Pipe Deployed Ultrasonic Logging

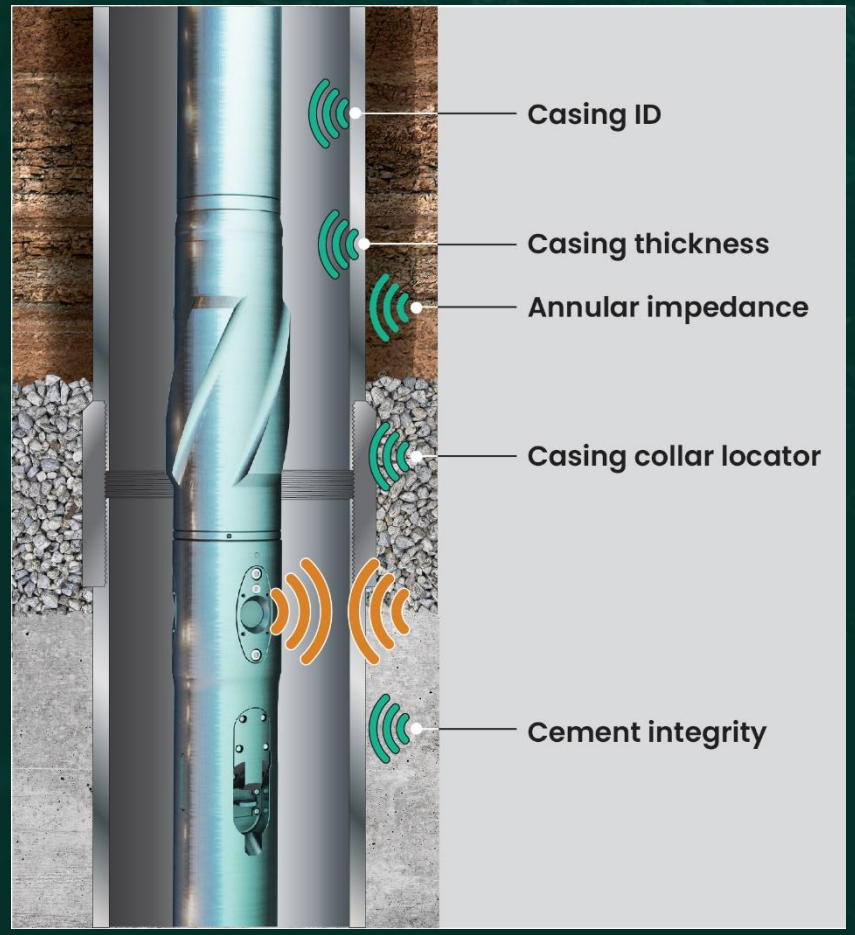
Casing Inspection and Cement Mapping:

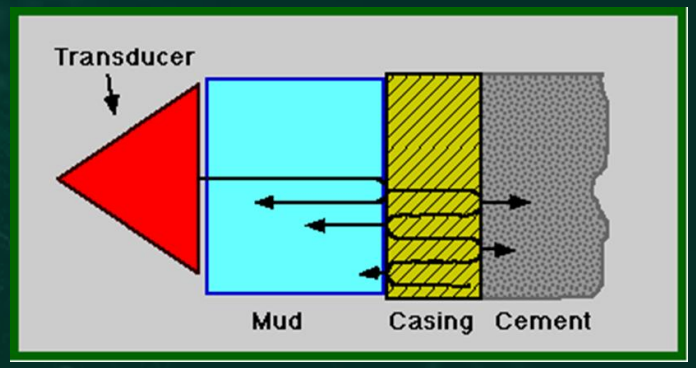
CICM

Øystein Meling

June 11, 2025

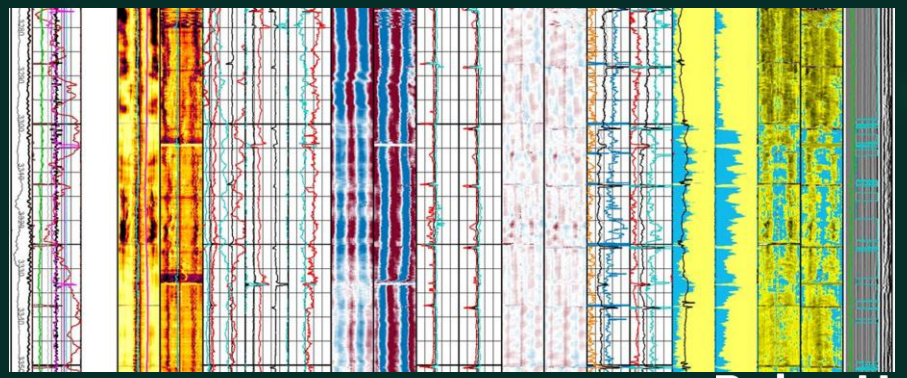
Measurements





Echo Amplitude = Casing Rugosity
Echo Transit Time = Internal Caliper
Waveform Planar model and geometric correction = Casing Thickness and Acoustic Impedance

Amplitude Caliper Thickness Impedance



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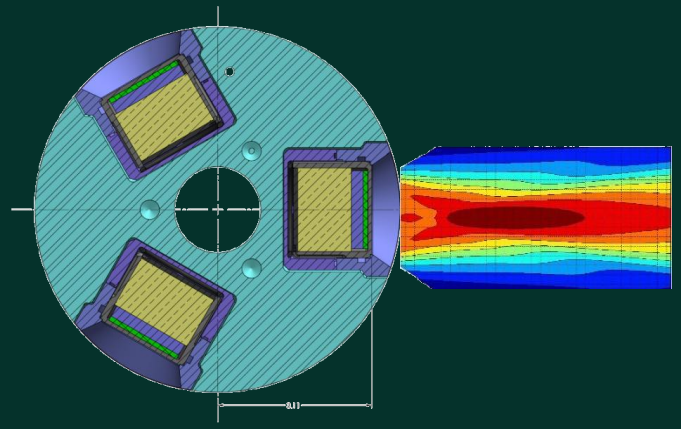
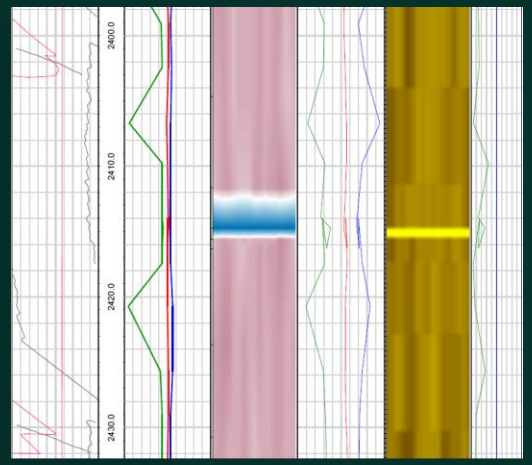
The deliverables

- **Tool Size: 6-3/4 & 9 ½**
- **Casing OD: 9-5/8 → 14**
- **Oil base and water base drilling fluids**
- **150°C, 25,000 psi**
- **Up to 1.64 sg OBM or WBM**
- **Up 0.8 inch csg WT**



Real time curves:

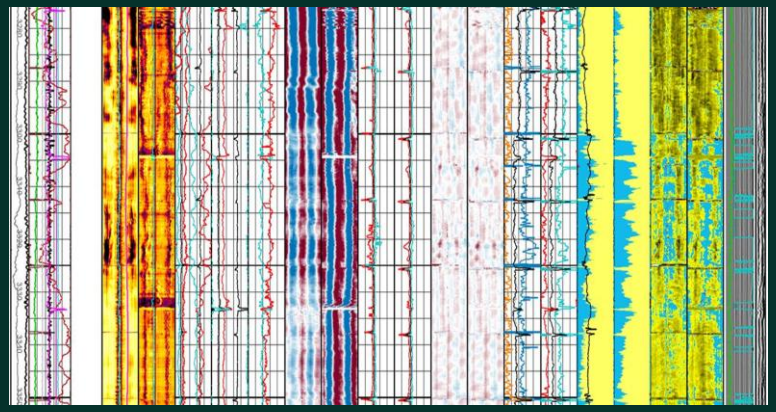
- Amplitude – min, max, average
- Caliper – min, max, average
- Casing thickness – min, max, average
- Annular impedance – min, max, average
  - 16-sector real time image
- Casing collars
- Orientation



Live 16 sector image

Wellsite post processing:

- Field casing integrity and annular impedance images



Recorded Mode Processing

Geoscience post processing:

- Advanced processing for casing integrity and annular impedance

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Applications

The technology gives valuable well integrity measurements across the well lifecycle any time you run pipe downhole. Applications include but are not limited to the following:

Slot recovery/ casing exits

- Evaluate reusability of casing above kickoff point
- Accurately locate casing collars and stabilizers to avoid milling through them
- Identify presence of cement to improve milling performance
- Verify well barriers in real time
- Orient the whipstock

Well abandonment/ Cut and pull

- Obtain casing annular measurements to confirm what is behind the casing and optimize cut location
- Evaluate free pipe
- Avoid multiple cut and pull attempts
- Verify well barriers in real time
- Confirm cement integrity

Additional drilling and completion operations

- Confirm casing integrity and top of cement during drillout
- Confirm cement integrity during liner cementing
- Verify casing cleaning before running in completion equipment
- Optimize downhole isolation placement
- Identify casing eccentricity to orient perforation and cutting to avoid outer casing damage

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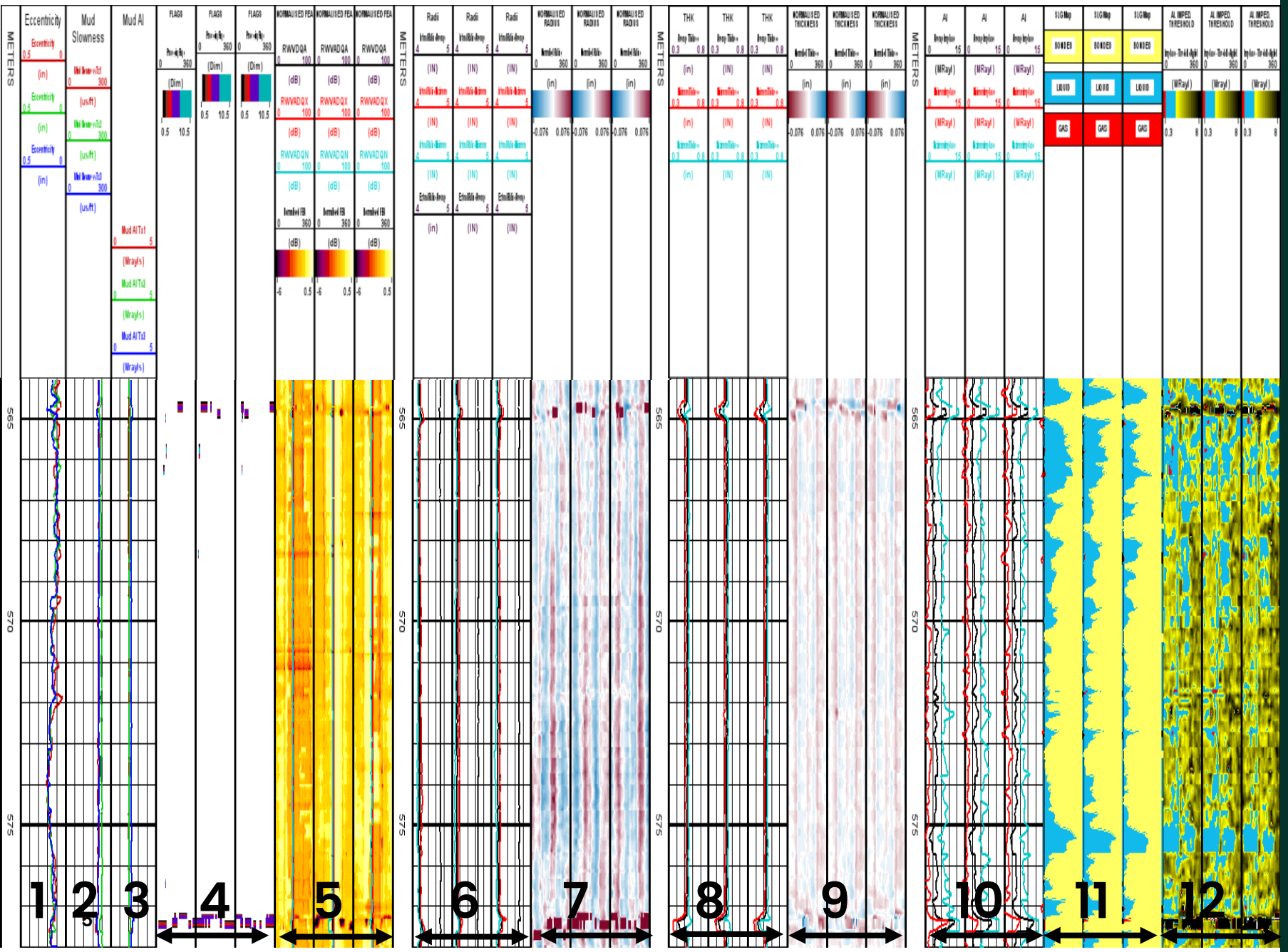

Deliverables

1. Eccentricity for Transducer 1, 2, and 3
2. Borehole Fluid Slowness
3. Borehole Fluid Impedance
4. QC Flags
5. Normalized First Echo Amplitude Map, Amplitude (Min, Max, Av)
6. Internal Radius (Min, Max, Av), External Radius (Av)
7. Normalized Radius Map
8. Thickness (Min, Max, Av)
9. Normalized Thickness Map
10. Acoustic Impedance (Min, Max, Av)
11. Solid/Liquid/Gas Map
12. Impedance Map (cutoffs applied)

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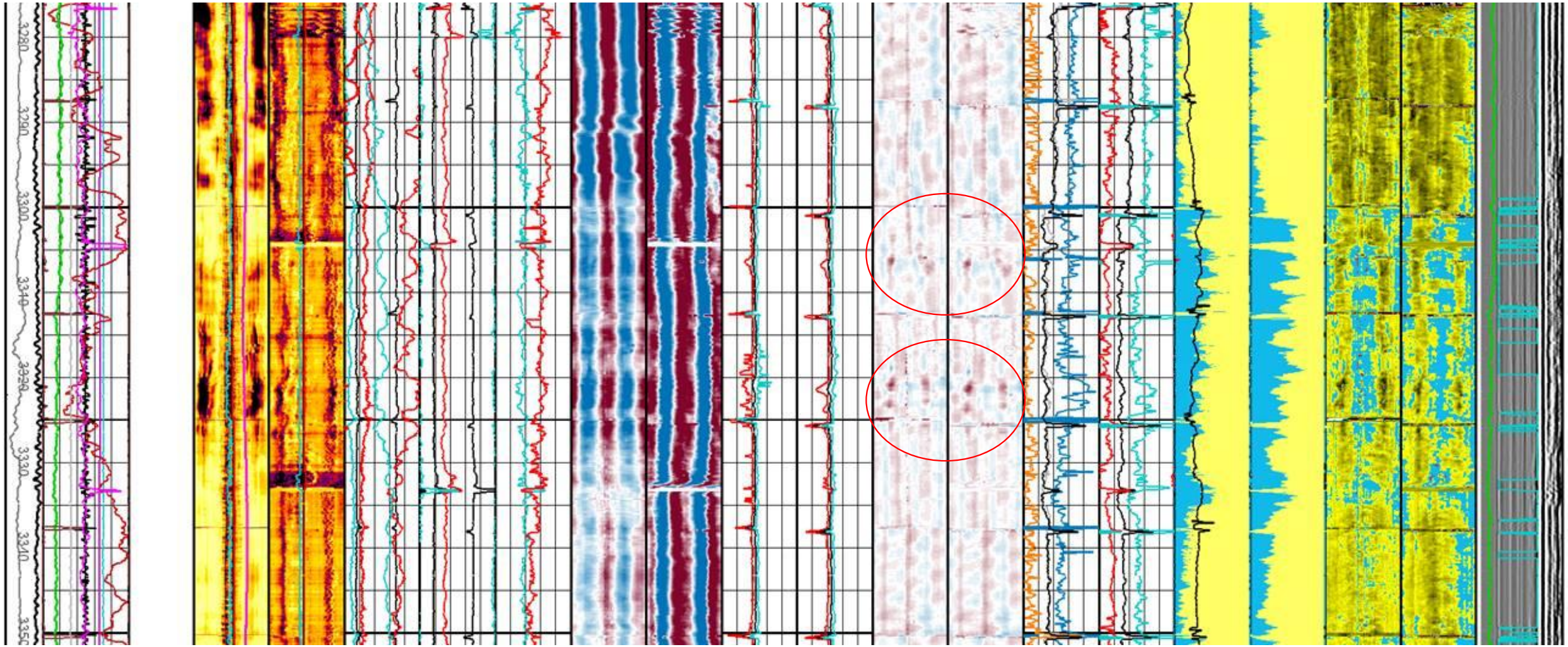
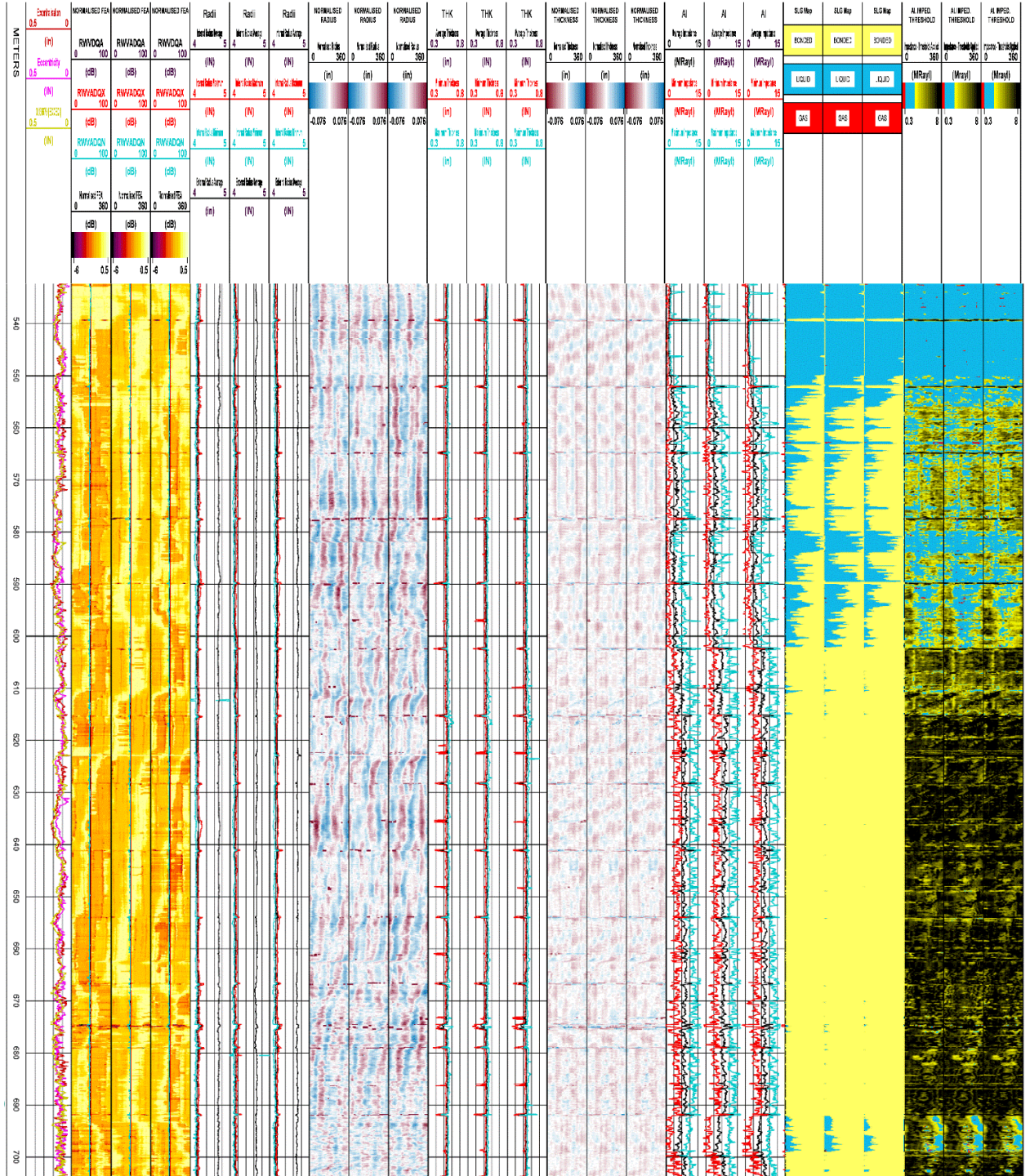
Norway 13 3/8” Wireline Comparison plus Casing Ports



Thickness and AI response Overlays Wireline Comparison

Top (m)	Bottom (m)	Interval Length (m)	Cement Bond Quality	Potential Well Barrier Element (WBE)	Annulus Content	Average Acoustic Impedance (Mrayls)	Analysis Comments
532	550	18	Free Pipe		Liquid	1.12	Section corresponding to an overlap between 13 3/8" casing and 9 5/81" liner. Interval identified as a free pipe with liquid behind the liner and no azimuthal solid presence. Data calibrated at depth 542m to an average acoustic impedance of 1 Mrayls (based on the average acoustic impedance from CAST log at the same depth)
550	602	52	Poor to Partial Cement		Solids / Liquid	3.29	Interval with poor to partial azimuthal solid presence with liquid and patchy cement behind the liner. Bond quality deemed to be poor to partial. This interval is not a potential well barrier element.
602	606.5	4.5	Good Cement	Likely	Solids	6.23	Short interval with high azimuthal solid presence and high acoustic impedance. TOC at depth 602 meters. This interval is likely to be a well barrier element with bond quality deemed to be good.
606.5	615	8.5	Partial Cement		Solids / Liquid	5.40	Interval with partial azimuthal solid presence and some liquid channels / pockets behind the pipe. Bond quality deemed to be partial.
615	692	77	Good Cement	Likely	Solids	7.13	77 meters long interval with high azimuthal solid presence and high acoustic impedance. This interval is likely to be a well barrier element with bond quality deemed to be good
692	700	8	Partial Cement		Solids / Liquid	5.10	Short interval with partial azimuthal solid presence and connected channels/pockets of liquid behind the pipe. Bond quality deemed to be partial. Based on the 9 5/8" tally, there is a completion change corresponding to the reamer shoe joint. This section needs to be processed separately with the corresponding casing inputs
700	702	2	Good Cement	Likely	Solids	6.98	Short interval with high azimuthal solid presence and high acoustic impedance. This interval is likely to be a well barrier element with bond quality deemed to be good
702	704	2	Partial Cement		Solids / Liquid	6.89	Short interval with partial azimuthal solid presence and some isolated liquid pockets. Bond quality deemed to be partial



Track record, NCS/UK

Run #	Date	Customer	Geomarket	Casing OD	Casing Weight	Nom. Thickness	Mud	Mud Weight	Service
1	2020-Mar-02	Test	Test	9 5/8	53.5	0.552	Brine	1.2	Test
2	2020-Apr-28	Test	Test	9 5/8	47	0.481	Brine	1.1	Test
3	2020-Apr-28	Test	Test	9 5/8	47	0.481	Brine	1.1	Test
4	2020-Aug-26	Equinor	Norway	9 5/8	47	0.481	WBM	1.4	Test
5	2020-Oct-08	Equinor	Norway	9 5/8	53.5	0.552	OBM	1.32	CCL RT
6	2020-Nov-28	ConocoPhillips	Norway	13 3/8	72	0.524	WBM	1.78	Test
8	2020-Dec-22	Equinor	Norway	10 3/4	65.7	0.606	WBM	1.2	CCL RT
10	2021-Feb-02	Equinor	Norway	14	114	0.808	WBM	1.2	CCL RT
12	2021-Mar-01	Equinor	Norway	14	114	0.808	WBM	1.5	CCL RT
14	2021-Mar-24	Equinor	Norway	13 3/8	72	0.524	WBM	1.03	Casing Wear
16	2021-Jul-03	Equinor	Norway	10 3/4	60.7	0.557	OBM	1.35	Casing Wear
17	2021-Jul-22	Equinor	Norway	9 5/8	53.5	0.552	OBM	1.35	Casing Wear
19	2021-Dec-04	Equinor	Norway	13 3/8	72	0.524	Brine	1.14	CCL
20	2022-Jan-19	Equinor	Norway	9 7/8	65.1	0.636	OBM	1.4	Settled Barite RT
22	2022-Feb-09	Equinor	Norway	13 3/8	72	0.514	WBM	1.03	Casing Wear
23	2022-Feb-18	Equinor	Norway	10 3/4	65.7	0.595	OBM	1.3	Casing Wear
24	2022-May-11	Aker BP	Norway	9 5/8	53.5	0.545	WBM	1.36	Cement Eval
28	2022-Jul-10	ConocoPhillips	Norway	9 5/8	47	0.481	WBM	1.74	Cement Eval
30	2022-Jul-22	Equinor	Norway	13 3/8	72	0.514	WBM	1.35	Cement Eval
37	2022-Sep-03	Equinor	Norway	14	100	0.8	Brine	1.1	CCL
39	2022-Sep-29	Equinor	Norway	13 3/8	72	0.514	WBM	1.35	Cement Eval
40	2022-Oct-15	Aker BP	Norway	13 3/8	72	0.514	OBM	1.42	Cement Eval
41	2022-Oct-30	Equinor	Norway	10 3/4	60.7	0.545	OBM	1.2	Casing Wear
42	2022-Oct-30	Equinor	Norway	13 5/8	88.2	0.625	WBM	1.12	TOC
43	2022-Oct-31	Equinor	Norway	13 3/8	68	0.48	Brine	1.03	Casing Wear
44	2022-Nov-01	Equinor	Norway	9 5/8	53.5	0.545	OBM	1.32	Casing Wear
49	2022-Dec-10	Equinor	Norway	13 3/8	72	0.514	WBM	1.25	Cement Eval
53	2023-Jan-05	Equinor	Norway	9 5/8	53.5	0.545	OBM	1.07	Casing Wear
54	2023-Jan-19	Equinor	Norway	13 3/8	72	0.514	OBM	1.7	Casing Wear
57	2023-Feb-23	Apache	Norway	9 5/8	53.5	0.545	Brine	1.03	Casing Wear
58	2023-Mar-18	Equinor	Norway	13 5/8	88.2	0.625	Brine	1.2	Casing Wear
59	2023-Apr-08	Aker BP	Norway	13 3/8	72	0.514	OBM	1.4	Cement Eval
62	2023-May-06	Equinor	Norway	9 5/8	53.5	0.545	Brine	1.03	Casing Wear
63	2023-May-29	Aker BP	Norway	9 5/8	53.5	0.545	OBM	1.2	Cement Eval
64	2023-May-29	Aker BP	Norway	13 3/8	72	0.514	OBM	1.2	Cement Eval
70	2023-Sep-22	Equinor	Norway	9 7/8	66.4	0.661	Brine	1.03	Settled Barite
71	2023-Sep-24	Aker BP	Norway	13 5/8	88.2	0.625	OBM	1.35	Cement Eval
72	2023-Oct-18	Aker BP	Norway	10 3/4	60.7	0.545	OBM	1.25	Cement Eval
73	2023-Nov-06	Equinor	Norway	13 3/8	68	0.48	Brine	1.15	Casing Wear
77	2023-Nov-28	BP	UK	9 5/8	53.5	0.545	Brine	1.15	CCL & Cement Eval
80	2023-Dec-10	Equinor	Norway	13 3/8	72	0.514	WBM	1.2	Settled Barite
81	2023-Dec-27	Equinor	UK	13 3/8	72	0.514	Brine	1.06	Casing Wear
82	2023-Dec-27	Equinor	UK	9 5/8	53.5	0.545	Brine	1.06	Casing Wear
83	2024-Jan-02	Aker BP	Norway	9 5/8	47	0.472	WBM	1.72	Cement & Creeping Shale
86	2024-Feb-25	Aker BP	Norway	9 5/8	47	0.472	WBM	1.71	Settled Barite & wear
87	2024-Mar-11	Aker BP	Norway	13 3/8	72	0.514	WBM	1.71	Cement, Barite & Wear
88	2024-Mar-17	TotalEnergies	UK	9 5/8	53.5	0.545	WBM	1	Cement, Barite & Cut & Pull
89	2024-Mar-24	TotalEnergies	UK	9 5/8	53.5	0.545	WBM	1	Cement, Barite & Cut & Pull
90	2024-Mar-24	Equinor	Norway	13 3/8	68	0.48	WBM	1.42	Wear, CCL and Ovality
91	2024-Mar-28	Equinor	Norway	13 3/8	68	0.48	Brine	1.03	Wear, CCL, Corrosion and Ovality
92	2024-Mar-28	Aker BP	Norway	13 3/8	72	0.514	OBM	1.3	Cement Eval
93	2024-Apr-18	Aker BP	Norway	9 5/8	53.5	0.545	OBM	1.2	Cement Eval
94	2024-Apr-18	ConocoPhillips	Norway	13 5/8	88.2	0.625	OBM	1.7	Cement Eval & Wear
95	2024-Apr-22	Neptune Energy	Norway	9 5/8	53.5	0.545	OBM	1.22	Cement Eval
96	2024-Apr-24	Equinor	Norway	13 3/8	72	0.514	Brine	1.28	Wear and Ovality
97	2024-Apr-27	Aker BP	Norway	9 5/8	53.5	0.543	WBM	1.71	Cement Eval & Wear
98	2024-May-04	Aker BP	Norway	13 3/8	72	0.514	WBM	1.71	Cement Eval, Creeping Formation, Settled Barite & CC
99	2024-May-07	Aker BP	Norway	9 5/8	53.5	0.545	Brine	1.14	Cement Eval & Wear
100	2024-May-15	Equinor	Norway	9 5/8	53.5	0.545	OBM	1.3	Cement Eval & CCL
102	2024-May-20	Aker BP	Norway	11 3/4	65	0.534	WBM	1.71	Formation Creep
103	2024-Jun-06	Equinor	UK	13 3/8	72	0.514	Brine	1.06	Cement Eval & Wear
105	2024-Jun-23	Aker BP	Norway	13 3/8	72	0.514	WBM	1.72	Cement Eval
106	2024-Jun-26	Equinor	Norway	10	73.9	0.732	WBM	1.68	Cement Eval, Gas, Formation Creep & CCL
107	2024-Jun-27	Shell	UK	9 7/8	66.9	0.668	Brine	1	AI/Solids, wear & CCL
108	2024-Jul-21	Equinor	Norway	13 3/8	72	0.514	OBM	1.45	Wear, CCL and Ovality
109	2024-Jul-24	Equinor	Norway	9 5/8	47	0.472	WBM	1.27	Wear, Settled Barite and Shallow Gas
110	2024-Jul-30	OMV	Norway	9 5/8	53.5	0.545	OBM	1.28	TOC, Cement - Real Time Image
112	2024-Aug-10	Equinor	Norway	13 3/8	68	0.48	WBM	1.5	Cement, wear & corrosion
113	2024-Aug-11	Equinor	Norway	9 5/8	53.5	0.545	Brine	1.07	Cement, AI, wear, CCL & ovality
114	2024-Aug-13	Equinor	Norway	13 5/8	88.2	0.625	Brine	1.13	Cement, AI, wear, CCL & ovality
115	2024-Aug-16	Aker BP	Norway	13 5/8	88.2	0.625	OBM	1.58	Cement Eval
116	2024-Aug-22	BP UK	UK	13 3/8	72	0.514	Brine	1.08	Cement Eval
117	2024-Aug-22	Aker BP	Norway	9 7/8	66.4	0.661	OBM	1.53	Cement Eval
118	2024-Aug-28	Aker BP	Norway	9 7/8	66.4	0.661	OBM	1.17	Cement Eval
119	2024-Aug-30	Equinor	Norway	9 5/8	53.5	0.545	Brine	1.06	Wear and CCL
120	2024-Oct-10	Aker BP	Norway	13 5/8	88.2	0.625	OBM	1.54	Cement Eval
121	2024-Oct-11	Equinor	Norway	10 3/4	60.7	0.545	WBM	1.15	AI/Solids with real time image
122	2024-Oct-16	Harbour Energy	Norway	9 5/8	53.5	0.545	Brine	1.25	Cement Eval
124	2025-Jan-17	Equinor	Norway	13 3/8	68	0.48	Brine	1.03	Wear, CCL, Centralizers, Ovality & Cement Indication
125	2025-Jan-17	Equinor	Norway	13 3/8	72	0.514	OBM	1.3	Wear
126	2025-Jan-17	Equinor	Norway	13 3/8	72	0.514	OBM	1.3	Wear
127	2025-Jan-17	Aker BP	Norway	13 5/8	88.2	0.625	OBM	1.78	Cement Eval
128	2025-Jan-29	Equinor	Norway	10 3/4	60.7	0.545	OBM	1.58	Casing Wear
129	2025-Feb-03	Vår Energi	Norway	9 5/8	53.5	0.545	DW	1	Cement Eval
131	2025-Feb-15	Equinor	Norway	13 5/8	88.2	0.625	Brine	1.13	Verify Cement
132	2025-Feb-28	Vår Energi	Norway	13 3/8	72	0.514	OBM	1.45	Cement Eval
134	2025-Mar-19	Vår Energi	Norway	9 5/8	53.5	0.545	OBM	1.1	Cement Eval
135	2025-Mar-24	Vår Energi	Norway	9 5/8	53.5	0.545	OBM	1.1	Cement Eval
136	2025-Apr-05	Equinor	Norway	10 3/4	60.7	0.545	OBM	1.18	Wear
137	2025-Apr-06	Equinor	Norway	9 5/8	53.5	0.545	OBM	1.18	Wear
138	2025-Apr-13	Harbour Energy	Norway	9 7/8	66.7	0.661	OBM	1.26	Cement Eval
139	2025-Apr-16	Equinor	Norway	13 3/8	72	0.514	WBM	1.2	CCL & AI for settled barite

Aker BP's Hod P&A Campaign, DP conveyed logging scope executed

- A-1 Logging 13 3/8 in the section milled window of 9 5/8
- A-2 Logging 9 5/8 and 13 3/8
- A-4 Logging 9 5/8
- A-5 Logging 13 3/8 and 9 5/8
- A-7 Logging 11 3/4

Highlights

- World's first logging **inside section milled window**
- Logged casing after having milled 134 m of tbg on the same run
- 6-12 hours of rig time saved per section

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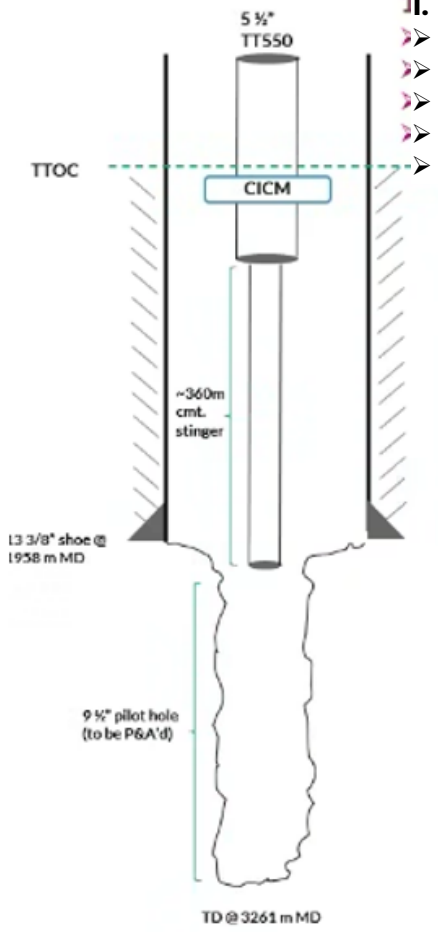
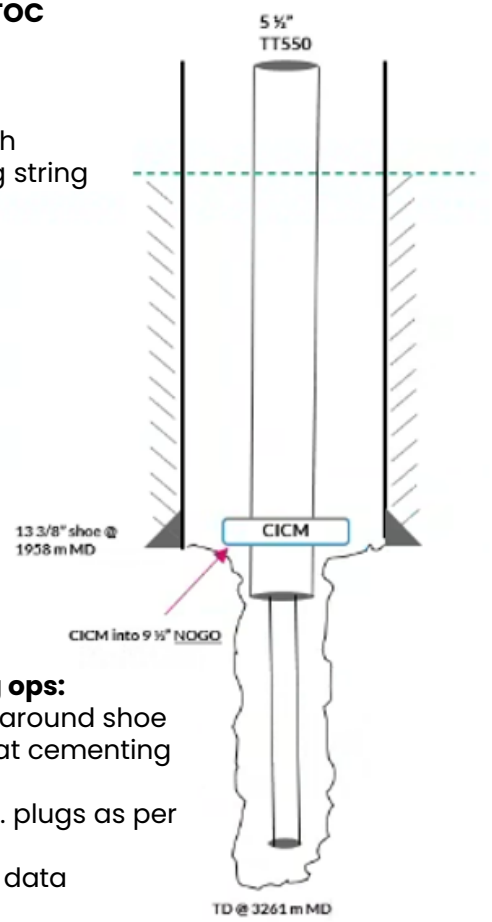
Piggy backed on cement stinger

Logging 13 3/8" in memory mode

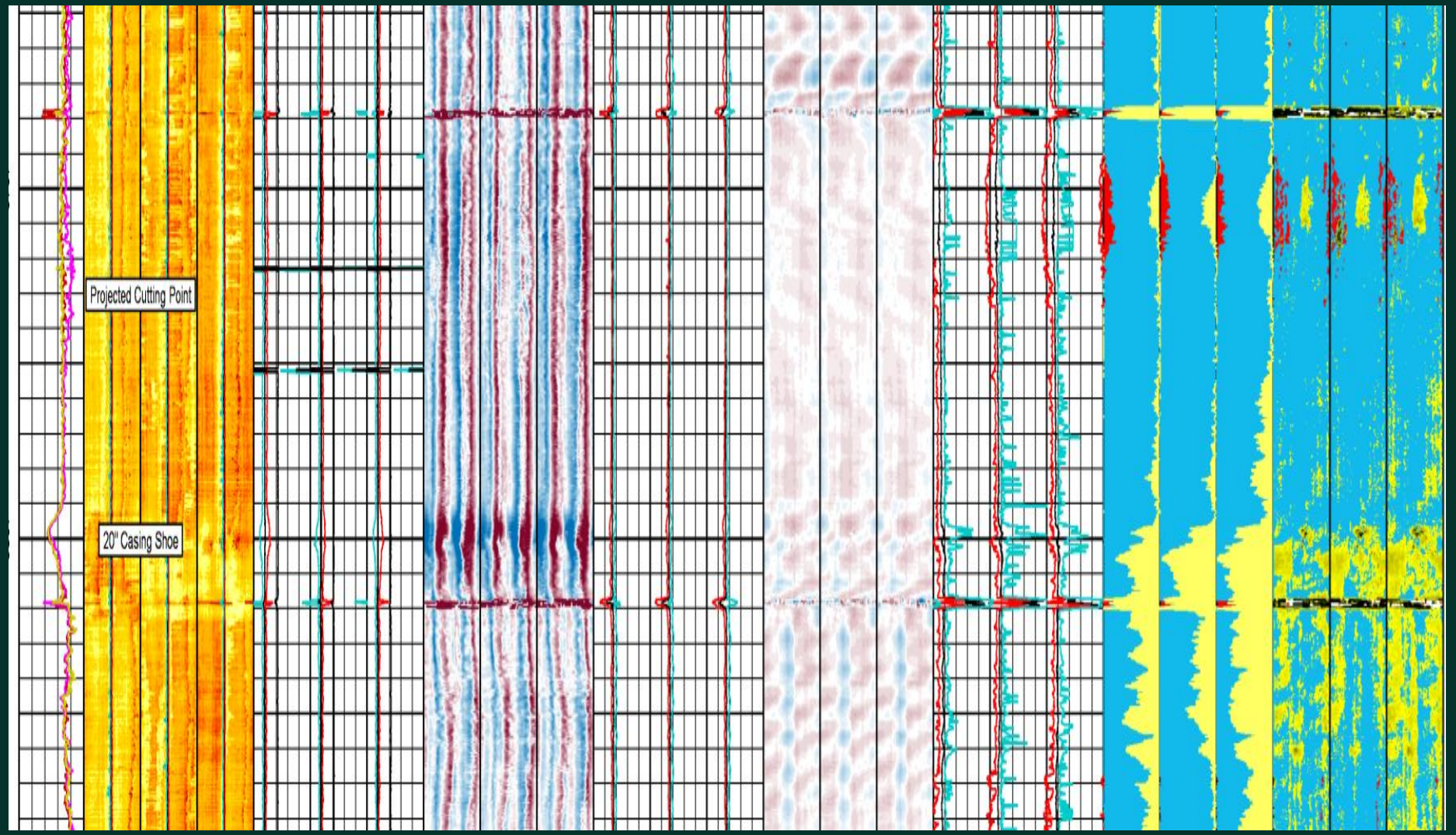


1. **Log on the way in from above TTOC**
   - 800 m/hr
   - 60 RPM
   - 800 lpm flow
   - Start/Stop logging at same depth
   - Obtain RPM at bit prior to moving string



2. **Commence cementing ops:**
   - CICM spaced out to be around shoe when stinger bit depth at cementing TD
   - Set 4x Wet-on-Wet cmt. plugs as per plan
   - POOH & dump memory data

Cut and pull strategy for 13 3/8” csg



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CASE STUDY: Offshore Norway

Real Time Logging 10 ¾" casing using CICM - saving 24 hr. rig time

CHALLENGES

- Challenged by customer to reduce time for P&A operations
- Avoid multiple cut & pull attempts on 10 ¾" casing
- Real Time Telemetry Image to prove capability for one trip logging, cut & pull
- Reduce carbon footprint, POB, deck spread, and transport needs
- Reduce critical path time associated with WL logging operations

SOLUTION

- Development of CICM opens opportunities for performing more efficient logging operations through:
  - Combining logging runs with planned operations on drill pipe
  - Dual Frequency Transducers (2 x 250 kHz and 1 x 350 kHz)
  - Realtime 16 x 16 Image resolution or reduce 12 x 16 image for both Thickness and Acoustic Impedance
  - Minimize deck spread: 1 basket
- Remote operations reduced requirement of offshore personnel to TS and rig crew
- No red zone activity required

CICM: Casing Inspection and Cement Mapping Tool

RESULTS

- Successful surface decoding for both Thickness and Acoustic Impedance Image.
- Well site log and full waveform logs delivered.
- CICM logging provided strong indication for top of settled barite at expected depth.
- No personnel sent to the rig; Operation performed fully remote.
- Saved 24 h of rig time.
- Piggybacked on clean out BHA.
- Positive world first trial of CICM 16 x 16 Realtime image proving the potential for more complex and efficient P&A operations

LEARNINGS

- Free pipe logging before main pass logging for readings calibration
- Software stability improvements for 16 x 16 image due to decoding issues

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CASE STUDY: Offshore Norway

Cased hole logging for wear and cement on drillpipe using CICM, saving 38 hours of rig time.

CHALLENGES

- Eliminate the need for red zone WL rigging
- Reduce POB
- Reduce carbon footprint, deck spread, and transport needs
- Challenged by customer to reduce time spent drilling and completing the wells
- Reduce critical path time associated with WL logging operations

SOLUTION

- Development of a drill pipe conveyed ultras sonic logging tool (CICM) opens opportunities for performing more efficient logging operations thru:
  - Combining logging runs with planned operations on drill pipe
  - Remote operation for IWS rigs
  - Lower carbon footprint
  - Lower deck spread
- Remote operations reduced requirement of offshore personnel down to TS and rig crew, i.e., level 3 IO, a reduction of 4-6 persons
- No red zone activity required

CICM: Casing Inspection and Cement Mapping Tool

RESULTS

- Performed cased hole logging on drillpipe for both 9 5/8 and 13 3/8 csg
- Well site log and full waveform logs delivered
- CICM logs confirmed casing thickness, as well as cement presence in the annulus.
- No personnel sent to the rig; Operation supported from Beacon center
- Saved 38 h of rig time vs conventional logging for the 2 sections
  - 13 5/8" – 14hrs
  - 9 5/8" - 24 hrs
- Piggybacked on the cleanout BHAs

LEARNINGS

- Setting of timer delay to based on absolute best case scenario

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Casing Integrity and Cement Mapping Tool reduces rig time by 42%

CHALLENGES

Aker BP was looking to further increase their operational efficiency:

- Eliminate red zone for wireline rigging and minimize personnel on board (POB)
- Reduce carbon footprint, deck spread, and transportation requirements
- Minimize time spent on drilling, well completion, and critical path activities associated with wireline logging operations
- Ensure tool can withstand withstand the forces from drilling a 12 ¼ section and integrate with a 12 ¼ in. drilling BHA
- Enable effective logging to 13 3/8 in 1.58 sg OB

SOLUTION

Baker Hughes designed and deployed a 9½ in. version of the drill pipe conveyed ultra sonic logging tool (CICM) to:

- Combine logging runs with planed operations on drill pipe, reducing operational downtime
- Reduce deck spread and lower carbon footprint
- Reduce POB to two persons
- Enhance safety by eliminating red zone activity
- Provide operational efficiency piggybacking on a 12 ½ drilling BHA, drilling a 1300m section

RESULTS

- Saved 7 hours/42% of rig time vs conventional wireline logging
- Performed cased hole logging on 12 ¼ in. section drill pipe before and after drilling
- Confirmed qualification of the cement job with the CICM logs

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Conclusion

HSE

- No work in red zone required

Savings

- Time saving up to 24 h per section; No WL rigging/running
- Significant CO2 reduction.
- POB reduction of up to 7 personnel, OI level 3 for IWS rigs performed
- Low deck spread and transport requirements.

Applications

- Cement & settled barite evaluation , csg wear and CCL applications, cut & pull strategy, etc.
- Multiple combination runs possible on planned DP runs.
- Live (Mud pulse, 16 sector image) or memory applications.

Experience

- 80+ commercial runs in the North Sea
- Log quality at the level of existing WL deployed alternatives
- 108 deg deviation logging job performed
- P&A, new drill, and slot rec experience