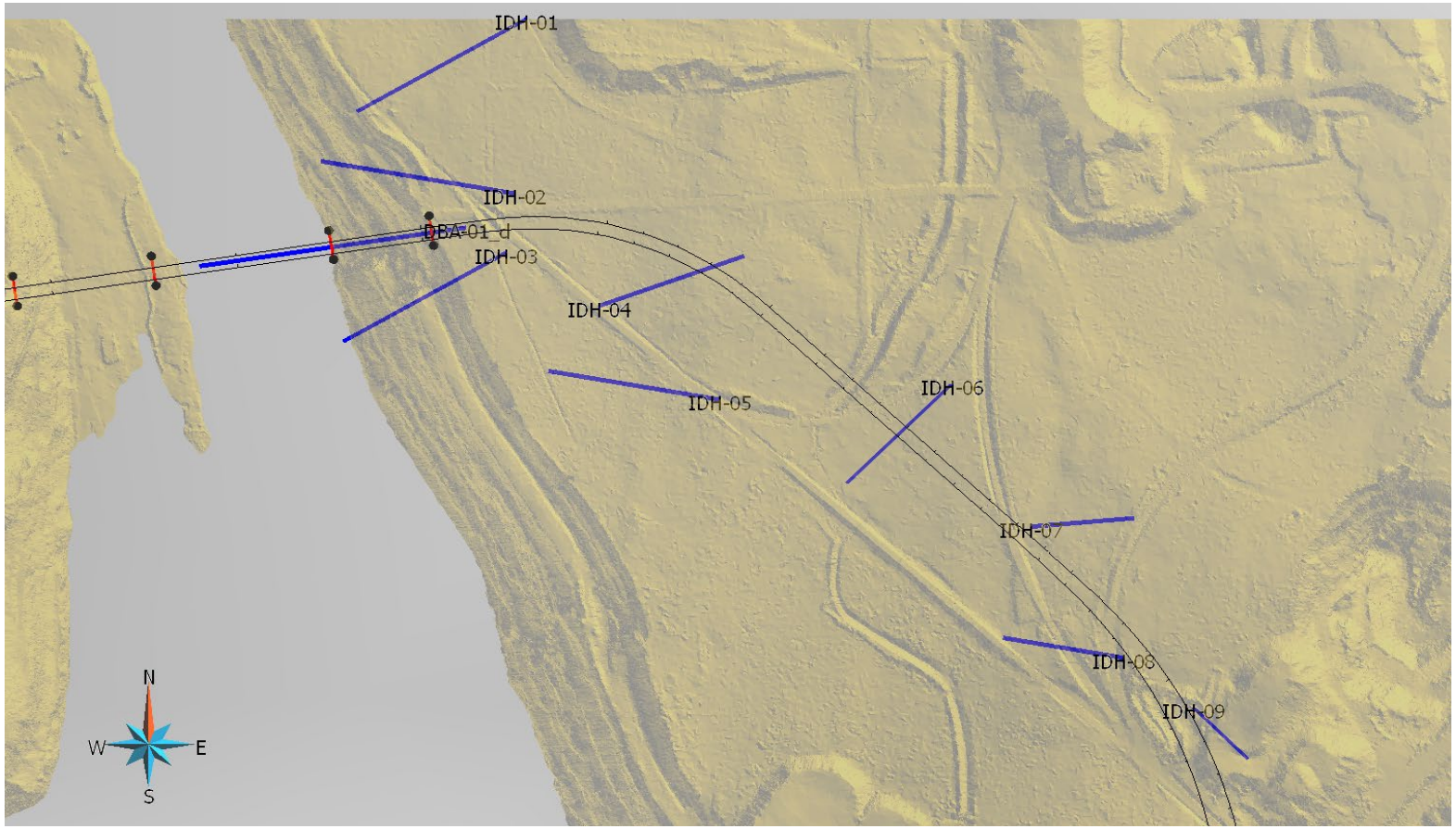
- Geological and geotechnical core logging (22 coreholes with approximately 7,000 ft of core)
- Laboratory testing
- Point load testing
- Downhole geophysical logging
- Photogrammetry



Drilling Program

- Two phases of drilling to assess geotechnical characteristics of bedrock at abutment locations
- 17 Angled Boreholes
- Geophysical Logging for Bedrock Structure

Initial Drillhole Layout – East Side



Drilling Program

- Poor rock quality within banded iron ore formation
- Problem maintaining open bedrock intervals
- Magnetic interference with logging probes from Banded Iron Formation
- Recommended solution for borehole logging program:

Drill Borehole → Grout Borehole → Re-drill Borehole → Log Borehole

Caliper, ATV, and OTV logging for bedrock structure, gyroscopic deviation logging due to banded iron formations

Banded Iron Formation (zones of poor RQD)


32.5
34.5
36
38
39.5


714.5
716
716.5
717.5

Geotechnical Log

SDVOSB Service Disabled Veteran Owned Small Business

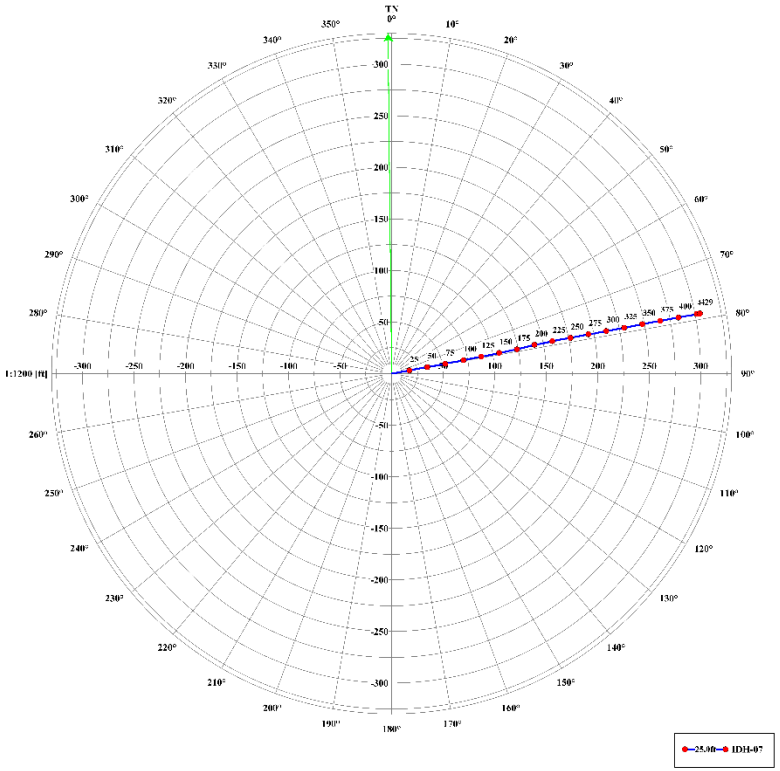
COLLIER GEOPHYSICS

Angled Hole Drilling, Grouting & Re-Drilling

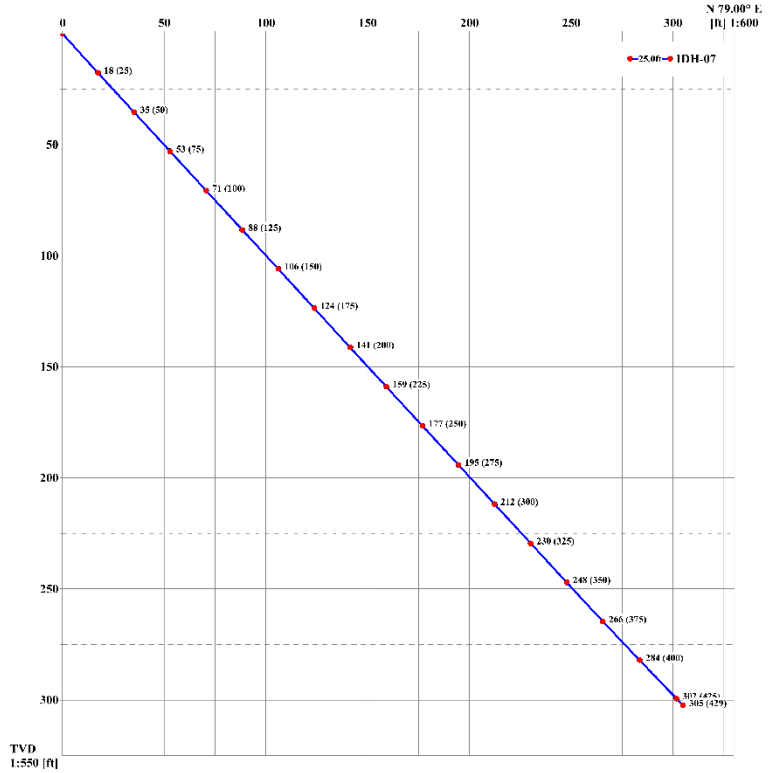
Geophysical Logging in Angled Boreholes

Deviation Logging in Angled Borehole

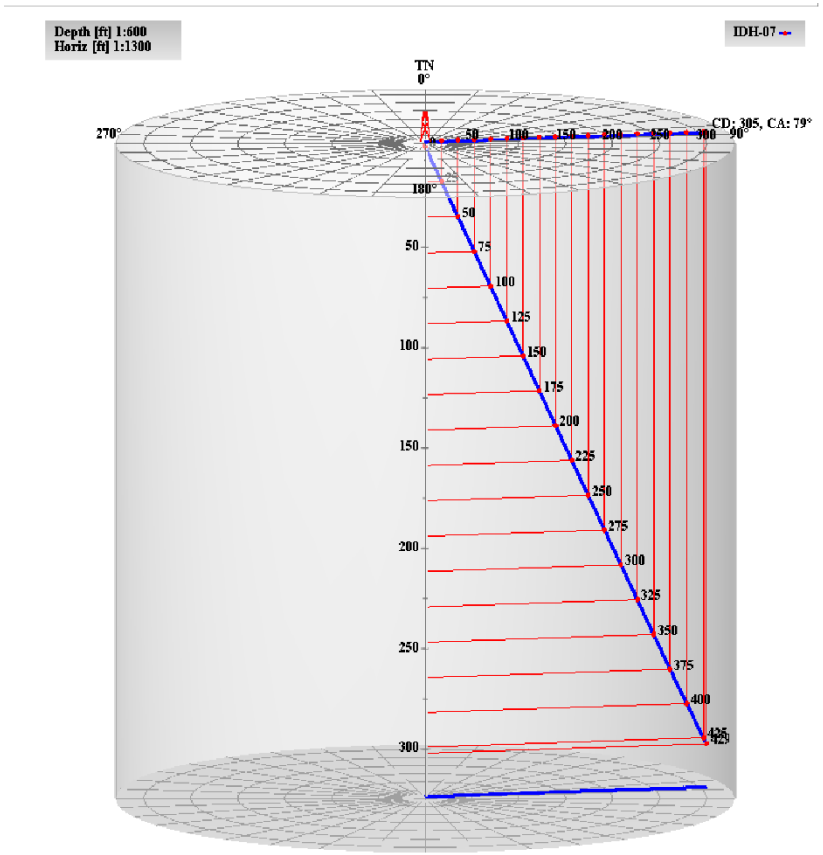
Bull's Eye Deviation Plot



Vertical Profile Deviation Plot

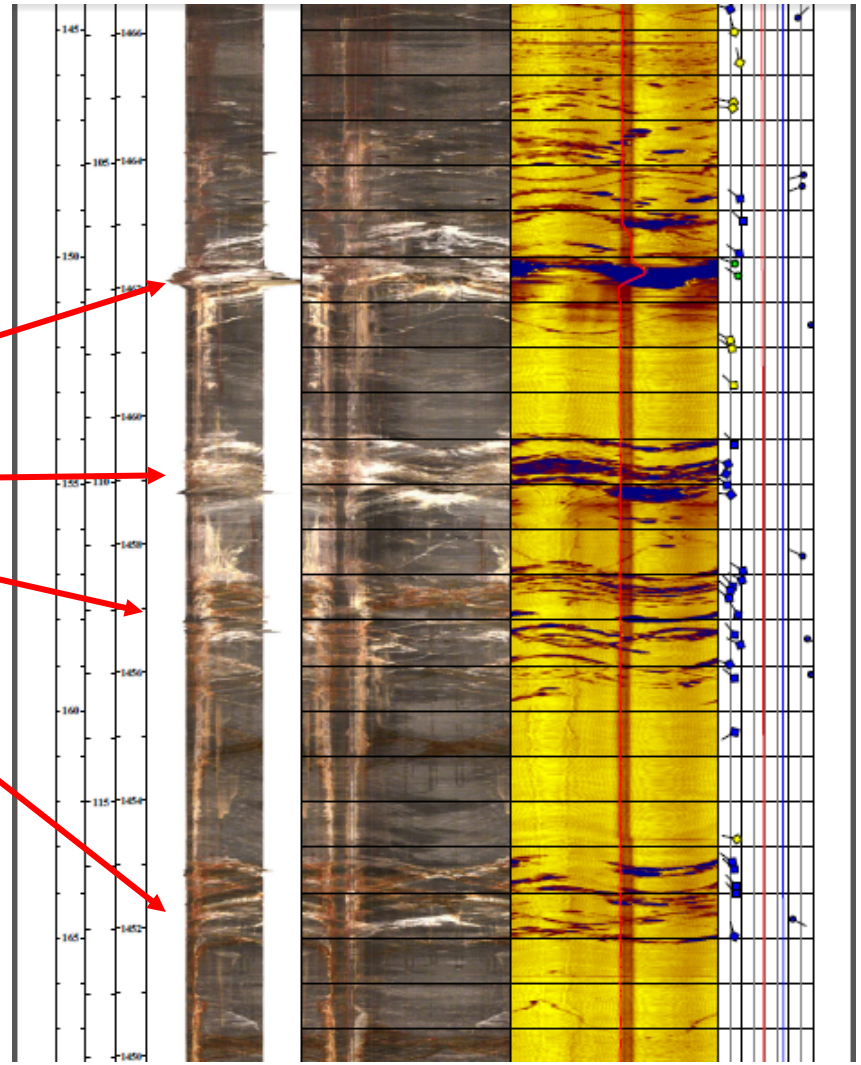


3D Deviation Plot

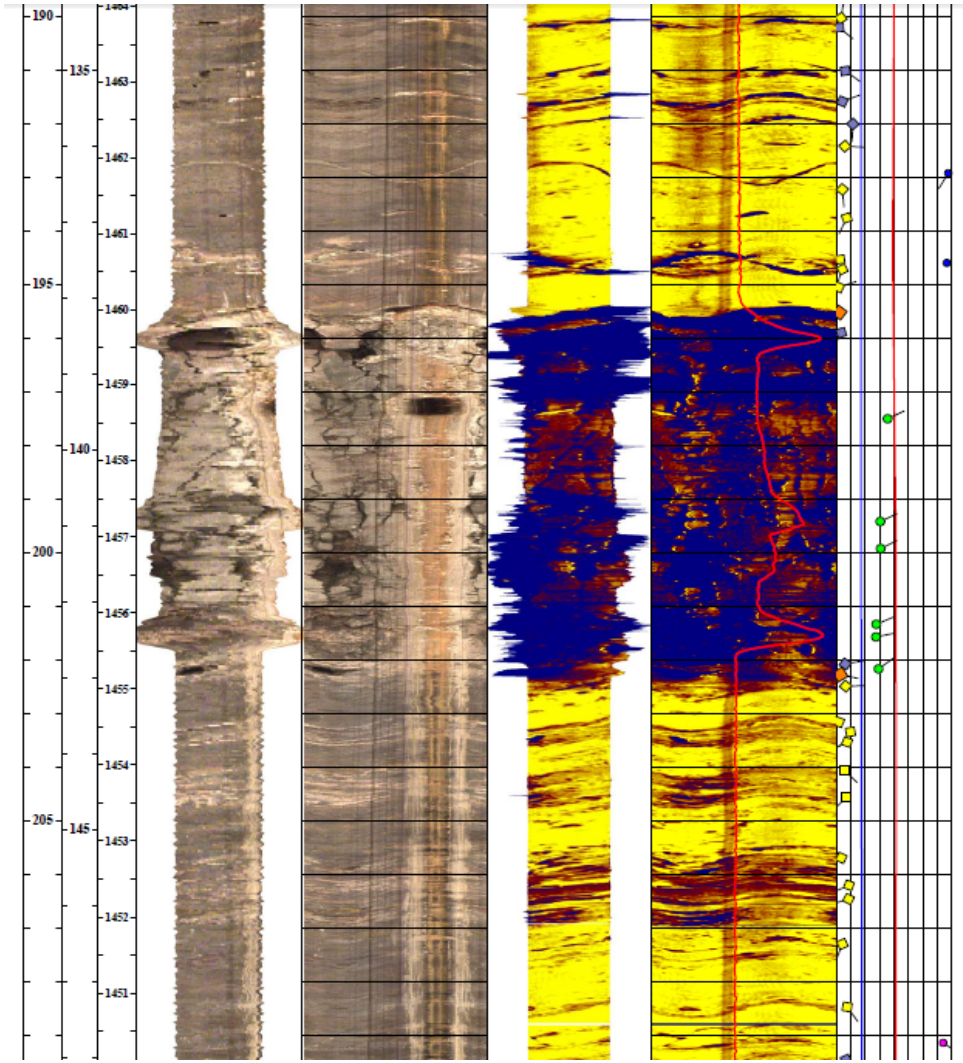


Geophysical Logging

Grout Filled Discontinuities



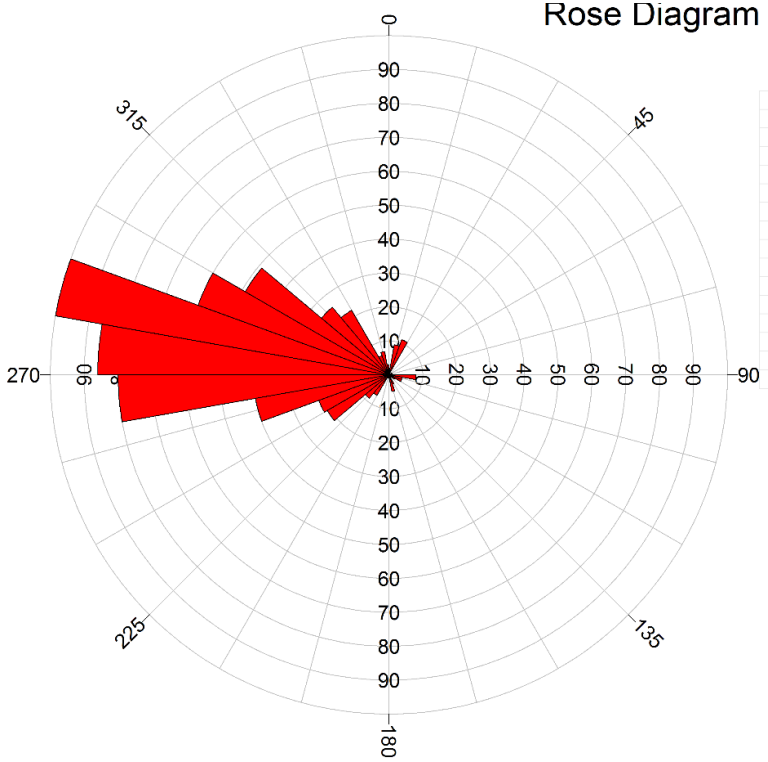
Geophysical Logging



Grout Filled Breakout

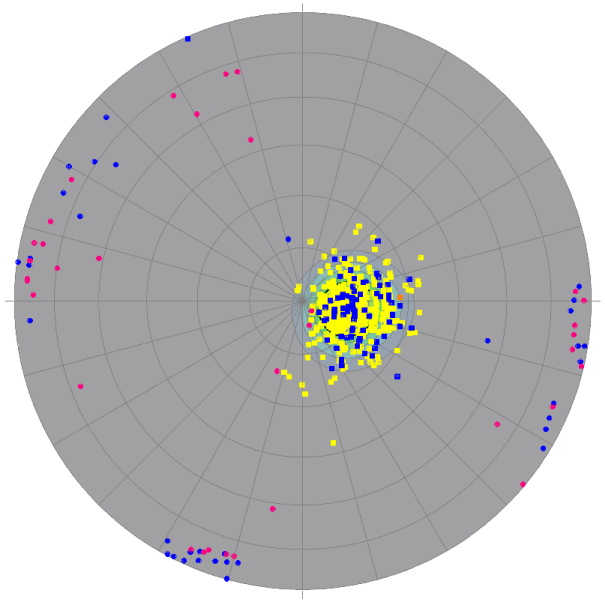
Bedrock Structure Data in Angled Borehole

Rose Diagram IDH-11 (ALL DATA)



Statistical Summary	
Calculation Method:	Frequency
Class Interval:	10.0 Degrees
Azimuth Filtering:	Deactivated
Data Type:	Unidirectional
Population:	592
Total Length of All Lineations:	592.0
Maximum Bin Population:	100.0
Mean Bin Population:	19.73
Standard Deviation of Bin Population:	27.77
Maximum Bin Population (%):	16.89
Mean Bin Population (%):	3.33
Standard Deviation of Bin Population (%):	4.69
Maximum Bin Length:	100.0
Mean Bin Length:	19.73
Standard Deviation of Bin Lengths:	27.77

Dip Azimuth and Angle Azimuth IDH-11 (ALL DATA)



Statistical Summary	
Projection:	Schmidt (Equal Area)
Number of Sample Points:	592
Mean Lineation Azimuth:	100.2
Mean Lineation Plunge:	75.2
Great Circle Azimuth:	282.8
Great Circle Plunge:	89.3
1st Eigenvalue:	0.872
2nd Eigenvalue:	0.076
3rd Eigenvalue:	0.052
LN (E1 / E2):	2.436
LN (E2 / E3):	0.389
(LN(E1/E2)] / (LN(E2/E3)):	6.269
Spherical Variance:	0.1084
Rbar:	0.8916

105	Large
106	Moderate
107	Small
108	Foliation/Cleavage/Fabric
109	Bedding/Banding
109.5	Open Bedding/Banding
110	Tight
111	Vein
112	Contact

T.H. 53 Relocation Completed: September 2017

Minnesota Department of Transportation, “Hwy 53 Bridge Relocation Project, 9/17”, (2017). https://www.youtube.com/watch?v=gPH09BzVs8I.

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THANK YOU

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