# Instrumented Drilling and Downhole Geophysical Logging

## A Complementary Survey to Rotary Coring

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# Science vs. Engineering

"A good scientist is a person with original ideas. A good engineer is a person who makes a design that works with as few original ideas as possible."

*Freeman Dyson "Disturbing the Universe", 1979*

# Report Statements

- "It is clear that additional work will be required before a complete understanding ....."
- "Three of the samples were chosen for detailed study …"
- "Typical results are shown …"
- "It has long been known that …"
- "Based on engineering judgment …."

- I don't understand it
- The results on the others didn't make any sense and were ignored.
- The best results are shown
- I haven't bothered to look up the original reference
- Cannot find any proof to back me up

# Outline

- Current deployed methodology
- Alternative/integrated solutions
- Benefits /Conclusions
- Risk assessment

# Current Methodologies

- QCS
- BS EN ISO Standards
- ASTM

- Centered on coring, sampling, lab testing, in-situ testing.

# Current Methodologies

## Limitations:

- Discrete sampling and testing
- Bias sampling and testing
- Rock mass properties from borehole data

*Large room for assumptions.*

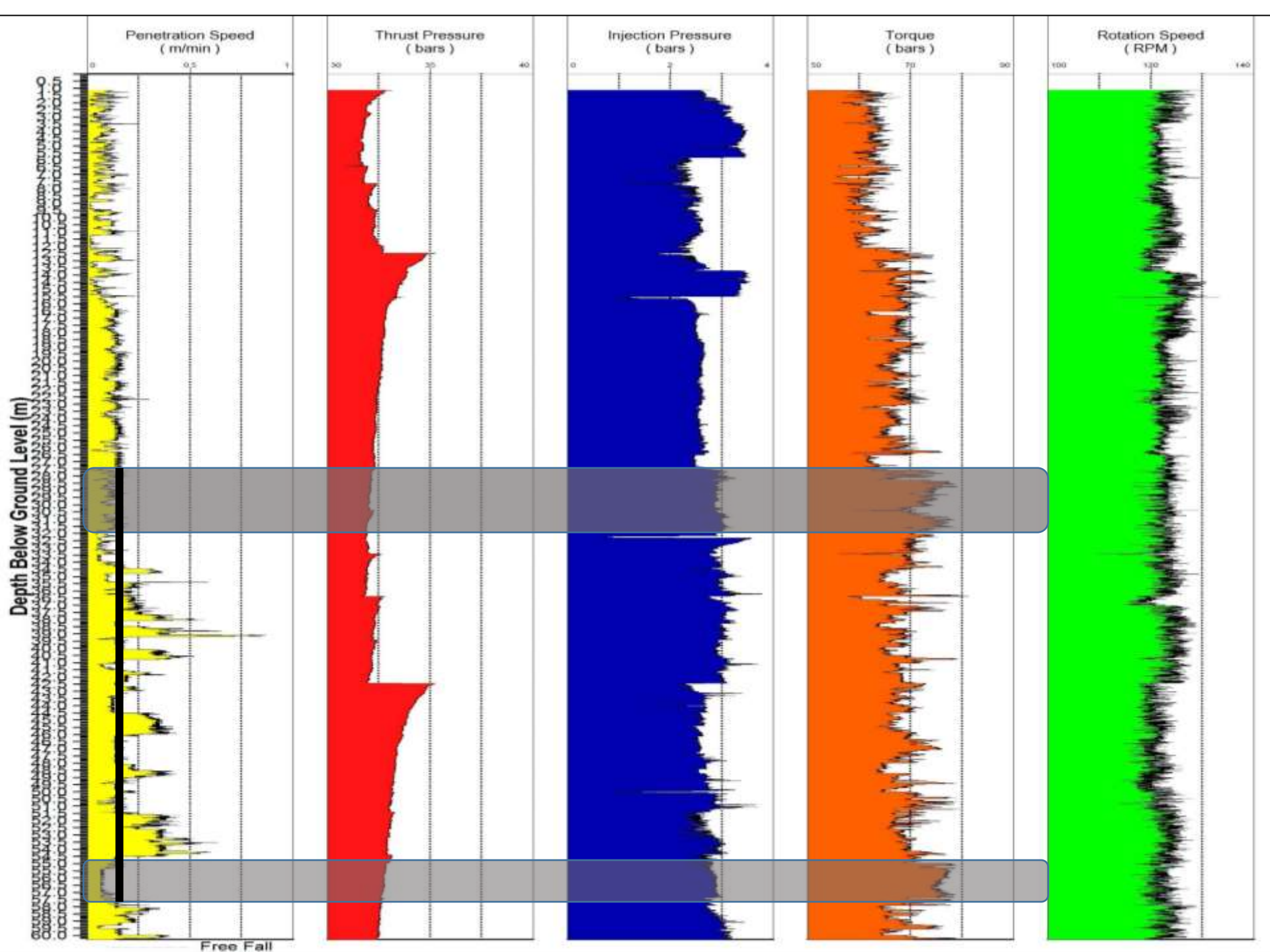
# Alternative Methods

- Diagraphy (instrumented) drilling
- Downhole geophysical tools
  - *Caliper*
  - *Natural Gamma, Spectral Gamma, Gamma-Gamma*
  - *Full wave sonic*
  - *Acoustic / Optical Imaging*
  - *Resistivity / Conductivity*
  - *Video Imaging*

# Diagraphy Drilling

- Thrust on bit (W') – (net thrust)
- Rotation speed ($\varpi_d$) – generally set based on the type of drilling conditions taking into account the type of rig and the wear and tear of the bid (lithology dependent)
- Torque ($T_q$)
- Fluid pressure (p)
- Time / drilling speed (u)

- Hold-back pressure – it prevents the drilling rods from penetrating too fast, especially into the very soft ground, or from "free fall".


Penetration Speed
( m/min )
0
0.5
1
Thrust Pressure
( bars )
30
35
40
Injection Pressure
( bars )
0
2
4
Torque
( bars )
50
70
90
Rotation Speed
( RPM )
100
120
140
Depth Below Ground Level (m)
Free Fall

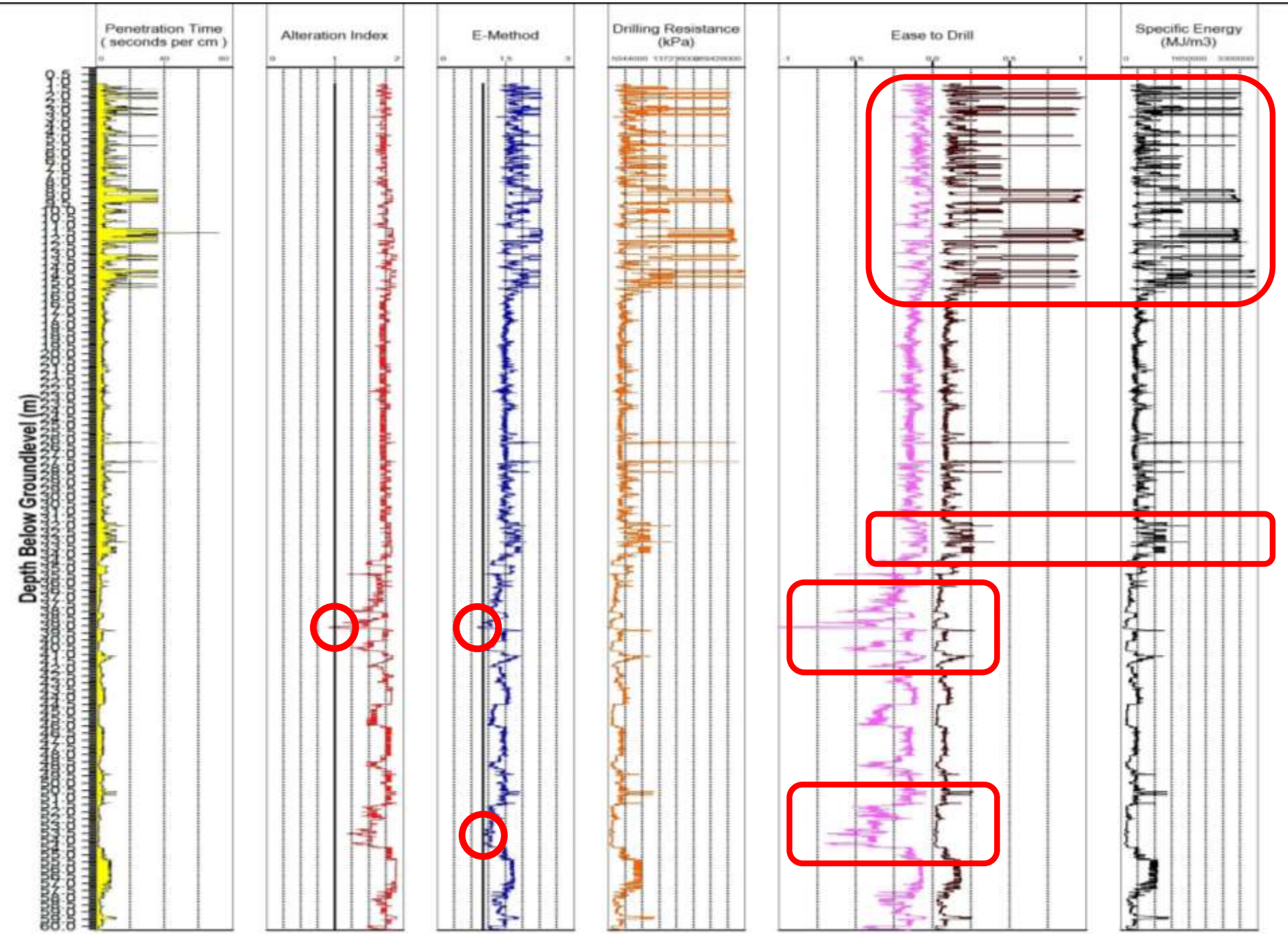
# Diagraphy Drilling

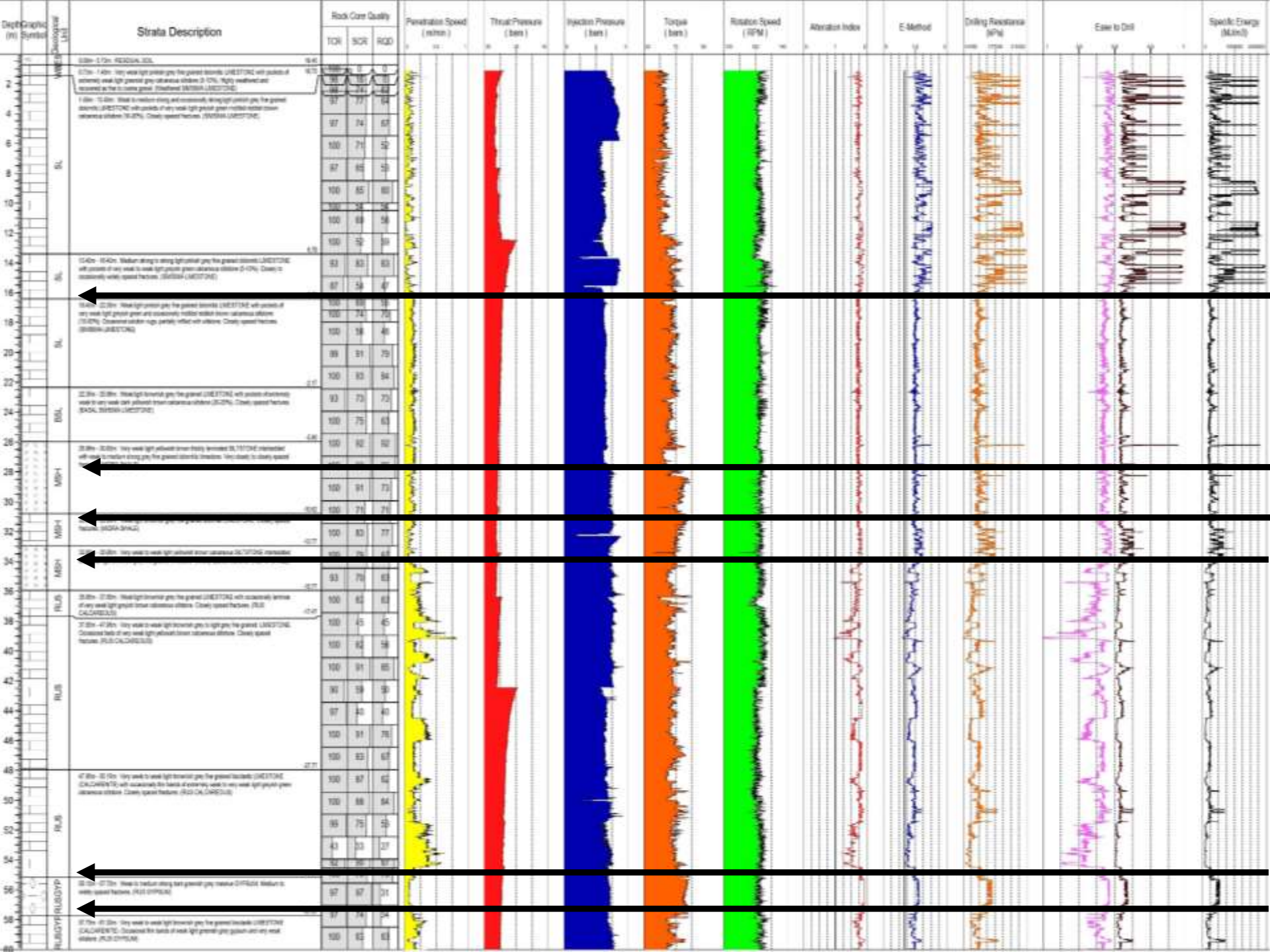
Parameters influenced by velocity

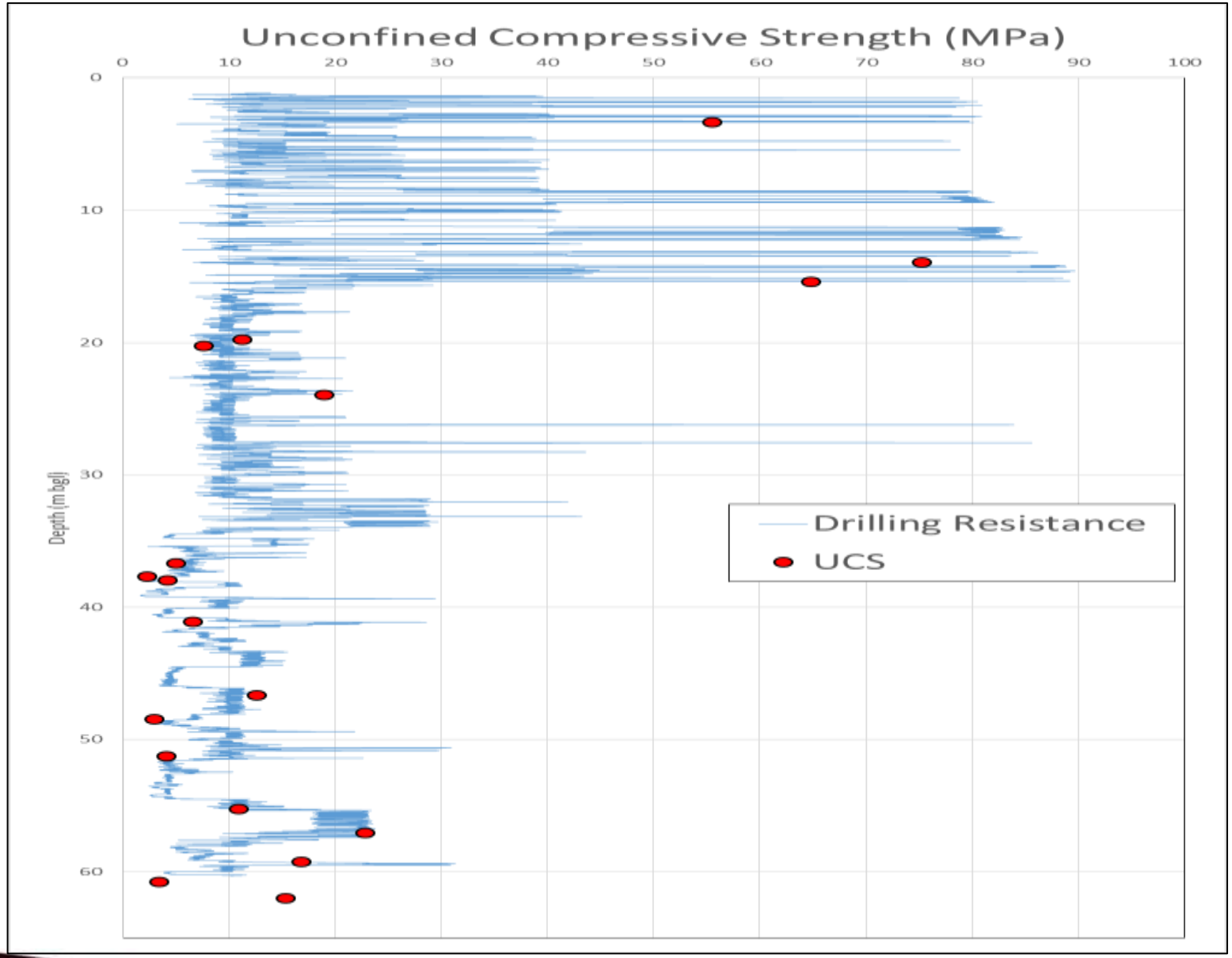
$$\Gamma_v = V_d / (\varpi_d * D)$$

Parameters influenced by forces

$$\Gamma_f = W' / (T_q * D)$$

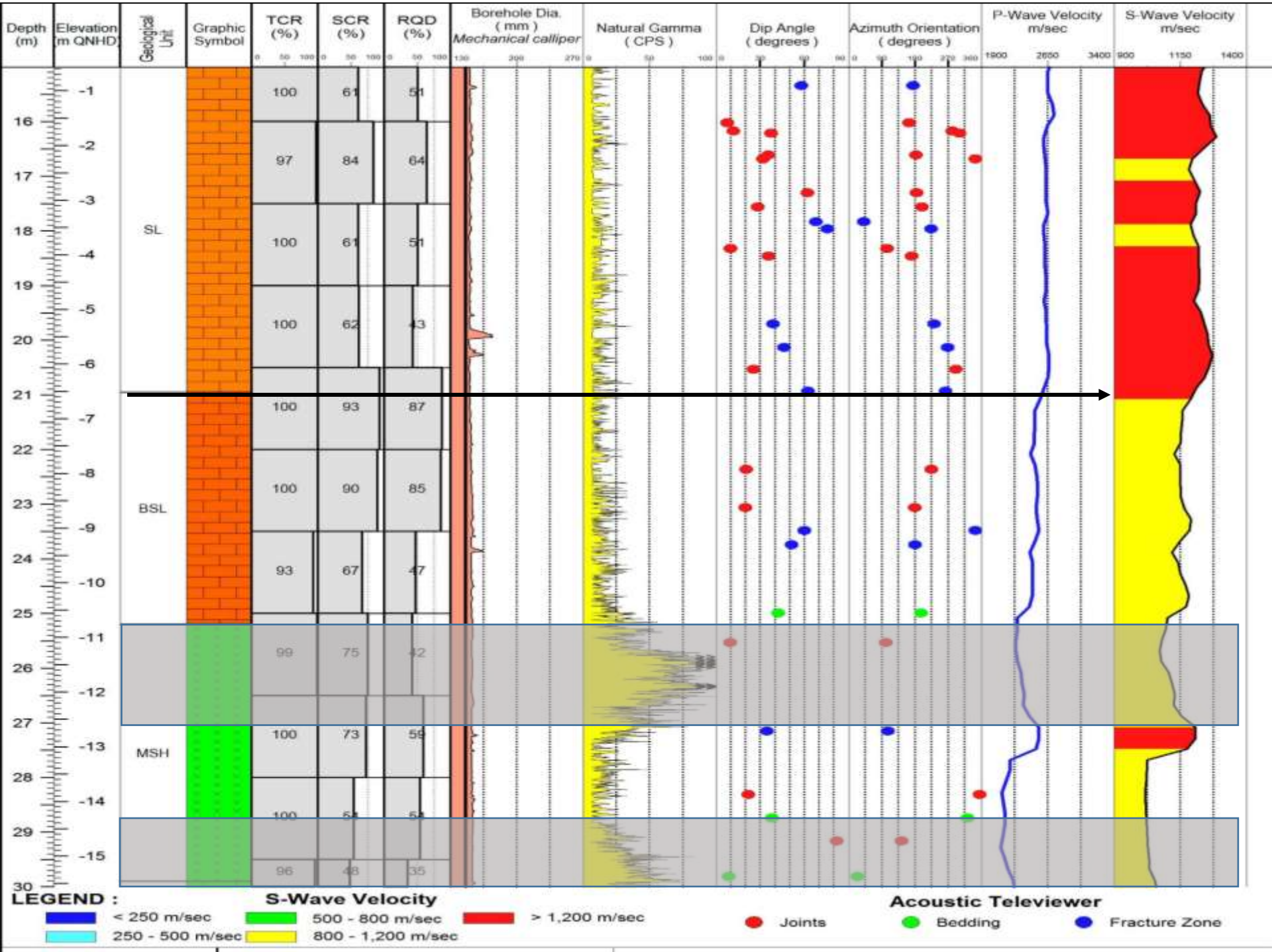

Penetration Time
( seconds per cm )
Alteration Index
E-Method
Drilling Resistance
(kPa)
Ease to Drill
Specific Energy
(MJ/m3)
Depth Below Groundlevel (m)

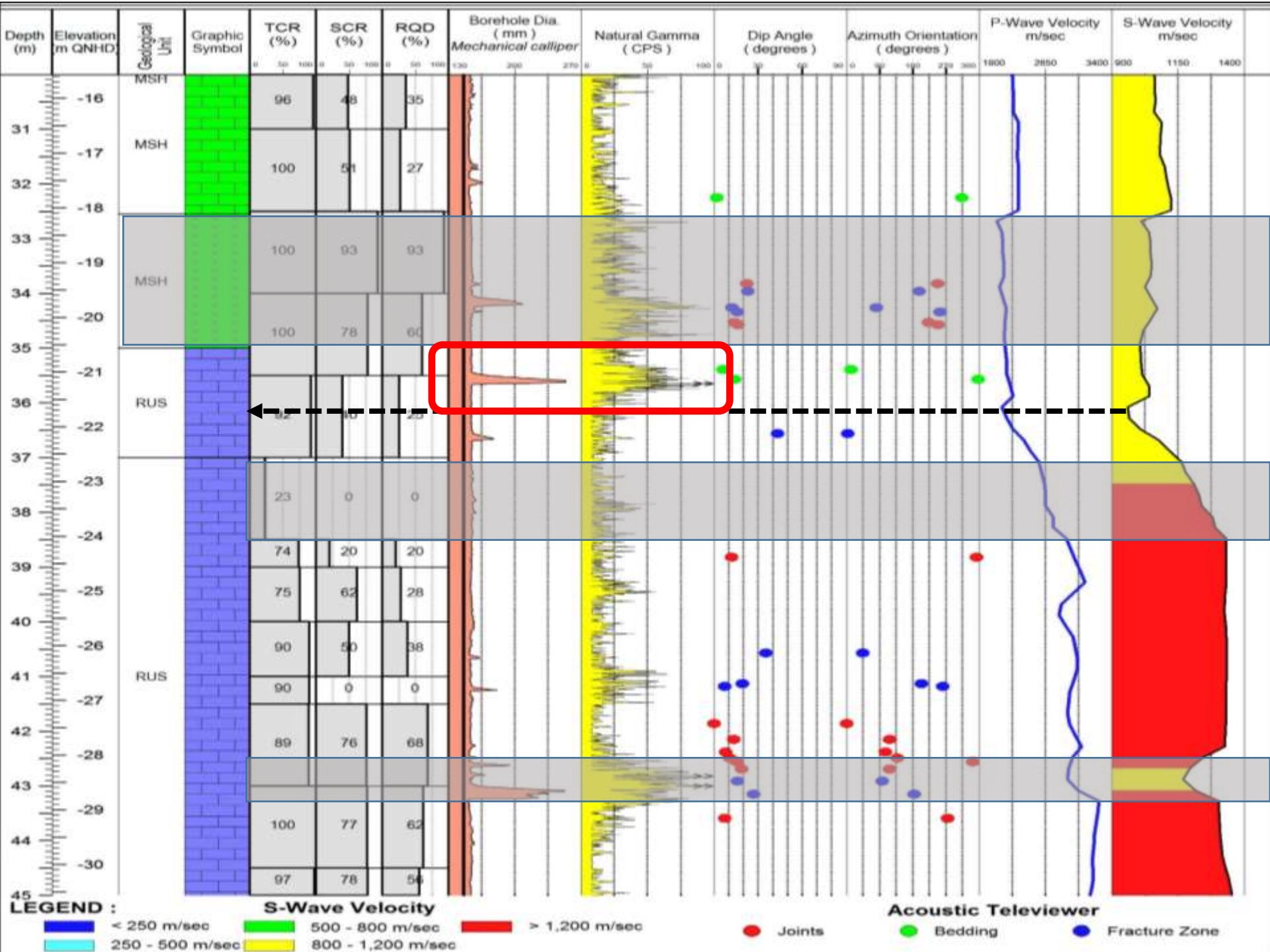

Depth (m)
Graphic Symbol
Lithostratigraphic Unit
Strata Description
Rock Core Quality
TCR
SCR
RQD
Penetration Speed ( m/min )
Thrust Pressure ( bars )
Injection Pressure ( bars )
Torque ( bars )
Rotation Speed ( RPM )
Abrasion Index
E-Method
Drilling Resistance (kPa)
Ease to Drill
Specific Energy (MJ/m3)
WMSL
SL
BL
BSL
MBH
RUB
RUBGYP

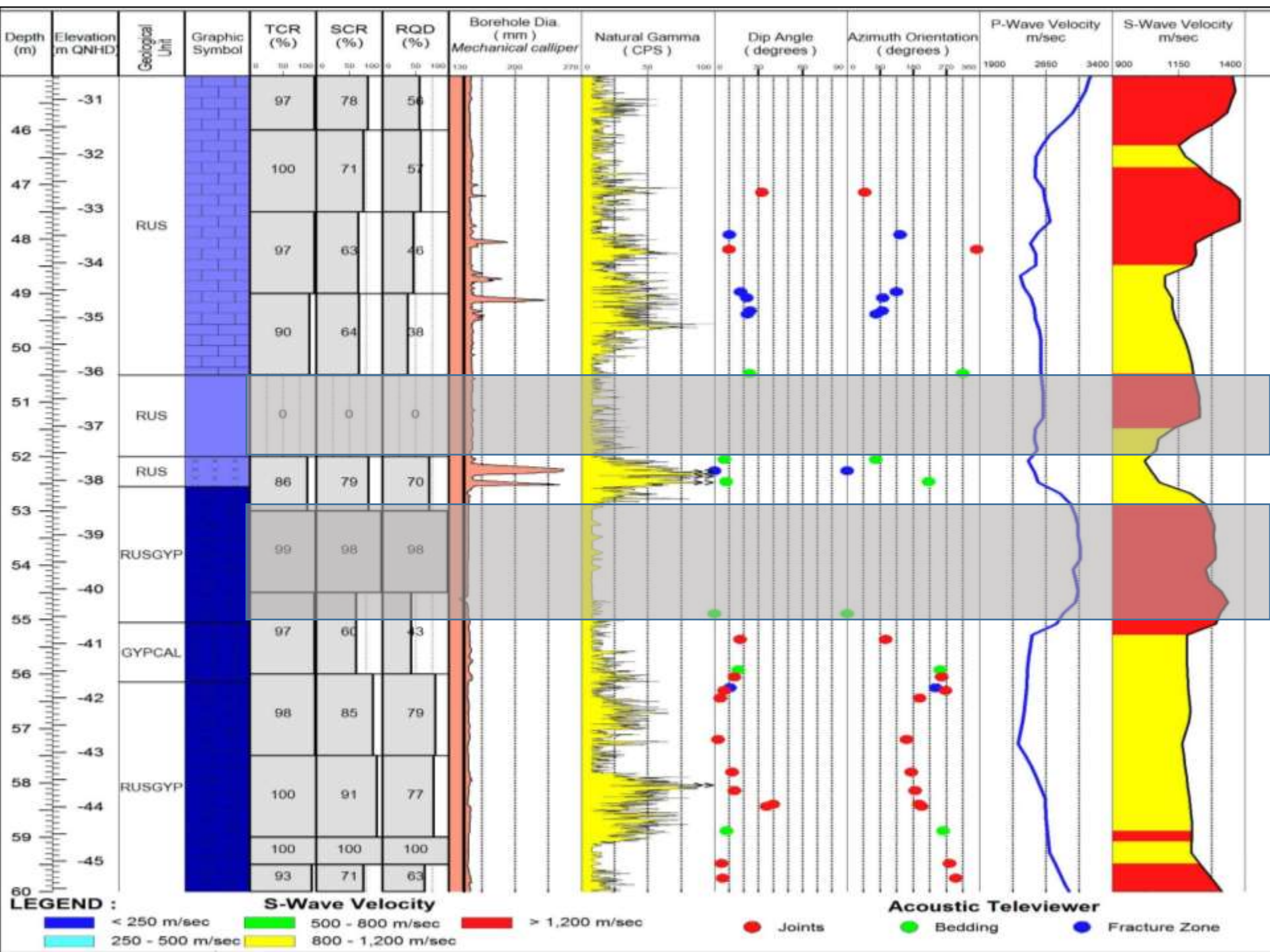


# Downhole Geophysical Logging

- Caliper – correlation with RQD (?)
- Natural gamma – correlation with clay content
- Acoustic imaging – fracture identification and description
- Full wave sonic – P/S velocities – correlation with stiffness/strength


Depth (m)
Elevation (m QNHD)
Geological Unit
Graphic Symbol
TCR (%)
SCR (%)
RQD (%)
Borehole Dia. ( mm )
Mechanical calliper
Natural Gamma ( CPS )
Dip Angle ( degrees )
Azimuth Orientation ( degrees )
P-Wave Velocity m/sec
S-Wave Velocity m/sec
SL
BSL
MSH
100
61
51
97
84
64
100
61
51
100
62
43
100
93
87
100
90
85
93
67
47
99
75
42
100
73
59
100
54
54
96
48
35
LEGEND :
S-Wave Velocity
< 250 m/sec
250 - 500 m/sec
500 - 800 m/sec
800 - 1,200 m/sec
> 1,200 m/sec
Acoustic Televiewer
Joints
Bedding
Fracture Zone


Depth (m)
Elevation m QNHD
Geological Unit
Graphic Symbol
TCR (%)
SCR (%)
RQD (%)
Borehole Dia. ( mm )
Mechanical calliper
Natural Gamma ( CPS )
Dip Angle ( degrees )
Azimuth Orientation ( degrees )
P-Wave Velocity m/sec
S-Wave Velocity m/sec
MSH
MSH
MSH
RUS
RUS
RUS
96
48
35
100
51
27
100
93
93
100
78
60
23
0
0
74
20
20
75
62
28
90
50
38
90
0
0
89
76
68
100
77
62
97
78
56
LEGEND :
S-Wave Velocity
< 250 m/sec
250 - 500 m/sec
500 - 800 m/sec
800 - 1,200 m/sec
> 1,200 m/sec
Acoustic Televiewer
Joints
Bedding
Fracture Zone

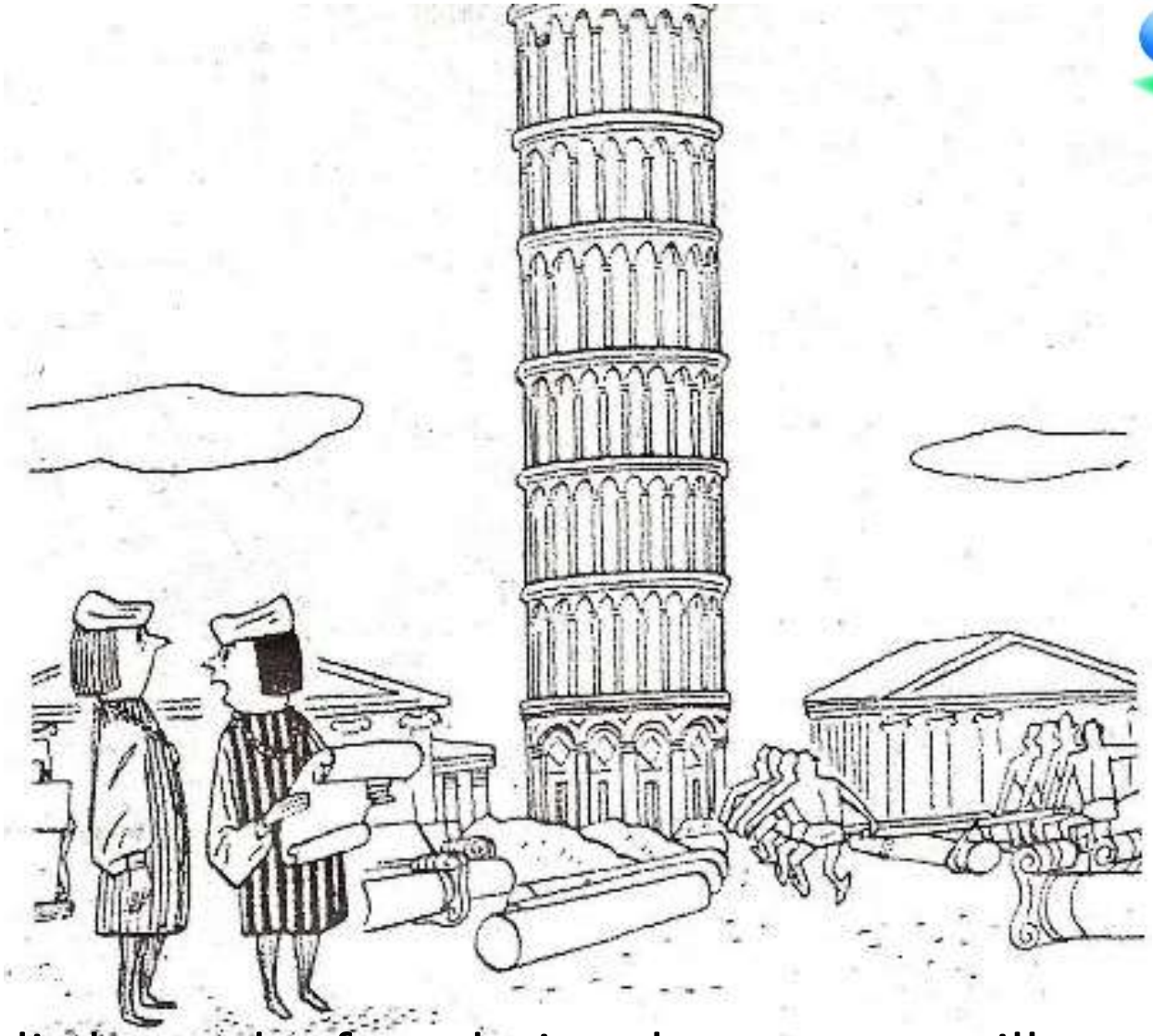

Depth (m)
Elevation m QNHD
Geological Unit
Graphic Symbol
TCR (%)
SCR (%)
RQD (%)
Borehole Dia ( mm )
Mechanical calliper
Natural Gamma ( CPS )
Dip Angle ( degrees )
Azimuth Orientation ( degrees )
P-Wave Velocity m/sec
S-Wave Velocity m/sec
RUS
RUS
RUS
RUSGYP
GYPCAL
RUSGYP
97 78 56
100 71 57
97 63 46
90 64 38
0 0 0
86 79 70
99 98 98
97 60 43
98 85 79
100 91 77
100 100 100
93 71 63
LEGEND :
S-Wave Velocity
< 250 m/sec
250 - 500 m/sec
500 - 800 m/sec
800 - 1,200 m/sec
> 1,200 m/sec
Acoustic Televiewer
Joints
Bedding
Fracture Zone

# Benefits / Conclusion

- Complementary to coring activities
- Continuous records / sampling
- Qualitative and quantitative data
- Fast and cheap

# Risk Assessment

- Reduced work quality
- Conservative design
- Expensive construction
- Deviation from standards to reach project deadlines
- Equipment overloading



I skimped a little on the foundation, but no one will ever know it!!