

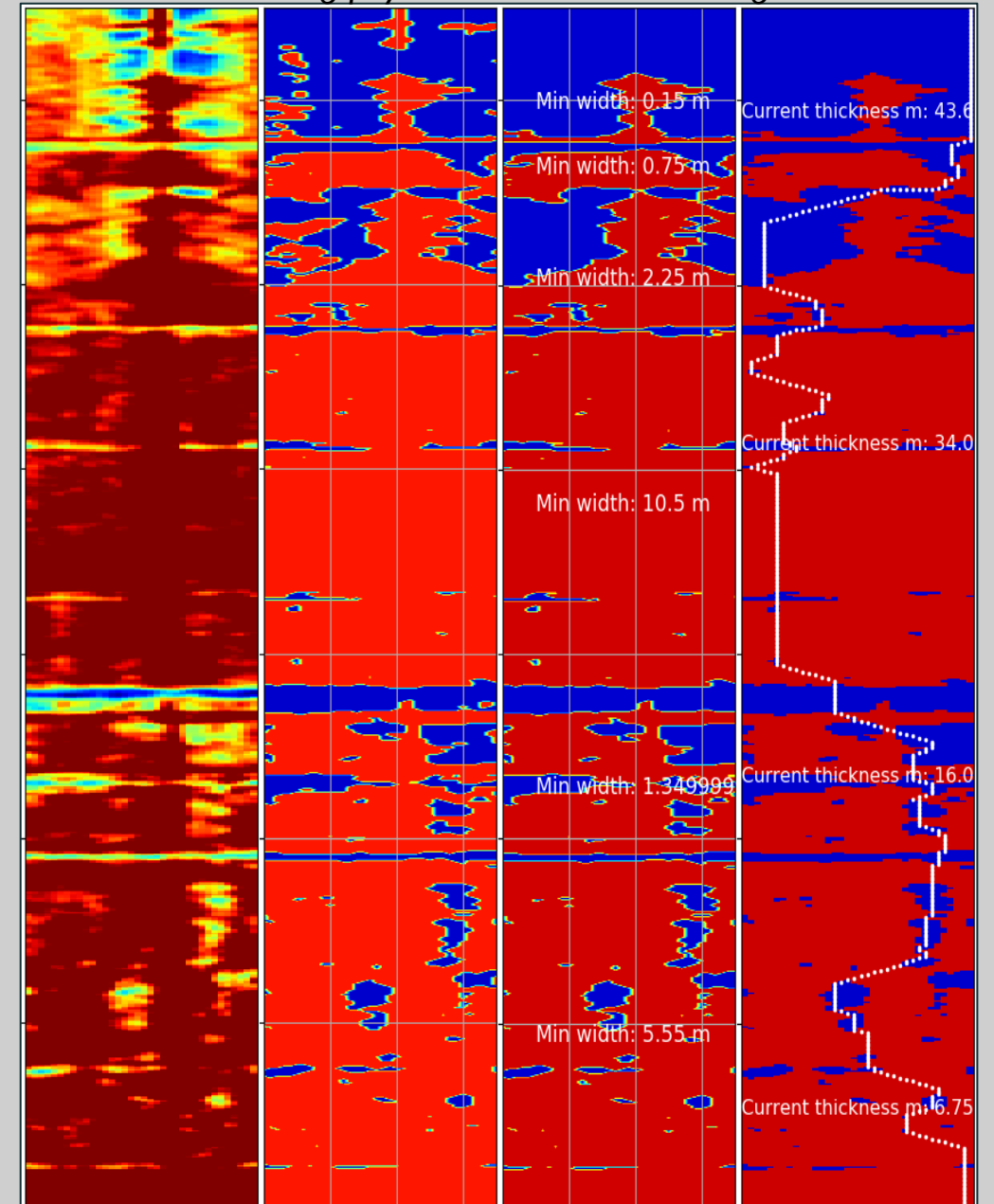
10th Norwegian Plug & Abandonment Seminar

Automating the interpretation

By Tore Sirevaag (Ph.D)

20.10.2022

Combining physics and machine learning





WHAT DO I PRESENT TODAY?

- Interpretation of cased hole logging
- Combining underlying physics with machine learning to extract more information within the data

WHY?

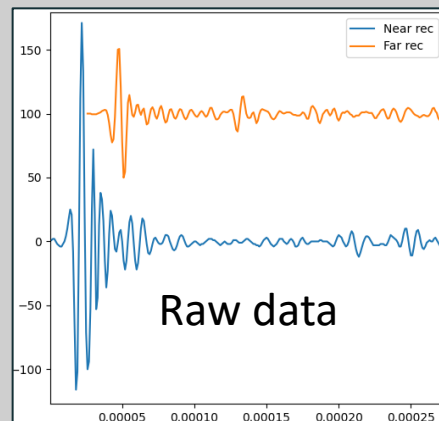
- Equanostic has developed product that can help solve some of the challenges related to cased hole logging

Data to be interpreted



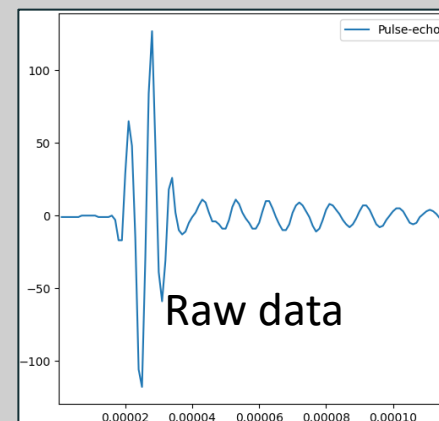
Flexural attenuation

Ultrasonic
pitch-catch



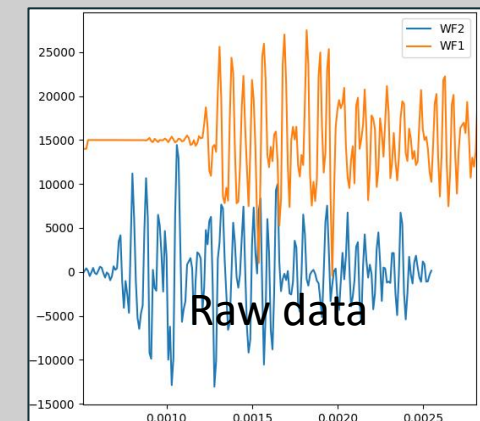
Acoustic impedance

Ultrasonic
pulse-echo

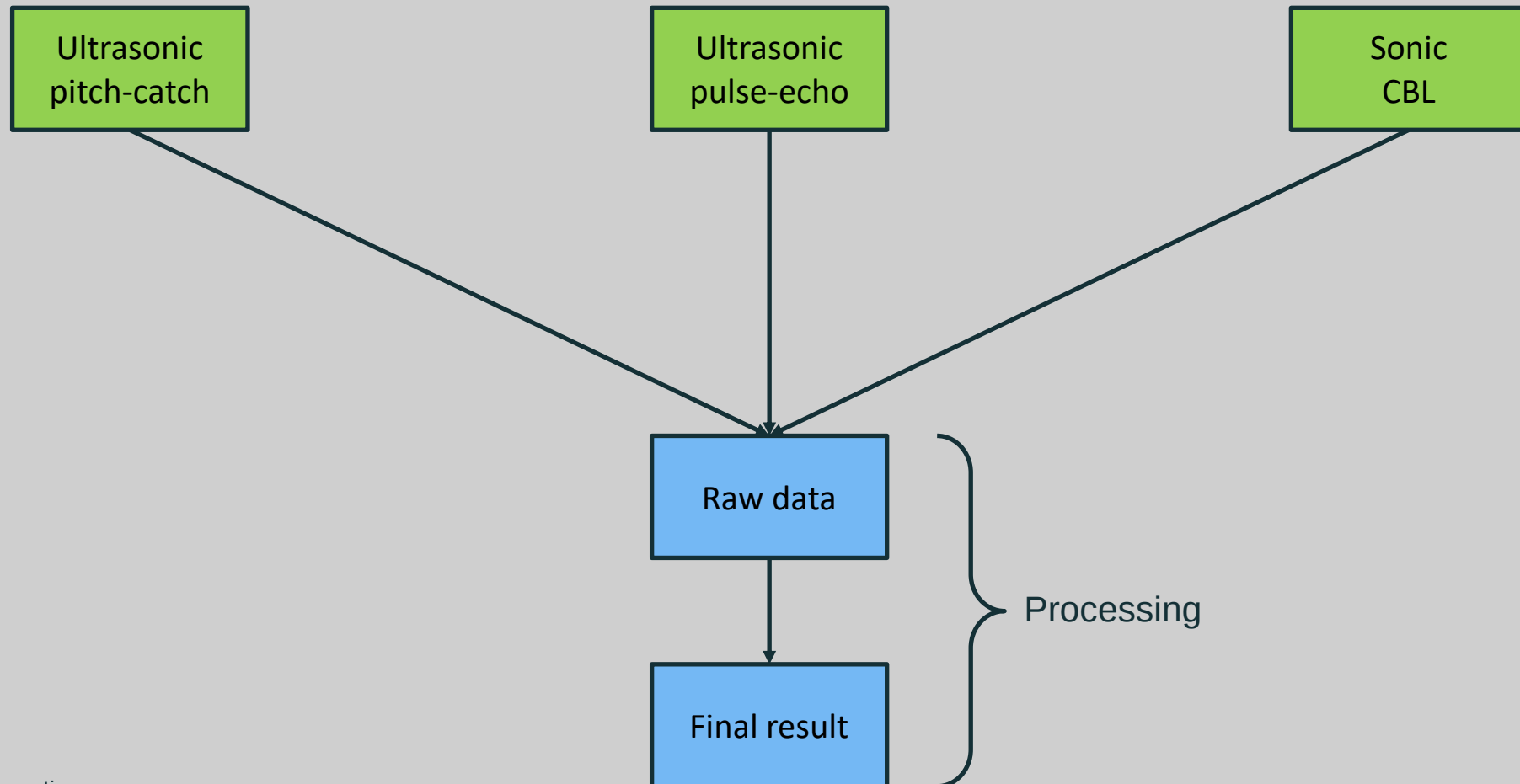


VDL log and cement / formation bonding

Sonic
CBL



Data to be interpreted



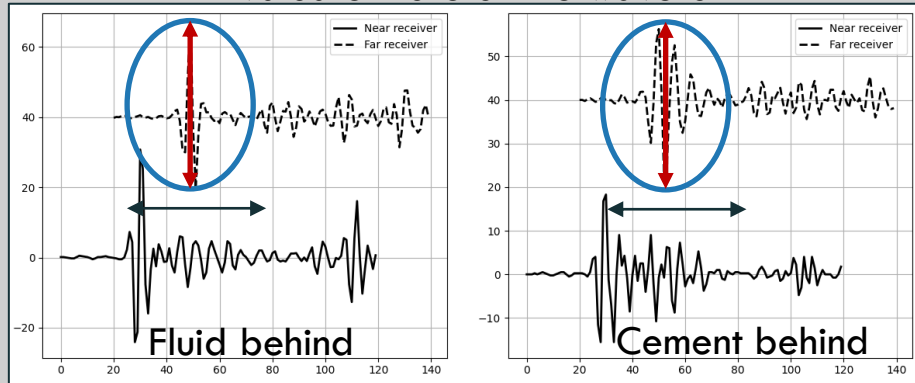
We combine the knowledge from the industry with



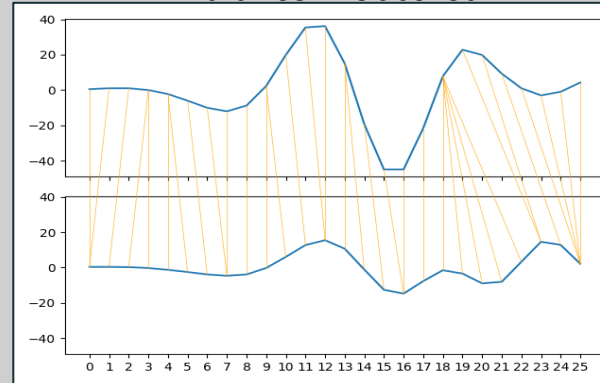
Clustering of data to sort measurements based on characteristics of the signal such as:

- **Shape, amplitude and evaluate more of the waveform**
- **Distance measures and phase**
- **Correlation**

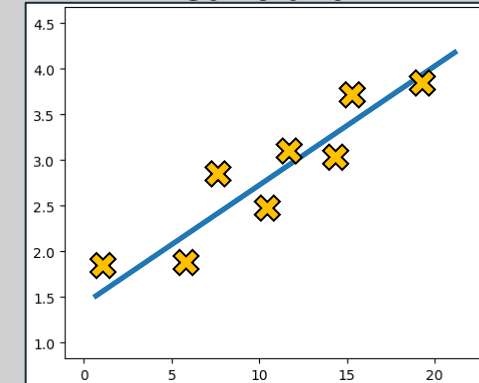
Evaluate more of the waveform



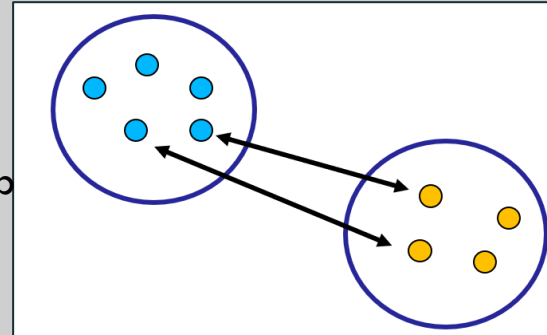
Distance measures



Correlation

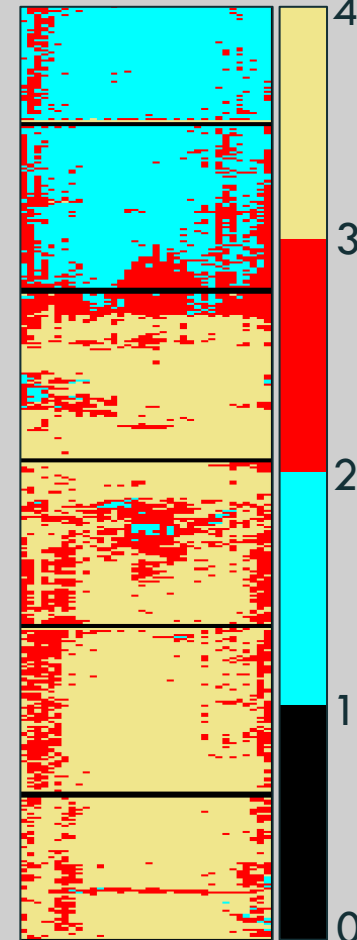


Identify measurements that is similar and group



Plot as a petrophysical log

Clustering of data



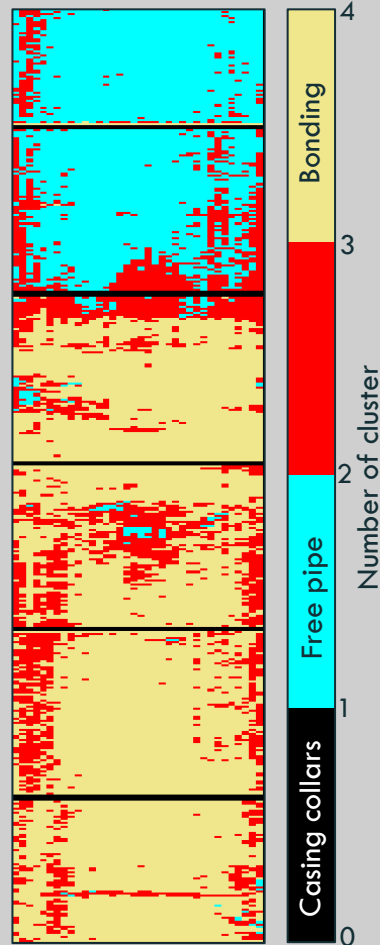
Apply the strength of modern computers



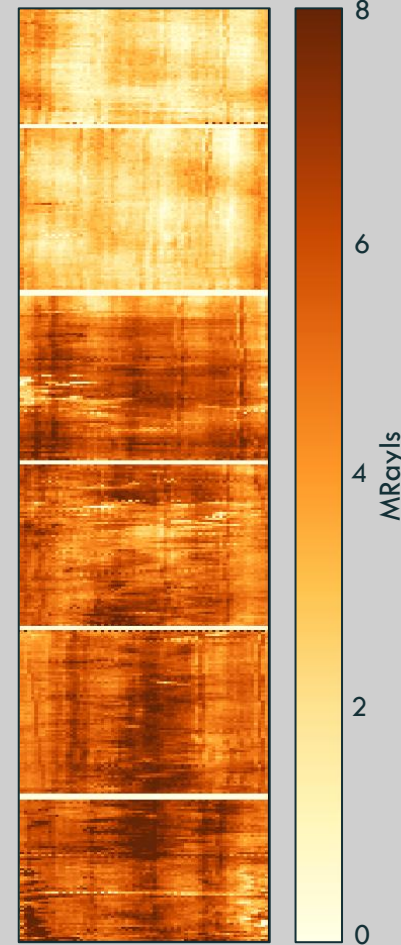
Clustering of data:

- Not a quantitative method
- Needs underlying physics to identify each cluster
- A more sophisticated machine learning technique was applied to help evaluate each cluster
- Evaluate more data within the waveform

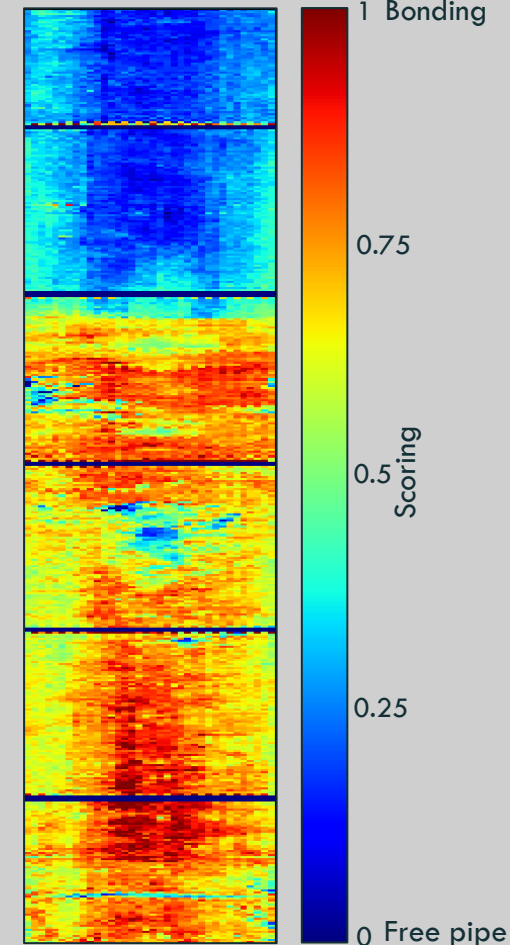
Clustering of data



Acoustic impedance



Scoring of clusters



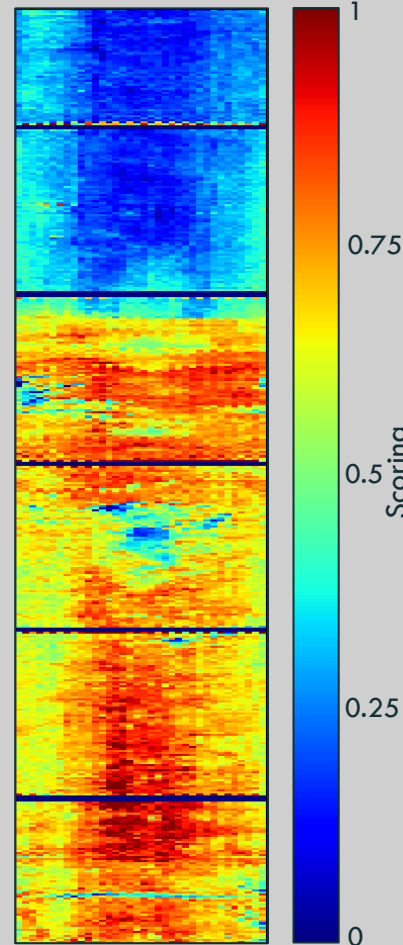
Utilize new understanding in the physics to enhance separation



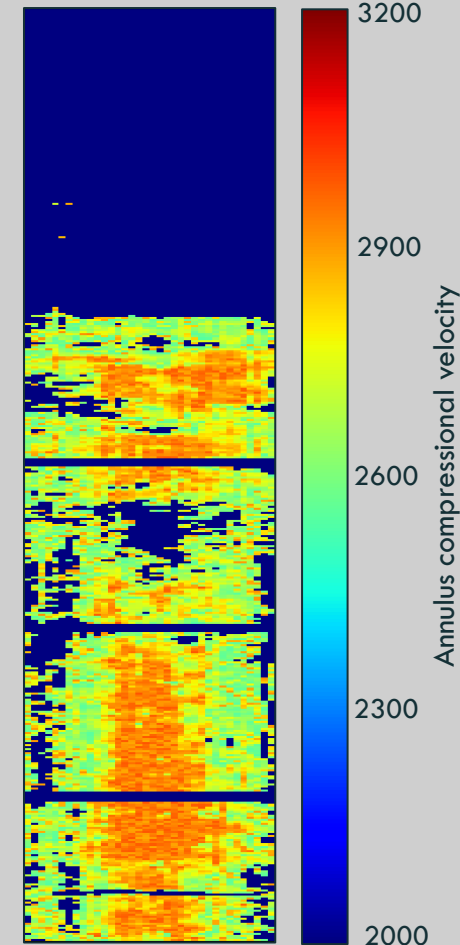
Compute the velocity of the annulus:

- If annulus velocity overlaps the dispersive phase velocity of the flexural wave, a physical phenomenon happens that can be utilized
- Believe this was first documented by Benoit Froelich (SLB, 2008) and later applied by Zeroug et al. (SLB, 2015)
- Equanostic has developed a robust method to estimate the velocity

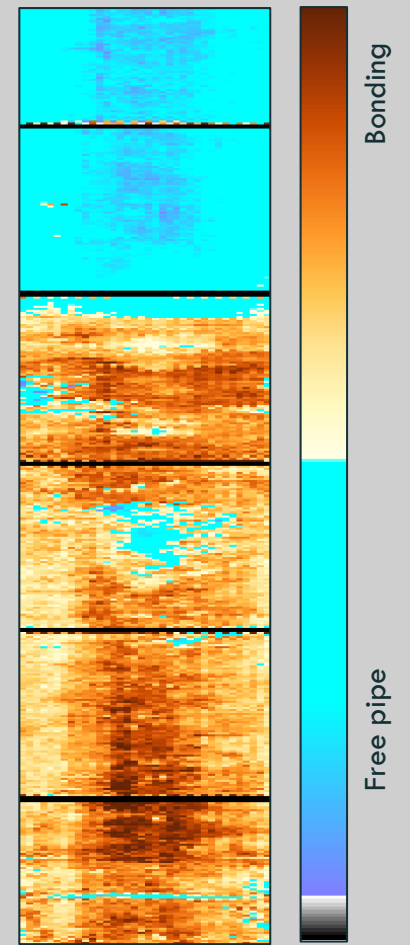
Scoring of clusters



Velocity annulus



Fluid solid plot

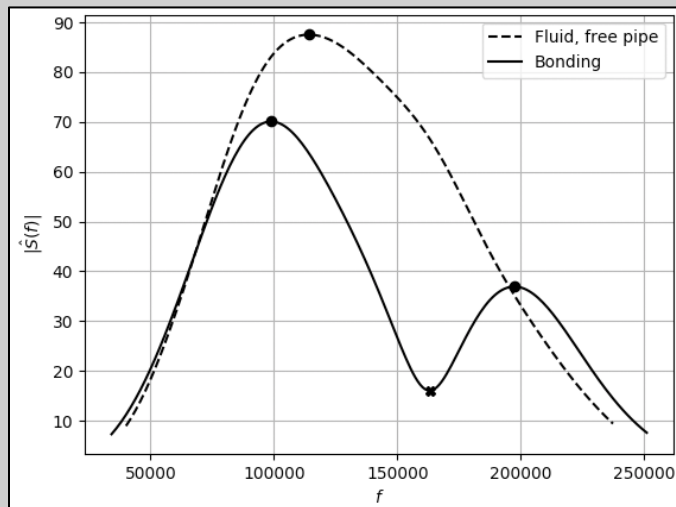


Utilize new understanding in the physics to enhance separation

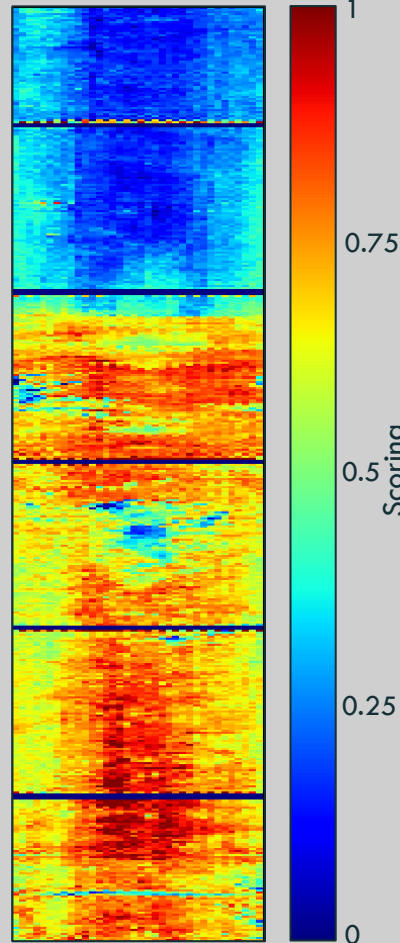


Compute the velocity of the annulus:

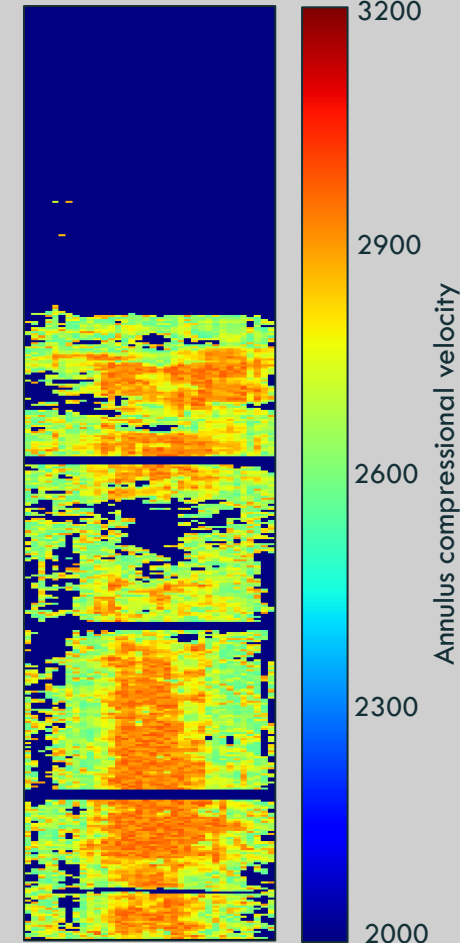
- Distinct and consistent difference in signature



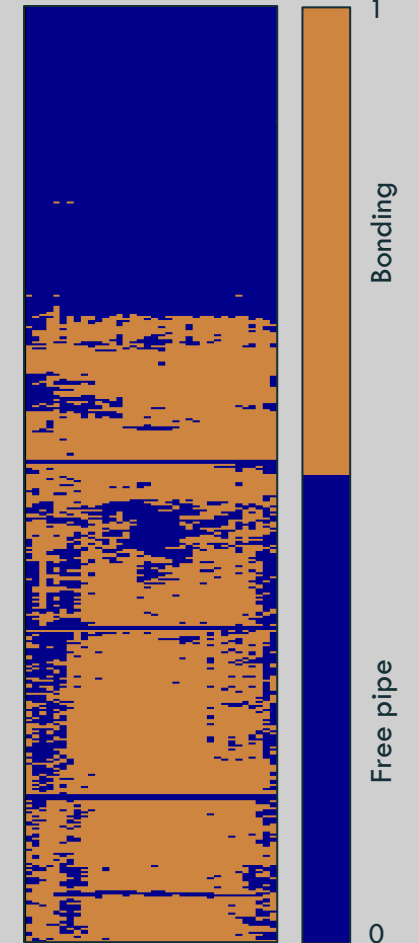
Scoring of clusters



Velocity annulus



Bonding – free pipe



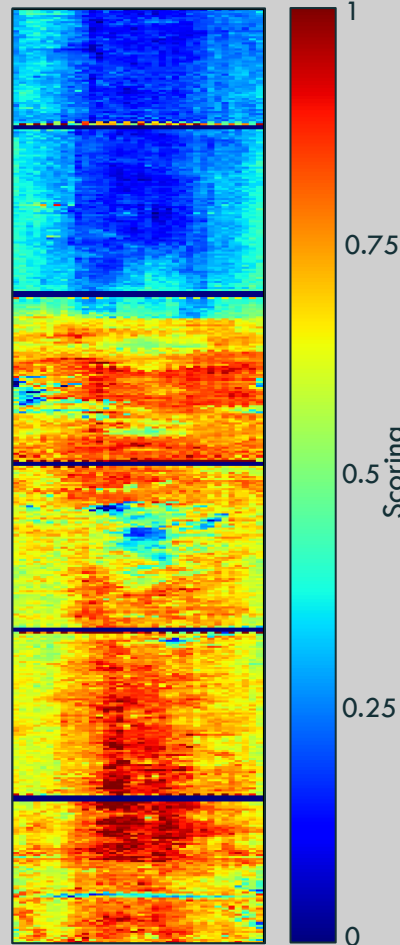
Develop algorithms to help the interpretation



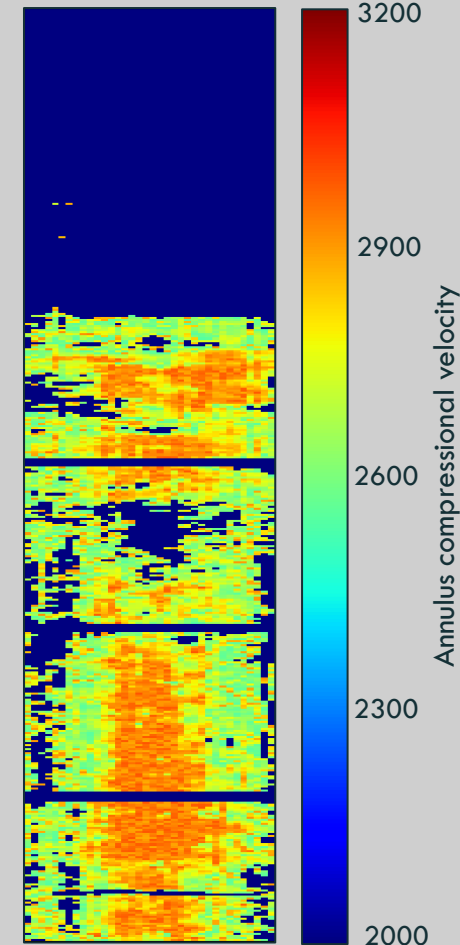
Visual representation:

- Compute the shortest path for oil & gas to mitigate up to the surface
- **Green color** shows where oil & gas can move freely through fluid
- **Red color** indicates where it is forced, due to zonal isolation, to move through bonding
- Automatically calculates meter of bonding (indicated by number in white)
- Helps detect channels and isolated fluid pockets

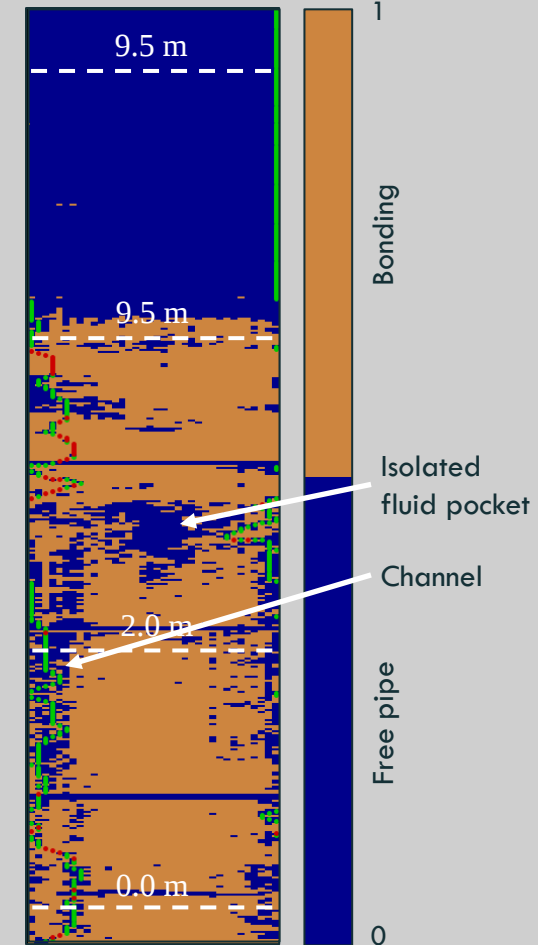
Scoring of clusters



Velocity annulus



Bonding – free pipe

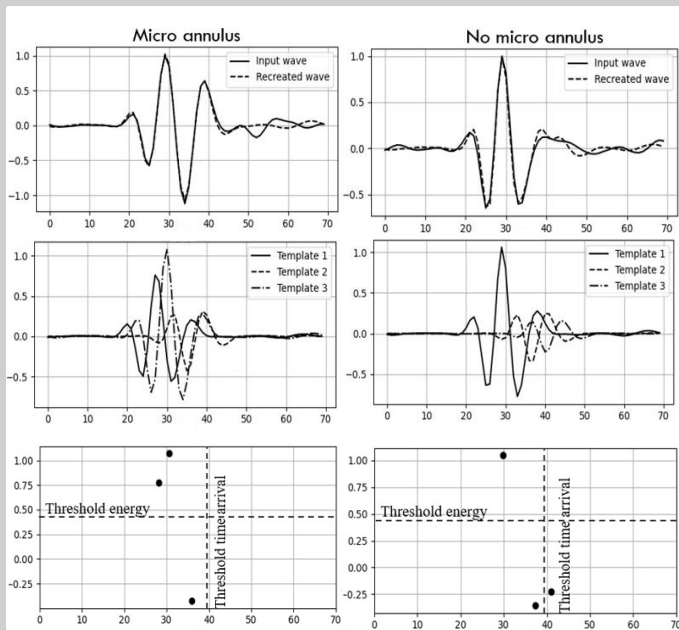


Filling in gaps



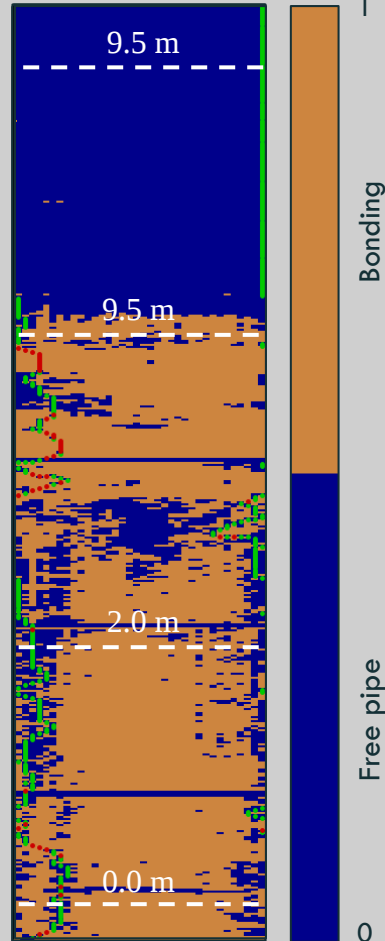
Identifying micro annulus:

- Apply decomposition to recreate the pulse(s)

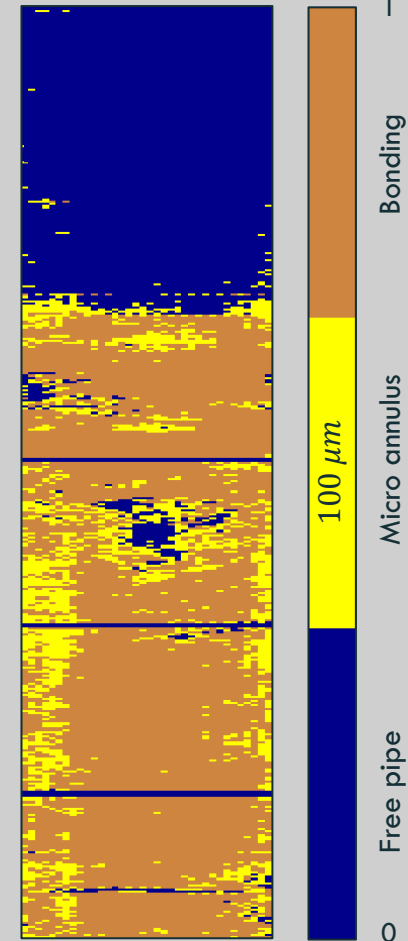


- Hardware seems to be the limitation

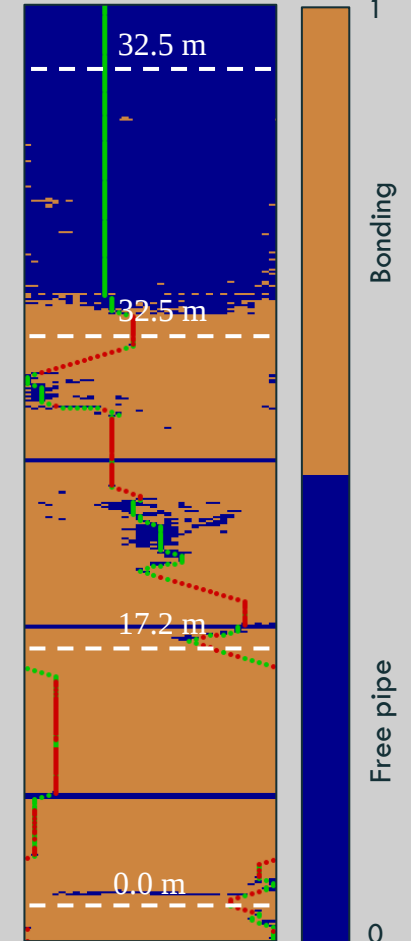
Bonding – free pipe



Micro annulus



Bonding – including micro annulus

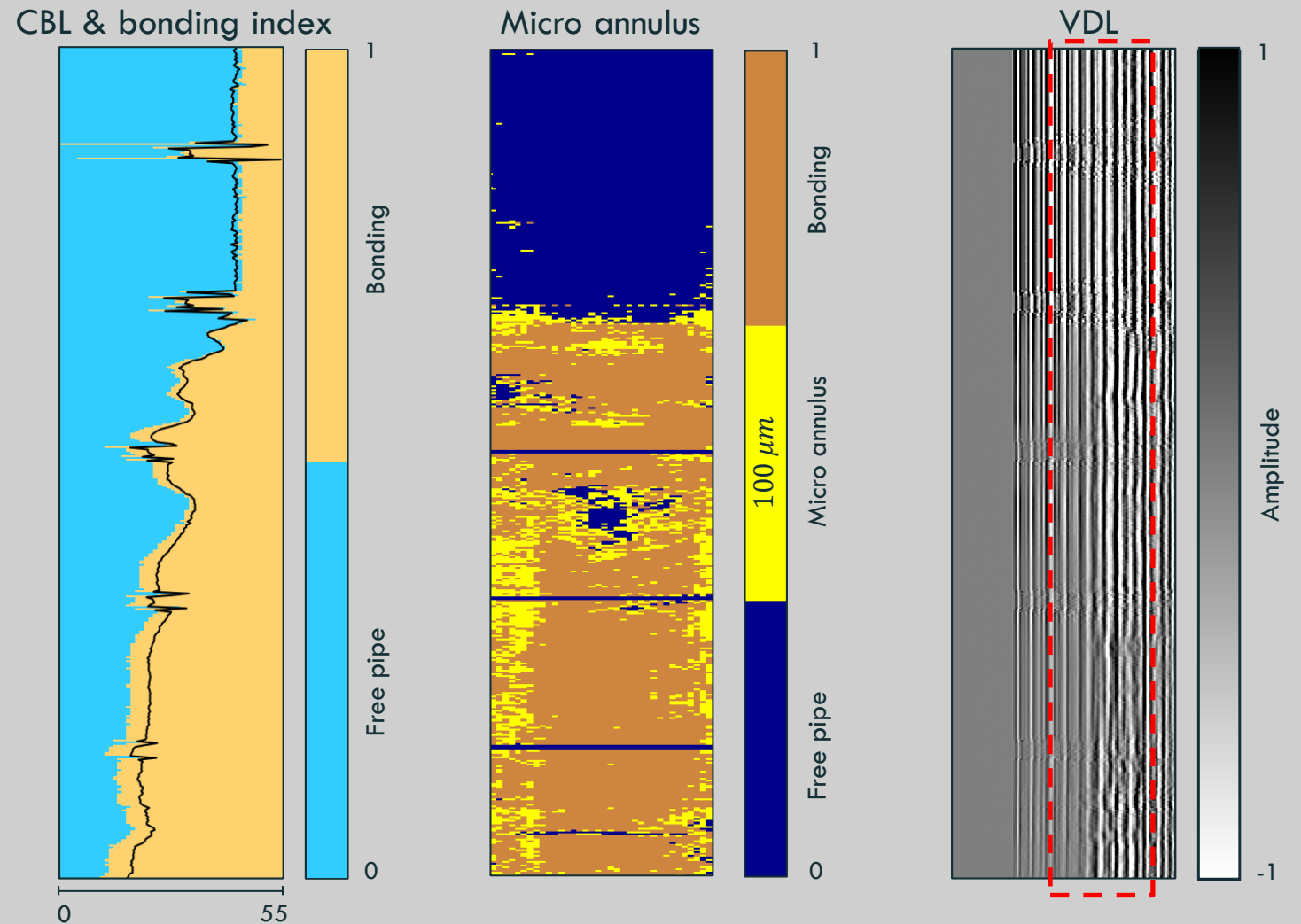


Comparing with CBL



Clustering sonic data:

- Want to cluster the waveforms in the VDL to extract information about bonding between cement and formation

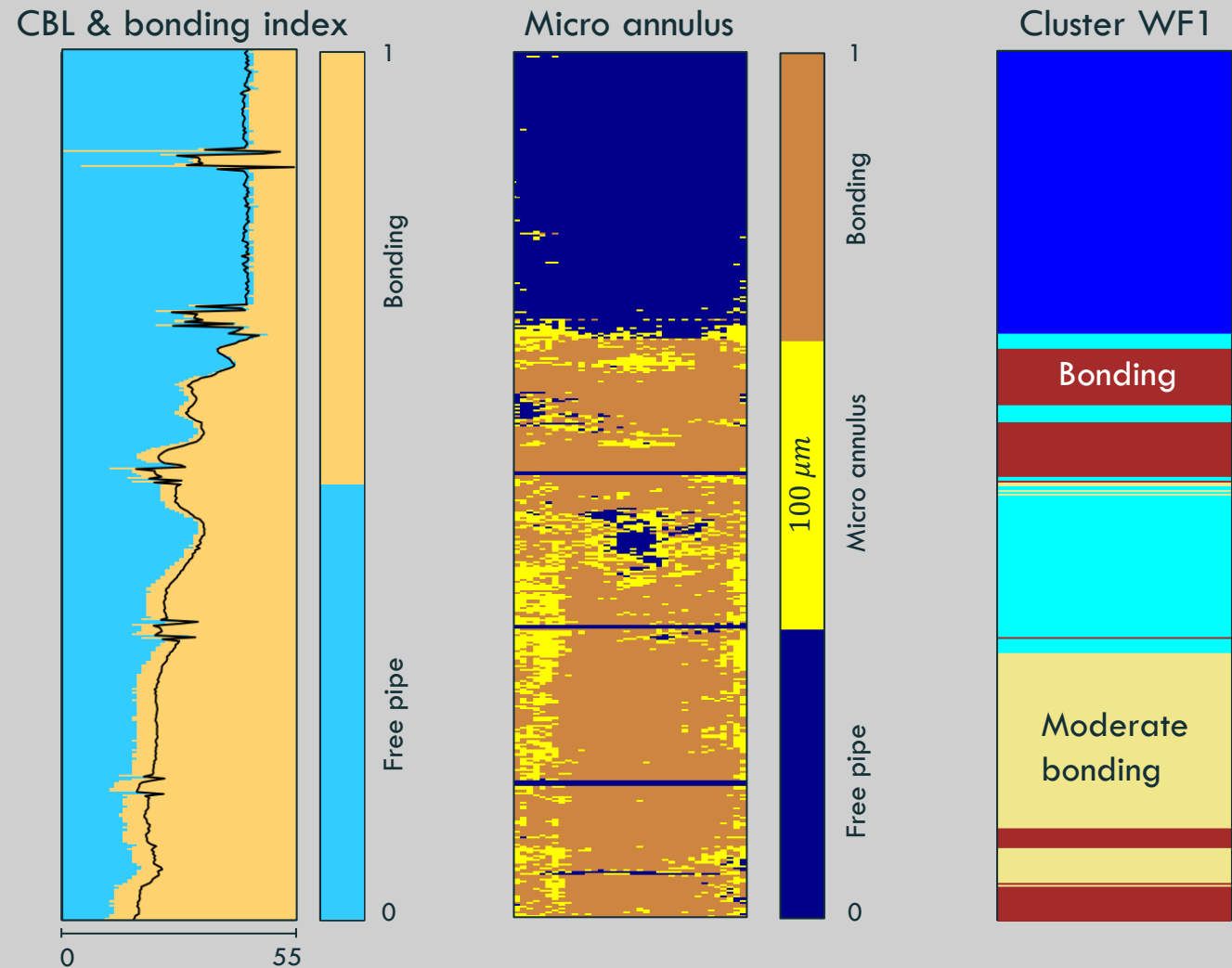


Comparing with CBL



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Comparing with CBL

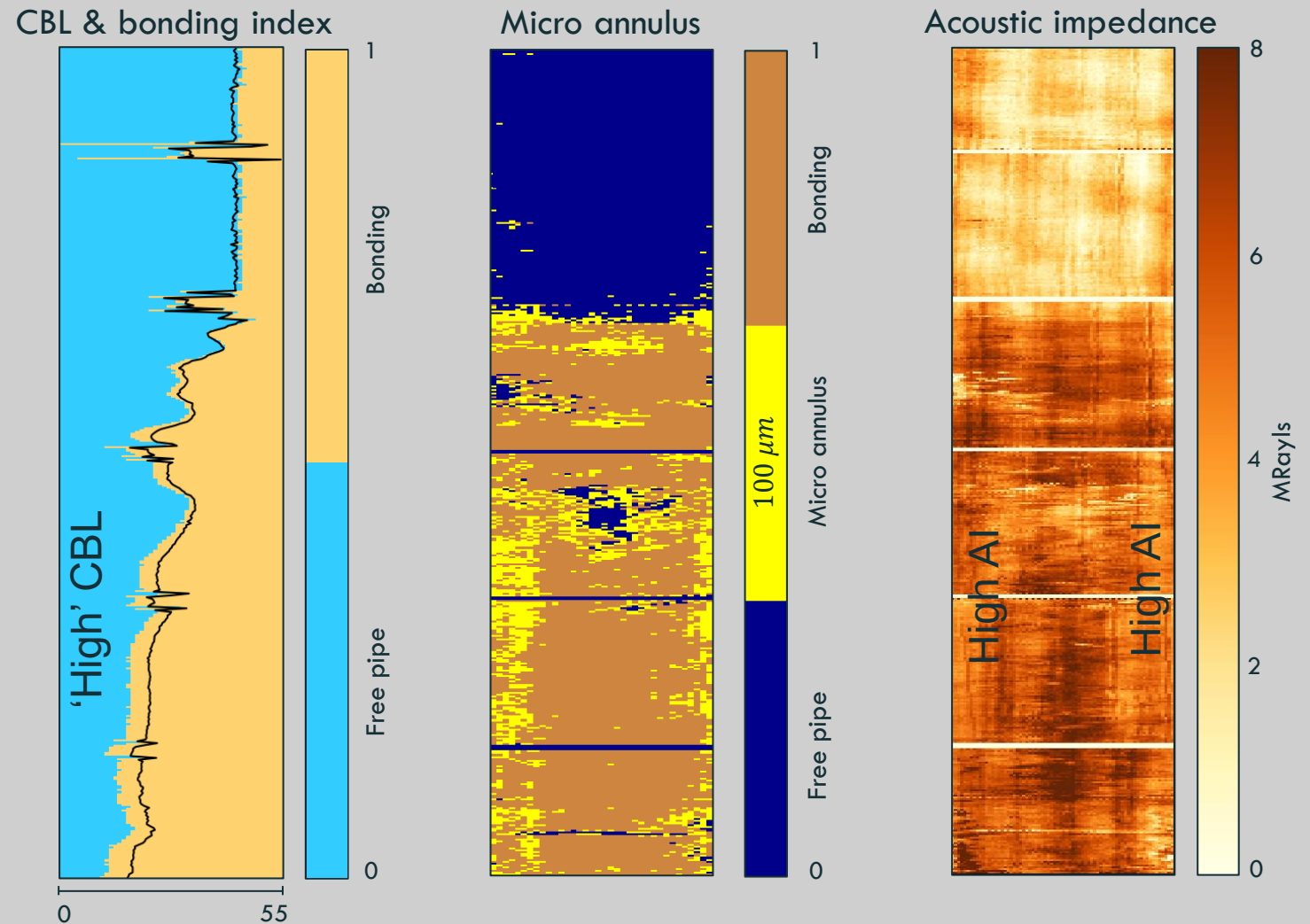


Clustering sonic data:

- Want to cluster the waveforms in the VDL to extract information about bonding between cement and formation

Compare CBL with Acoustic impedance:

- 'High' CBL and 'High' acoustic impedance



Comparing with CBL

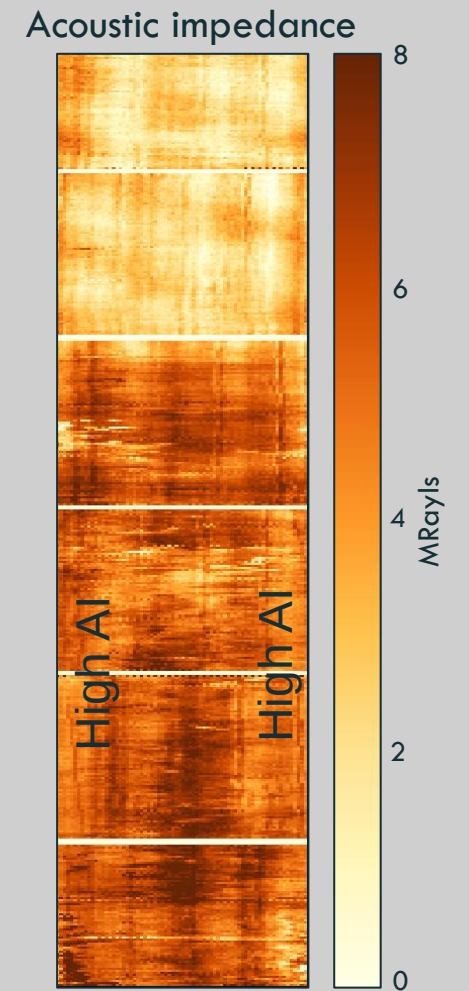
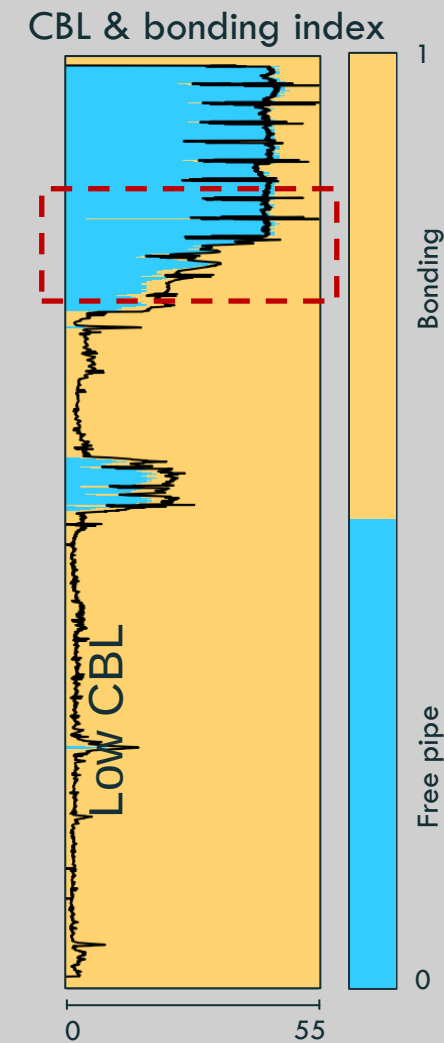
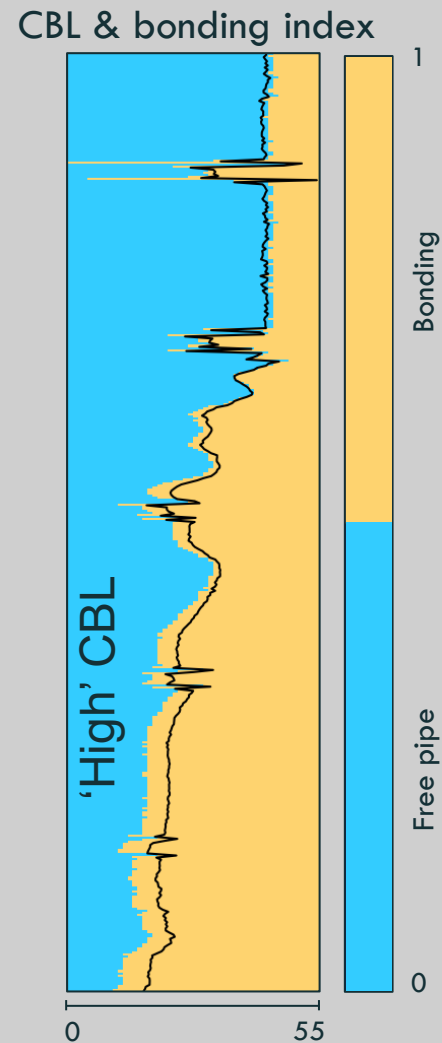


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Comparing with CBL

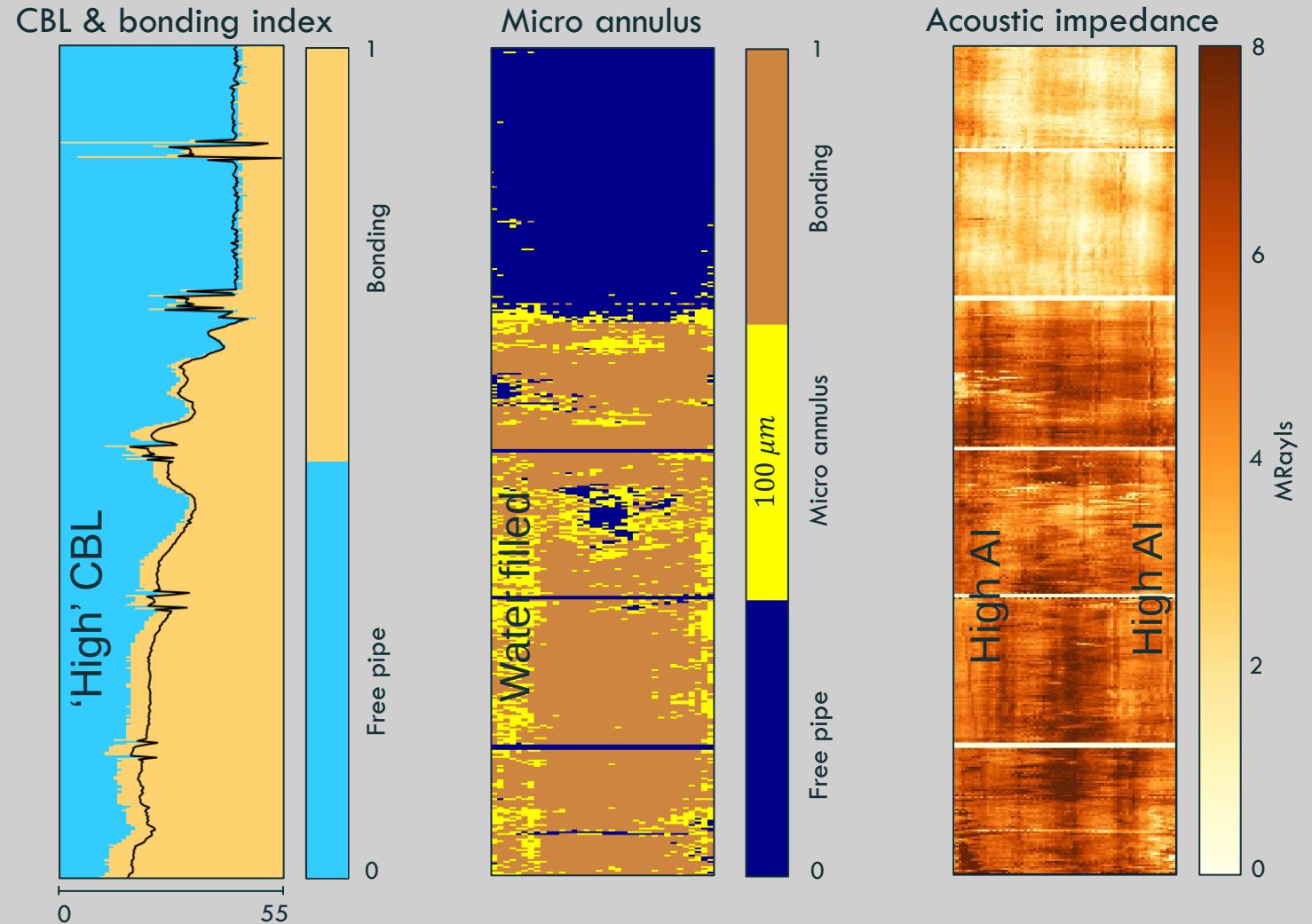


Clustering sonic data:

- Want to cluster the waveforms in the VDL to extract information about bonding between cement and formation

Compare CBL with Acoustic impedance:

- 'High' CBL and 'High' acoustic impedance
- Water filled micro-annulus



Product



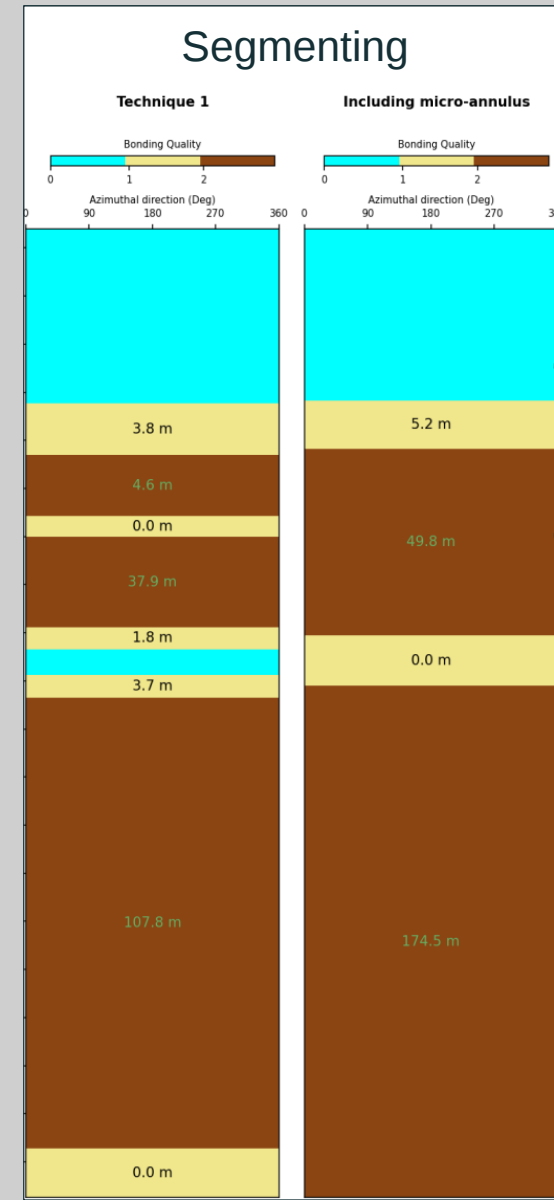
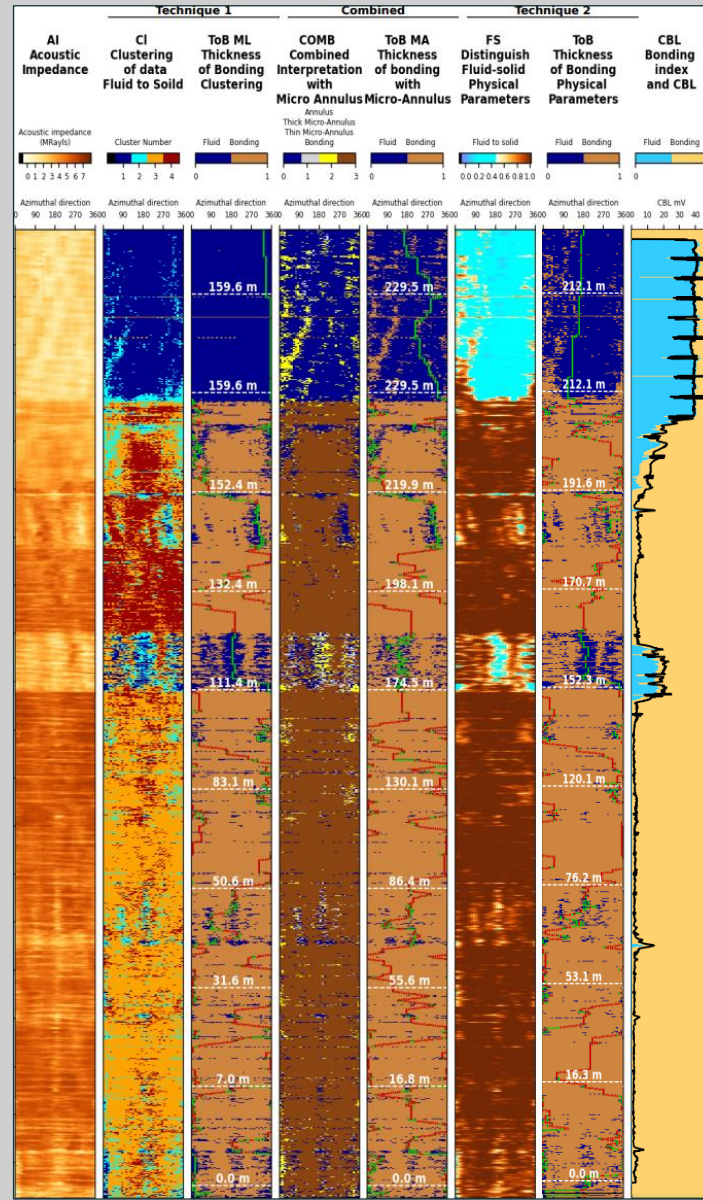
Processing on cased hole logging based on high quality software

Equanostic aims to provide a high throughput, accurate, 'open box' solution for well processing and visualization

Machine based interpretation delivered with human supervision

*Software as a service – we run and deliver report to customer.
Self service web application with interactive analysis tool for inhouse experts*

Product - logs



29.3 m

Automated report generation



Automatically generated reports containing:

- *Petrophysical logs*
- *Summary of results*
- *Conclusion of annulus integrity*
- *Segmentation of well*
- *Key results*

Zone (Technique 1)		Annulus information Note: all data is in meters and not ft				Additional information
Start (MD)	End (MD)	Quality (Technique 1)	Length of bonding(m)			Comments
			Technique 1	Including micro-annulus	Technique 2	
1496,3	1601,7	Poor	0,0	0,0	0,0	
1601,9	1632,8	Moderate	3,8	5,2	18,6	
1633,0	1669,7	Good	4,6	5,6	15,5	
1669,8	1682,2	Moderate	0,0	0,0	0,0	
1682,3	1736,6	Good	37,9	41,7	45,0	
1736,8	1749,9	Moderate	1,8	2,4	1,2	
1750,0	1765,6	Poor	0,0	0,0	0,0	
1765,7	1779,0	Moderate	3,7	3,8	3,7	
1779,1	2050,8	Good	107,8	170,7	211,7	
2051,0	2080,4	Moderate	0,0	0,0	2,4	
Total			159,6	229,5 (incl. micro-annulus)	298,1	

All data within in table is automatically filled out, no human error
(numbers are synthetic)

Questions?



Special thanks to Paal Ludvik Jørgensen and Arve Huse (Aker BP)

Thanks to Laurent Delabroy, Andreas Bauer & Tron Kristiansen (Aker BP), Ivar Blaauw (retired, CoP) and the Research Council of Norway

Web application



Pipe Scanner 1.0

Load data

Unique ID for Scan

ff695fde710b4dd889c115a2fe160f68

* Required for processing & storage of results

Load dlis-file

Choose logged well

Choose...

Ultrasound Settings

Choose channels to be processed

Choose...

Added channels

"internal_report_logs": ["PB", "DTW_pc", "RE_pe", "IFA", "VĀ", "SD_T", "SD_A", "FS"],

Start processing

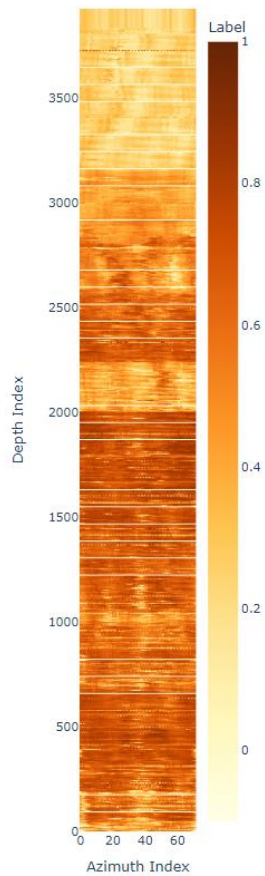
Web application



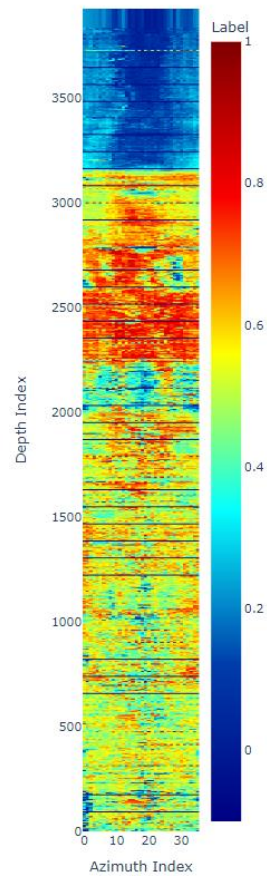
Select logs:

A10_T2_20160107_1

Pulse Echo Ringing Energy



Integral Flexural Attenuation



Estimated time window for clustering:

Start index

20

End index

40

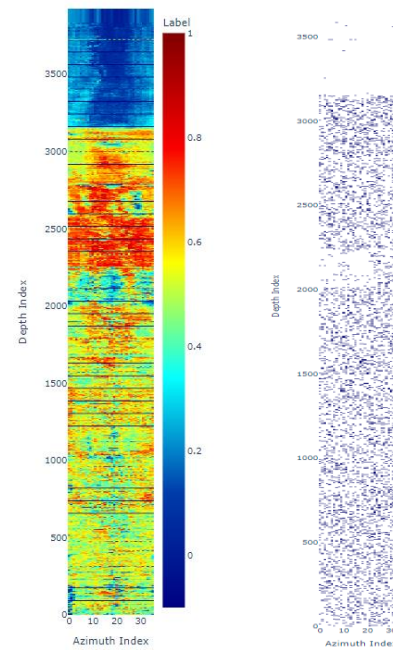
Select data to evaluate

Integral Flexural Attenuation

Select segment to examine:

15

Integral Flexural Attenuation



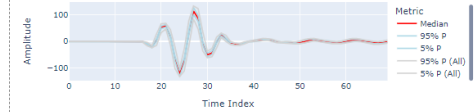
Clicked Data

Click on log plots to view specific waveforms

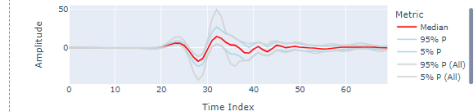
Cluster Metrics

- ☒ Percentiles (+ data overview)
- ☐ Percentiles (Cluster only)
- ☐ Mean & std (Cluster only)

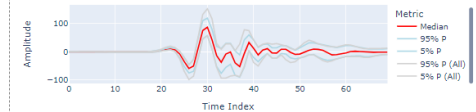
PE (Synced)



PC-F (Synced)



PC-N (Synced)



Start processing