MERC 2025 - Session 3

TELEVIEWERS, CALIBRATION AND DATA MANAGEMENT

ACOUSTIC AND OPTICAL TELEVIEWERS

Televiewer Surveys

- **Acoustic and Optical Televiewers incorporates;**
  - Orientation measurements
  - Imaging of the borehole
  - Telemetry system

- **Typical Borehole Conditions;**
  - 2”-3” to 20” borehole size – BQ and up – probe diameter ~40mm
  - -90 (Vertical) to -45 with conventional, gravity fed systems
  - Centralization
  - Drilling Method / Rugosity

Televiewer Applications: Oriented Core Alternative

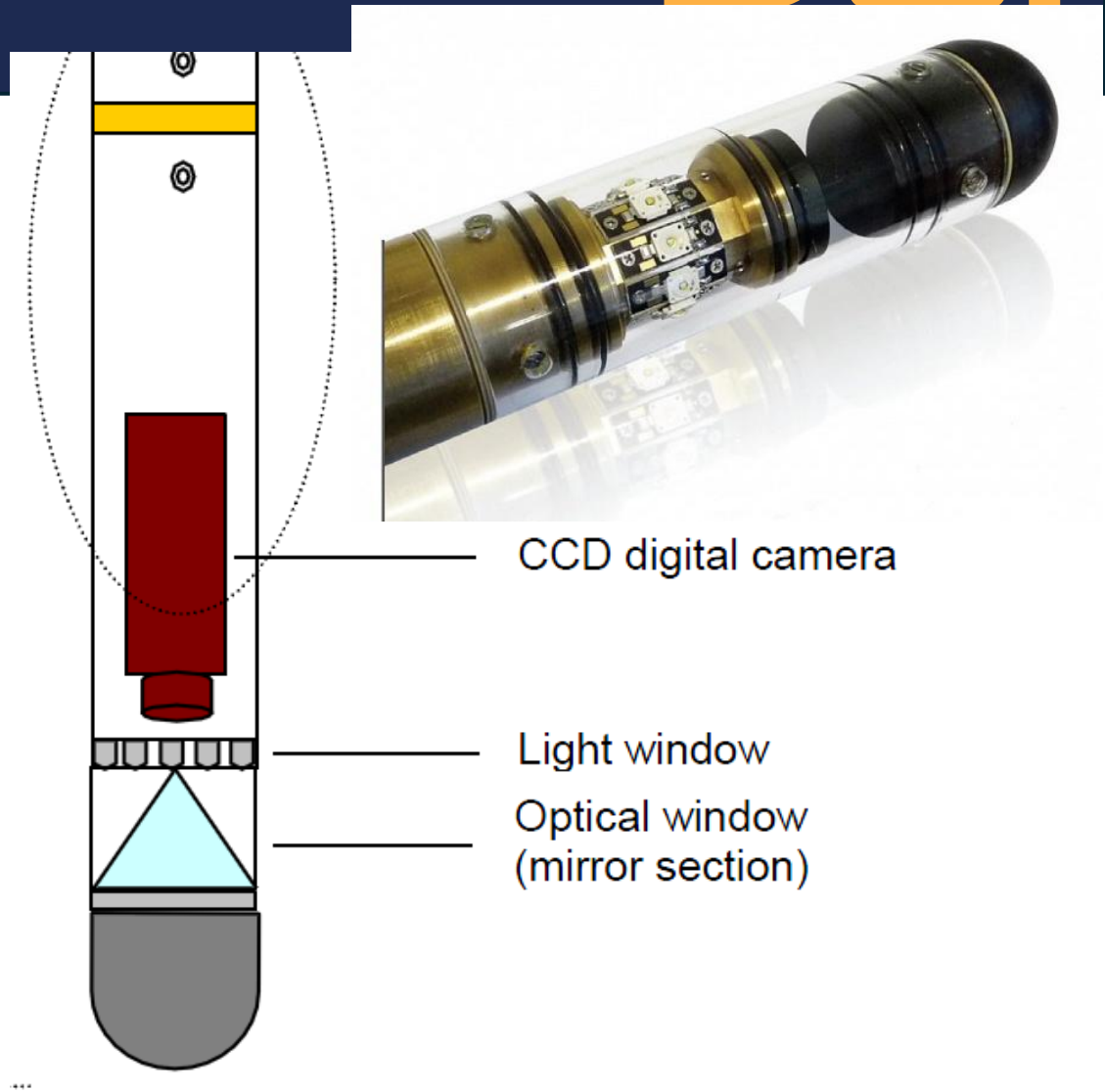
- Drill core is the geologists objective on a diamond drill program.
- However, oriented core from diamond drilling is expensive. Not all drill programs result in oriented drill core.
- Oriented Core allows true strike and dip measurements. Critical for structural modelling.

- **Challenge:** What if I now need to do geological modelling?
- **Solution**: Acquire televiewer data to take advantage of *already-drilled boreholes*.
- Quality control for oriented core.

Accurate inputs for structural modelling, and hence true orientations, are critical for the geologist. Especially in more complex geological environments.

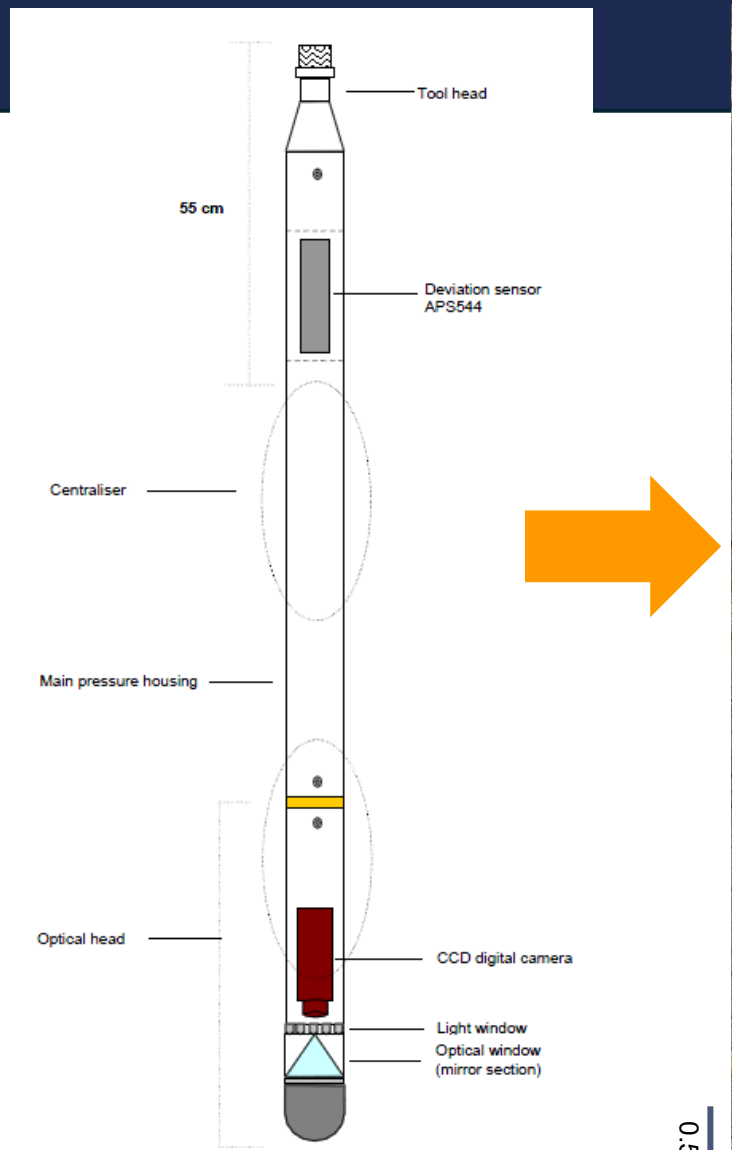
Optical Televiewer (OTV)

- **Theory of Operation:**
  - CCD digital camera captures the reflection of the mirror providing a 360° image of the surrounding borehole
- **Probe Parameters:**
  - Pixel height and width
  - Light level
  - White balance
  - Exposure
- **Limitations:**
  - Image clarity, magnetic interference, centralization



Optical Televiewer Applications

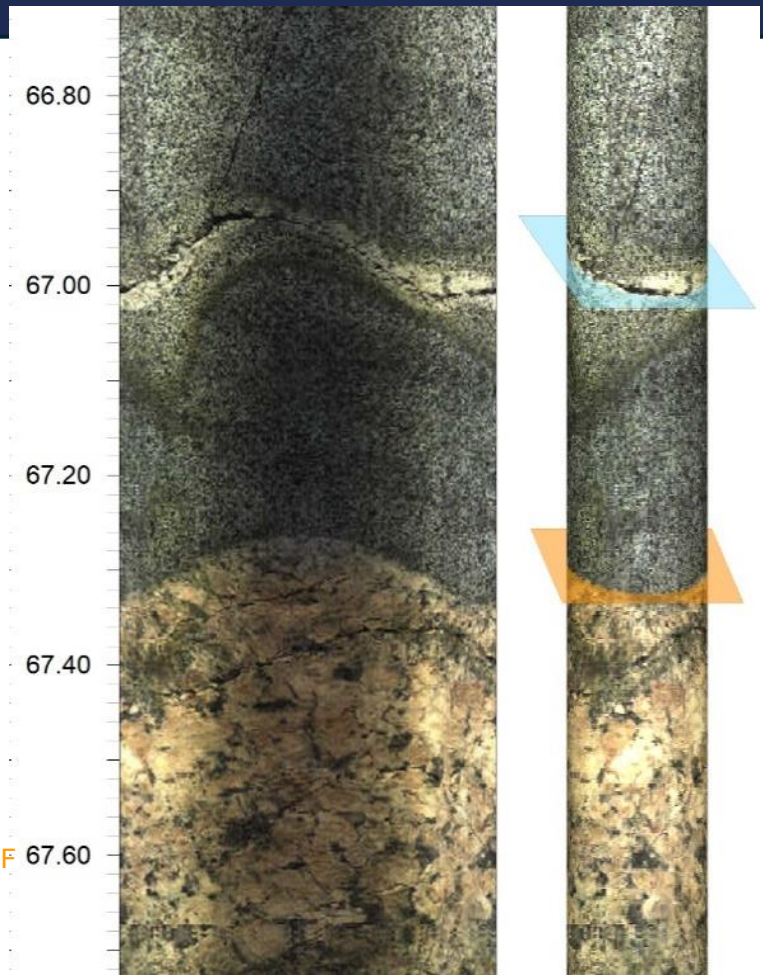
- Oriented Core Alternative
- RC and Blast Holes
- Low RQD Zone Core Recovery
- True Strike and Dip
- Bedding/Banding/Foliation
- Shear Zones
- Fault Orientation
- Fold Geometry
- Fracturing
- Contacts
- Veins



VIRTUAL CORE ACQUIRED IN A RC DRILLED BOREHOLE

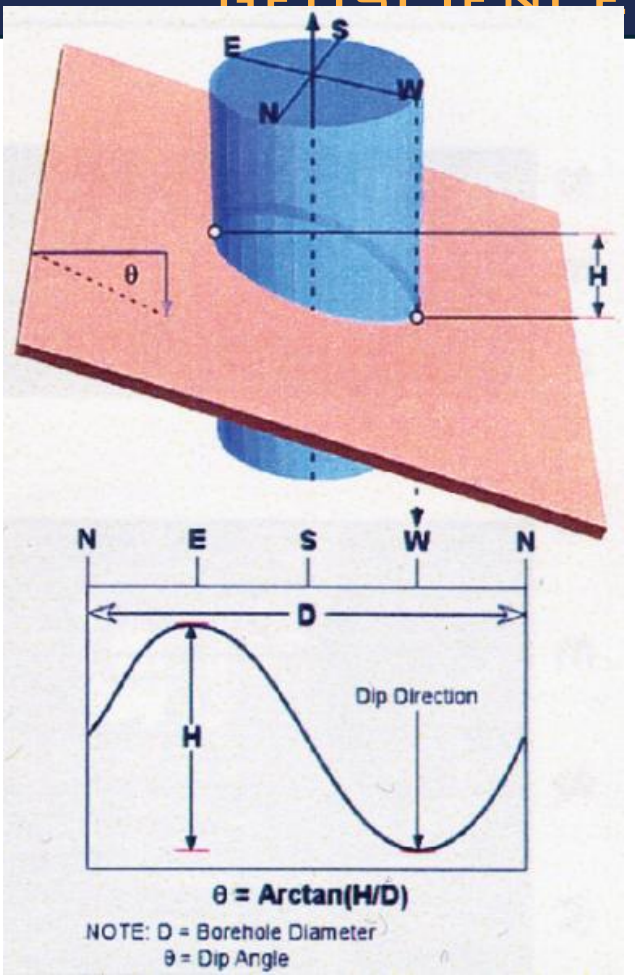
Optical Televiewer (OTV) - Operation

- Planar geologic features intersect the borehole
- Strike and dip can be measured accurately
- Simultaneously measure borehole path
- Image oriented to a reference point, allowing for oriented structural measurements

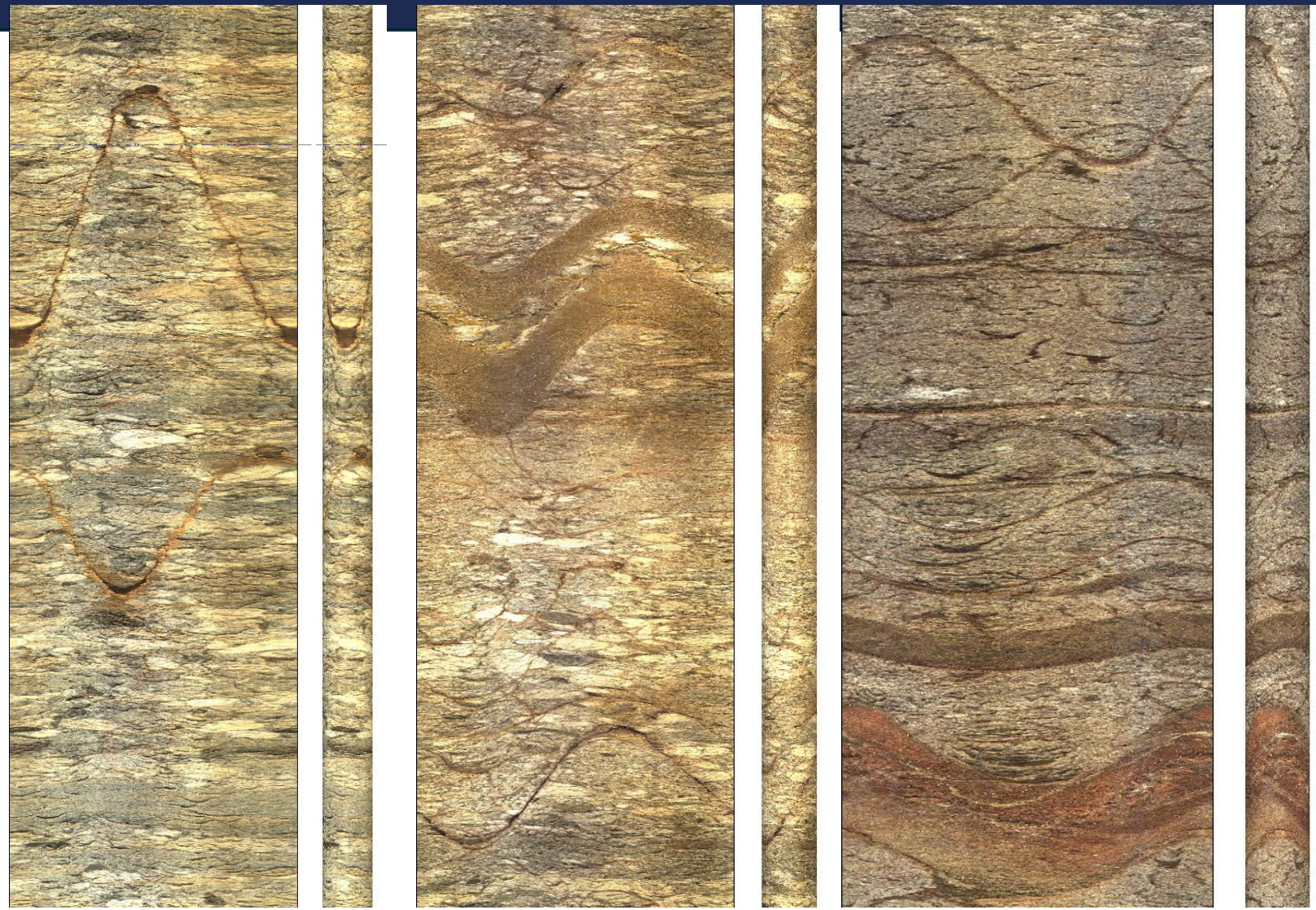


UNWRAPPED 360-VIEW OF BOREHOLE WALL

VIRTUAL 3D CORE



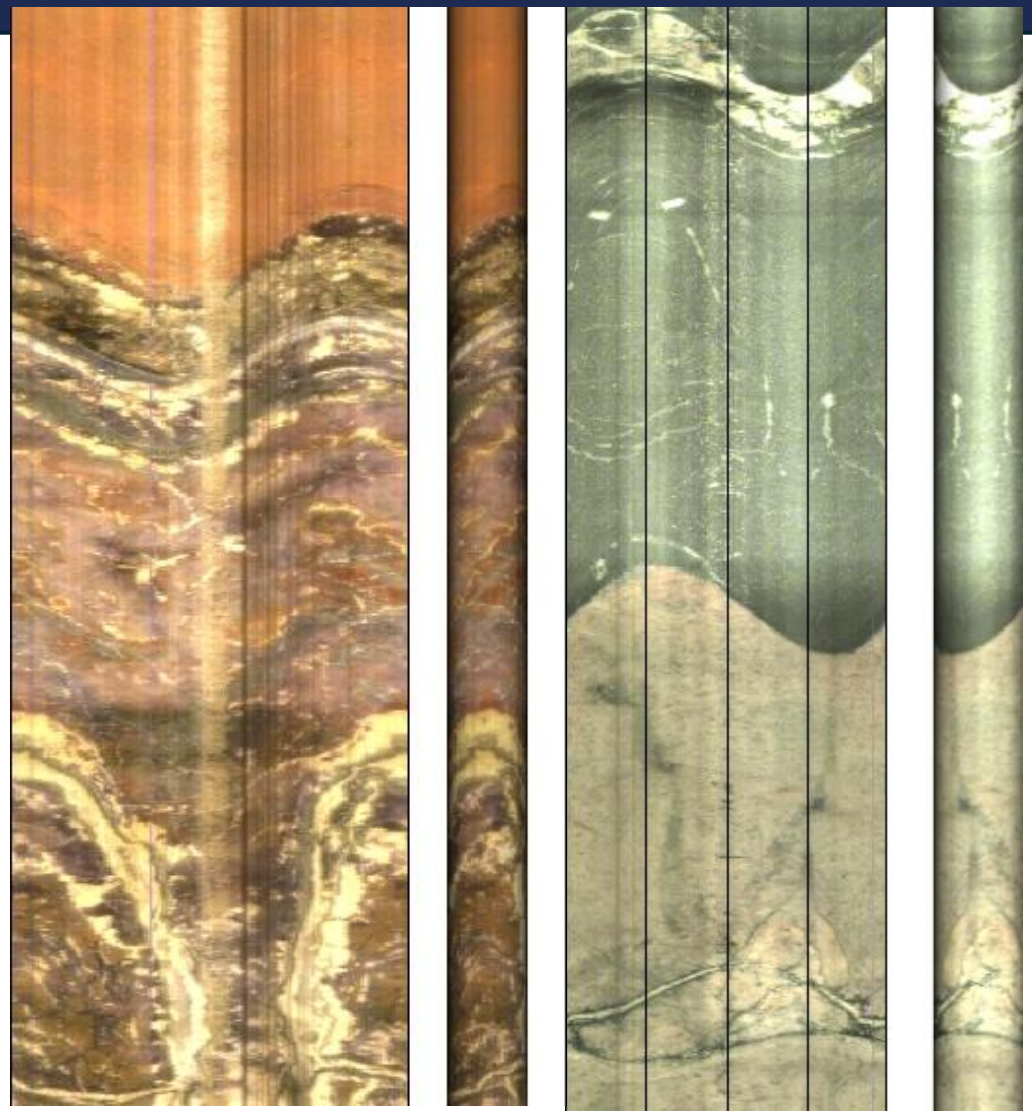
Sample Optical Televiewer (OTV) Images



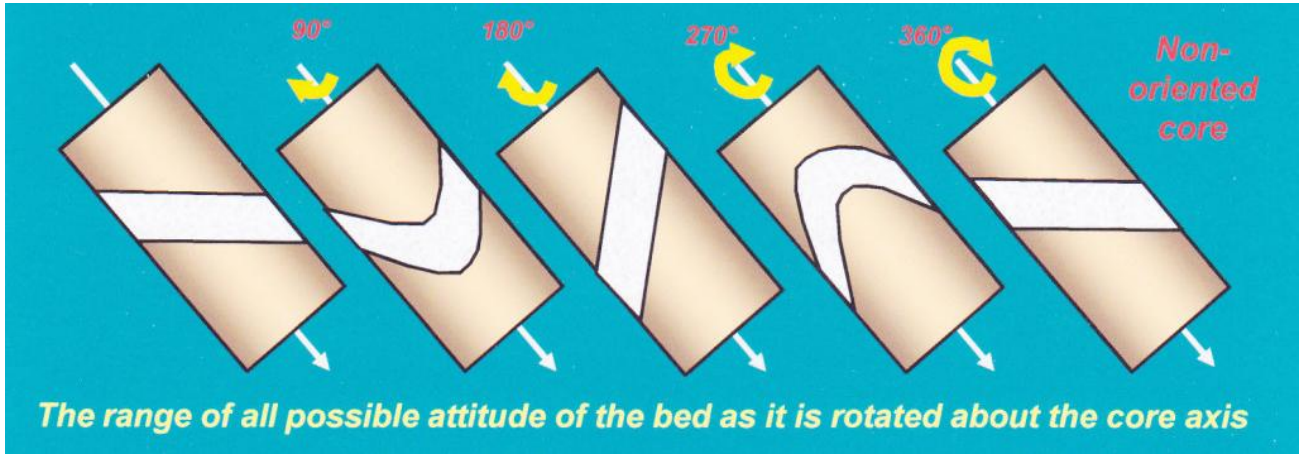
Major Benefits

- Oriented image
- Measure fractures, veins, contacts, foliation, bedding, faults, etc.
- Relative to core axis or converted to true co-ordinates
- Acquire for the entire hole
- Does not need borehole fluid

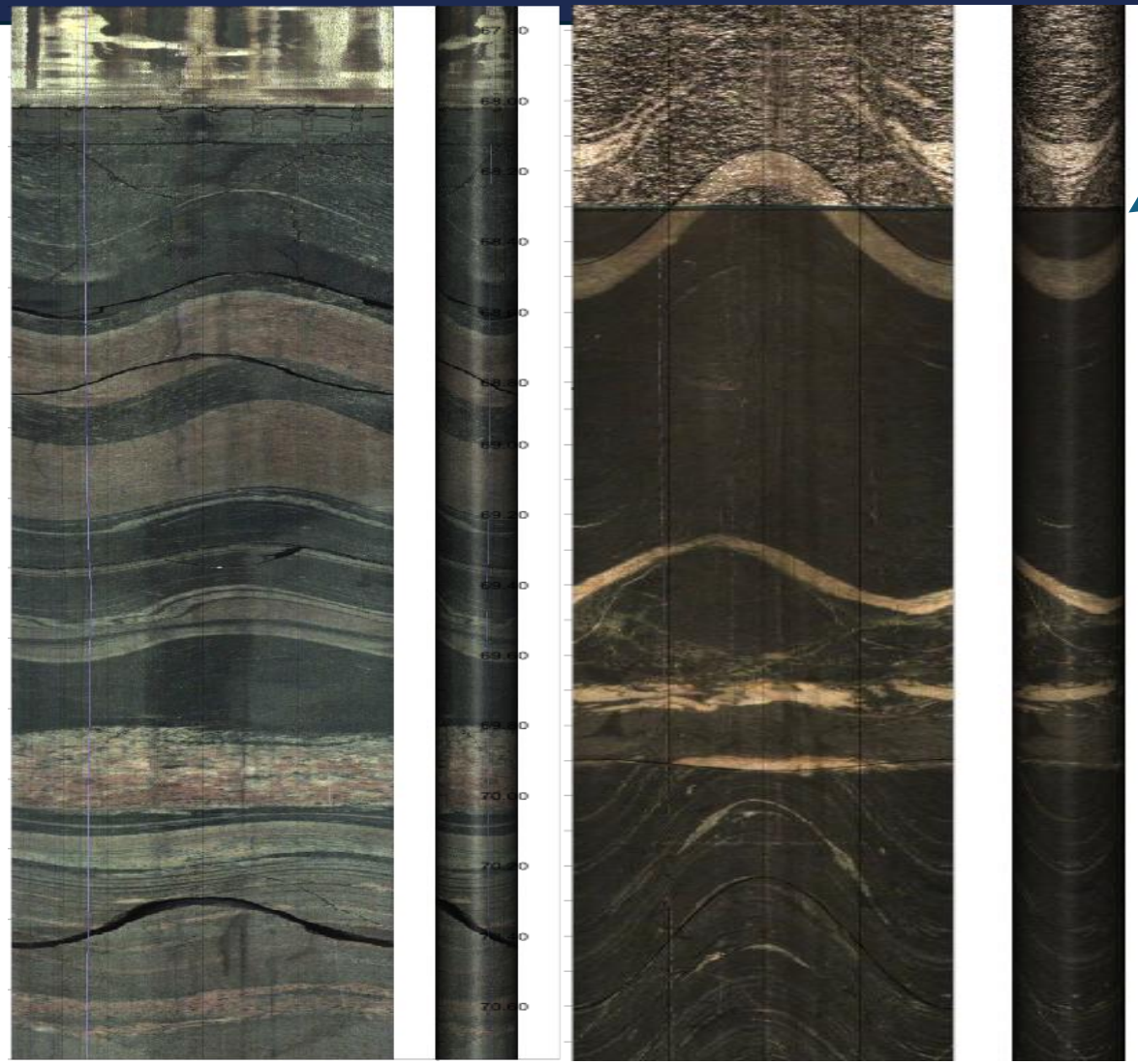
Structural Information: True Dip and Dip Direction



- **Purpose**
  - Obtain a high resolution, oriented, image of the borehole wall and features
  - Optimal for structural applications and the measurement of veins, bedding and contacts
  - Joints identifiable, but acoustic is preferred method
  - Obtain in current or previously drilled holes



Cored versus Non-Cored Drilling



Cored

Percussion Drilled

Televiewer Applications: RC Drilling

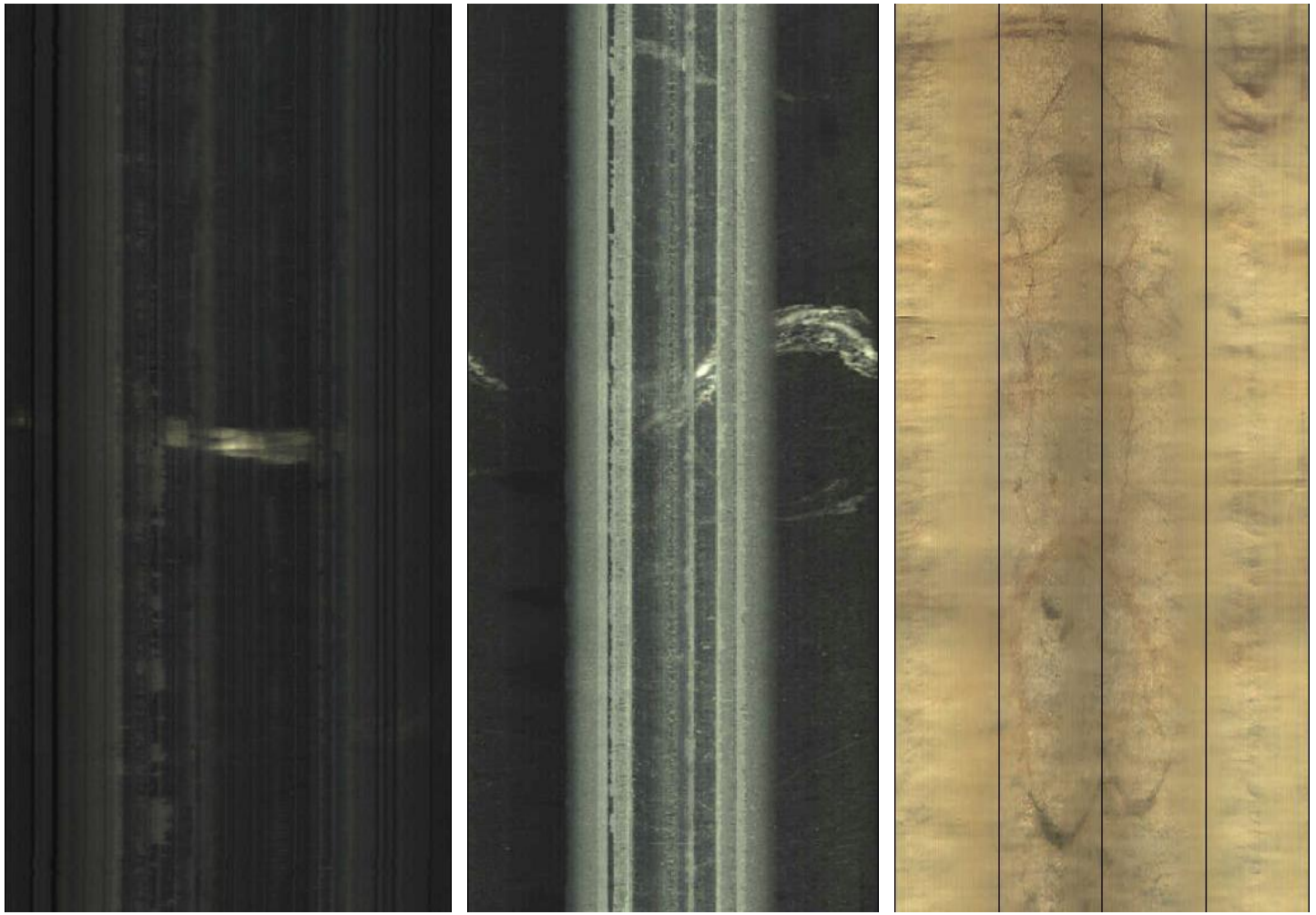
RC DRILLING CHIPS: FAST, CHEAP, NO RECOVERABLE CORE.

Obtain structural measurements from Reverse Circulation drilling

Diamond drilling oriented core strike and dip alternative

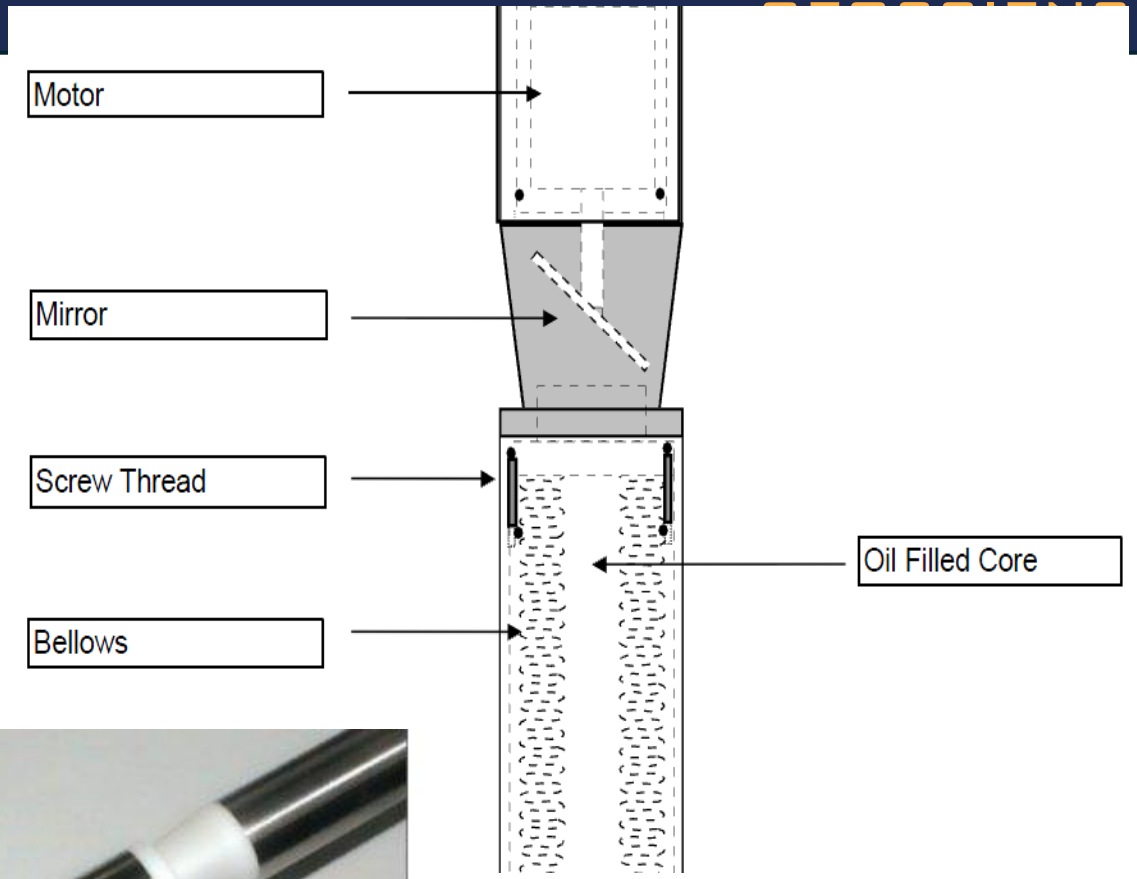
Borehole Conditions

- Fluid/borehole quality
  - Flushing
  - Flocculant
  - Brushing
- Smearing/Grease
- Aquifer interaction

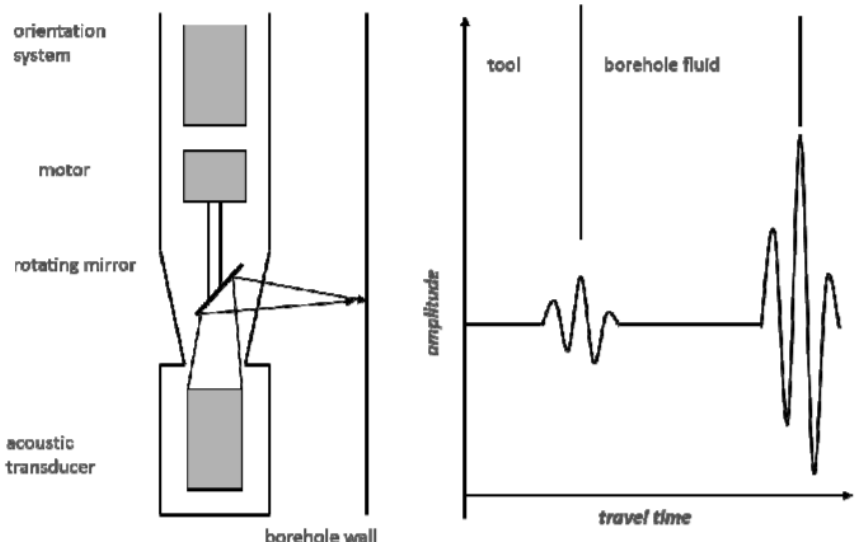


Acoustic Televiewer (ATV)

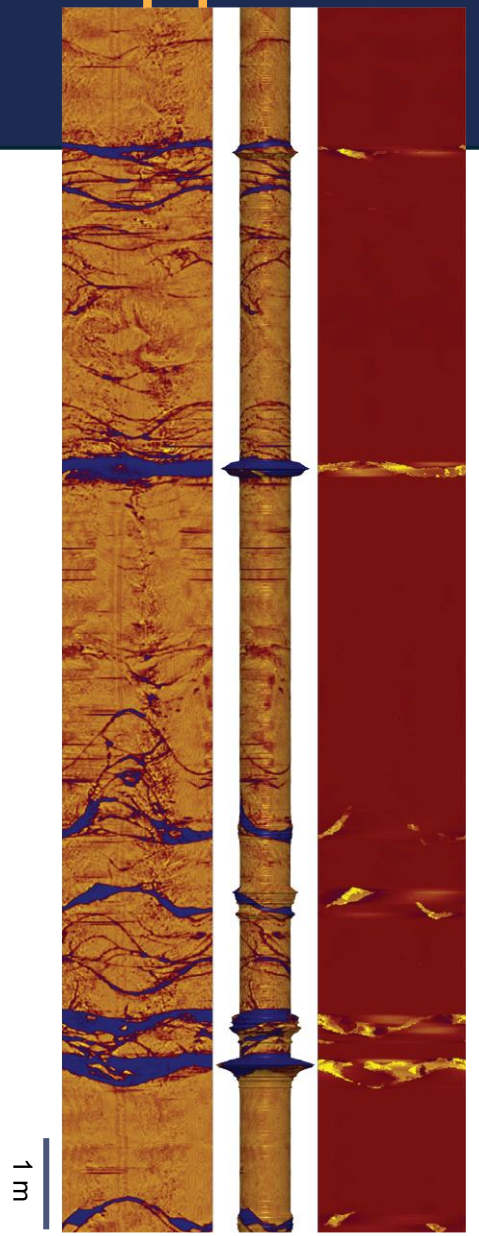
- Theory of Operation:
  - Image is generated by a rotating sensor that emits ultrasound pulses and records the amplitude and travel time
- Probe Parameters:
  - Azimuthal Resolution
  - Echo Processing
- Ability to see behind casing
- Limitations:
  - Fluid required
  - Magnetic Interference
  - Centralization



Acoustic Televiewer (ATV) – Applications



- An acoustic image is produced by recording echoes of the acoustic signal
- Works independent of borehole water quality
- Creates synthetic caliper



Geotechnical Analysis

Hazard Detection

Rapid RQD and Fracture Frequency

Breakout Analysis

Stress Modelling

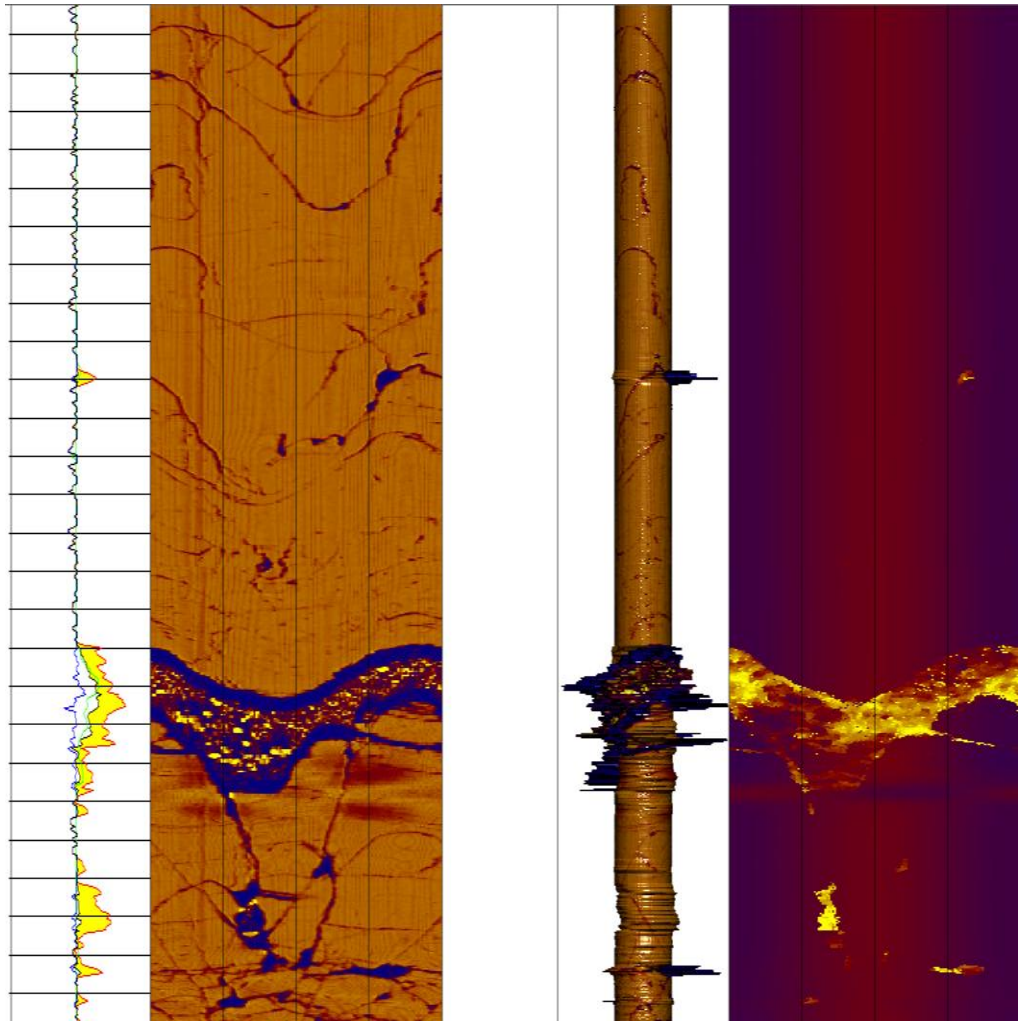
Pastefill Inspection

True Strike and Dip

Fault Orientation

Fracturing

Acoustic Televiewer (ATV)



Amplitude

Travel Time

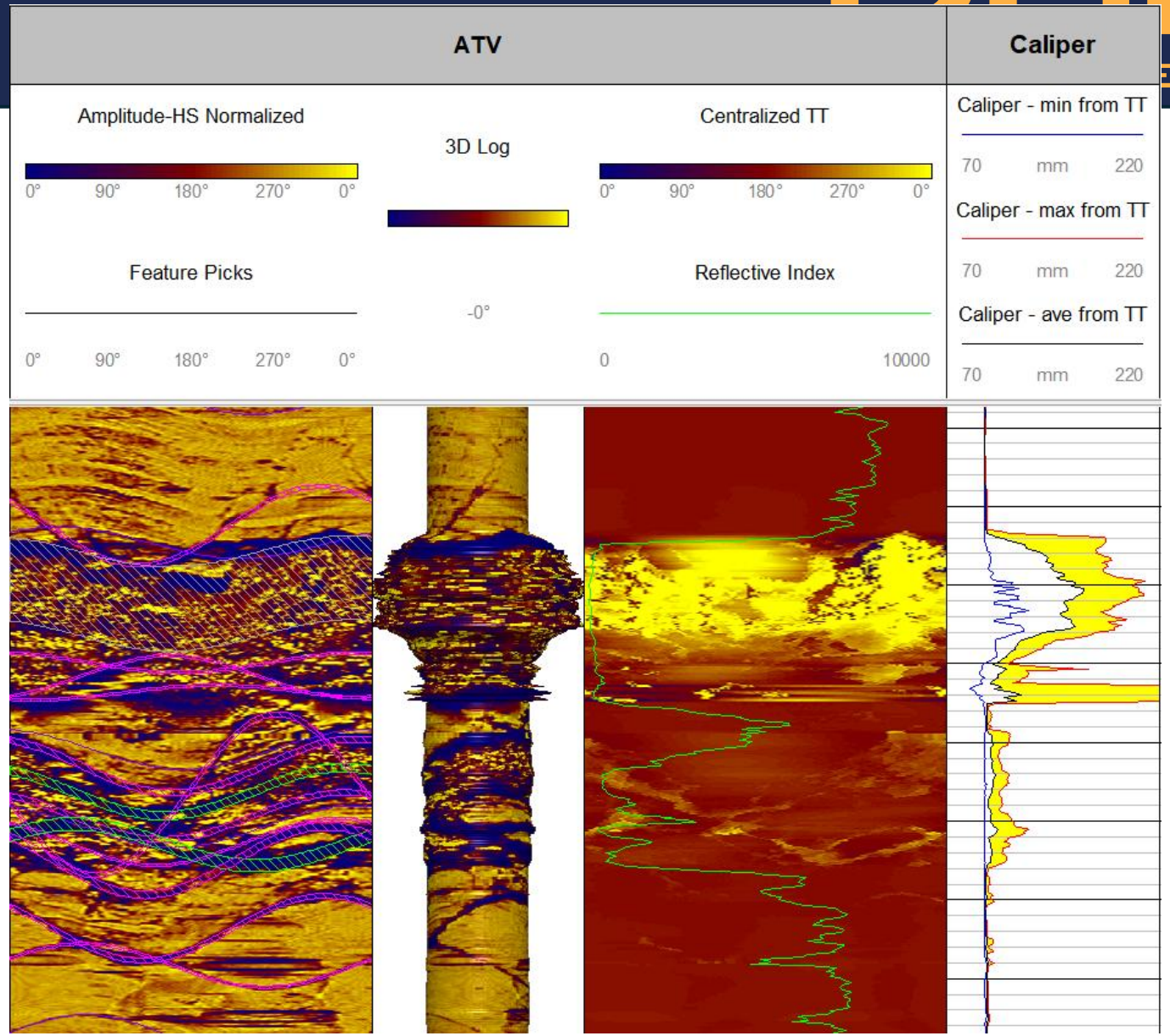
- Image based on amplitude and travel time of acoustic pulse
- Energy absorbed in fractures, voids
- Geotechnical and rock mechanics applications
- Complete core recovery
- Oriented image – true dip and dip direction of features in situ

Benefits of Televiewers

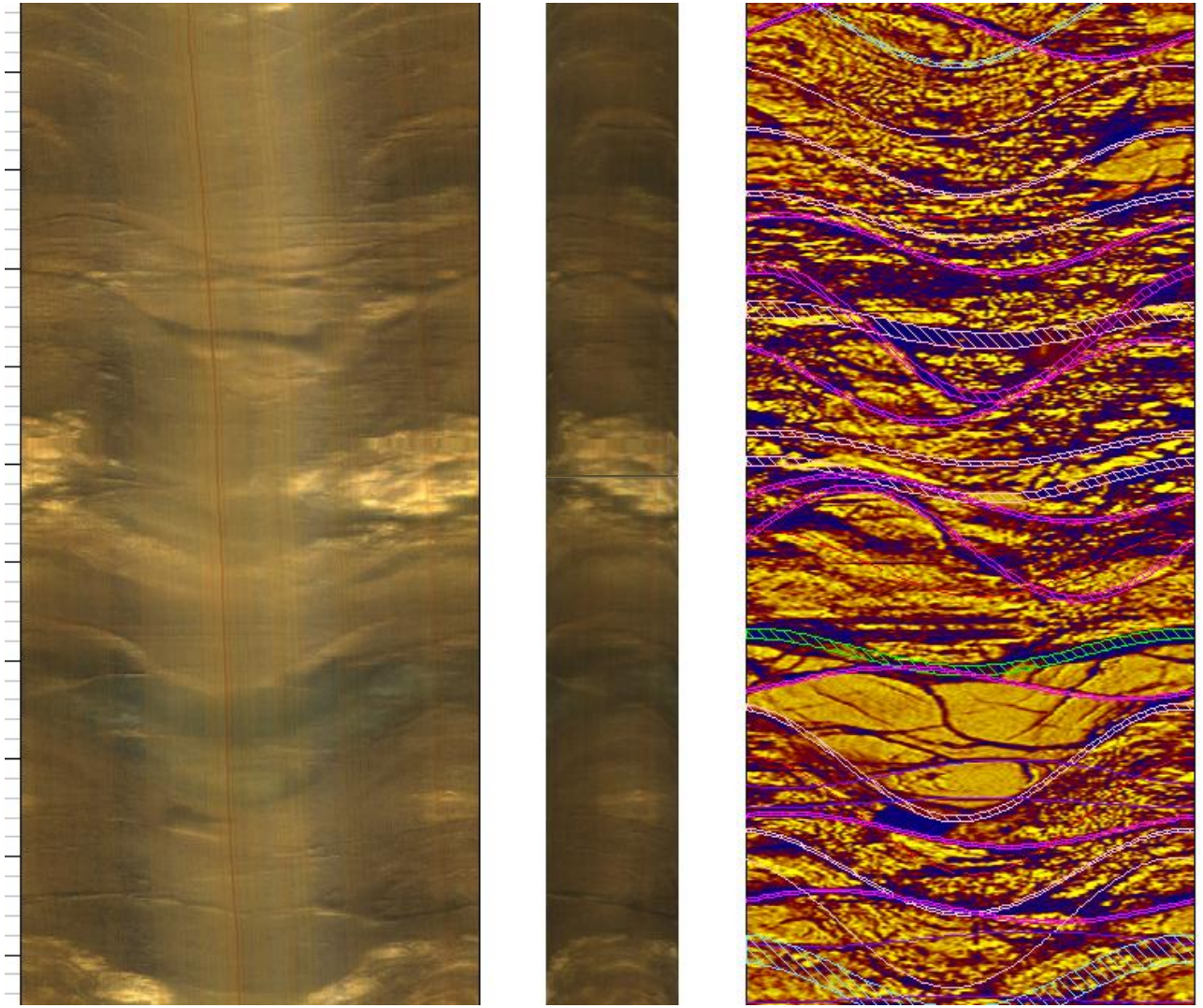
- True Dip and Dip Direction from the Entire hole
  - No missing data due to broken core, disking, rubble in the core box etc
- Measure orientation and stress magnitude of breakouts
- No concerns about interference with the core
- Digital Record
  - Permanent record
- Rapid
  - Data processed in days

Synthetic Caliper

- Acoustic Televiewer can create a synthetic caliper
- Good QAQC of caliper or back up if caliper is broken
- Faster and therefore cheaper

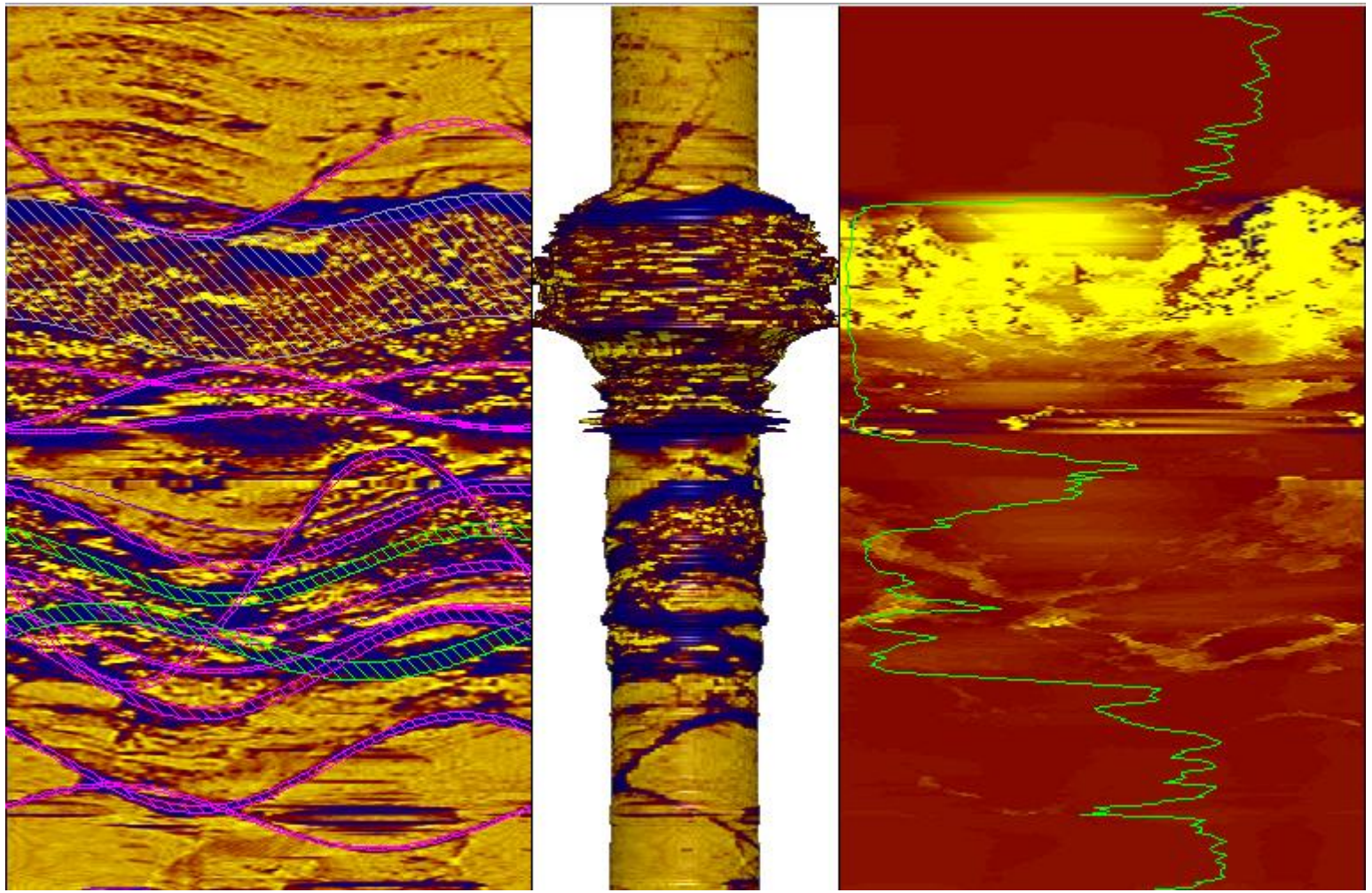


Feature Picks



- **Borehole features appear as sine waves:**
  - **Dip Angle:** Amplitude
  - **Dip Direction:** Radial position of sine wave minimum
- **Common Features Picked:**
  - Veins
  - Bedding/Banding/Foliation
  - Fractures/Joints
  - Lithological Contacts

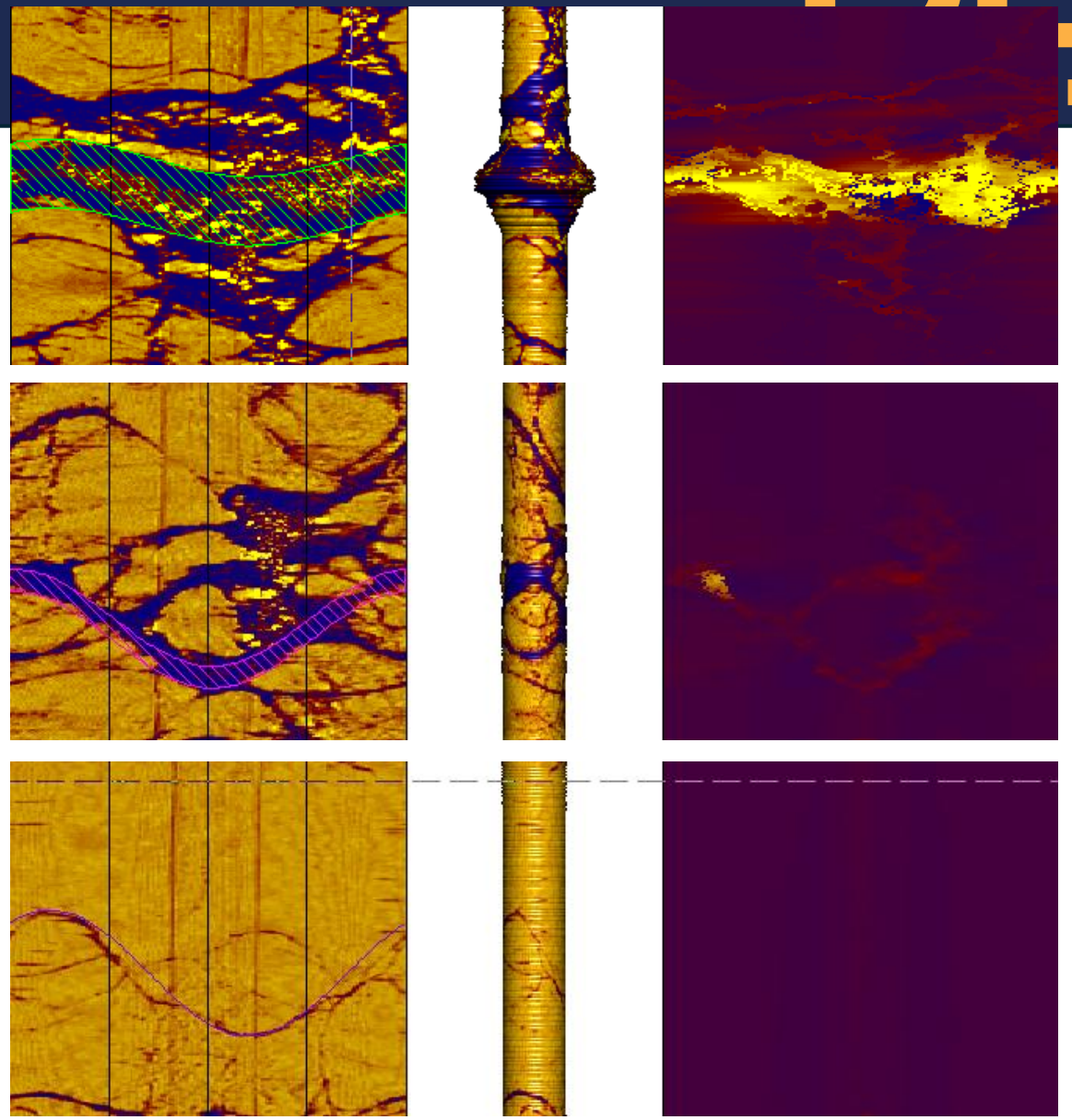
Feature Picks



- Fully customisable
- Bespoke Deliverables
- Can focus on one geological component e.g., veins
- Easier to pick out features
- Are orientated and therefore can be used for analysis

Classification - Example

- **Major Open Fracture** (complete visibility in travel time log)
  - These features are often seen in the OTV where inside of the feature is visible. Major open joint/fractures have an aperture greater than 5 mm.
- **Partially Open Fracture** (incomplete visibility in travel time log)
  - Partially open joint/fractures have an aperture between 1 and 5mm.
- **Minor Fracture** (no visibility in travel time log)
  - Minor joint/fractures have an aperture between 0 and 1mm.



Tadpoles

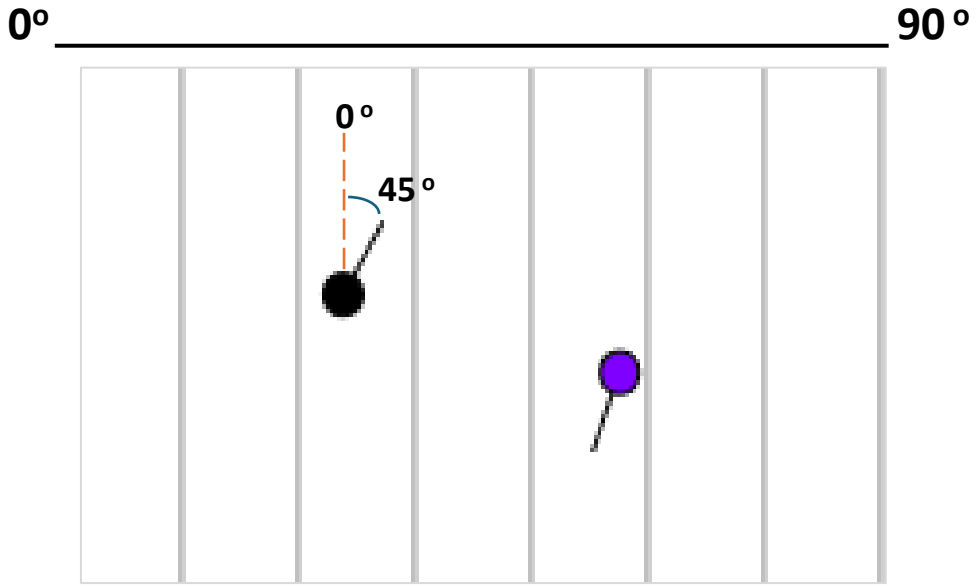
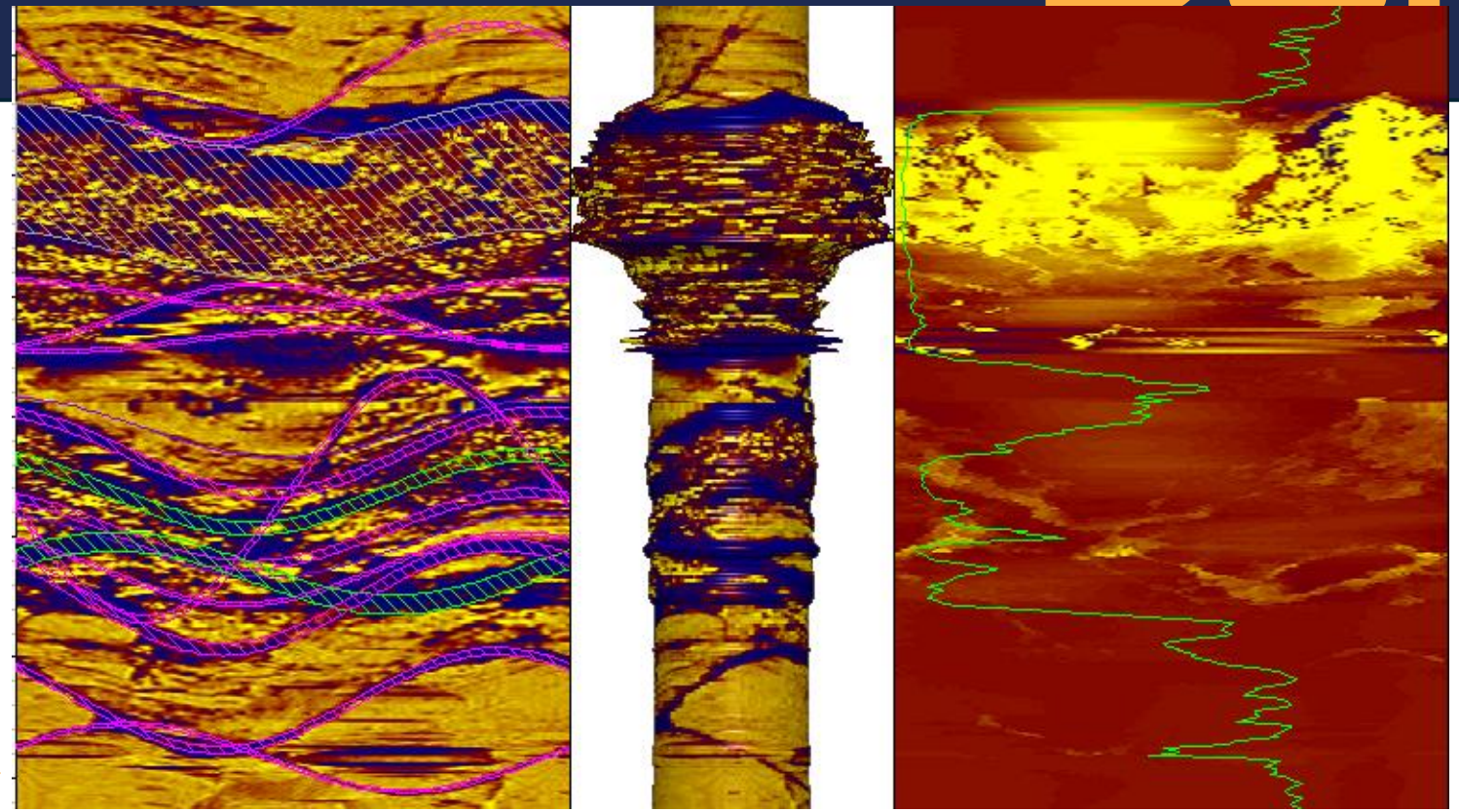


Figure: section of a tadpole log. The black tadpole has a dip and dip direction of 24/45.

- Tadpoles are used to represent the dip and dip direction of structural features.
- The horizontal position of the tadpole represents the dip, while the radial position of the ‘tail’ represents the dip direction.
- The colour of the tadpole indicates the type of feature.

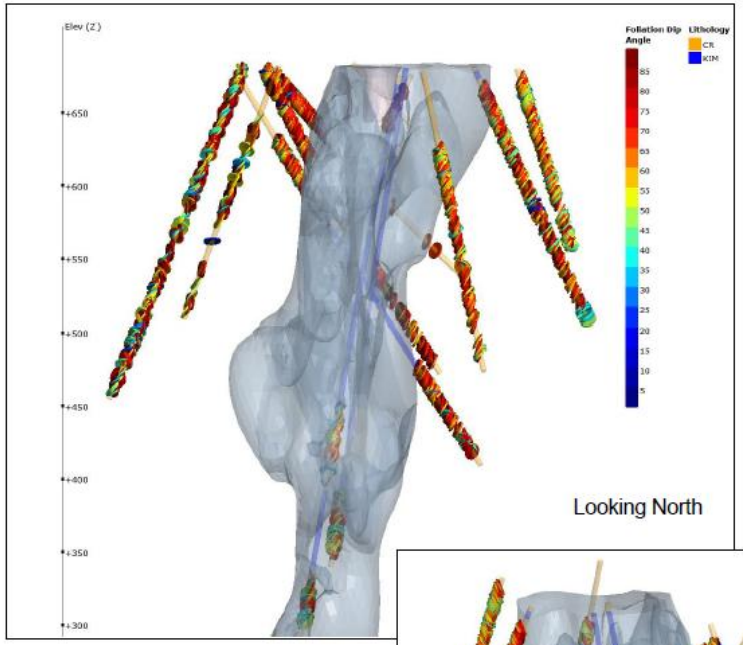
Feature Aperture/Width

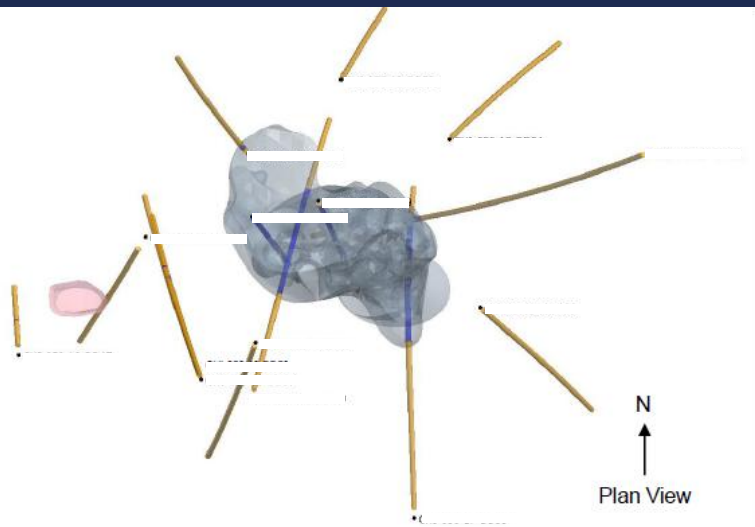
- CSV, Las, excel etc., exports
  - Export aperature, width, orientation, type, depth etc
- Can then be imported into Geological interpretation and modeling software
  - E.g., Leapfrog

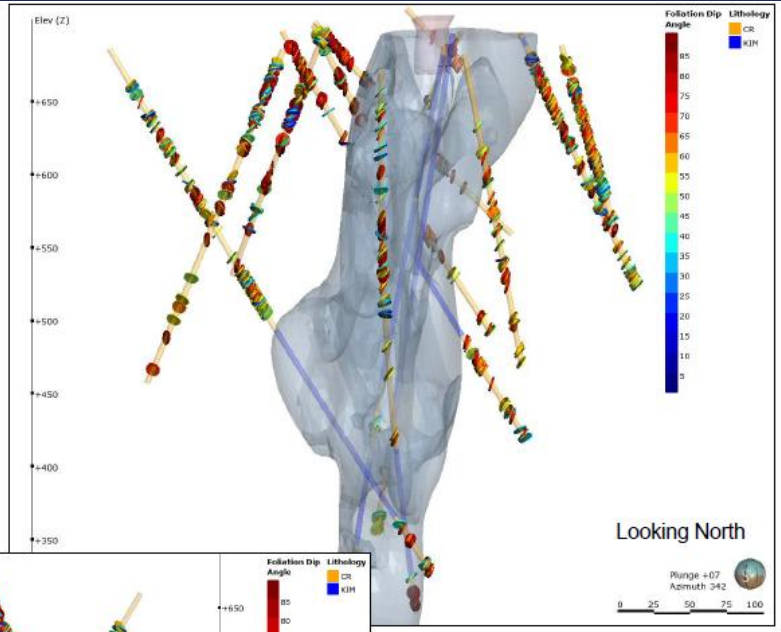


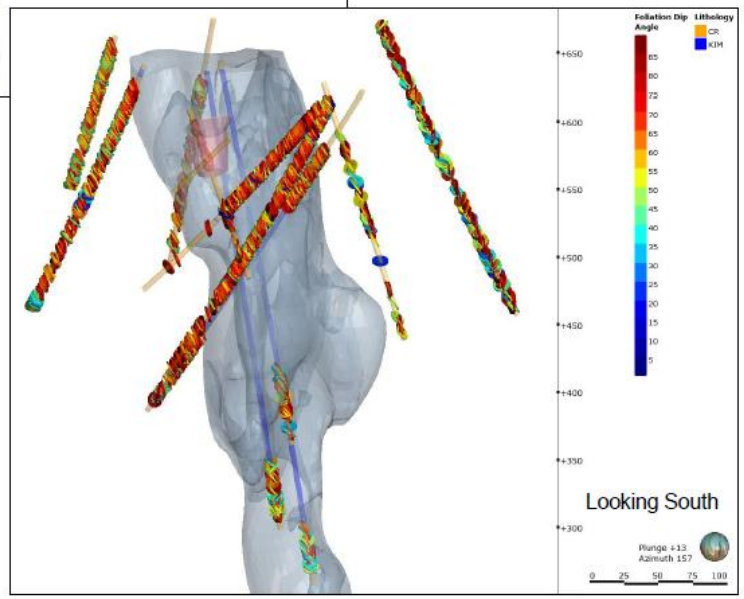
Depth [m]	Dip Direction [deg]	Dip [deg]	Aperture [mm]	Type	Description
28.51	96.51	50.46	0	F4	Joint/Fracture - Tight (0-1mm)
28.85	347.37	66.75	3.9	F3	Joint/Fracture - Open (1-10mm)
28.89	82.51	42.47	0	F4	Joint/Fracture - Tight (0-1mm)
29.02	17.42	43.02	165.21	F1	Joint/Fracture - Wide Open (30mm+)
29.2	27.32	31.26	4.85	F3	Joint/Fracture - Open (1-10mm)
29.23	194.85	44.3	4.03	F3	Joint/Fracture - Open (1-10mm)
29.27	247.26	17.67	5.6	F3	Joint/Fracture - Open (1-10mm)
29.42	30.38	49.92	0	F4	Joint/Fracture - Tight (0-1mm)
29.46	20.22	58.61	9.76	F3	Joint/Fracture - Open (1-10mm)
29.53	10.72	55.18	13.6	F2	Joint/Fracture - Moderately Open (10-30mm)

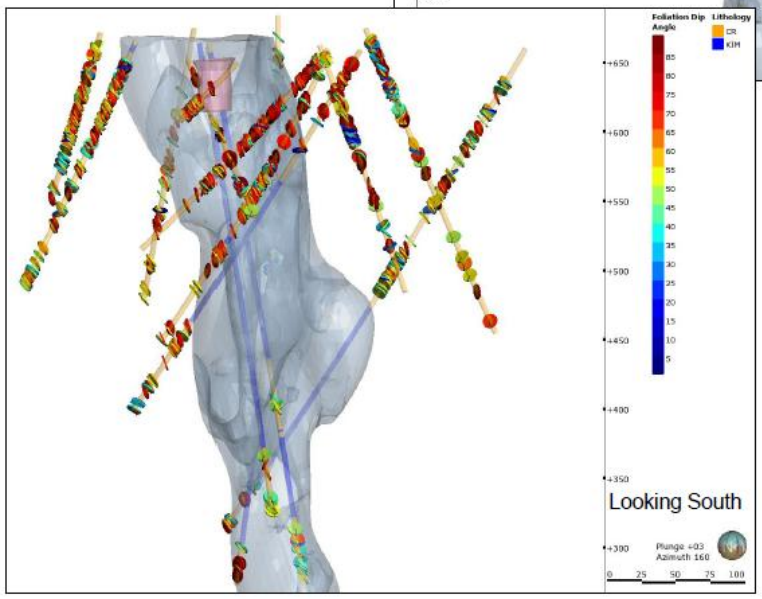
3D View


Looking North


N
Plan View

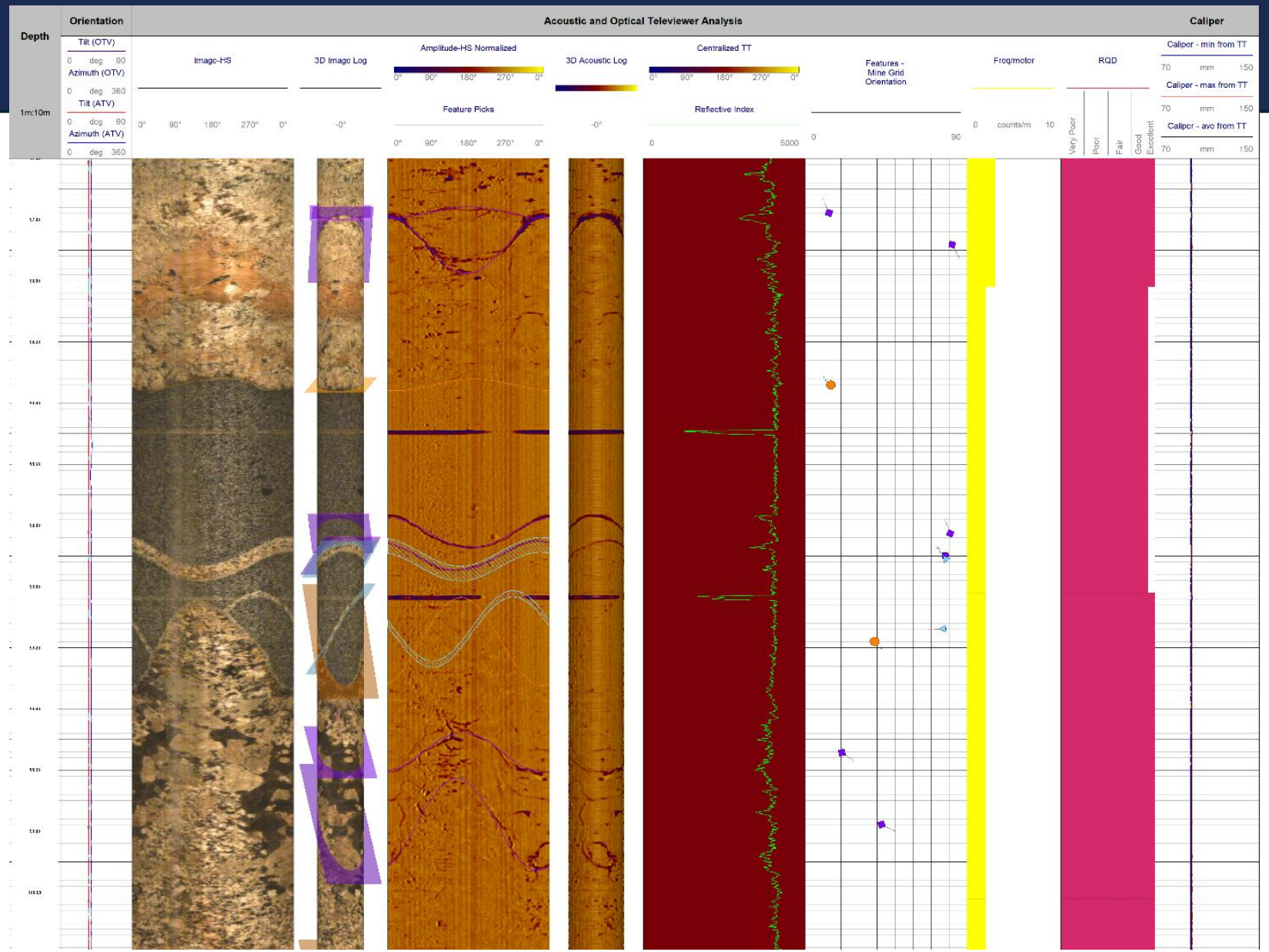

Looking North


Looking South


Looking South

SRK

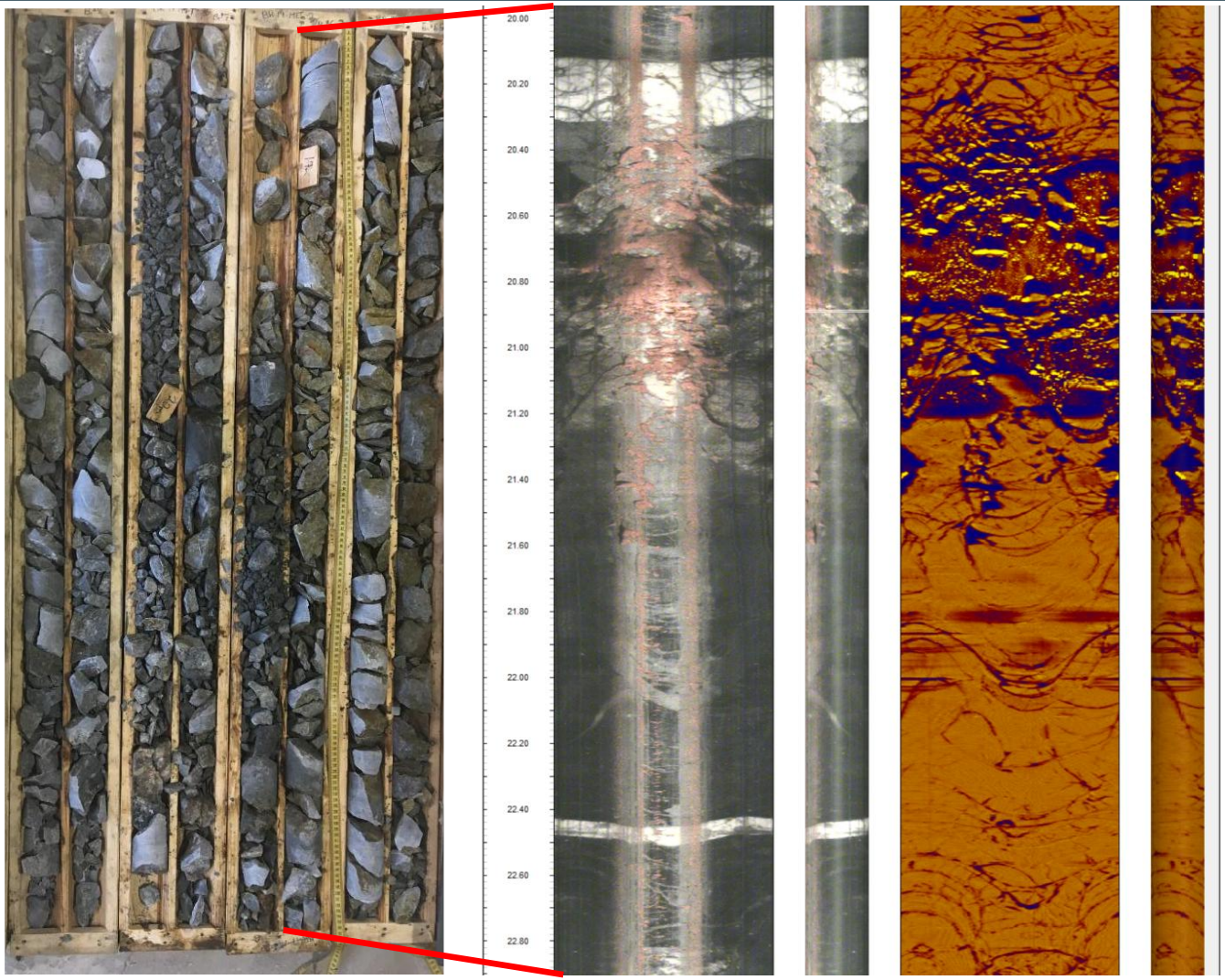
Acoustic and Optical Televiewer



- Used in conjunction to maximise benefits
- Negates any issues encountered such as poor water conditions or no water!
- Visually powerful

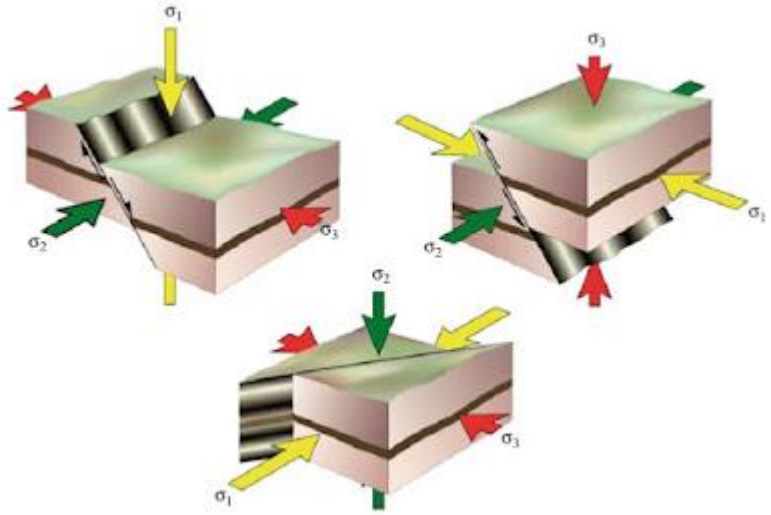
Acoustic Televiewer: RQD, Fracture Frequency, Fracture/Joint Set Orientations

- QAQC mechanism for core box derived measurements.
  - Compare televiewer derived RQD to core derived RQD. Some breaks can be mechanical/due to core handling by the drillers.
  - Orientations visible in the core but not in televiewer may indicate mechanical fracturing being measured as natural fracturing.



Geologic Stress

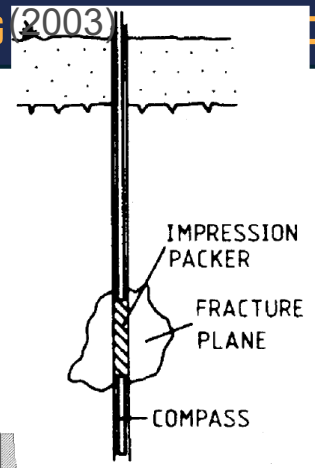
- Understanding the state of stress is important for many geological engineering problems
- Stress is represented mathematically by 3 orthogonal vectors ($\sigma_1\ \sigma_2\ \sigma_3$)
- Text-book stress models consider gravity and tectonic forces that are generally vertical or horizontal.
- Actual stresses can be complex due to local effects.
  - Loading, excavation, paleofractures, groundwater, geothermal gradients, etc
- *In-situ* stress measurements are helpful to understand local stress directions & magnitude



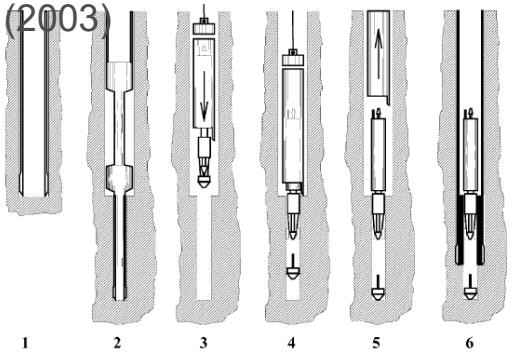
Stress Estimation from Breakouts

- Stress is traditionally a challenging property to measure because:
  - It can be highly variable across region of interest.
  - The available methods for measuring it can subject to **high levels of uncertainty**, **sparse, low success levels, time consuming** and **expensive**.
    - Overcoring (Field)
    - Acoustic Emission Kaiser Effect (Laboratory)
    - Mini Hydraulic Fracture (Field)
    - Microseismic Moment Tensor Inversion (Field)
    - Microseismic – Geomechanics (Field)

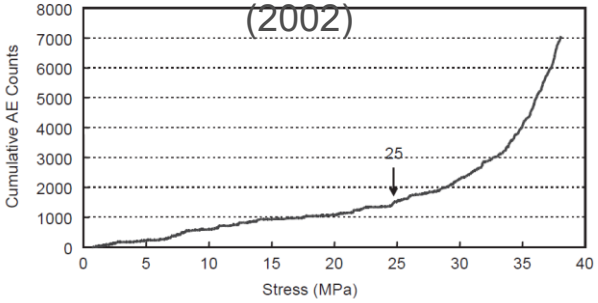
Ljunggren et al. (2003)



Ljunggren et al. (2003)



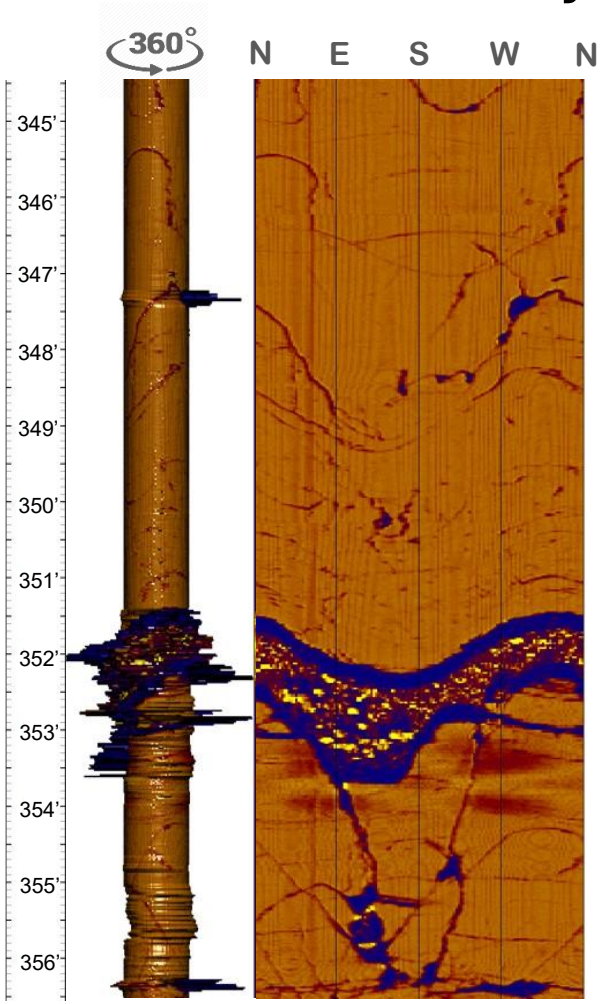
Villaesusa et al. (2002)



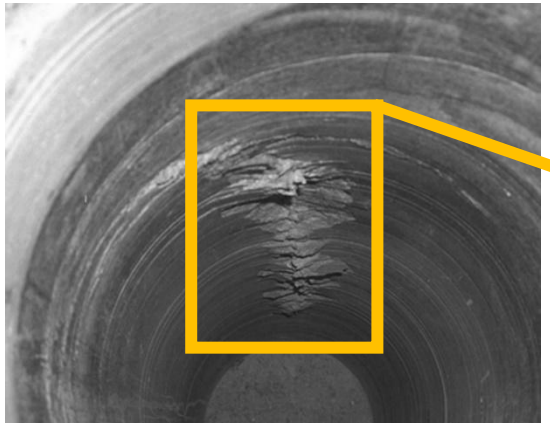
Acoustic Televiewer Data - Breakouts

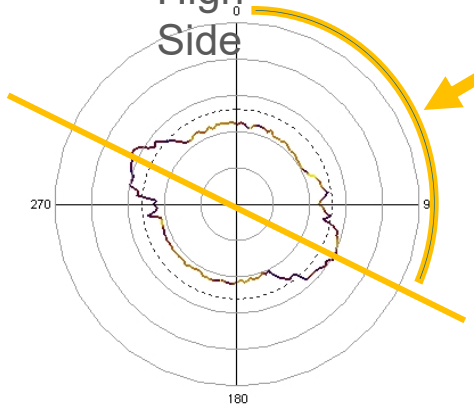
DGI GEOSCIENCE

- Fracture Analysis

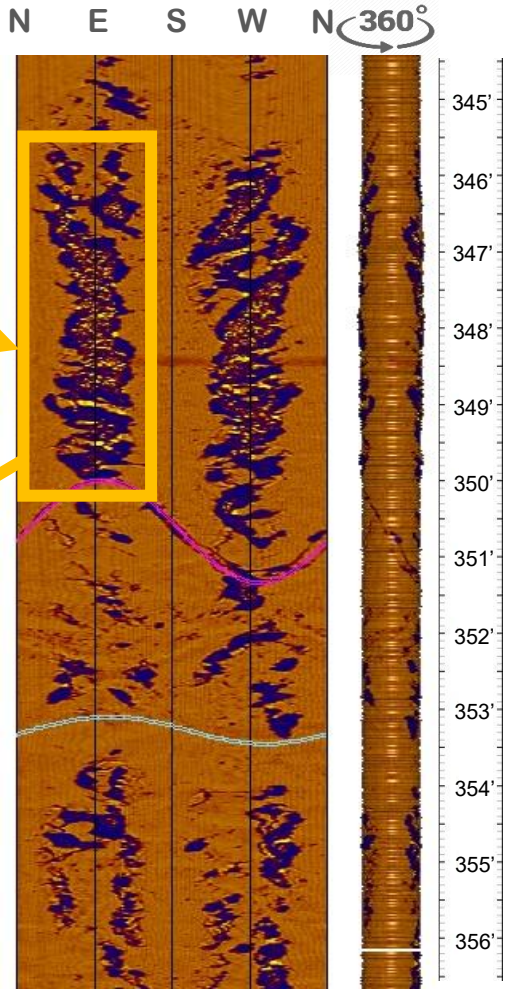


- Breakout Analysis

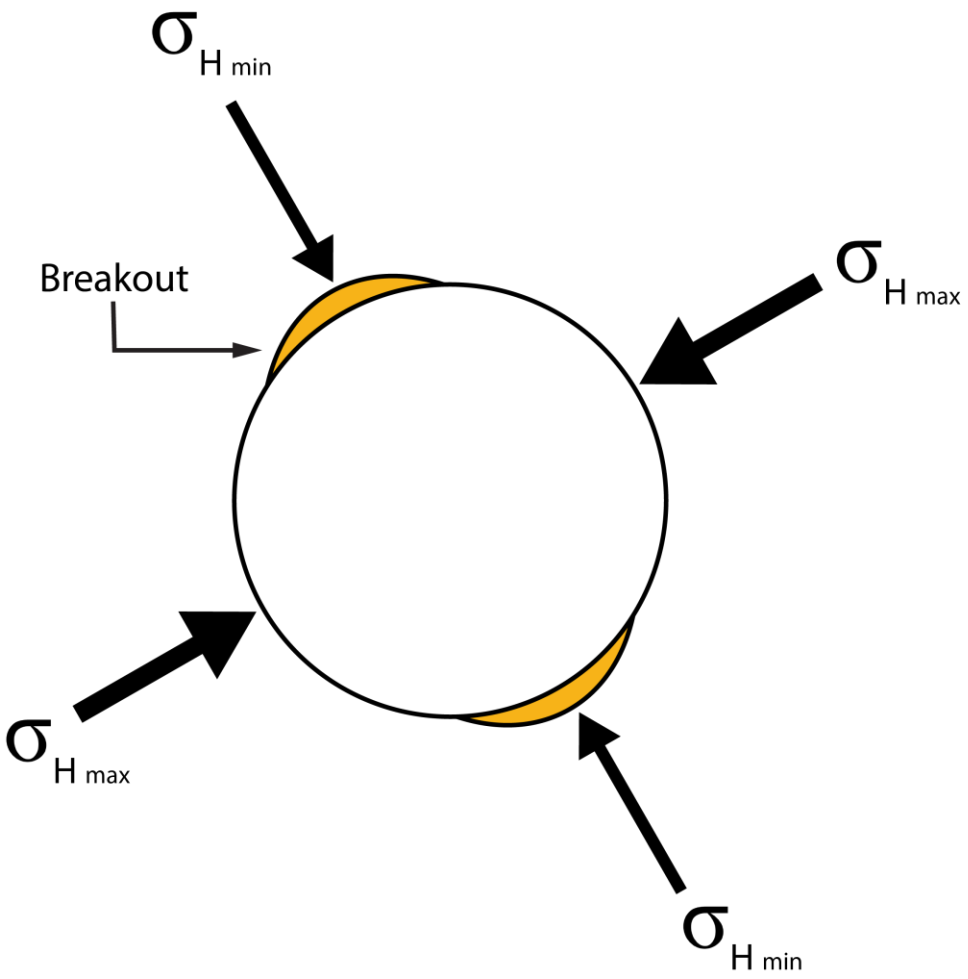


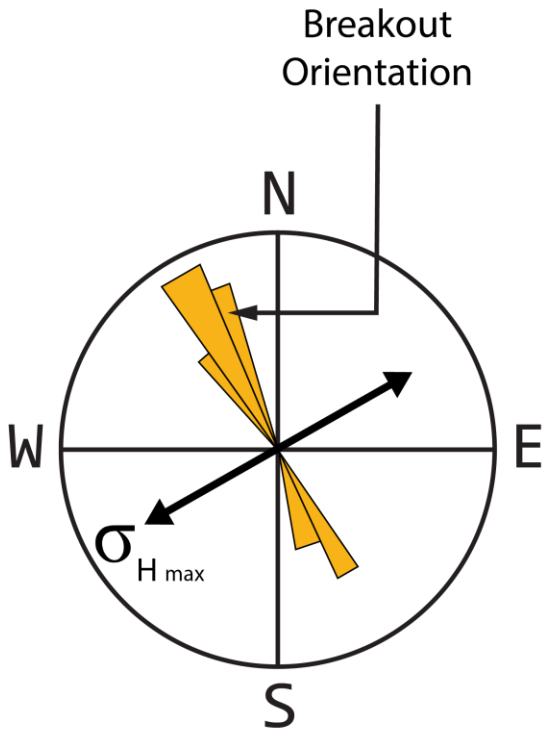


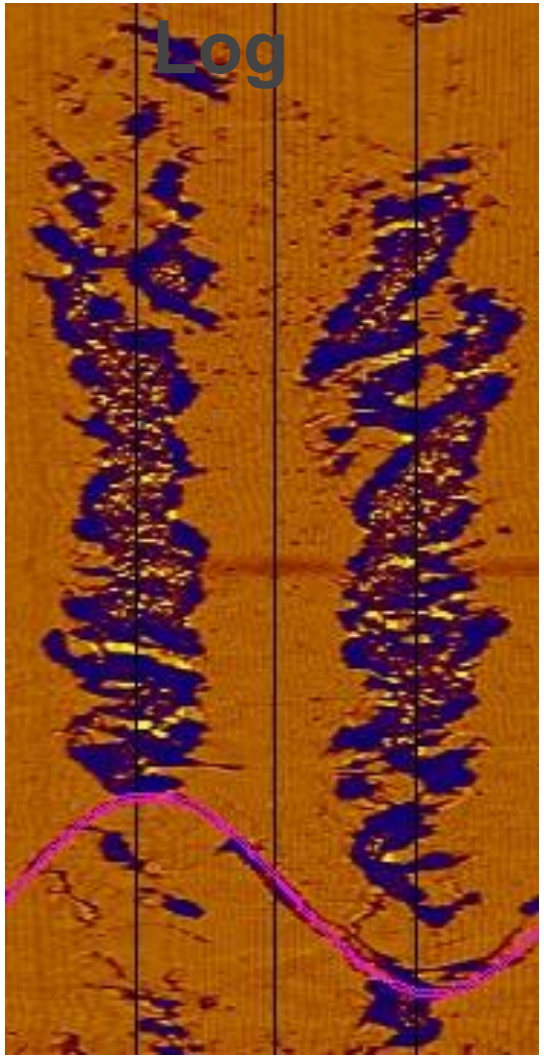
Breakout
Angle



Acoustic Televiewer Data - Breakouts



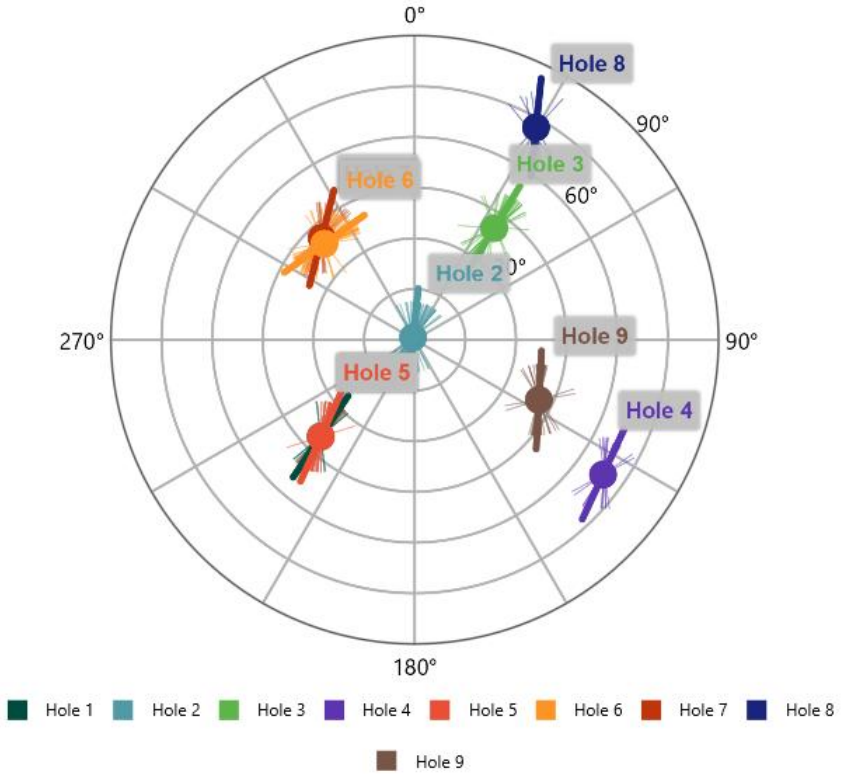




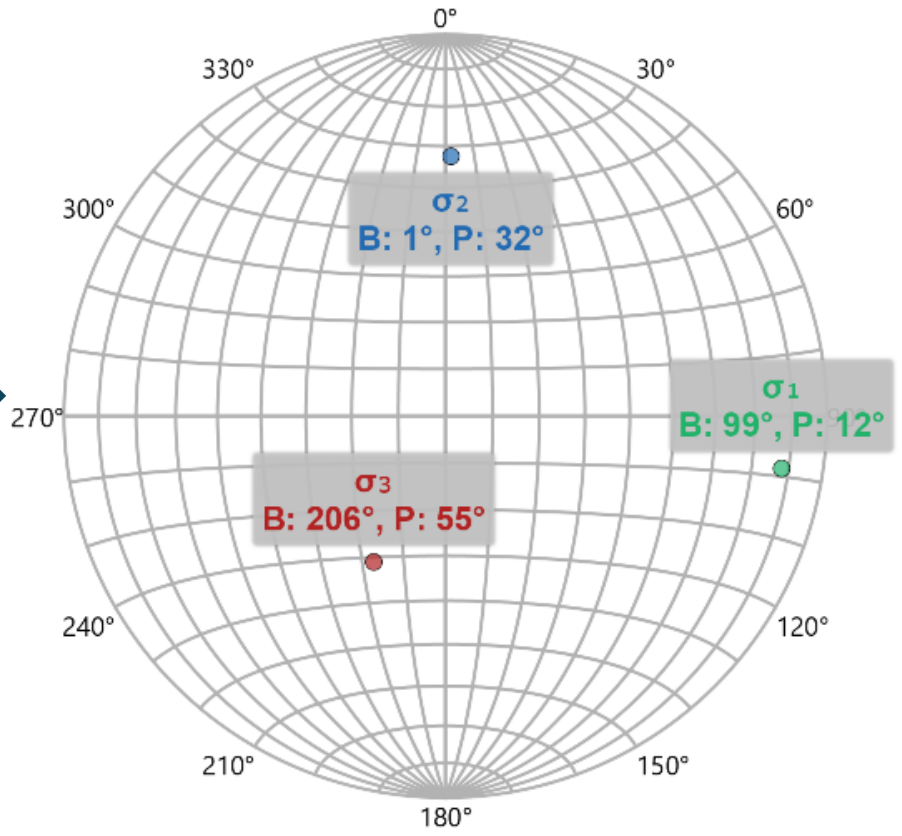
Stress Estimation

DGI GEOSCIENCE

Multiple Deviated Holes with Breakout Data



Best Fit Stress Model



CALIBRATION

Calibrations

- **Importance**
- Standards
  - Auditable Trail
  - Process
- Types of Calibration
  - Factory Calibration
  - Field/jig calibration
  - Calibration holes
    - On site versus established

Calibrations

- **Considerations**
  - Temperature drift
  - Hole size
  - Fluid conditions
  - Measurement Range

Calibrations

- Sign off certificates
- Calibrate and document regularly

Test #1 - Aluminum Block

Aluminum Block (g/cc):	2.6

Test File Name: 446_MSDT_5167_4081CO_Aluminum_011718

Near Density	g/cc	Far Density	g/cc
Min:	2.628	Min:	2.586
Max:	2.766	Max:	2.811
Average:	2.701	Average:	2.699
Difference:	0.101	Difference:	0.099

Total number of sample data points: 1118

Test Results: ☑ Passed ☐ Needs Re-calibration

Test #2 - Hardy Test Hole 200m-370m

Reference Average (g/cc):	2.942

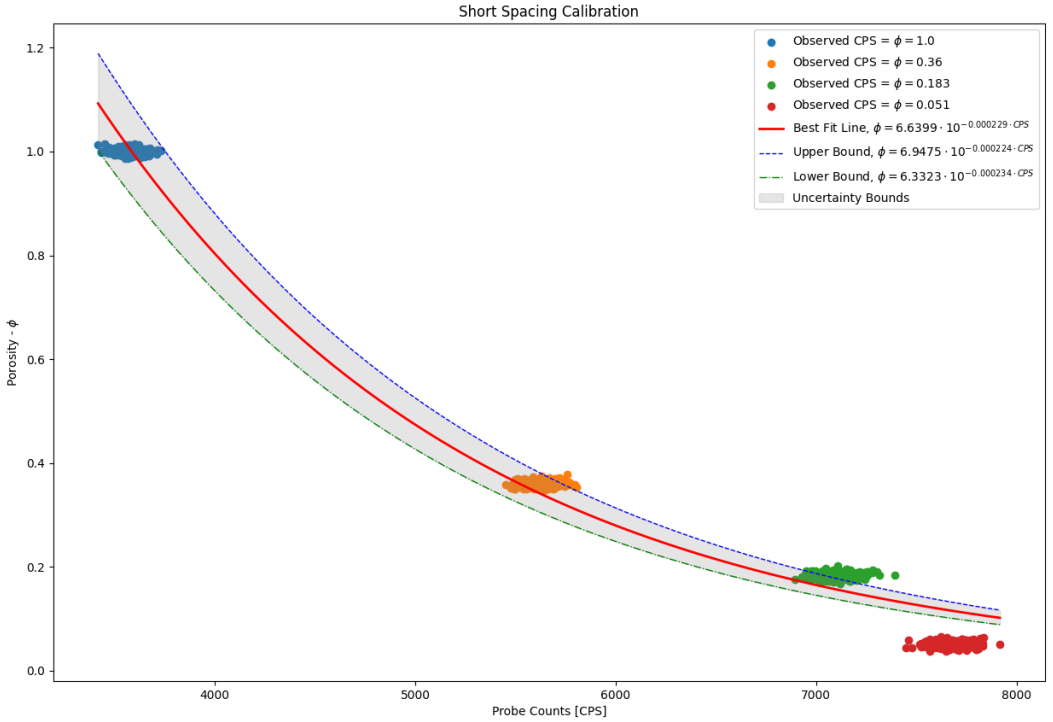
Test File Name: 000_MSDT_5167_4081CO_u1_011818

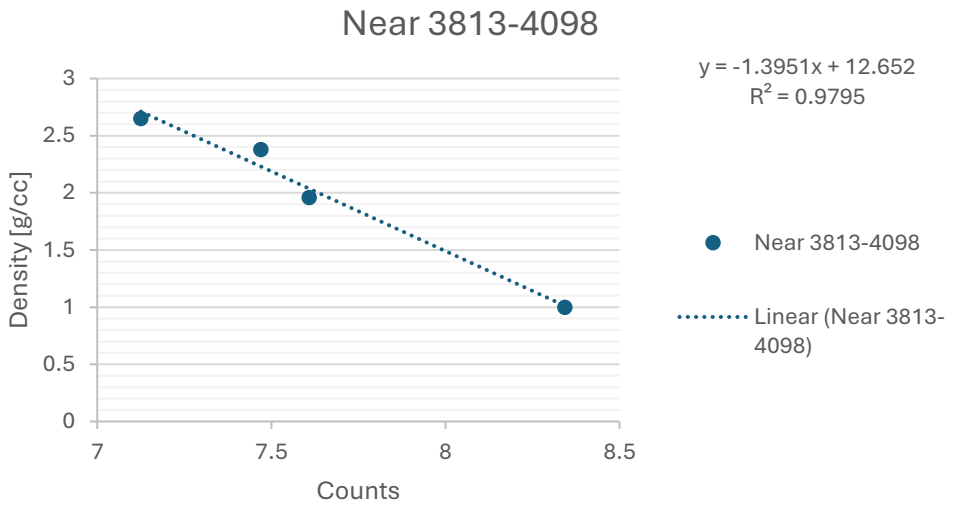
Near Density	g/cc	Far Density	g/cc
Average:	2.942	Average:	2.942
Difference Average Values:	-0.001	Difference Average Values:	0.000

Total number of sample data points: 1669

Test Results: ☑ Passed ☐ Needs Re-calibration

Calibration





DATA MANAGEMENT AND SOFTWARE

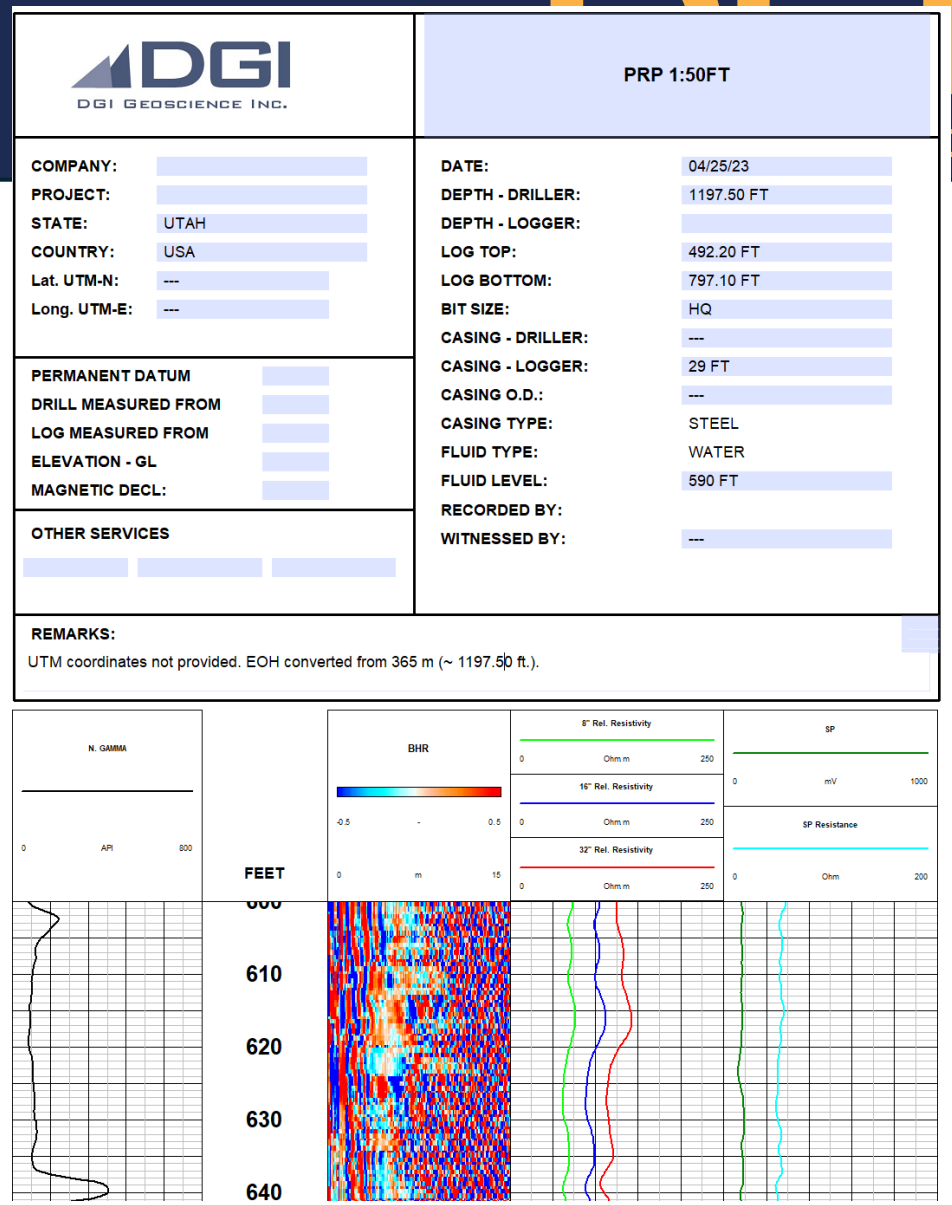
Data Formats - TFD

- Most slim-line probes will create a **TFD** file.
  - This file format is the primary format for Advanced Logic Technology (ALT) and Mont Sopris Instruments (MSI).
  - ALT is the developer of WellCAD and Logger Suite software.
    - They also perform research and development of acquisition systems and new probes.
  - MSI is a popular manufacturer of probes, winches and logging consoles.
    - They work in partner with several development firms (includes ALT) to manufacture probes.
  - **TFD** is a proprietary binary file format, that can only be read by WellCAD software.
  - The header information of the file can be viewed in plaintext in a text editor.
- Only used for **RAW** data, processed data is never stored in this format.

```
I'NULNULNULNULNULNULI'NULNULSONULSOHNULNULNUL
NULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULçBE
ToolName=2AMC 4-Cond GDA-3813 Source 4098CO for Matrix
DriverName=Multich

;9-25-06 2SMA modem modified with ALT telemetry, auto voltage
;
; ****************************************************************
; Data browsers
;
;replaced MSIProc with MCHProc
[Process]
Process1=mch\MchProc.exe
Process2=mch\MChNum.exe
Process3=mch\MChCurve.exe
Process4=mch\RecDebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
Process4=Browser,NoStart

; ****************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRate=1000
TimeSamplingRateMin=200
TimeSamplingRateMax=100000
DepthSamplingRate=0.1


; ****************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=130
Current=200
ToolTopNominalVoltage=100
ToolTopNominalCurrent=110
AutoAdjust=yes
VoltMeterYellow=90
VoltMeterGreen=135
VoltMeterRed=150
AmpMeterYellow=180
AmpMeterGreen=225
AmpMeterRed=275

; ****************************************************************
; Tool telemetry protocol
;
[Protocol]
NbOfProtocol=1
SerialMode=Asynchronous
LengthMode=VariableWord
LengthAddress=0
LengthMultiplier=1
LengthOffset=0
LengthMax=104
ChecksumMode=none
TimeOut1=800
TimeOut2=200
SamplingCmdLength=1
SamplingCmd=255

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
```

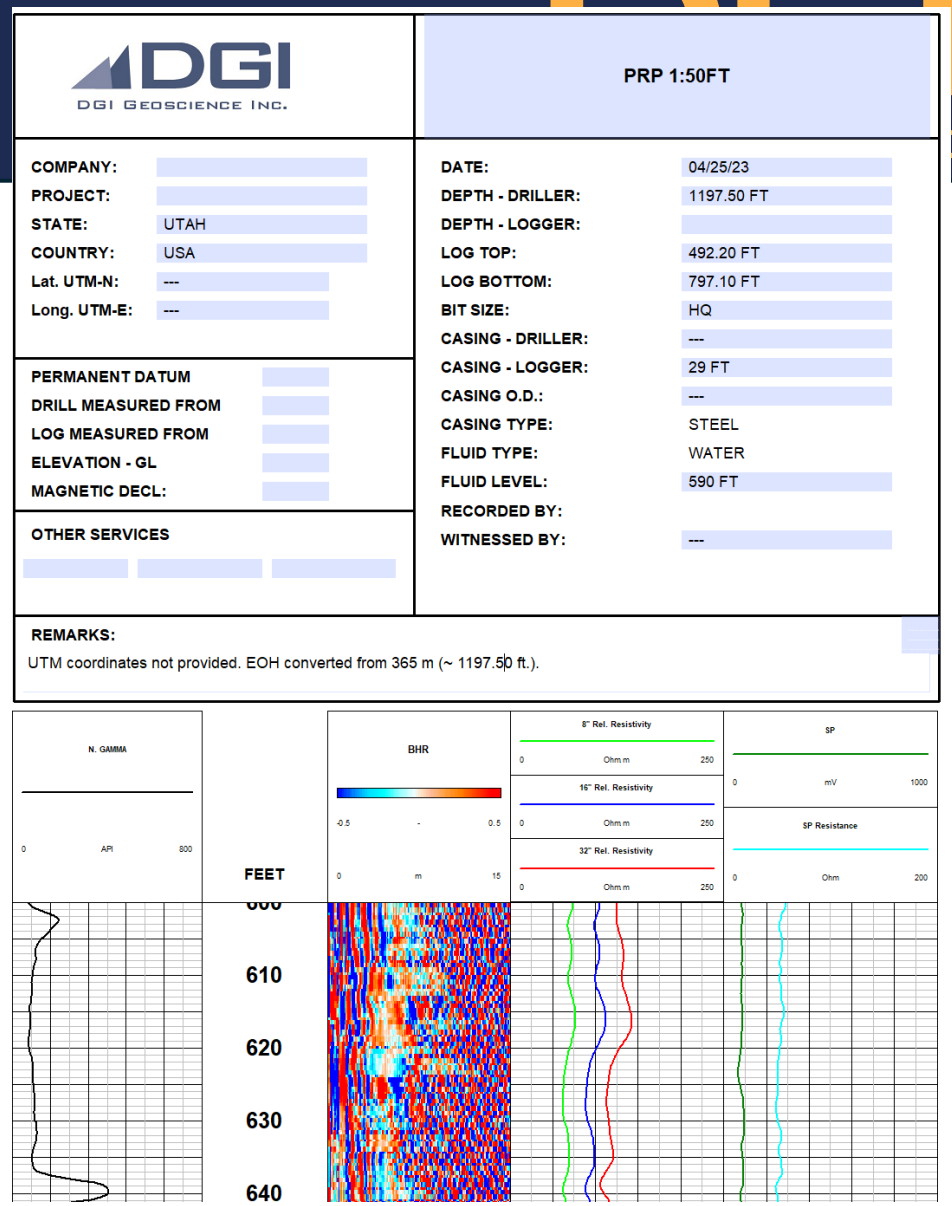
Data Formats - WCL

- WellCAD is by far the most common software to view and process data acquired from borehole logging for slimline logging.
- WCL is proprietary binary file format that can be only opened in the fully licensed and reader versions of WellCAD.



Data Formats - WCL

- Support for almost any type of data that can be acquired within a borehole.
  - Point, Interval and Array data.
  - Categorical
  - Images.
  - Annotations and Text.
- Commonly used to format logs into plots for printing to PDF or paper.



DGI GEOSCIENCE INC.

PRP 1:50FT

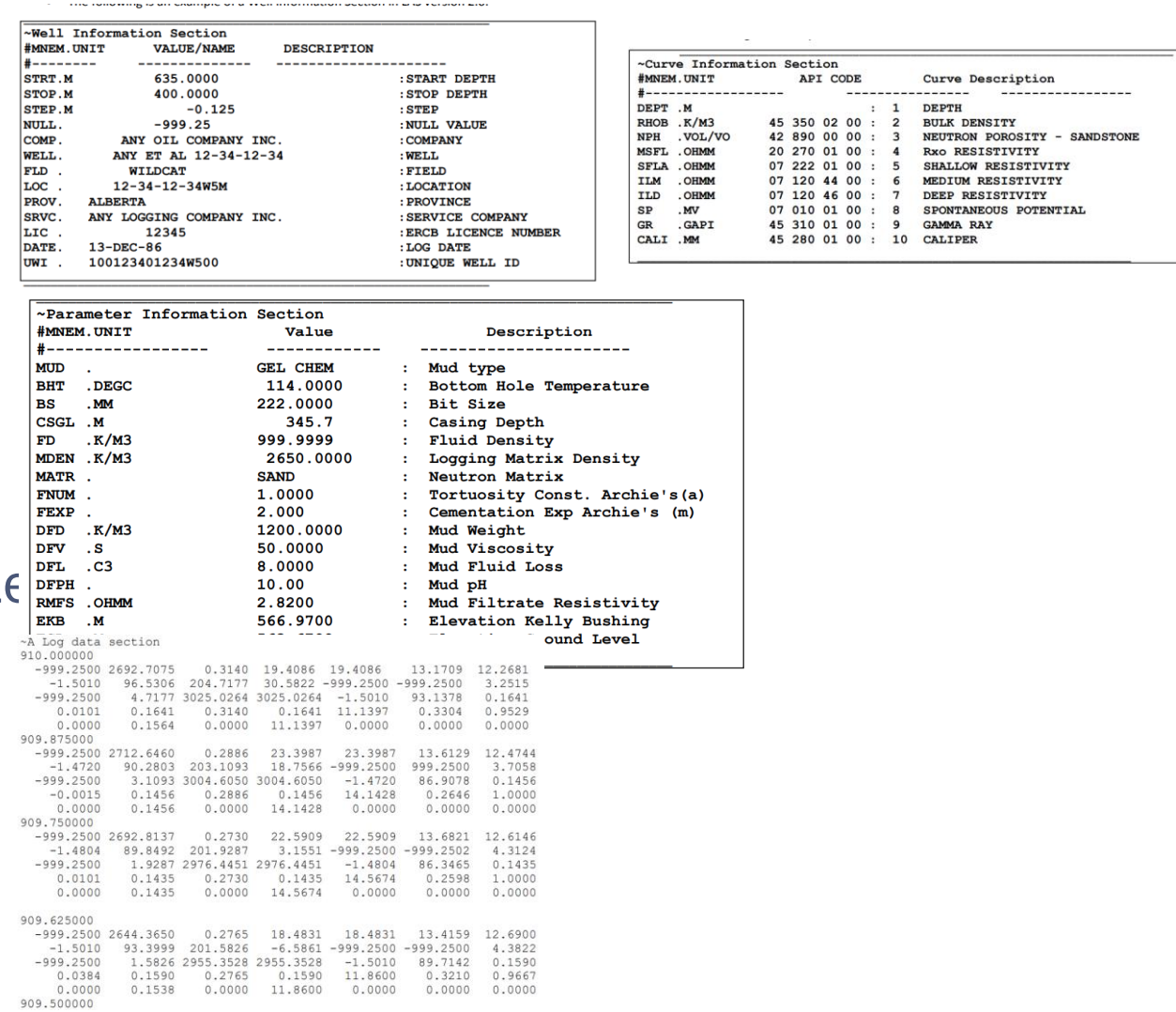
COMPANY:		DATE:	04/25/23
PROJECT:		DEPTH - DRILLER:	1197.50 FT
STATE:	UTAH	DEPTH - LOGGER:	
COUNTRY:	USA	LOG TOP:	492.20 FT
Lat. UTM-N:	---	LOG BOTTOM:	797.10 FT
Long. UTM-E:	---	BIT SIZE:	HQ
		CASING - DRILLER:	---
PERMANENT DATUM		CASING - LOGGER:	29 FT
DRILL MEASURED FROM		CASING O.D.:	---
LOG MEASURED FROM		CASING TYPE:	STEEL
ELEVATION - GL		FLUID TYPE:	WATER
MAGNETIC DECL:		FLUID LEVEL:	590 FT
		RECORDED BY:	
OTHER SERVICES		WITNESSED BY:	---

REMARKS:

UTM coordinates not provided. EOH converted from 365 m (~ 1197.50 ft.).

Data Formats - LAS

- Has existed as a file format for several decades.
  - Some say was originally based on punch card
- Developed by the Canadian Well Logg Society.
  - The current version is 3.0
  - The most supported version is 2.0.
  - Version 2.0 only supports regularly sample numeric data.
  - Version 3.0 has support for irregularly sampled data, as well as categorical and array data.



```
~Well Information Section
#MNEM.UNIT      VALUE/NAME      DESCRIPTION
#--------      --------------  ----------------------
STRT.M            635.0000                :START DEPTH
STOP.M            400.0000                :STOP DEPTH
STEP.M              -0.125                :STEP
NULL.             -999.25                 :NULL VALUE
COMP.        ANY OIL COMPANY INC.         :COMPANY
WELL.       ANY ET AL 12-34-12-34         :WELL
FLD .         WILDCAT                     :FIELD
LOC .       12-34-12-34W5M                :LOCATION
PROV.    ALBERTA                          :PROVINCE
SRVC.    ANY LOGGING COMPANY INC.         :SERVICE COMPANY
LIC .           12345                     :ERCB LICENCE NUMBER
DATE.    13-DEC-86                        :LOG DATE
UWI .    100123401234W500                 :UNIQUE WELL ID
```

```
~Curve Information Section
#MNEM.UNIT            API CODE         Curve Description
#------------------  ---------------  -----------------
DEPT .M                          :  1  DEPTH
RHOB .K/M3          45 350 02 00 :  2  BULK DENSITY
NPH  .VOL/VO        42 890 00 00 :  3  NEUTRON POROSITY - SANDSTONE
MSFL .OHMM          20 270 01 00 :  4  Rxo RESISTIVITY
SFLA .OHMM          07 222 01 00 :  5  SHALLOW RESISTIVITY
ILM  .OHMM          07 120 44 00 :  6  MEDIUM RESISTIVITY
ILD  .OHMM          07 120 46 00 :  7  DEEP RESISTIVITY
SP   .MV            07 010 01 00 :  8  SPONTANEOUS POTENTIAL
GR   .GAPI          45 310 01 00 :  9  GAMMA RAY
CALI .MM            45 280 01 00 :  10 CALIPER
```

```
~Parameter Information Section
#MNEM.UNIT                Value                Description
#------------------    ------------    ----------------------
MUD   .                 GEL CHEM        :  Mud type
BHT   .DEGC              114.0000       :  Bottom Hole Temperature
BS    .MM                222.0000       :  Bit Size
CSGL  .M                    345.7       :  Casing Depth
FD    .K/M3              999.9999       :  Fluid Density
MDEN  .K/M3               2650.0000     :  Logging Matrix Density
MATR  .                 SAND            :  Neutron Matrix
FNUM  .                 1.0000          :  Tortuosity Const. Archie's(a)
FEXP  .                 2.000           :  Cementation Exp Archie's (m)
DFD   .K/M3             1200.0000       :  Mud Weight
DFV   .S                50.0000         :  Mud Viscosity
DFL   .C3               8.0000          :  Mud Fluid Loss
DFPH  .                 10.00           :  Mud pH
RMFS  .OHMM             2.8200          :  Mud Filtrate Resistivity
EKB   .M                566.9700        :  Elevation Kelly Bushing
                                           ound Level
```

```
~A Log data section
910.000000
  -999.2500 2692.7075    0.3140   19.4086   19.4086    13.1709   12.2681
    -1.5010   96.5306  204.7177   30.5822 -999.2500  -999.2500    3.2515
  -999.2500    4.7177 3025.0264 3025.0264   -1.5010    93.1378    0.1641
     0.0101    0.1641    0.3140    0.1641   11.1397     0.3304    0.9529
     0.0000    0.1564    0.0000   11.1397    0.0000     0.0000    0.0000
909.875000
  -999.2500 2712.6460    0.2886   23.3987   23.3987    13.6129   12.4744
    -1.4720   90.2803  203.1093   18.7566 -999.2500   999.2500    3.7058
  -999.2500    3.1093 3004.6050 3004.6050   -1.4720    86.9078    0.1456
    -0.0015    0.1456    0.2886    0.1456   14.1428     0.2646    1.0000
     0.0000    0.1456    0.0000   14.1428    0.0000     0.0000    0.0000
909.750000
  -999.2500 2692.8137    0.2730   22.5909   22.5909    13.6821   12.6146
    -1.4804   89.8492  201.9287    3.1551 -999.2500  -999.2502    4.3124
  -999.2500    1.9287 2976.4451 2976.4451   -1.4804    86.3465    0.1435
     0.0101    0.1435    0.2730    0.1435   14.5674     0.2598    1.0000
     0.0000    0.1435    0.0000   14.5674    0.0000     0.0000    0.0000

909.625000
  -999.2500 2644.3650    0.2765   18.4831   18.4831    13.4159   12.6900
    -1.5010   93.3999  201.5826   -6.5861 -999.2500  -999.2500    4.3822
  -999.2500    1.5826 2955.3528 2955.3528   -1.5010    89.7142    0.1590
     0.0384    0.1590    0.2765    0.1590   11.8600     0.3210    0.9667
     0.0000    0.1538    0.0000   11.8600    0.0000     0.0000    0.0000
909.500000
```

Data Formats - LAS

- Includes a header section for metadat
- Supported in most geologic software packages.

```
~Well Information Section
#MNEM.UNIT      VALUE/NAME      DESCRIPTION
#--------     --------------   ---------------------
STRT.M            635.0000                    :START DEPTH
STOP.M            400.0000                    :STOP DEPTH
STEP.M              -0.125                    :STEP
NULL.             -999.25                     :NULL VALUE
COMP.        ANY OIL COMPANY INC.             :COMPANY
WELL.       ANY ET AL 12-34-12-34             :WELL
FLD .         WILDCAT                         :FIELD
LOC .       12-34-12-34W5M                    :LOCATION
PROV.    ALBERTA                              :PROVINCE
SRVC.    ANY LOGGING COMPANY INC.             :SERVICE COMPANY
LIC .            12345                       :ERCB LICENCE NUMBER
DATE.    13-DEC-86                           :LOG DATE
UWI .    100123401234W500                    :UNIQUE WELL ID
```

```
~Curve Information Section
#MNEM.UNIT            API CODE         Curve Description
#------------------  ---------------  ------------------
DEPT .M                          :  1  DEPTH
RHOB .K/M3          45 350 02 00 :  2  BULK DENSITY
NPH  .VOL/VO        42 890 00 00 :  3  NEUTRON POROSITY - SANDSTONE
MSFL .OHMM          20 270 01 00 :  4  Rxo RESISTIVITY
SFLA .OHMM          07 222 01 00 :  5  SHALLOW RESISTIVITY
ILM  .OHMM          07 120 44 00 :  6  MEDIUM RESISTIVITY
ILD  .OHMM          07 120 46 00 :  7  DEEP RESISTIVITY
SP   .MV            07 010 01 00 :  8  SPONTANEOUS POTENTIAL
GR   .GAPI          45 310 01 00 :  9  GAMMA RAY
CALI .MM            45 280 01 00 :  10 CALIPER
```

```
~Parameter Information Section
#MNEM.UNIT                Value                 Description
#------------------    ------------    ----------------------
MUD   .                 GEL CHEM        :  Mud type
BHT   .DEGC              114.0000       :  Bottom Hole Temperature
BS    .MM               222.0000       :  Bit Size
CSGL  .M                   345.7        :  Casing Depth
FD    .K/M3             999.9999       :  Fluid Density
MDEN  .K/M3              2650.0000      :  Logging Matrix Density
MATR  .                 SAND            :  Neutron Matrix
FNUM  .                 1.0000          :  Tortuosity Const. Archie's(a)
FEXP  .                 2.000           :  Cementation Exp Archie's (m)
DFD   .K/M3             1200.0000       :  Mud Weight
DFV   .S                50.0000         :  Mud Viscosity
DFL   .C3               8.0000          :  Mud Fluid Loss
DFPH  .                 10.00           :  Mud pH
RMFS  .OHMM             2.8200          :  Mud Filtrate Resistivity
EKB   .M                566.9700        :  Elevation Kelly Bushing
                                             ound Level
```

```
~A Log data section
910.000000
  -999.2500 2692.7075    0.3140   19.4086   19.4086    13.1709   12.2681
    -1.5010   96.5306  204.7177   30.5822 -999.2500 -999.2500    3.2515
  -999.2500    4.7177 3025.0264 3025.0264   -1.5010   93.1378    0.1641
     0.0101    0.1641    0.3140    0.1641   11.1397    0.3304    0.9529
     0.0000    0.1564    0.0000   11.1397    0.0000    0.0000    0.0000
909.875000
  -999.2500 2712.6460    0.2886   23.3987   23.3987   13.6129   12.4744
    -1.4720   90.2803  203.1093   18.7566 -999.2500  999.2500    3.7058
  -999.2500    3.1093 3004.6050 3004.6050   -1.4720   86.9078    0.1456
    -0.0015    0.1456    0.2886    0.1456   14.1428    0.2646    1.0000
     0.0000    0.1456    0.0000   14.1428    0.0000    0.0000    0.0000
909.750000
  -999.2500 2692.8137    0.2730   22.5909   22.5909   13.6821   12.6146
    -1.4804   89.8492  201.9287    3.1551 -999.2500 -999.2502    4.3124
  -999.2500    1.9287 2976.4451 2976.4451   -1.4804   86.3465    0.1435
     0.0101    0.1435    0.2730    0.1435   14.5674    0.2598    1.0000
     0.0000    0.1435    0.0000   14.5674    0.0000    0.0000    0.0000

909.625000
  -999.2500 2644.3650    0.2765   18.4831   18.4831   13.4159   12.6900
    -1.5010   93.3999  201.5826   -6.5861 -999.2500 -999.2500    4.3822
  -999.2500    1.5826 2955.3528 2955.3528   -1.5010   89.7142    0.1590
     0.0384    0.1590    0.2765    0.1590   11.8600    0.3210    0.9667
     0.0000    0.1538    0.0000   11.8600    0.0000    0.0000    0.0000
909.500000
```

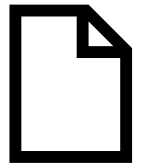
Data Formats - ASCII

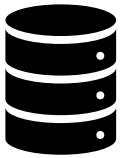
- ASCII formats such as CSV and TXT formats are also common.
- These file formats are supported in many software packages.
  - Can easily view data in Excel.
- Lack support for metadata.
- Flexible formatting and can include data from multiple holes for compilation.
- Support for Categorical type data.

```
Depth_m,natural_gamma,near_density,far_density,compensated_density,neutron_ss_counts,neutron_ls_cou
0.059,126.606,NaN,NaN,NaN,51.786,39.116,NaN,NaN,NaN,NaN,151.142,24.389,NaN,NaN,NaN
0.259,143.729,NaN,NaN,NaN,58.347,36.345,NaN,NaN,NaN,NaN,85.622,26.953,NaN,NaN,NaN
0.459,158.569,NaN,NaN,NaN,96.876,34.967,NaN,NaN,NaN,NaN,56.644,23.129,NaN,NaN,NaN
0.659,172.925,NaN,NaN,NaN,167.026,34.111,NaN,NaN,NaN,NaN,47.189,36.509,NaN,NaN,NaN
0.859,186.833,NaN,NaN,NaN,262.922,34.339,NaN,NaN,NaN,NaN,47.335,47.977,NaN,NaN,NaN
1.059,186.49,NaN,NaN,NaN,423.449,45.399,NaN,NaN,NaN,NaN,45.876,37.042,NaN,NaN,NaN
1.259,189.525,NaN,NaN,NaN,586.135,54.828,NaN,NaN,NaN,NaN,58.865,35.989,NaN,NaN,NaN
1.459,209.426,2.983,NaN,2.062,737.533,62.132,NaN,NaN,NaN,NaN,94.615,42.94,NaN,NaN,NaN
1.659,223.085,2.959,215.142,2.021,837.233,108.123,NaN,NaN,NaN,NaN,135.069,42.896,NaN,NaN,NaN
1.859,232.573,2.954,228.068,1.937,906.557,158.56,NaN,NaN,NaN,NaN,197.179,46.039,NaN,NaN,NaN
2.059,220.226,2.98,238.23,1.931,910.724,178.135,NaN,NaN,NaN,NaN,425.874,59.538,NaN,NaN,NaN
2.259,209.432,2.98,243.488,2.068,935.954,198.242,NaN,NaN,NaN,NaN,607.021,73.966,NaN,NaN,NaN
2.459,203.966,2.971,231.838,2.154,1001.743,218.852,NaN,NaN,NaN,NaN,733.928,88.938,NaN,NaN,NaN
2.659,230.307,2.947,214.853,2.21,998.563,NaN,NaN,NaN,NaN,NaN,846.41,134.074,NaN,NaN,NaN
2.859,268.9,2.921,212.32,2.159,972.515,NaN,NaN,NaN,NaN,NaN,937.466,178.659,NaN,NaN,NaN
3.059,234.672,2.892,217.863,2.033,1021.586,NaN,NaN,NaN,NaN,NaN,948.108,221.705,NaN,NaN,NaN
3.259,210.989,2.916,233.728,1.805,NaN,260.674,NaN,NaN,NaN,NaN,942.788,234.667,NaN,NaN,NaN
3.459,203.308,2.945,258.336,1.843,NaN,222.58,NaN,NaN,NaN,NaN,924.188,235.409,NaN,NaN,NaN
3.659,213.665,2.947,277.811,1.938,NaN,230.617,NaN,NaN,NaN,NaN,947.318,237.067,NaN,NaN,NaN
3.859,229.65,2.938,258.253,1.948,1004.542,232.457,NaN,NaN,NaN,NaN,958.514,243.555,NaN,NaN,NaN
4.059,244.336,2.921,250.859,1.955,989.786,215.338,NaN,NaN,NaN,NaN,924.527,256.469,NaN,NaN,NaN
4.259,265.394,2.917,254.798,1.957,978.525,NaN,NaN,NaN,NaN,NaN,917.977,266.069,NaN,NaN,NaN
4.459,293.467,2.918,255.603,1.841,970.669,NaN,NaN,NaN,NaN,NaN,927.924,271.061,NaN,NaN,NaN
4.659,279.198,2.931,260.54,1.754,976.663,NaN,NaN,NaN,NaN,NaN,916.05,254.681,NaN,NaN,NaN
4.859,259.5,2.941,280.195,1.836,NaN,276.34,NaN,NaN,NaN,NaN,918.861,237.504,NaN,NaN,NaN
5.059,251.778,2.95,277.624,1.884,NaN,251.793,NaN,NaN,NaN,NaN,950.38,219.552,NaN,NaN,NaN
5.259,252.619,2.943,260.022,1.909,NaN,248.878,NaN,NaN,NaN,NaN,957.442,242.047,NaN,NaN,NaN
5.459,260.338,2.95,257.52,1.818,NaN,253.754,NaN,NaN,NaN,NaN,953.3,258.534,NaN,NaN,NaN
5.659,278.407,2.988,257.523,1.769,872.397,263.138,NaN,141.119,NaN,7086.203,935.948,233.512,NaN,NaN,
5.859,282.657,2.997,261.457,1.834,854.936,259.587,83.831,140.941,11928.753,7094.498,911.843,228.301
```

Data Management and Metadata

- For every single ‘run’ up and down a hole, a file is produced.
- It’s critical to be consistent with file naming conventions and keep track of various metadata about the hole run.
  - Probe and equipment serial numbers.
  - Start and End Record Depths
  - Start and End Zero’s
  - Probe Velocity and Depth Increments.
  - Probe Telemetry
    - Different parameters may require unique settings to keep track of.
  - Hole and Location





Software

- Logger Suite
  - Data Acquisition Software
- WellCAD
  - Processing and Interpretation
- Excel
  - Everyone's favourite spreadsheet
- Python
  - This has been a game changer the last 10 years.

Software - Python

- IDE's and Platforms
  - PyCharm
    - Python IDE
  - DataSpell
    - IDE with more focus on data analysis.
    - Integration of Jupyter Notebooks
  - R Studio
    - IDE for use with the R statistical programming language.
  - VSCode
    - Lightweight code editor with a huge eco system of plug-ins and extensions.