FORGE
Post Hydraulic Fracturing Wells 16A & 16B
April 2024 Circulation Testing

Neubrex Fiber Optics Monitoring on 16B Shell UT Cable

Acquisition Date: April 2023

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During field operations, Neubrex worked with many operational experts and received critical assistance from many people, including John McLennan, Joseph Moore, Kevin England, Leroy Swearingen, Alan Reynolds, Garth Larson, Monty Keown, Dr. Mukul Sharma, Ben Dyer, Dr. Peter Meir, and Neubrex Ops Chief Wayne Fishback. The frac, drilling, water management crews and HSE managers were instrumental in getting the surface and downhole work accomplished in a safe and effective manner.

FORGE April 2024 Circulation Key Findings

Distributed fiber optic sensing was used in the 16B as a monitor well during Hydraulic Fracturing of 16A and 16B and during a limited duration post frac circulation test in 16B.

RFS DSS and DTS measurements were made on the Single Mode Fiber #2 and Multimode fiber in the Shell UT Cable of 16B during all operational phases in April 2024.

Circulation tests were monitored with RFS DSS and DTS interrogators and provided useful information about fluid flow from the 16A injector and across to the 16B producer well. The method relies on thermal changes along fiber.

Key Findings

- Benefit from integrating the cross-well strain change data (RFS DSS) from Hydraulic Fracturing periods with the Strain and Temperature data from 9-hour Circulation period. This work supports integrated understanding.

- Perforation depths that were created during the 16B frac are annotated on the circulation test plots and are examined in detail for evidence of fluid inflow and / or temperature change associated with inflow of geothermally heated water from the 16A well injection perforations.

- In 16B, there is an open hole section below the toe of the casing string and 5 stages with 20 total perforation clusters open during the circulation test. The connectivity of these clusters into the reservoir and potential conductivity with well 16A was unknown at time of circulation.

Key Findings

- 16B stage 1 perf cluster depths are associated with hydraulic fractures detected from fracture driven interactions detected on fiber from 16A stages 3R, 4, 5 and 6
  - There is clear evidence of fluid inflow and slugging up the 16B wellbore from this region.
  - A clear region of thermal change is interpreted from hydraulic fracture zones during the circulation period.

- 16B stage 2 perf clusters depths are associated with fracture driven interactions from 16A Stage7.
  - The upper heelward 3 clusters of the 5-cluster stage show strong thermal response during circulation period. Some thermal slugging can be seen to originate from all 5 clusters.

- 16B stage 3 perf clusters are in the region associated with the 16A stage 8 Fracture Driven Interactions during that hydraulic fracturing stage.
  - The lower toeward (bottom) two clusters in this stage show weak thermal response. The upper 3 clusters in this stage show strong and dominant thermal driven strain change response with both slugging and discrete heat signatures.

Key Findings

- <u>16B stage 4 </u>clusters are from the upper part of the 16A Stage 8 Hydraulic Fracture.
  - The fiber responses show strong thermal slugging with both fast and slow slugging velocities up the wellbore of 16B during circulation testing. This set of 16B clusters has a lot of strong evidence of thermal fluid input and travel up the wellbore.

- <u>16B stage 5 </u>clusters were only perforated and were not “stimulated” during the 16B frac period. Their position was designed based on 16A to 16B Fracture Driven Interactions.
  - This is different than all the other 16B frac stages.
  - These clusters show the best evidence of thermal slug presence and travel up the 16B well during the circulation test period.

Key Assessments about Post Frac Circulation Test

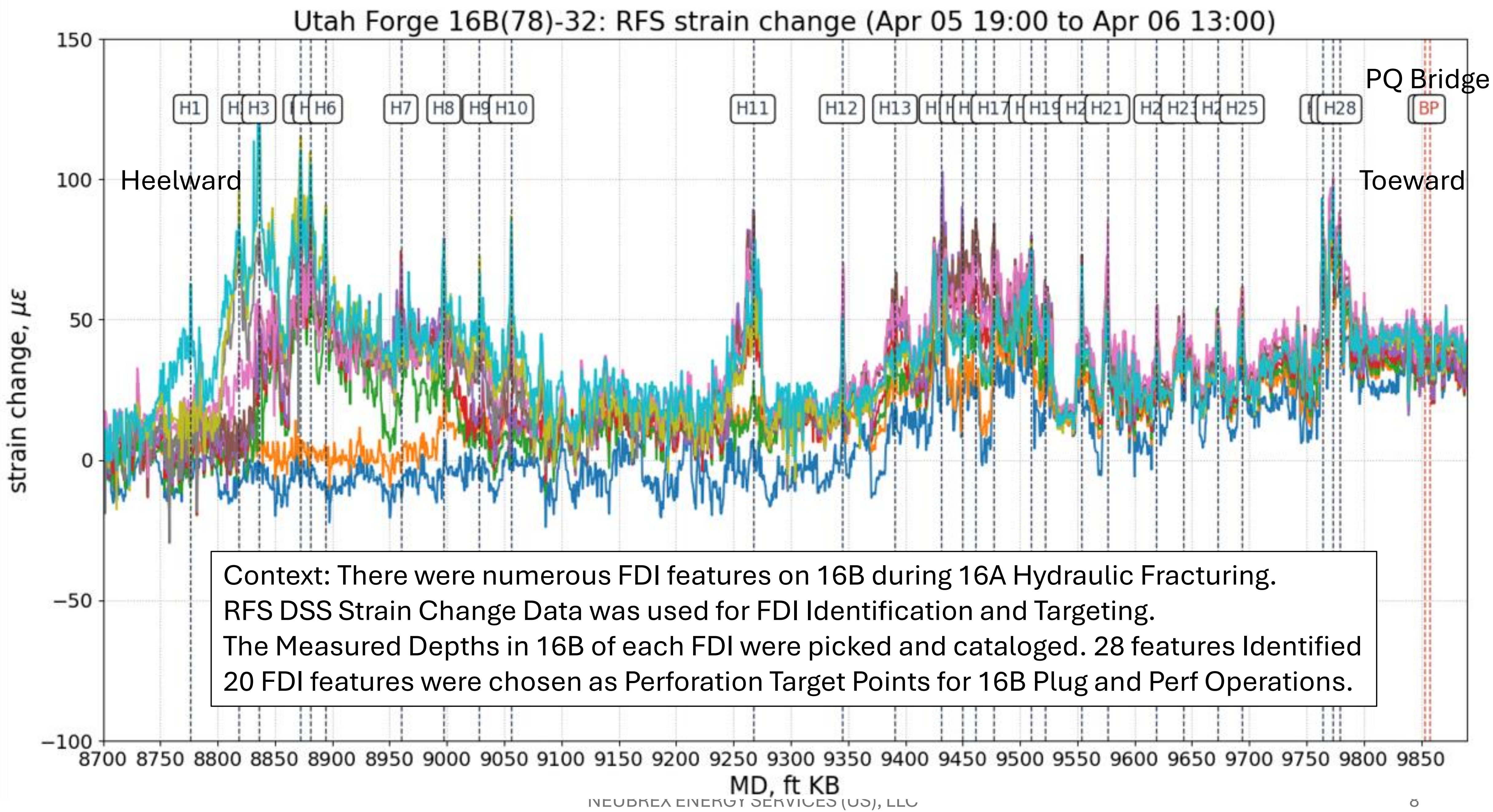
- Both RFS DSS strain and DTS temperature signals from 16B fibers are responding to thermally driven fluid in and around the 16B well and fluid entering the 16B at perf locations.

- Evidence shows clear association between the location of hydraulic fractures generated from the 16A frac process, the 16B frac process and the location of inflowing fluid driven temperature change signals.
    - The assumption is made that the RFS DSS signals are not dominated by mechanical strain change behind pipe during circulation period. If the fiber response on the SMF#2 and MMF are driven by thermal changes, then these data are evidence of hot fluids through the reservoir, into the near wellbore regions, through the perforations and moving up 16B casing to the surface.

- After 16A pumping was stopped there is a cool back period on 16B that also contains important information about which zones produced the most heated fluid, and these discrete signatures are also useful indicators of which fractures are most productive in terms of conductive fractures and inflow allocation.

- Fiber optic RFS DSS and DTS can be further used in combination with DAS data that was also acquired during this period in attempts to produce quantitative estimates of relative inflow contribution per clusters from all open clusters in the 16B well during the circulation test period.

(The integration of DAS data to support analysis of “relative fluid inflow production and relative allocation” is not yet completed at time of reporting.)

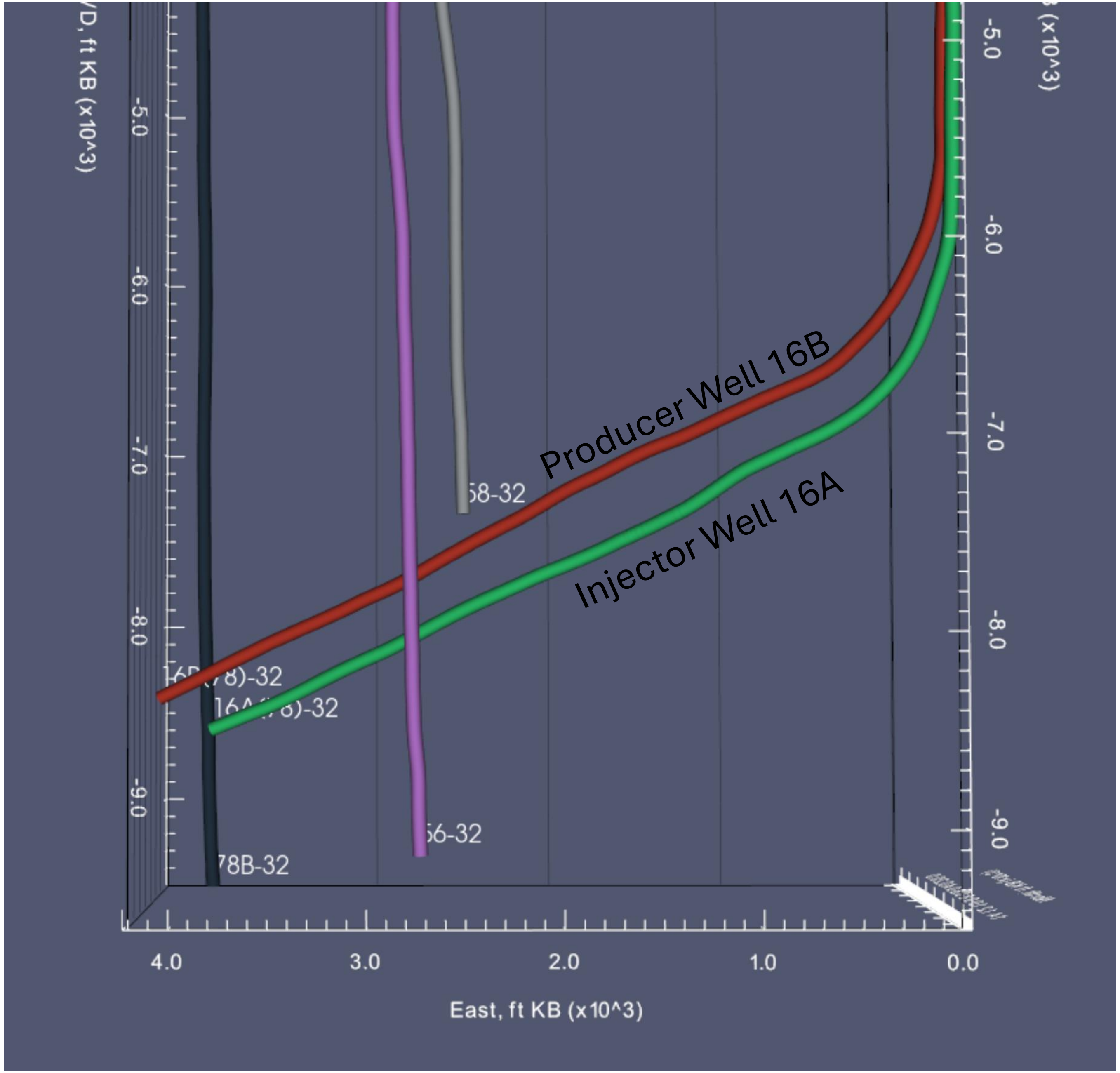


Context: There were numerous FDI features on 16B during 16A Hydraulic Fracturing.
RFS DSS Strain Change Data was used for FDI Identification and Targeting.
The Measured Depths in 16B of each FDI were picked and cataloged. 28 features Identified
20 FDI features were chosen as Perforation Target Points for 16B Plug and Perf Operations.

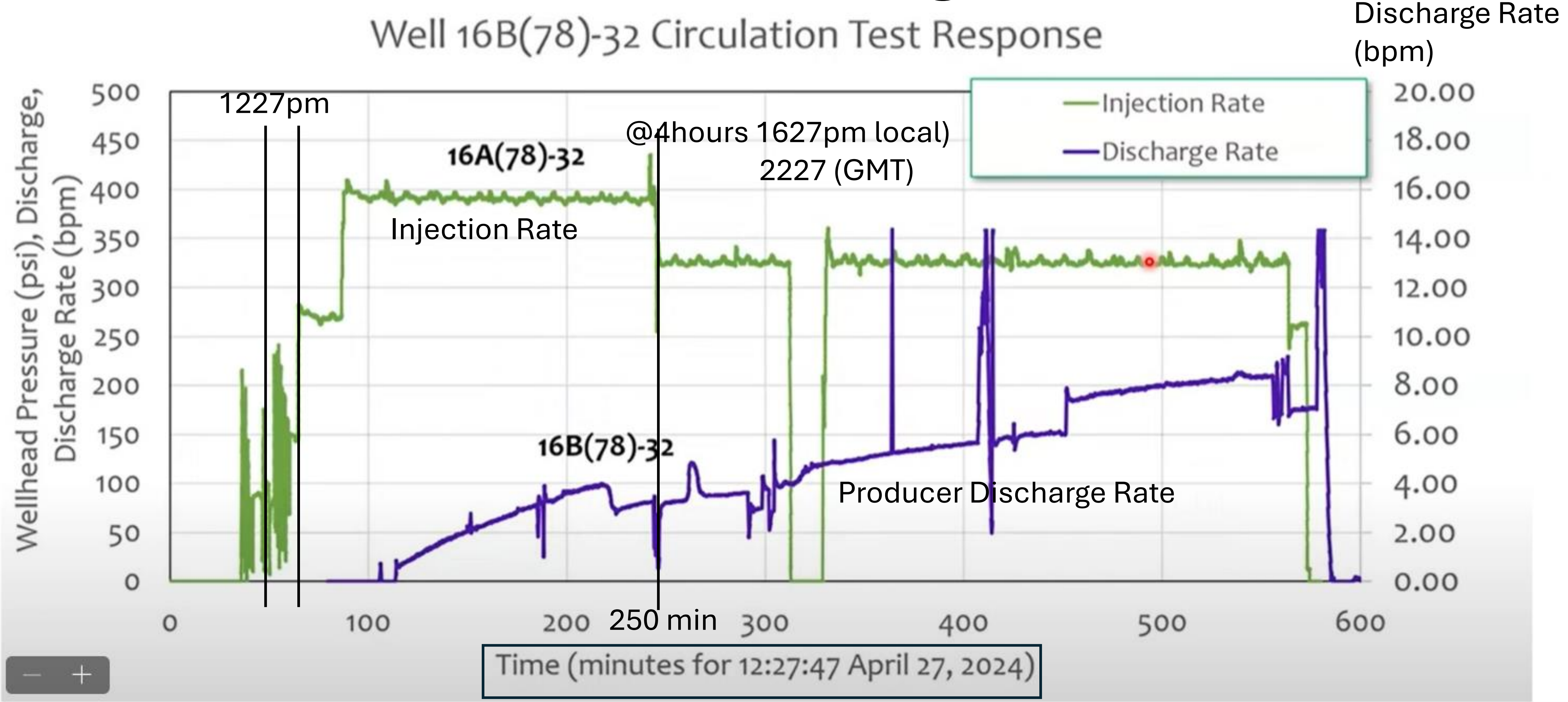
	Measured Depth (Referenced to KB = 31.5 ft)					
	Gun 1	Gun 2	Gun 3	Gun 4	Gun 5	Frac Plug Top
Frac Plug #1						9,777
Stage 1 (16B)	9,769 - 9,773	9,756 - 9,760	9,745 - 9,749	9,690 - 9,694		
Frac Plug #2						9,600
Stage 2 (16B)	9,508 - 9,512	9,475 - 9,479	9,459 - 9,463	9,447 - 9,451	9,429 - 9,433	
Frac Plug #3						9,415
Stage 3 (16B)	9,389 - 9,393	9,343 - 9,347	9,265 - 9,269			
Frac Plug #4						9,165
Stage 4 (16B)	9,054 - 9,058	9,026 - 9,030	8,995 - 8,999	8,958 - 8,962		
Frac Plug #5						~~8,915~~
Stage 5 (16B)	8,879 - 8,883	8,870 - 8,874	8,834 - 8,838	8,774 - 8,778		

20 FDI features were chosen as Perforation Points for 16B Plug and Perf Operations.
This is the table of Stage Plug and Perf Settings used in the 16B Hydraulic Frac Operation.

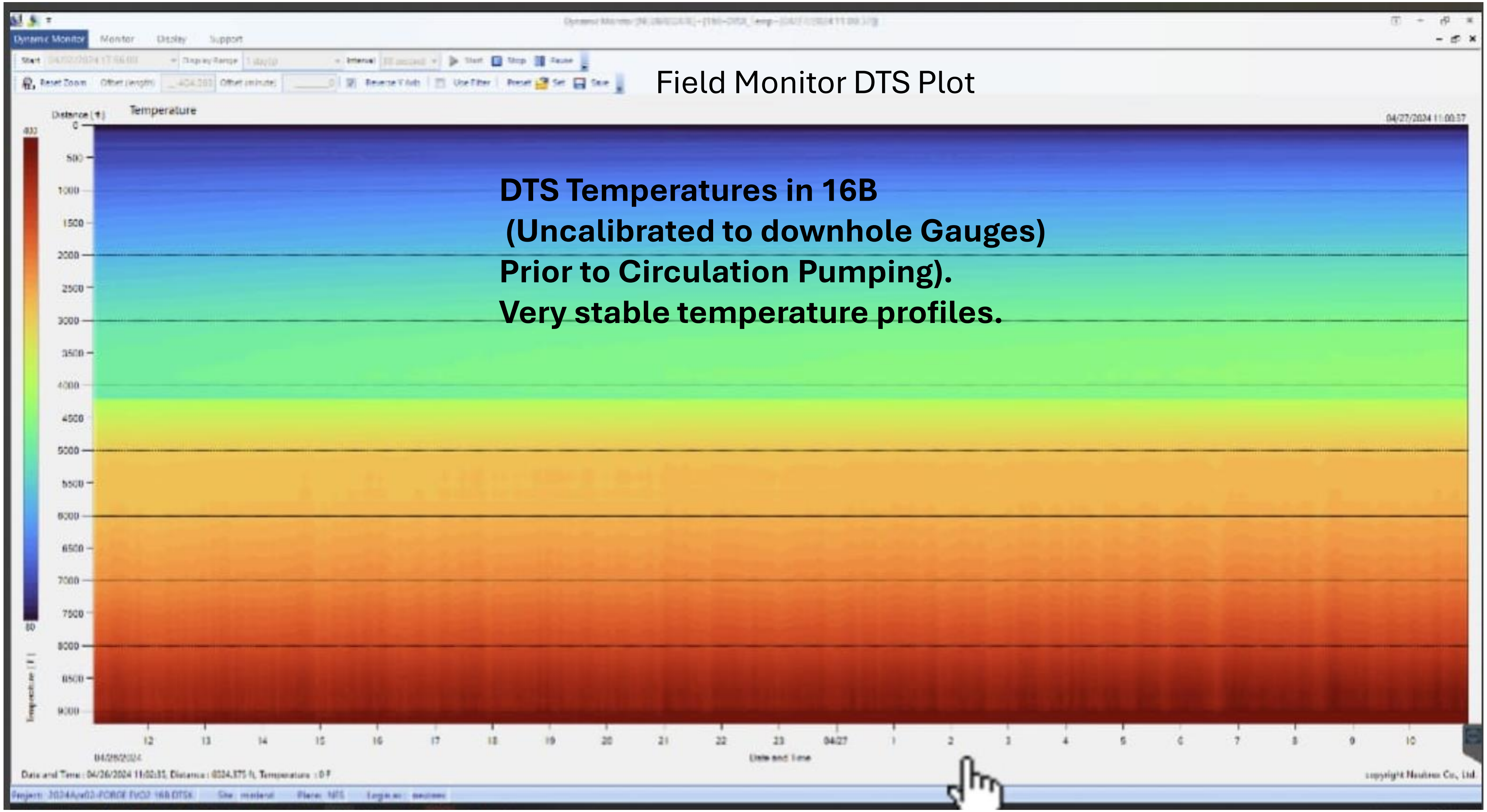
UTAH FORGE Wellbore Trajectory Diagram



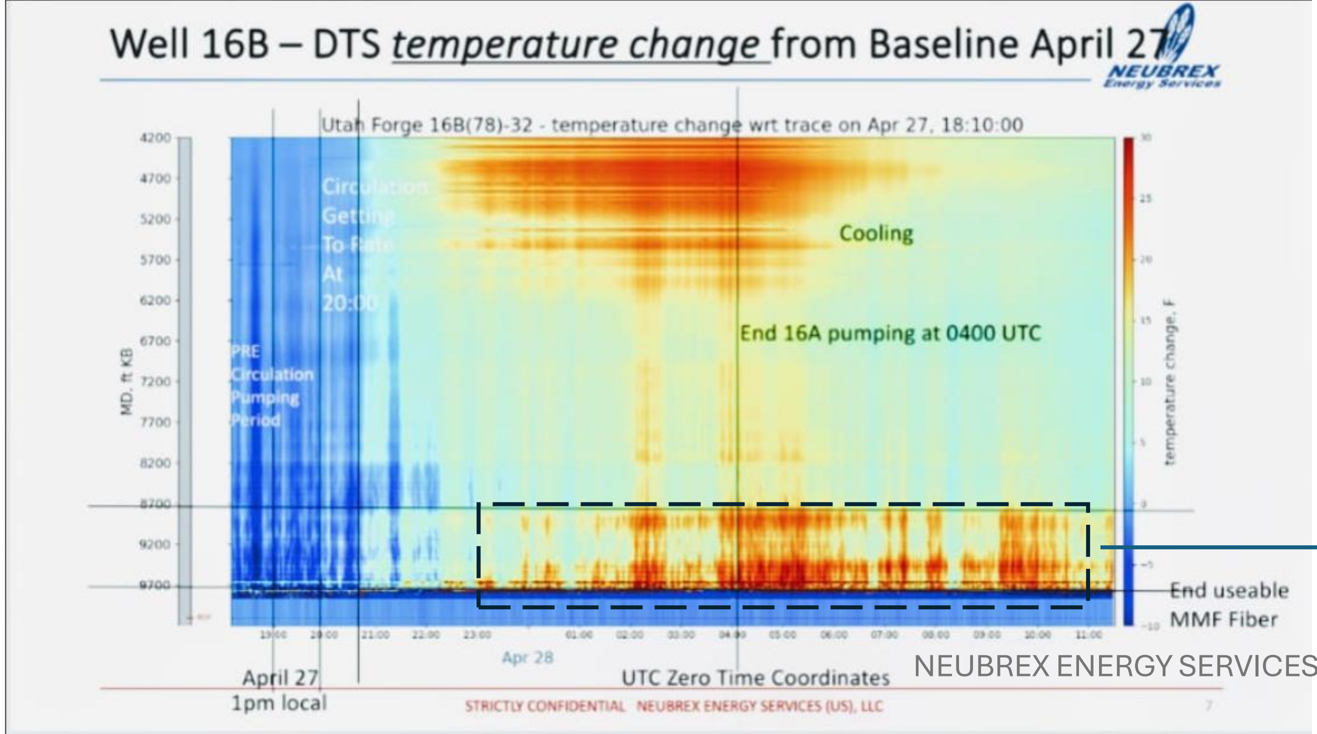
Well 16A Circulation Pumping Rate & Well 16B Discharge Rate

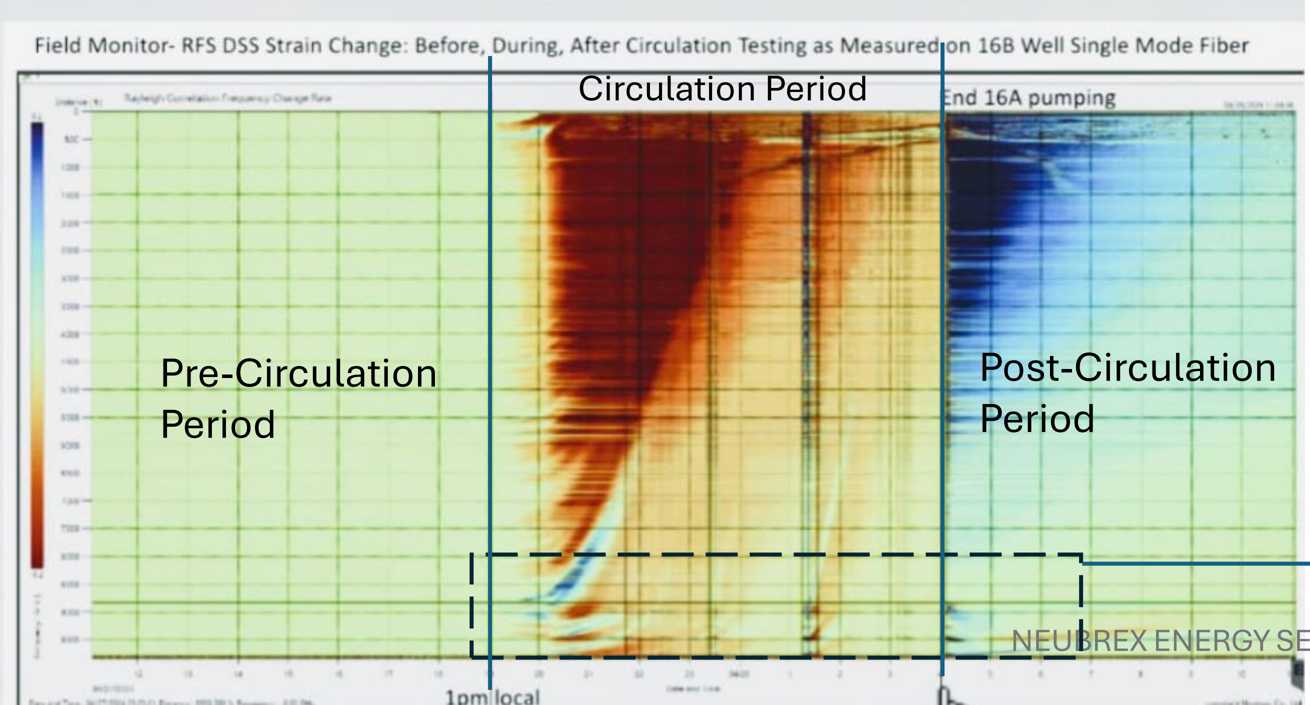


Field Monitor DTS Plot



DTS Temperatures in 16B
(Uncalibrated to downhole Gauges)
Prior to Circulation Pumping).
Very stable temperature profiles.





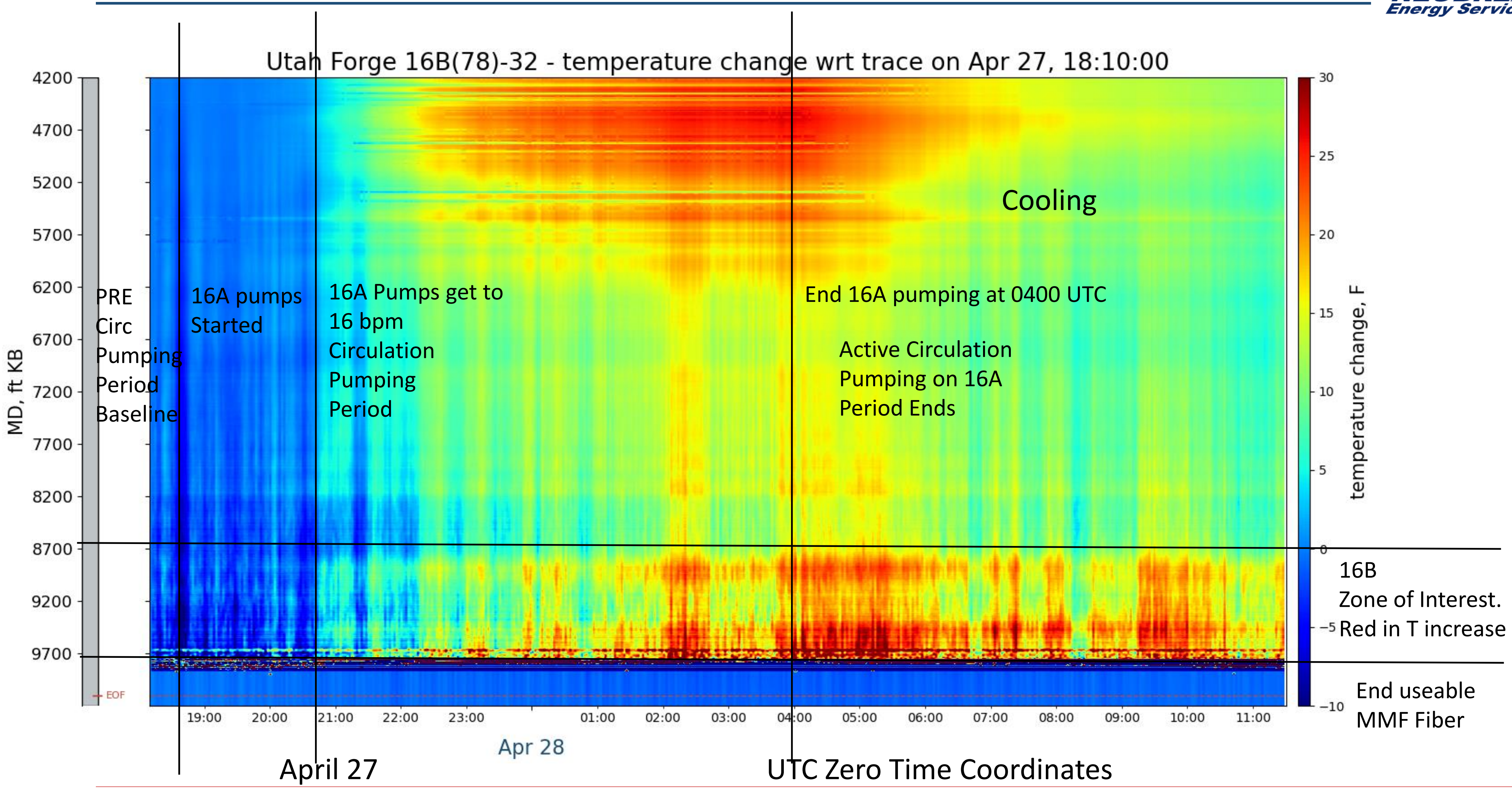
Fiber DTS Temperature Change.
From the April 27, 2024, Circulation Test Period.

Hydraulic fracture zones generated
From 16A cross well fractures and the 16B
hydraulic fracturing stages.

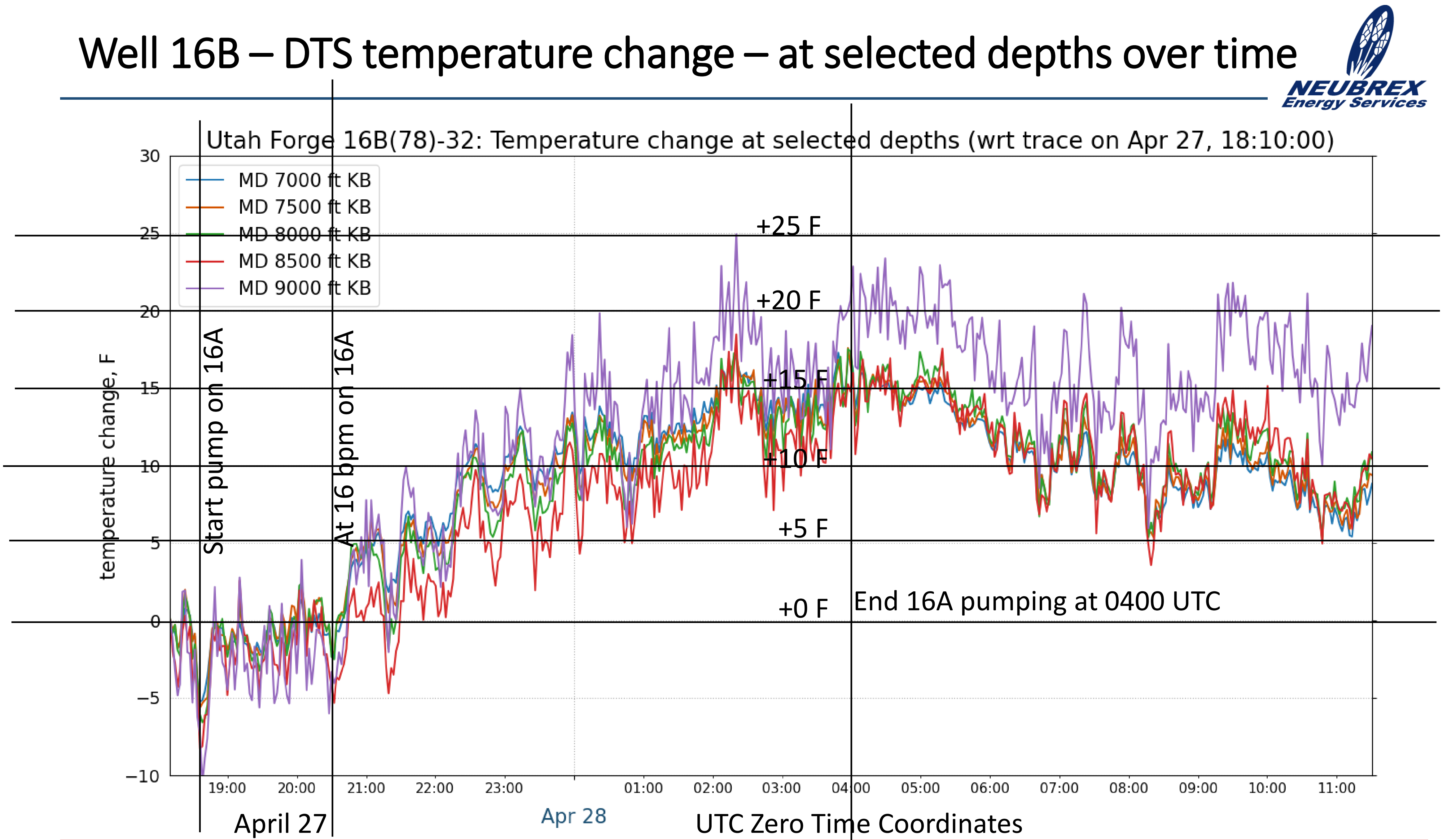
Fiber RFS DSS Strain Change.
From the April 27, 2024, Circulation Test Period.

Hydraulic fracture zone generated
From 16A cross well fractures and the 16B
In well hydraulic fracturing stages.

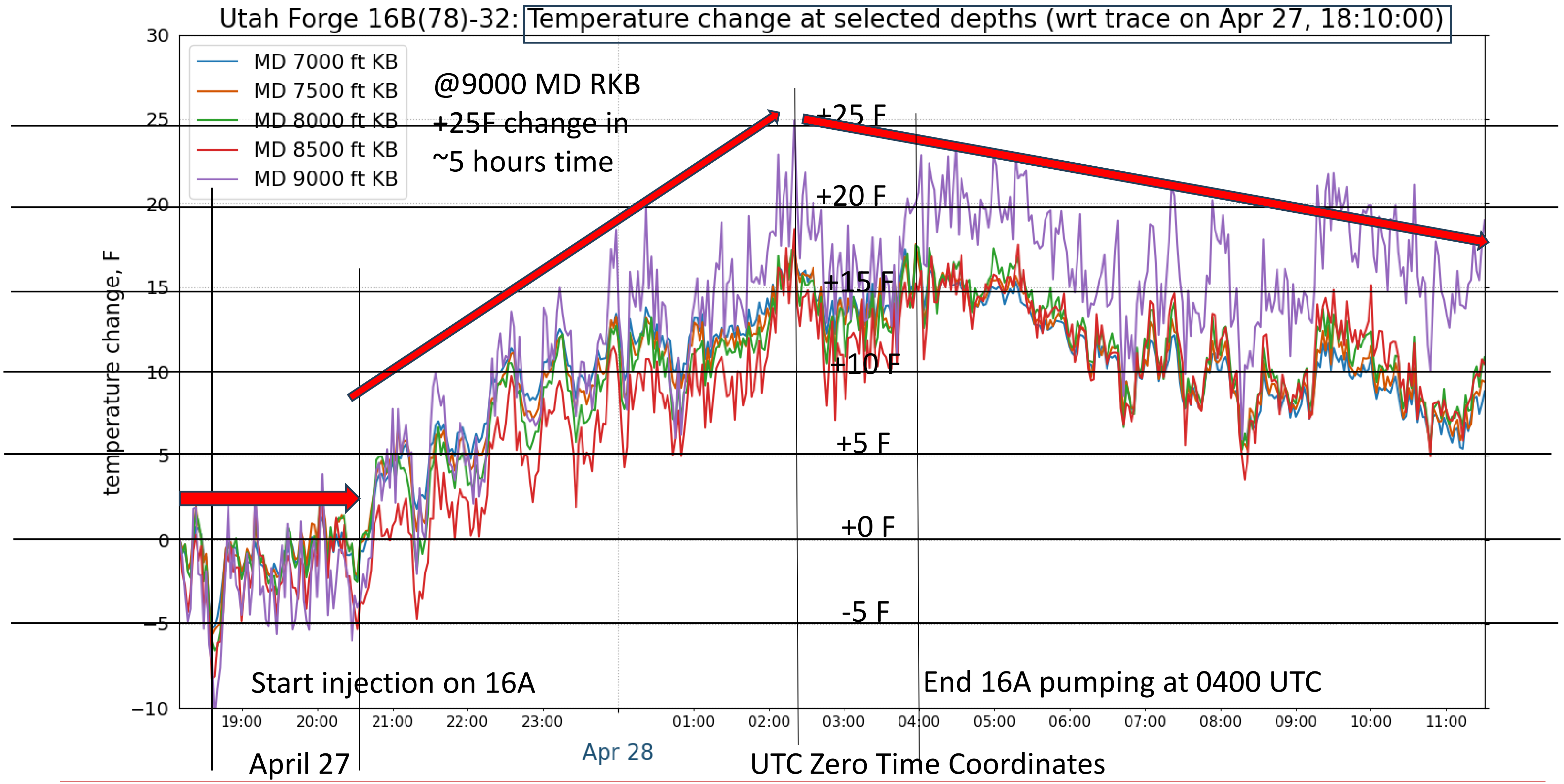
Well 16B – DTS temperature change relative to Baseline prior Circulation Period on April 27



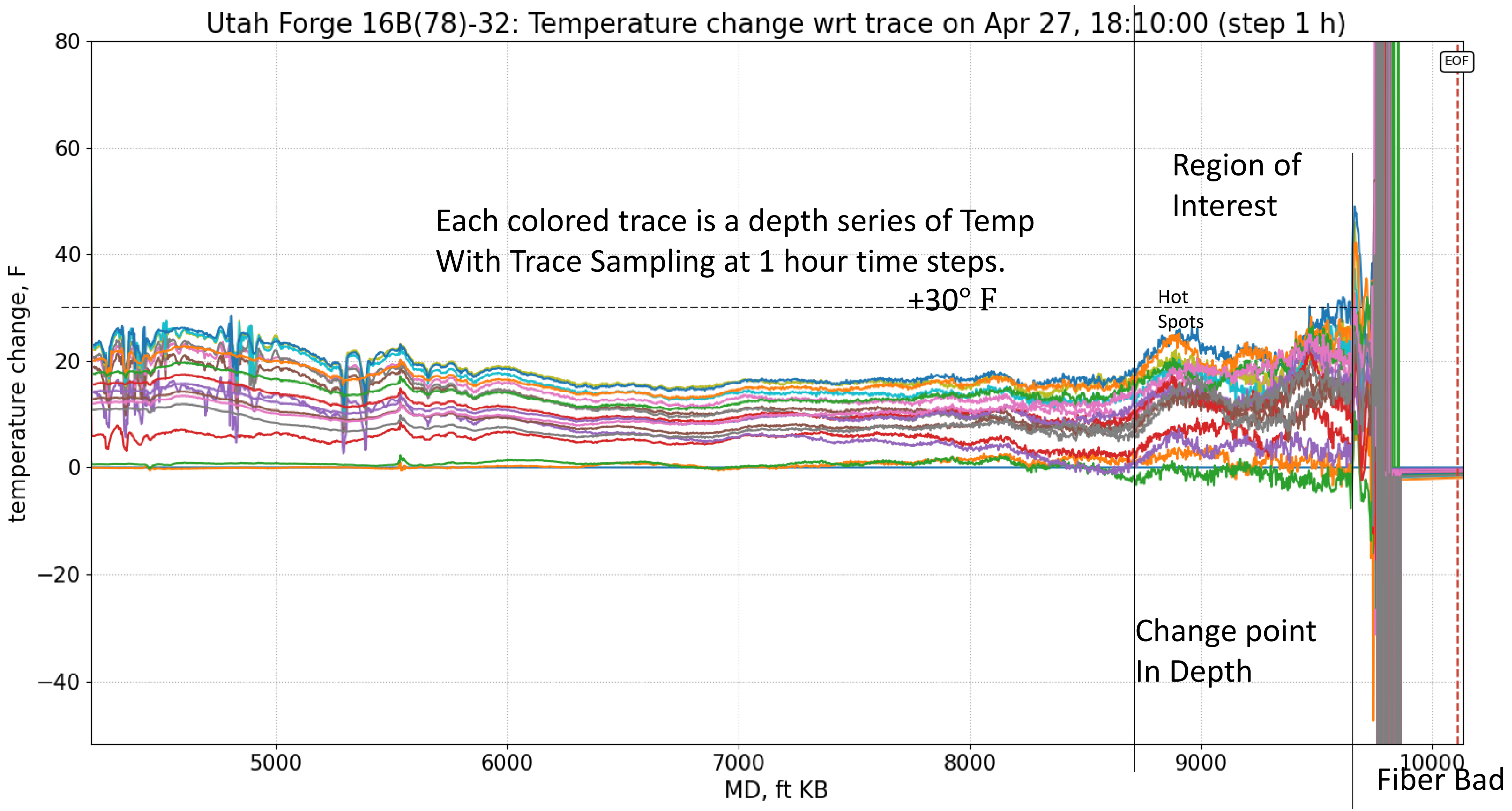
Well 16B – DTS temperature change – at selected depths over time



Well 16B – DTS temperature change depth series - annotated



Well 16B – DTS T change – selected times over well MD depth



All Depths
MD (ft) RKB
KB = 30.5 ft

16B RFS DSS Strain Change Rate

16A Frac Hit Depths
vs
16B Cluster Depths & Circulation Results

Planned 16B Frac Pump Schedule Stages 1 – 4

Stage 2 (16B) Fracturing Treatment Schedule

Step Name	Step Pump Rate (bpm)	Step Fluid Volume (bbl)	Step Fluid Type	Cum Fluid Volume (bbl)	Step Prop Conc (PPA)	Step Prop Type (US mesh)	Step Prop Volume (lbm)	Cum Prop Volume (lbm)	Step Slurry Volume (bbl)	Step Pump Time (min)	Cum Pump Time (min)
Pad	60	640	Slickwater	640	0.00		0	0	640	10.7	10.7
0.5 PPA	60	320	Slickwater	960	0.50	100	6,720	6,720	327	5.5	16.1
0.75 PPA	60	320	Slickwater	1,280	0.75	100	10,080	16,800	331	5.5	21.6
1.00 PPA	60	640	Slickwater	1,920	1.00	100	26,880	43,680	669	11.2	32.8
1.00 PPA	60	640	Slickwater	2,560	1.00	40/70	26,880	70,560	669	11.2	43.9
1.25 PPA	60	320	Slickwater	2,880	1.25	40/70	16,800	87,360	338	5.6	49.6
1.50 PPA	60	320	Slickwater	3,200	1.50	40/70	20,160	107,520	342	5.7	55.3
Flush	60	350	Slickwater	3,550	0.00		0	107,520	350	5.8	61.1

Slickwater	3,550 bbl	149,100 gal	100-mesh sand	43,680 lbm
			40/70-mesh sand	63,840 lbm

Well 16B(78)-32: Actual Pumped

Stage Name	Number of Clusters	Fluid Type	Fluid Volume (bbl)	Pump Rate (bpm)	100-mesh Prop Volume (lb_m)	40/70-mesh Prop Volume (lb_m)	Comments
Stage 1	4	Slickwater	3,624	60 (Avg = 55)	45,600	66,840	
Stage 2	5	Slickwater	4,734	60 (Avg = 56)	46,770	102,000	
Stage 3	3	Slickwater	4,321	60 (Avg = 51)	43,322	70,163	
Stage 4	4	Slickwater	3,800	60 (Avg = 56)	43,217	65,317	
Stage 5 *	4	Slickwater	N/A	N/A	N/A	N/A	Did not pump Stage 5. No able to set frac plug to isolate Stage 4.

* Note Stage 5 was perforated but not pumped with fluid or slurry

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Integrated Hydraulic Frac Fiber Optics and Circulation Period Data

- 16A Frac to 16B Strain FDI equals “Frac Log” (Left column)

- 16A Frac to 16B Strain FDI Data “Strain Rate Waterfall Plot”

- Green Arrows and Green Diamonds are the Average Perforation Cluster Depths of each Stage used on 16B Frac

- 16B Circulation Period Strain Waterfall Plot

EVO2 - 16A FRAC, EVO3 - 16B FRAC & CIRCULATION

16B RFS DSS Strain Change Rate

All Depths
MD (ft) RKB
KB = 30.5 ft

16A frac period
FDI Frac Log on
16B well

Depth Range:
9599 - 9933 ft (MD RKB)

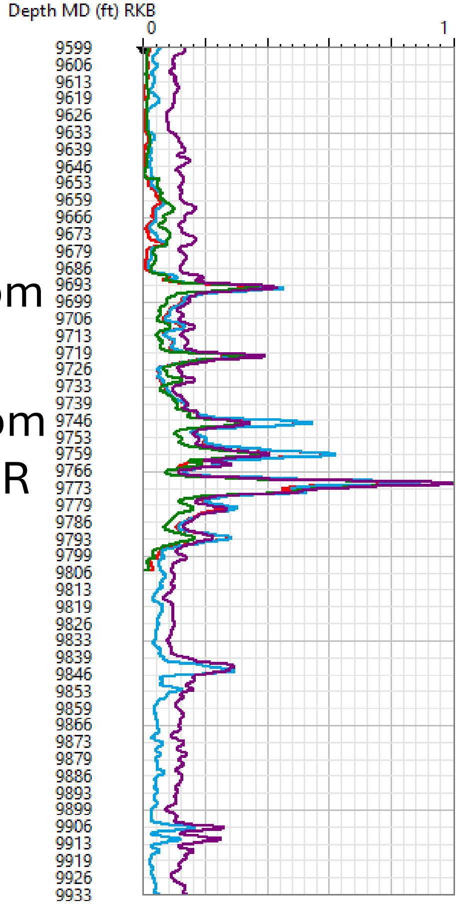
Time is Hours since Pump Start

DEPTH
MD RKB
(ft)

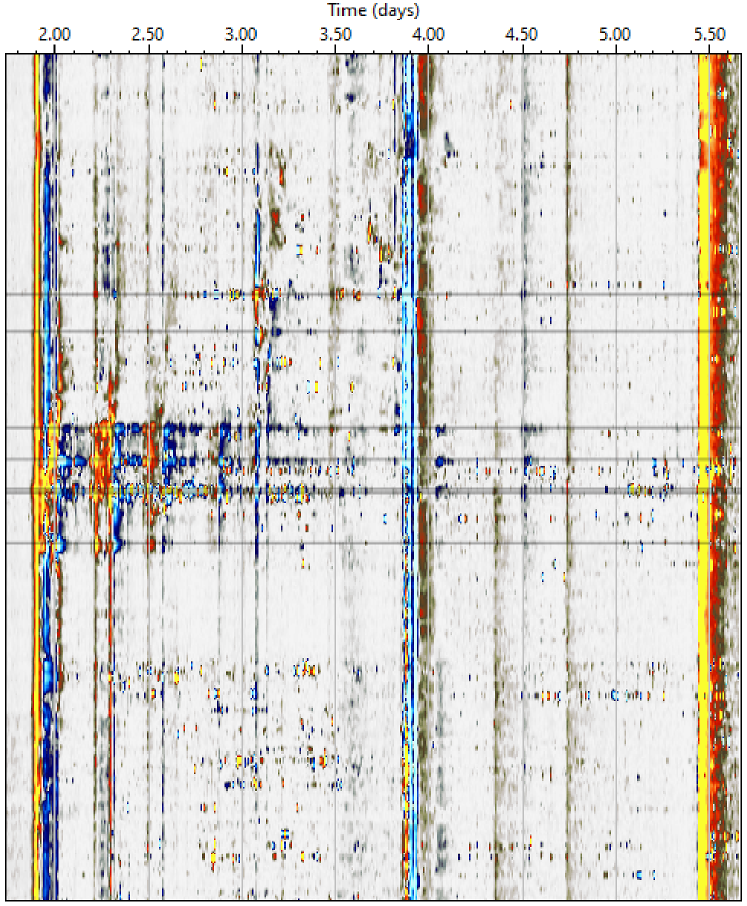
Fracs from
Stages 6

Fracs from
Stages 3R
4 and 5

TOE

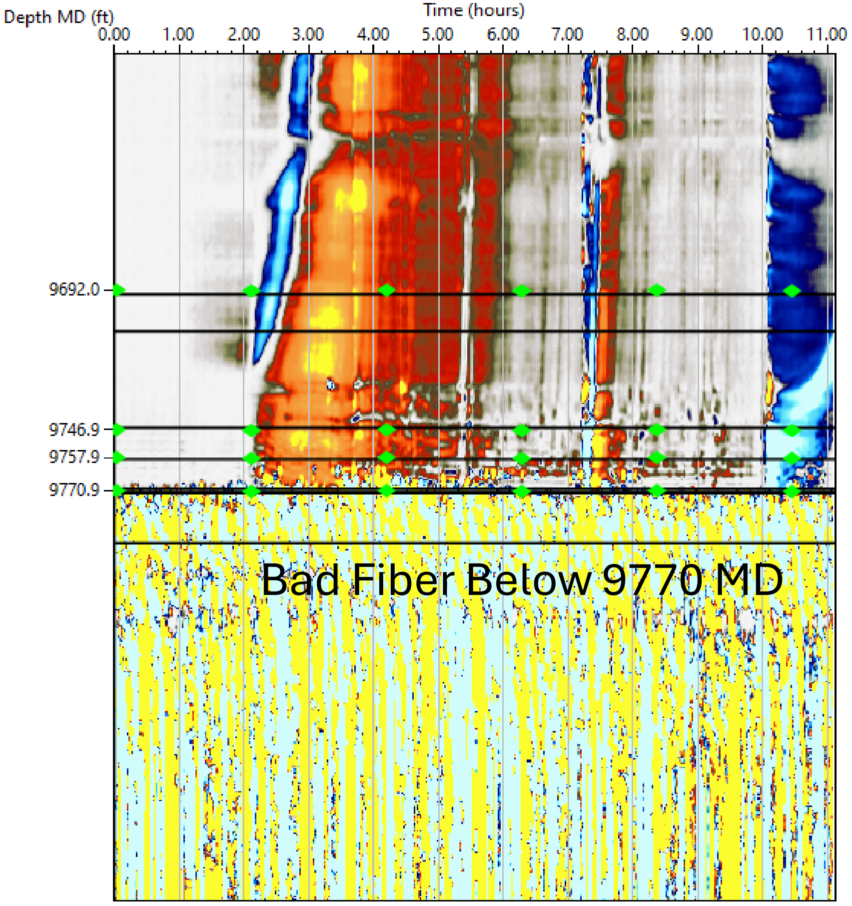


EVO2 16A FRAC Period Strain Data on 16B



EVO2 D1 STRAIN CHANGE RATE
— 16A Frac Hit Depths
-0.4 0.4

EVO3 16B CIRCULATION w Perf Locs RFS DSS



EVO3 D1 STRAIN CHANGE RATE
— 16A Frac Hit Depths
◆ 16B Perf Cluster Center Depth
-0.9 0.9

EVO2 - 16A FRAC, EVO3 - 16B FRAC & CIRCULATION

16B RFS DSS Strain Change Rate

All Depths
MD (ft) RKB
KB = 30.5 ft

Depth Range:
9299 - 9599 ft (MD RKB)

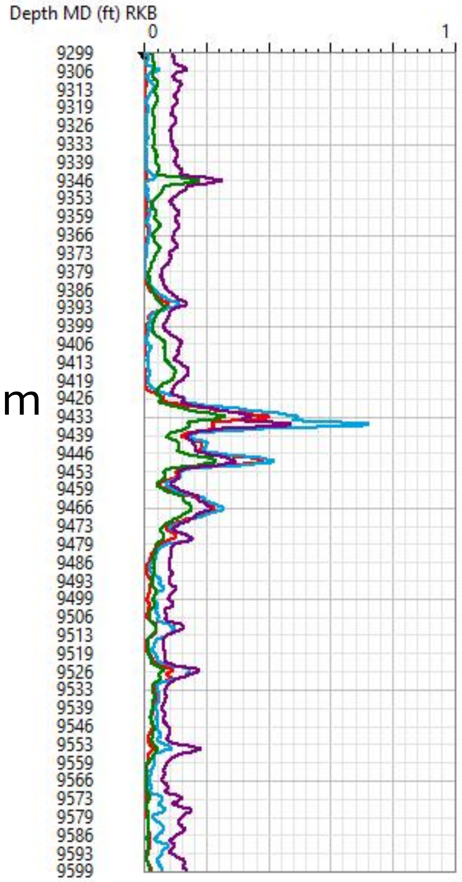
Time is Hours since Pump Start

DEPTH
MD RKB
(ft)

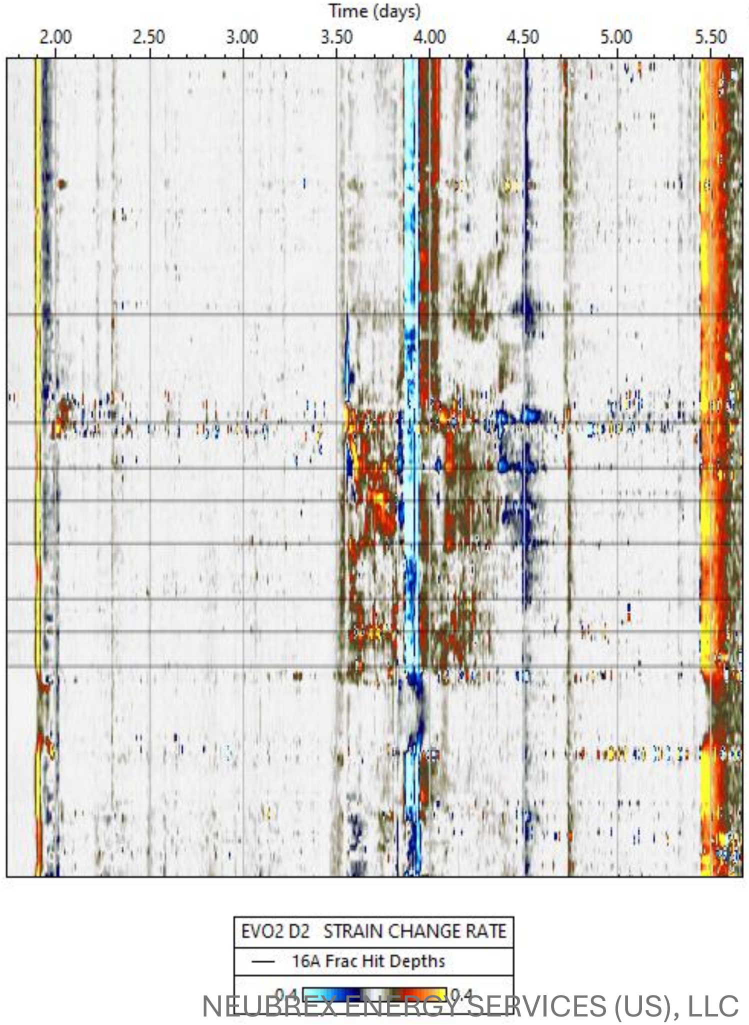
TOE

Fracs from Stages 7

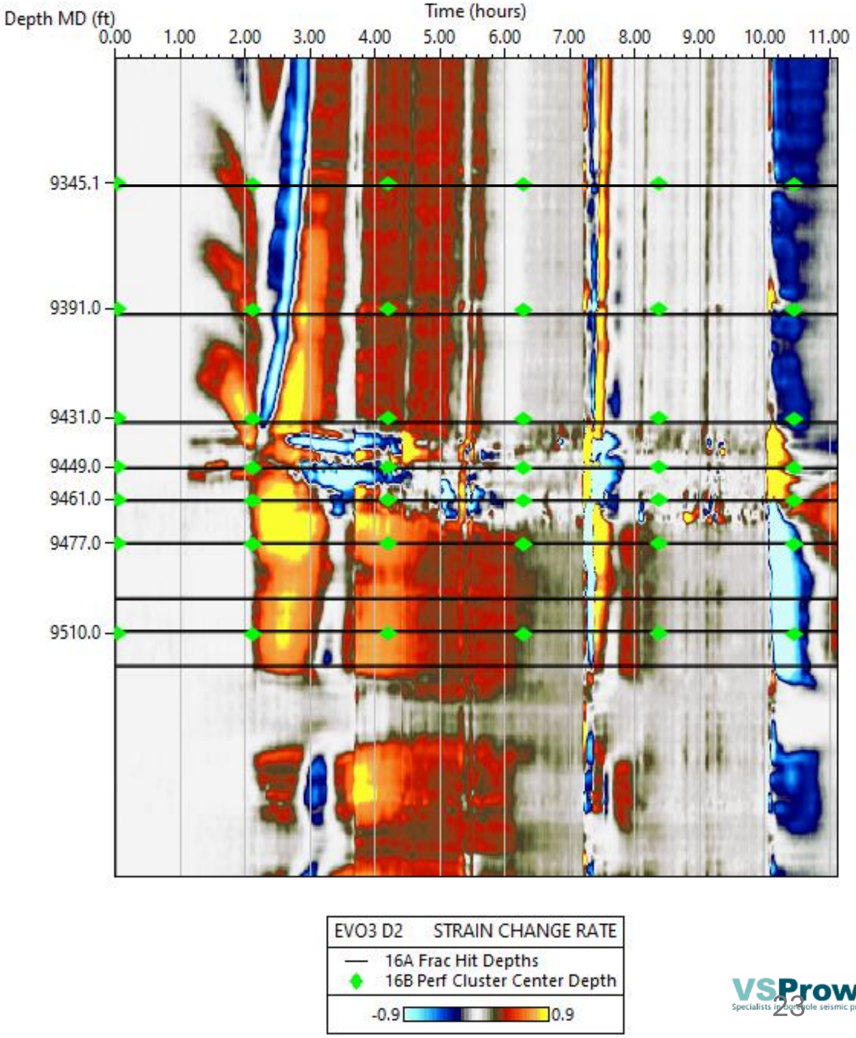
16A FDI Log



EVO2 16A FRAC



EVO3 16B FRAC, CIRCULATION



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EVO2 - 16A FRAC, EVO3 - 16B FRAC & CIRCULATION

16B RFS DSS Strain Change Rate

All Depths
MD (ft) RKB
KB = 30.5 ft

Depth Range:
8933 - 9299 ft (MD RKB)

Time is Hours since Pump Start

DEPTH MD RKB (ft)

16A FDI Log

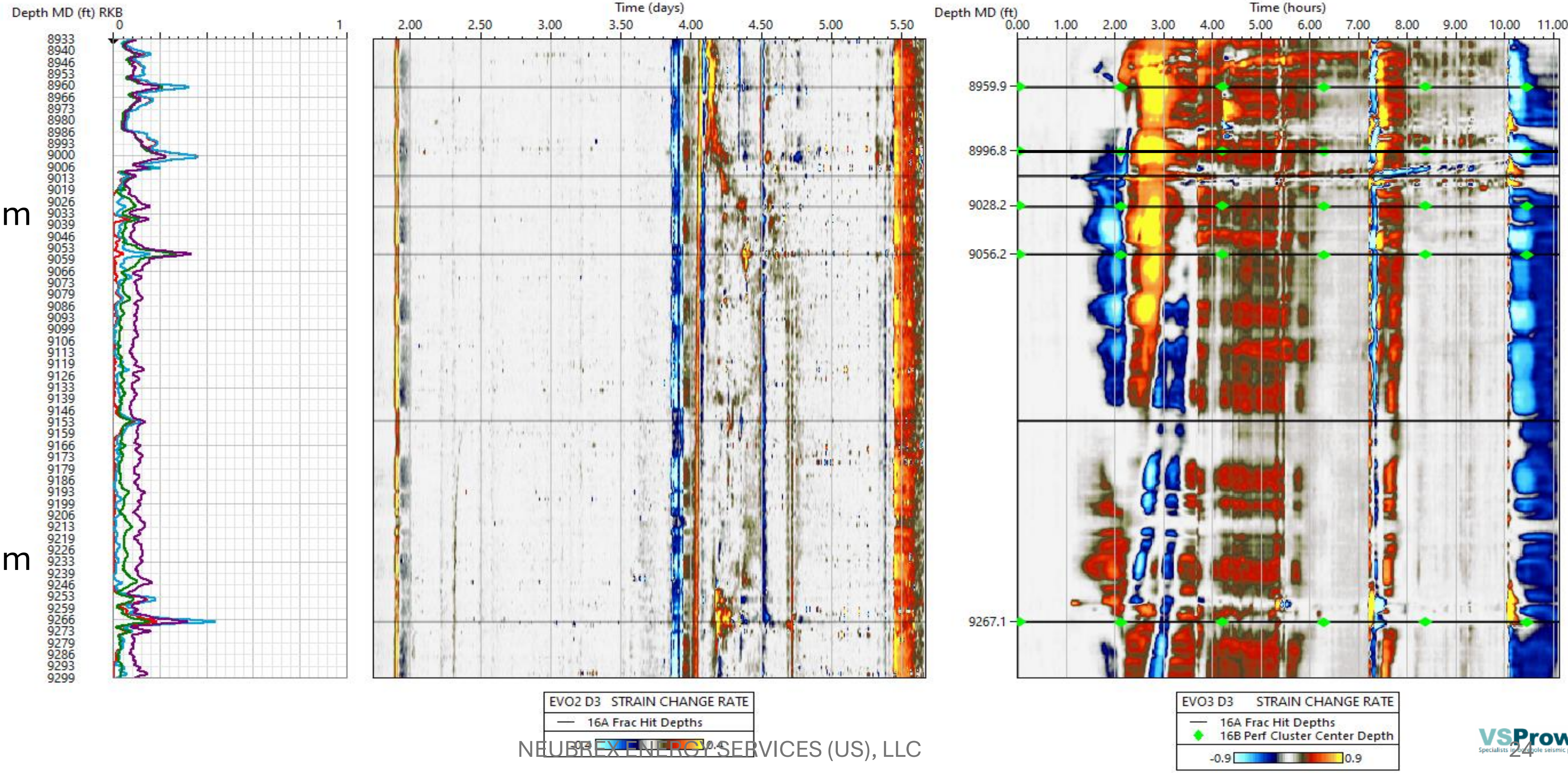
EVO2 16A FRAC

EVO3 16B FRAC, CIRCULATION

Fracs from Stages 8

Fracs from Stages 8

TOE

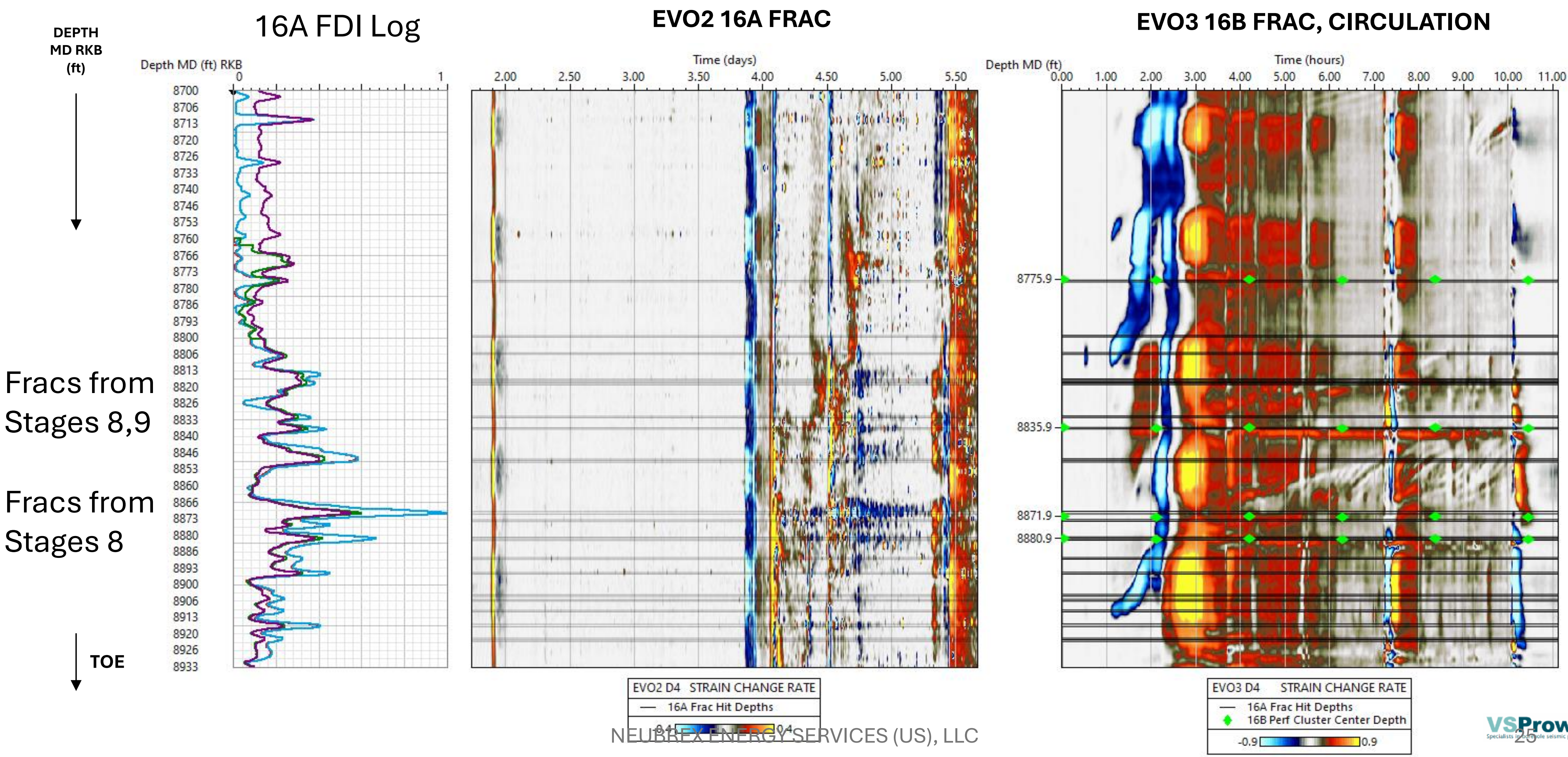


EVO2 - 16A FRAC, EVO3 - 16B FRAC & CIRCULATION

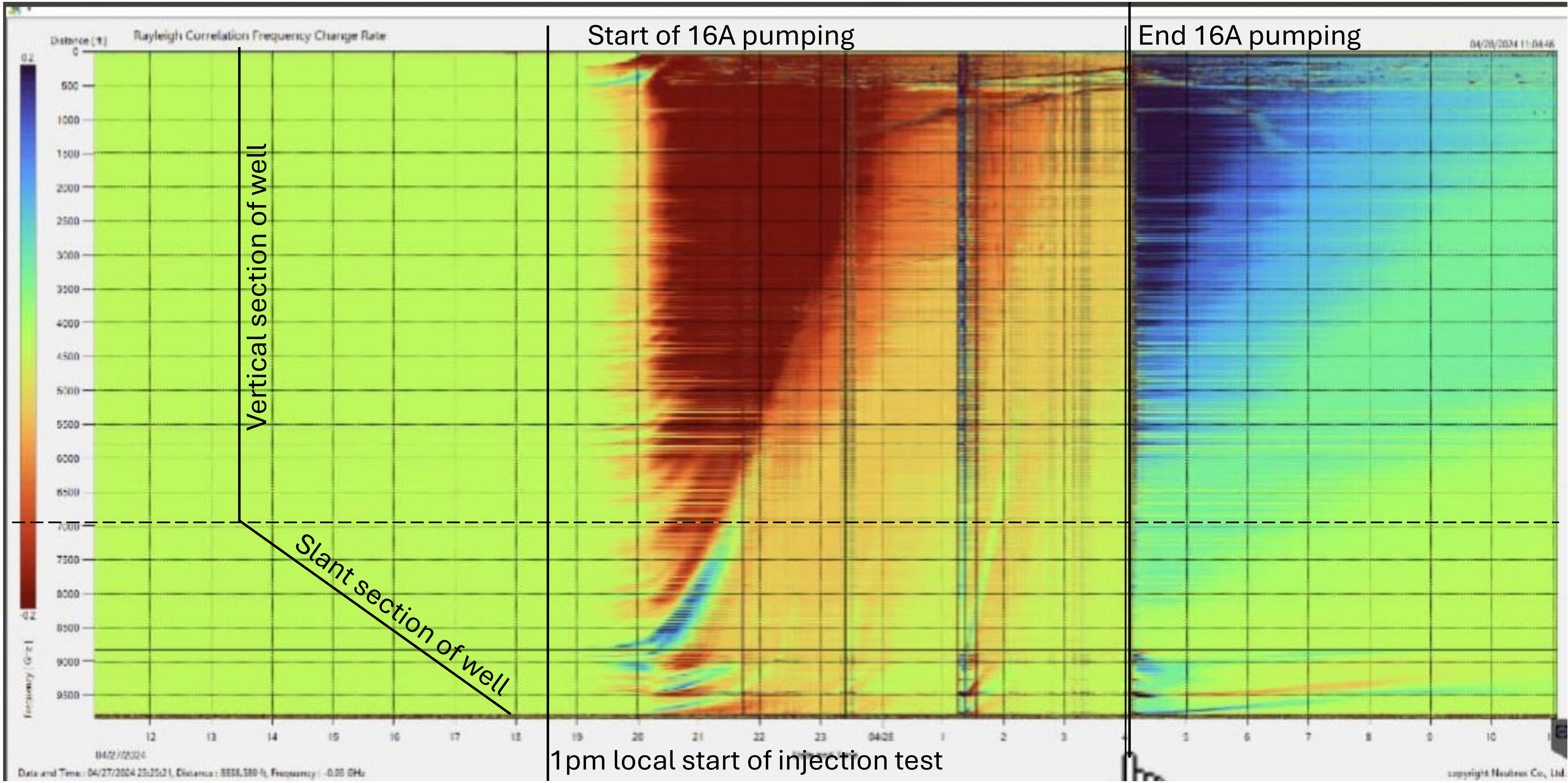
16B RFS DSS Strain Change Rate

All Depths
MD (ft) RKB
KB = 30.5 ft

Depth Range:
8700 - 8933 ft (MD RKB) Time is Hours since Pump Start



Field Monitor- RFS DSS Strain Change: Before, During, and After Circulation Testing on 16B Well Fiber behind Pipe



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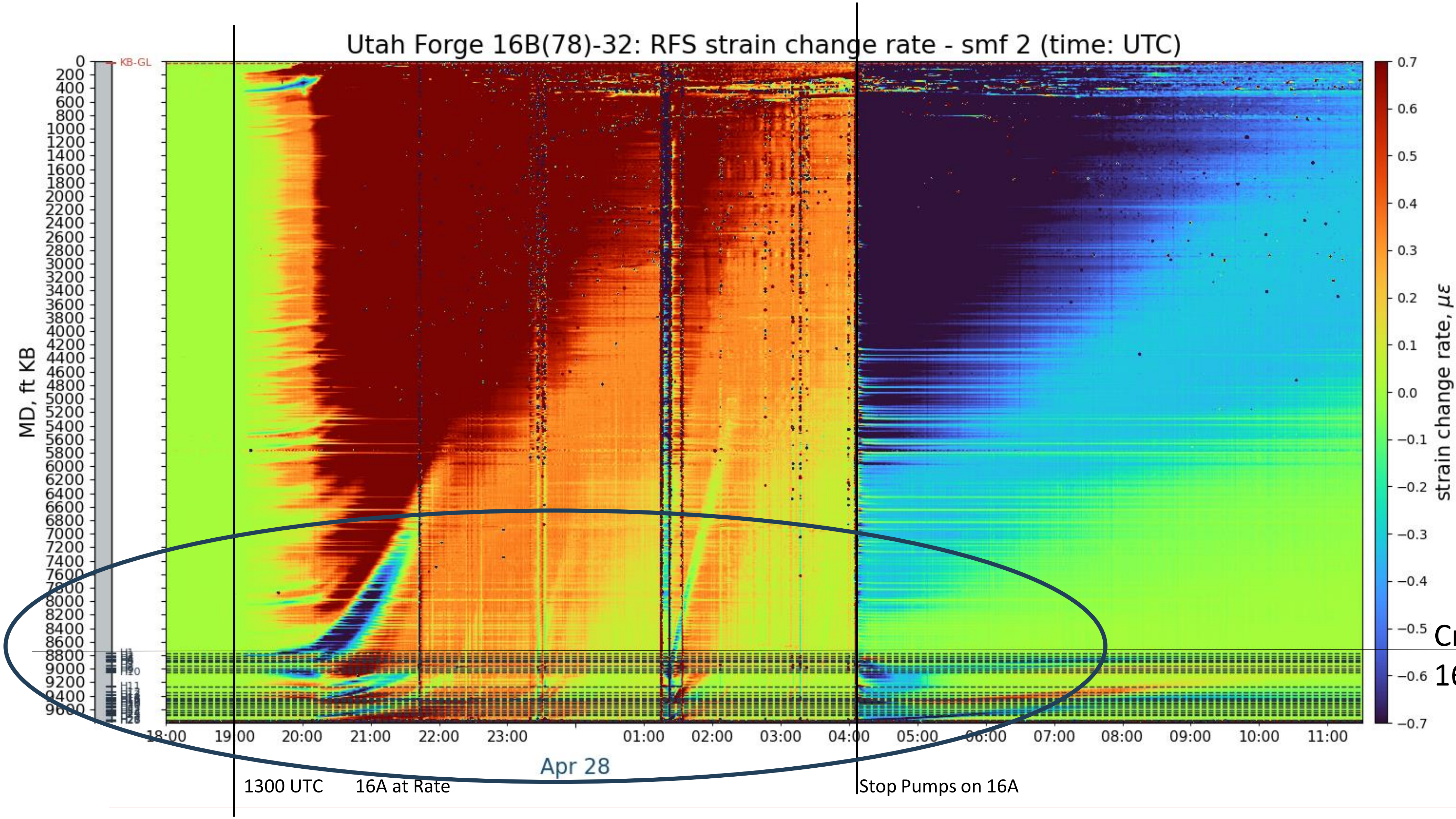
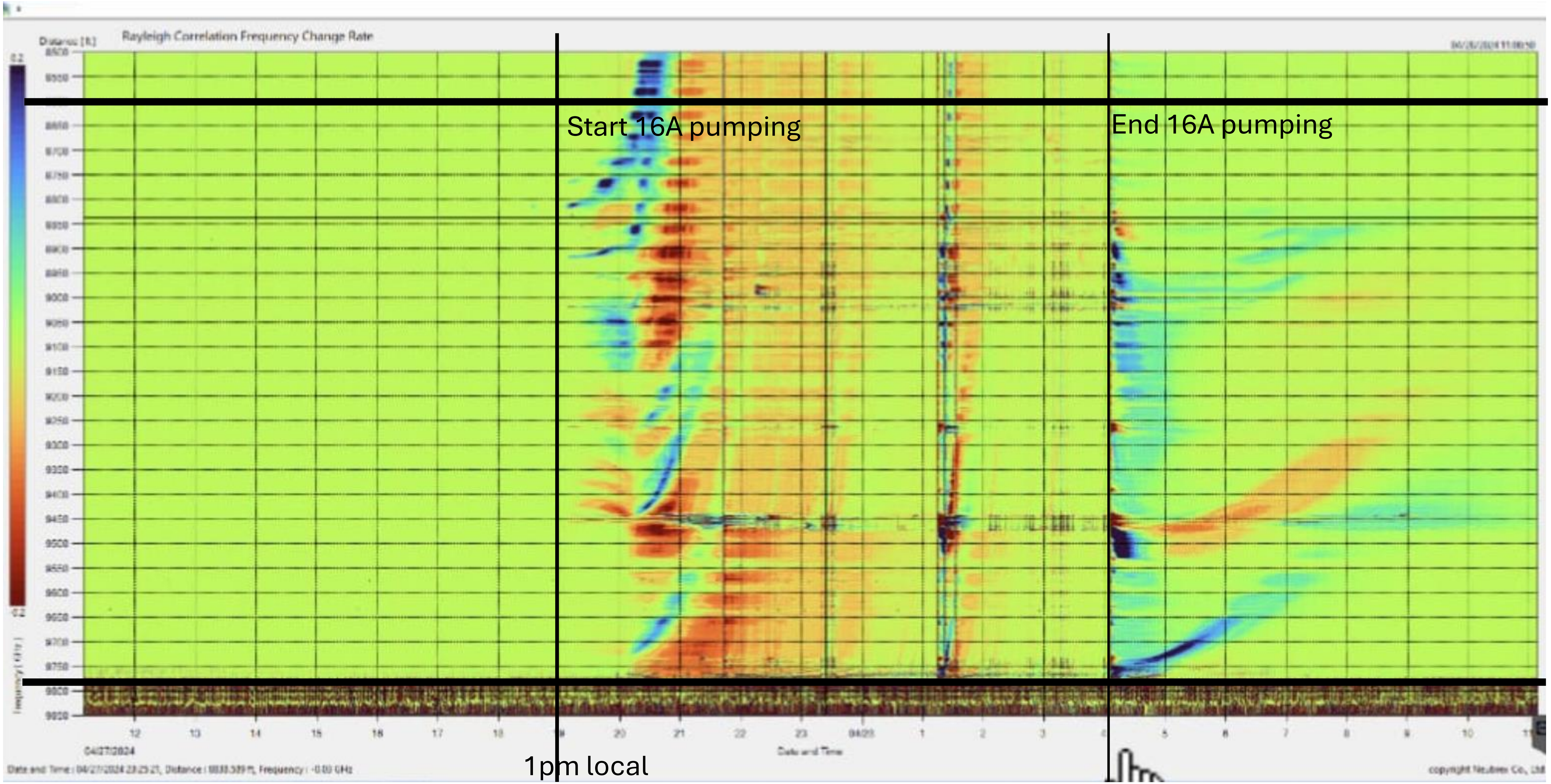
RFS DSS Strain Change RATE during circulation test



Cross Well FDI's from 16A frac annotated

Zoom Field Monitor- RFS DSS Strain Change RATE: Before, During, After Circulation Testing on 16B 8600 – 9777 MD



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EVO3 – 16B CIRCULATION - RFS DSS STRAIN CHANGE RATE

April, 2024

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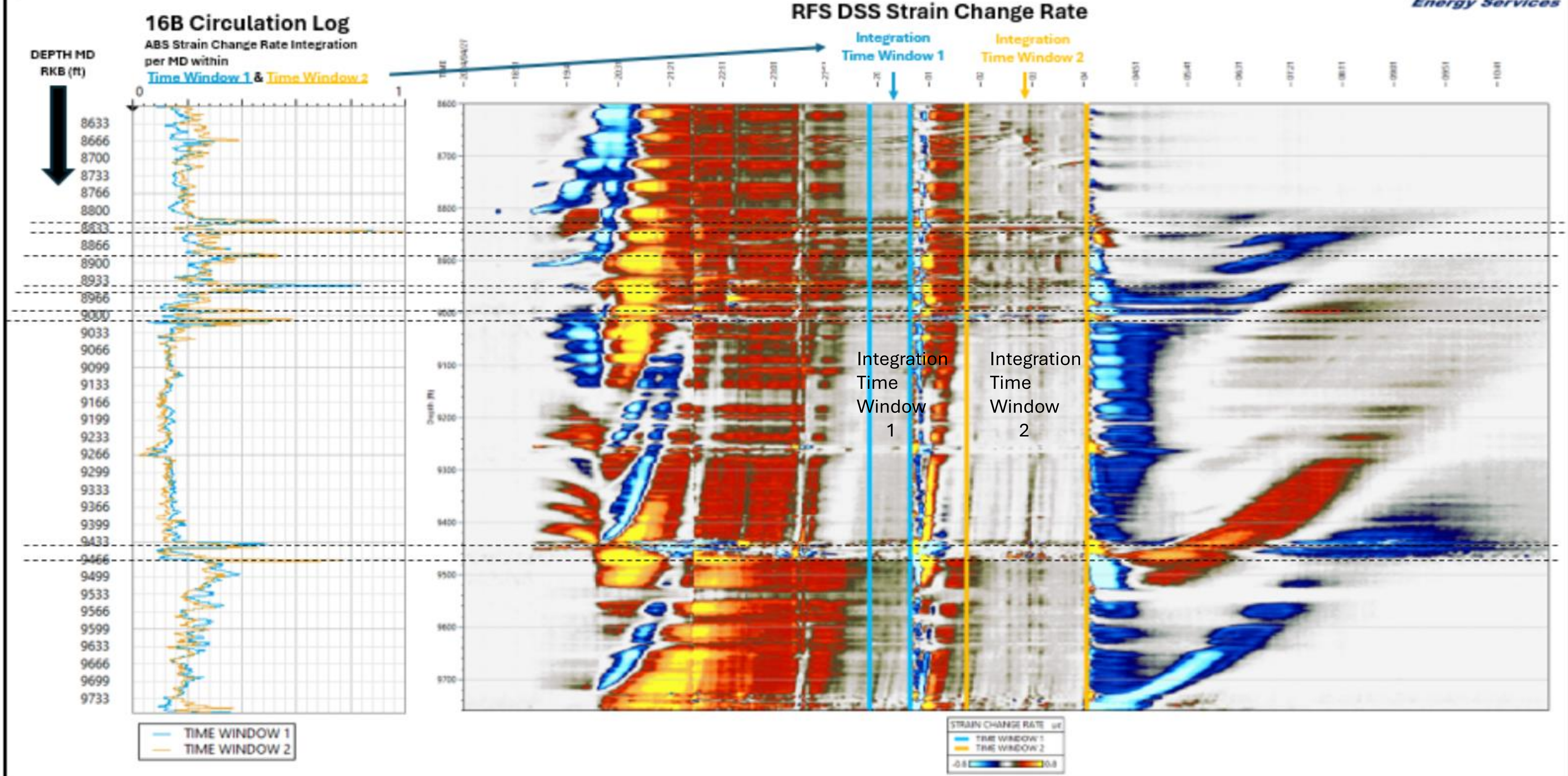

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EVO2 - 16A FRAC & EVO3 – 16B CIRCULATION

April 27, 2024

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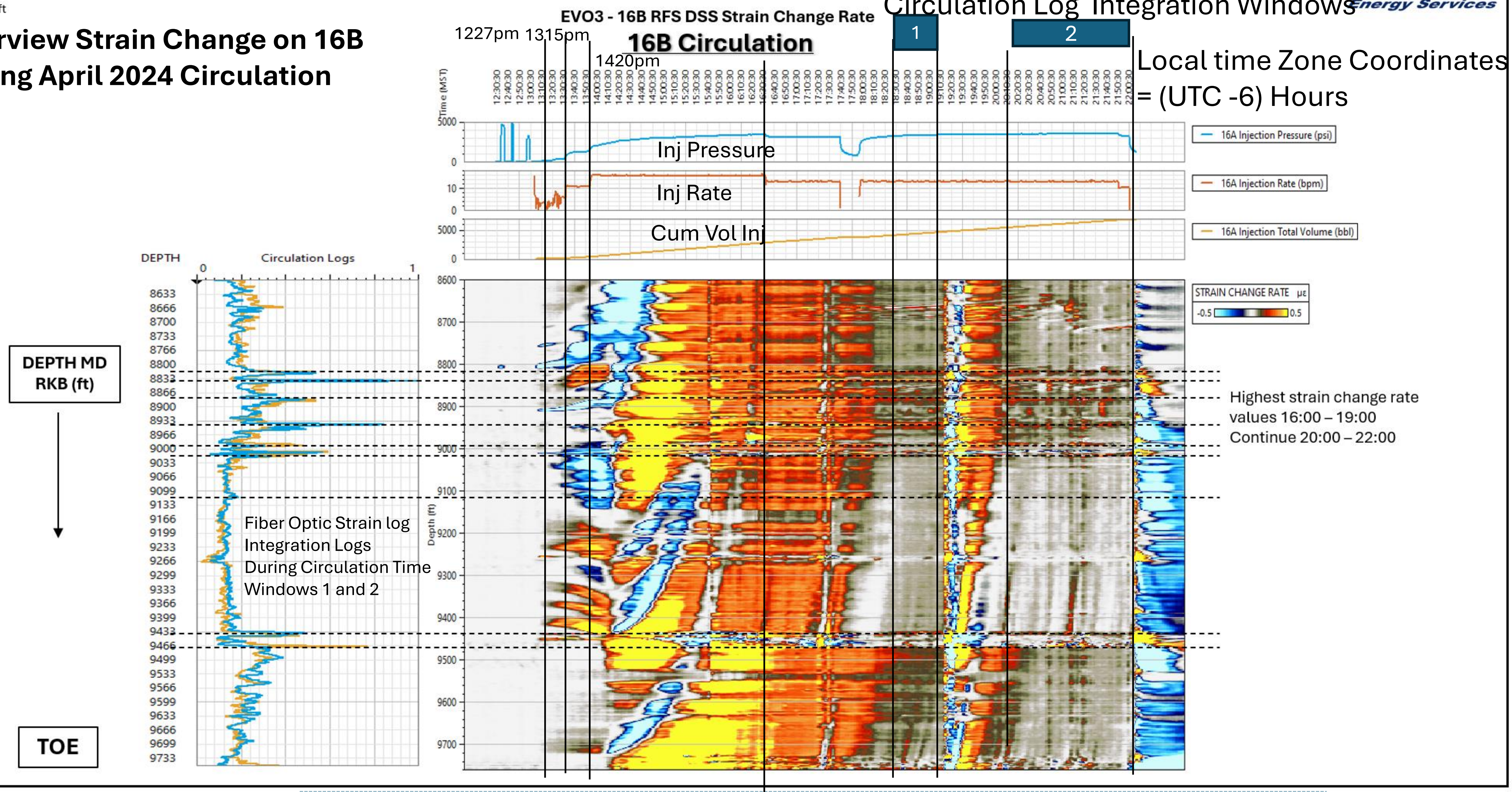
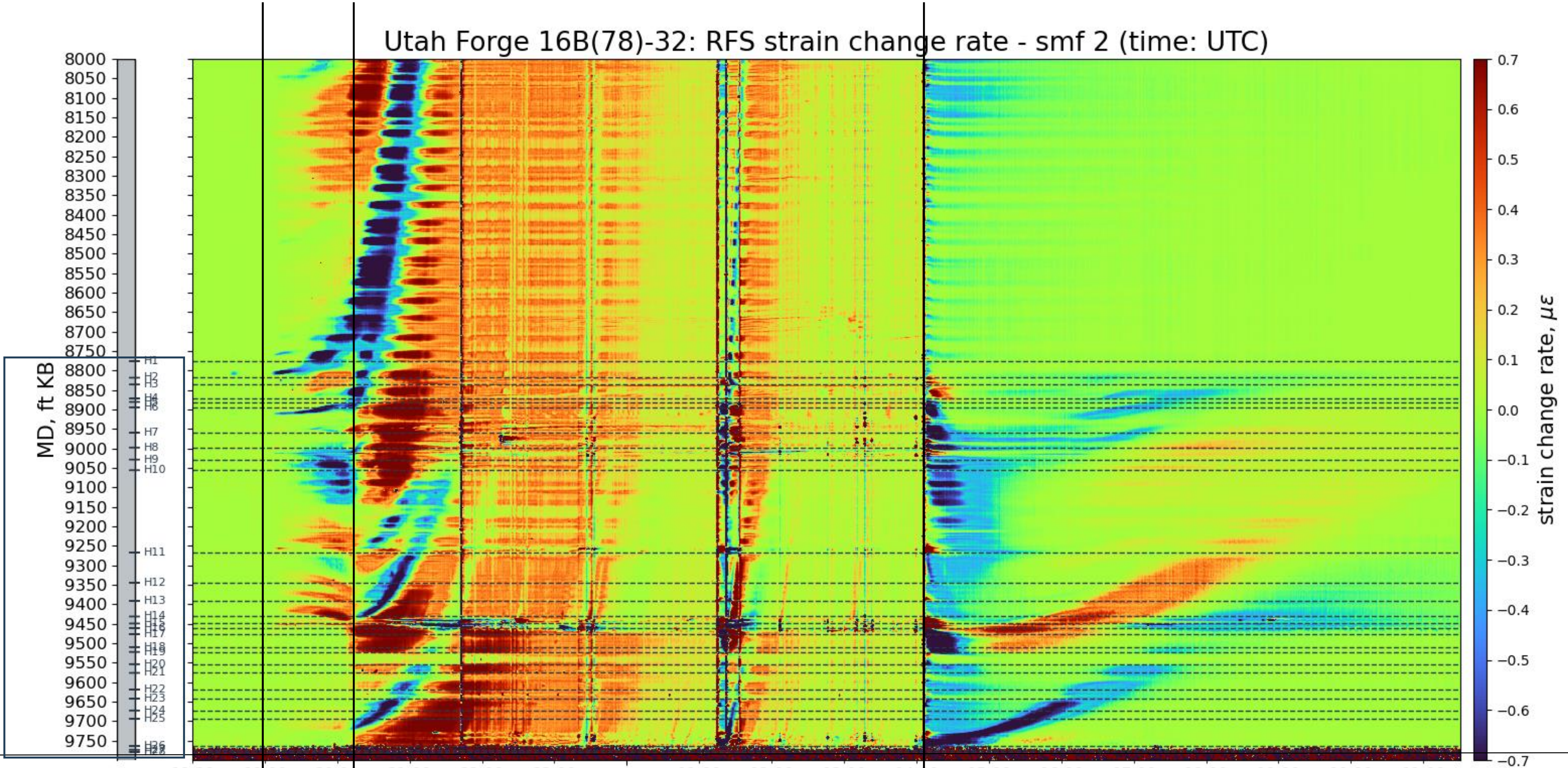
KB = 30.5 ft

Overview Strain Change on 16B During April 2024 Circulation



Well 16B – RFS strain change rate – with FDI Points



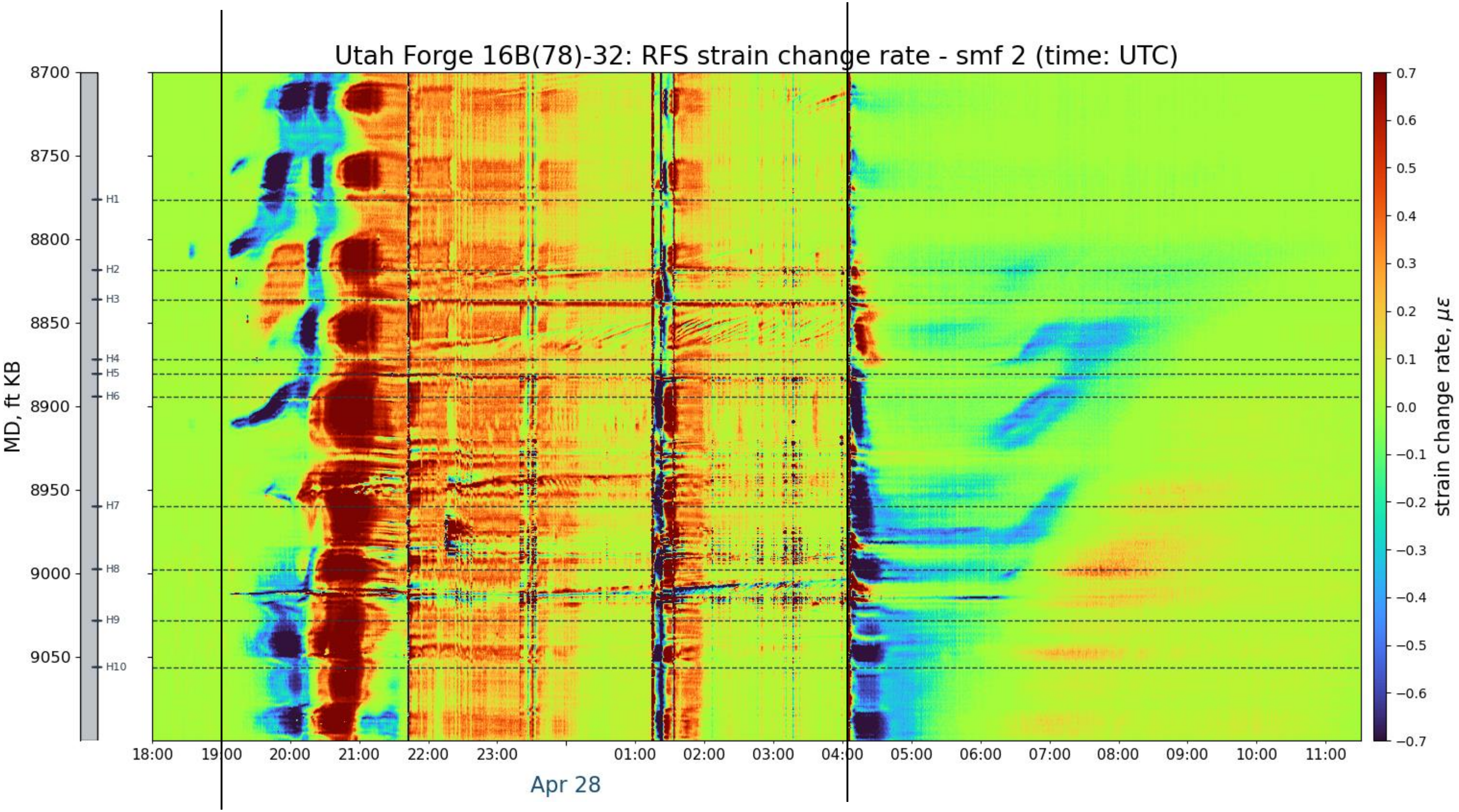
Frac Zone And FDI From 16A Frac

1300 Local

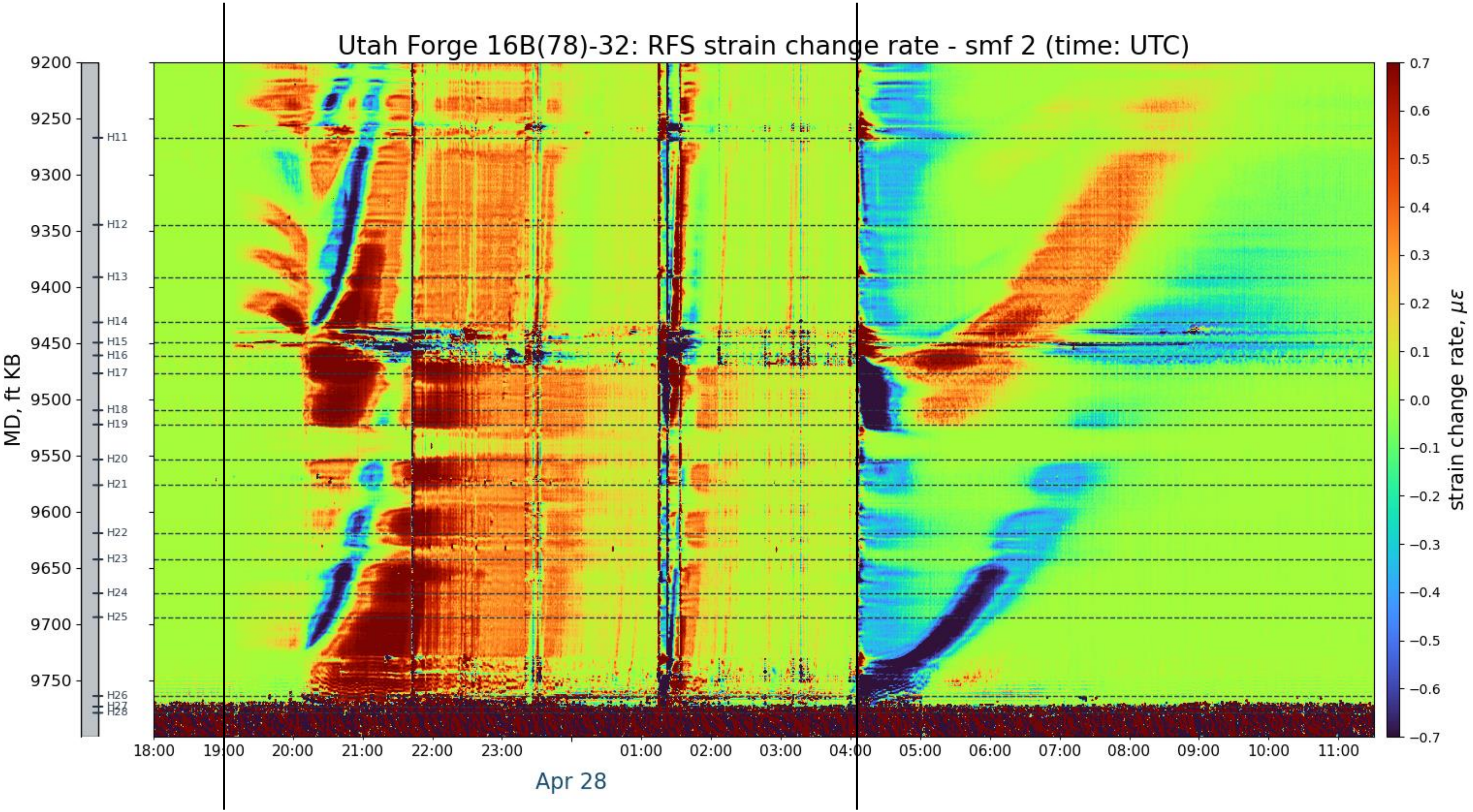
16A gets To rate

16A stops Injecting

Well 16B – RFS strain change rate– with FDI Points ZOOM



Well 16B – RFS strain change rate– with FDI Points ZOOM



Integrated Hydraulic Frac Fiber Optics and Circulation Period

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- 16A Frac to 16B Strain FDI “Frac Log” (Left column)
- 16A Frac to 16B Strain FDI Data “Strain Rate Waterfall Plot”
- Green Arrows and Green Diamonds are the Average Perforation Cluster Depth per Cluster of each Stage used on 16B Frac
- 16B Circulation Period Strain Waterfall Plot

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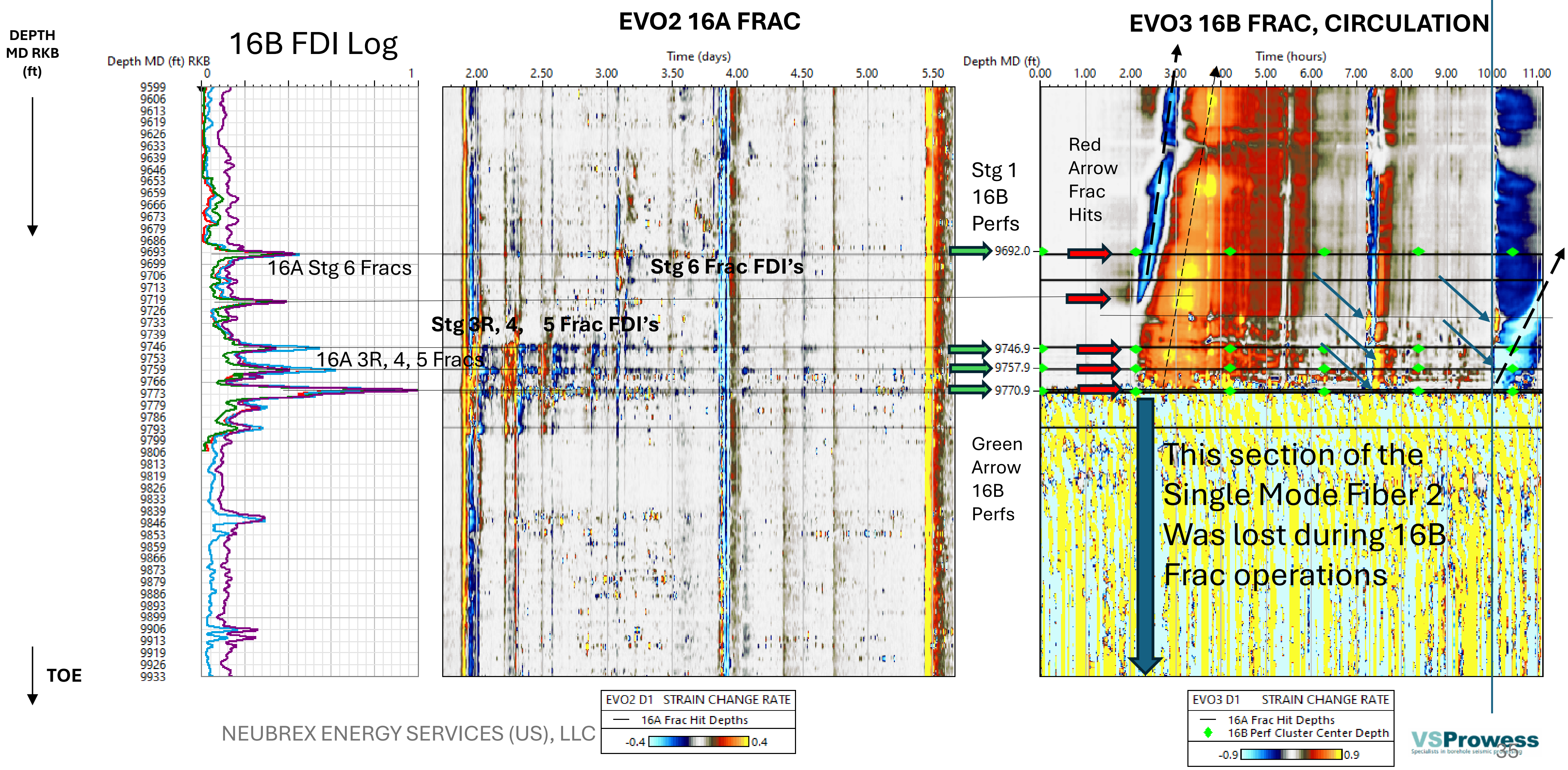
EVO2 - 16A FRAC, EVO3 - 16B FRAC & CIRCULATION

16B RFS DSS Strain Change Rate

All Depths
MD (ft) RKB
KB = 30.5 ft

Depth Range:
9599 - 9933 ft (MD RKB)

Strain change rate
On 16B Circulation Test



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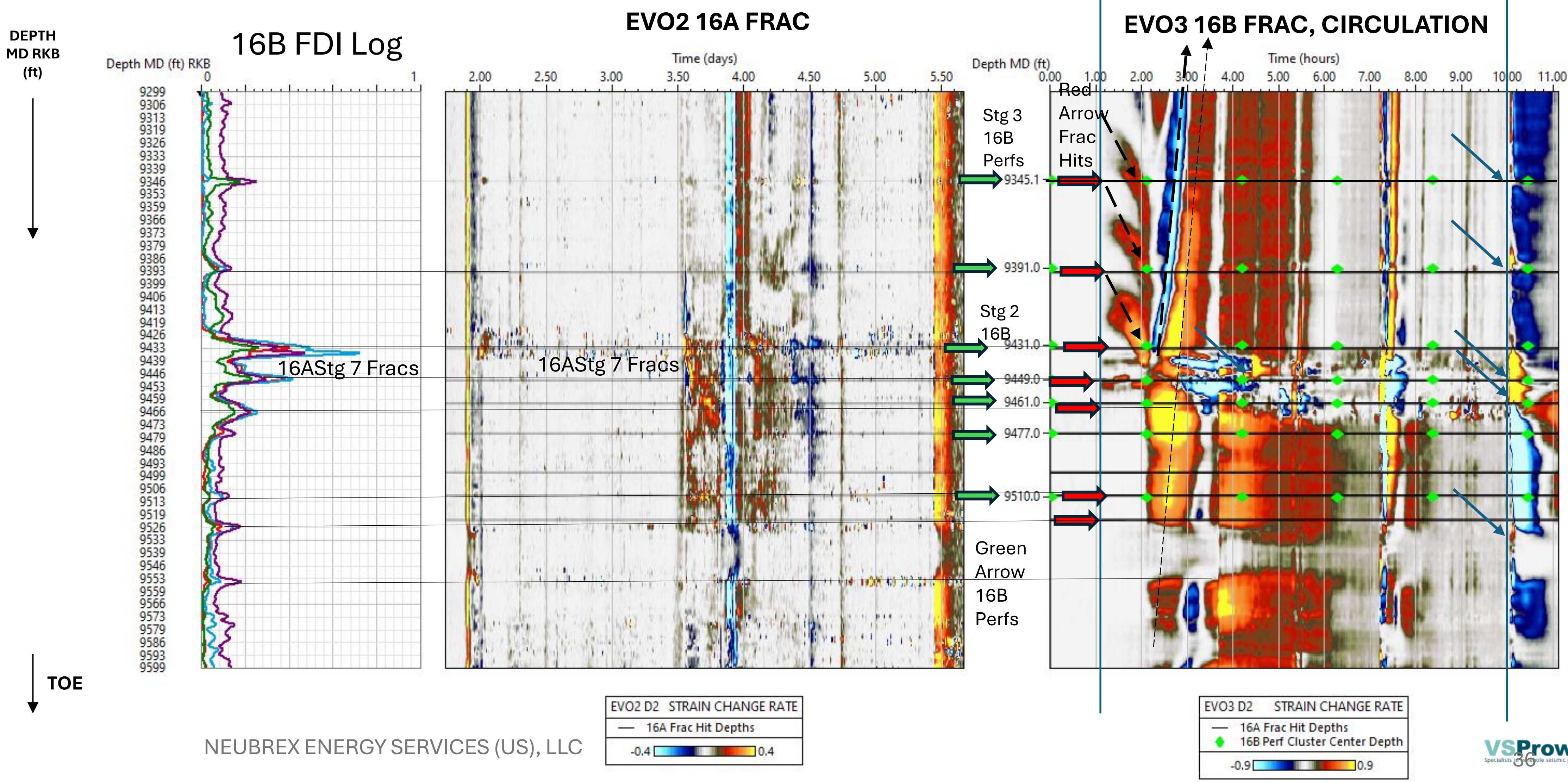
EVO2 - 16A FRAC, EVO3 - 16B FRAC & CIRCULATION

16B RFS DSS Strain Change Rate

All Depths
MD (ft) RKB
KB = 30.5 ft

Depth Range:
9299 - 9599 ft (MD RKB)

Strain change rate
On 16B Circulation Test



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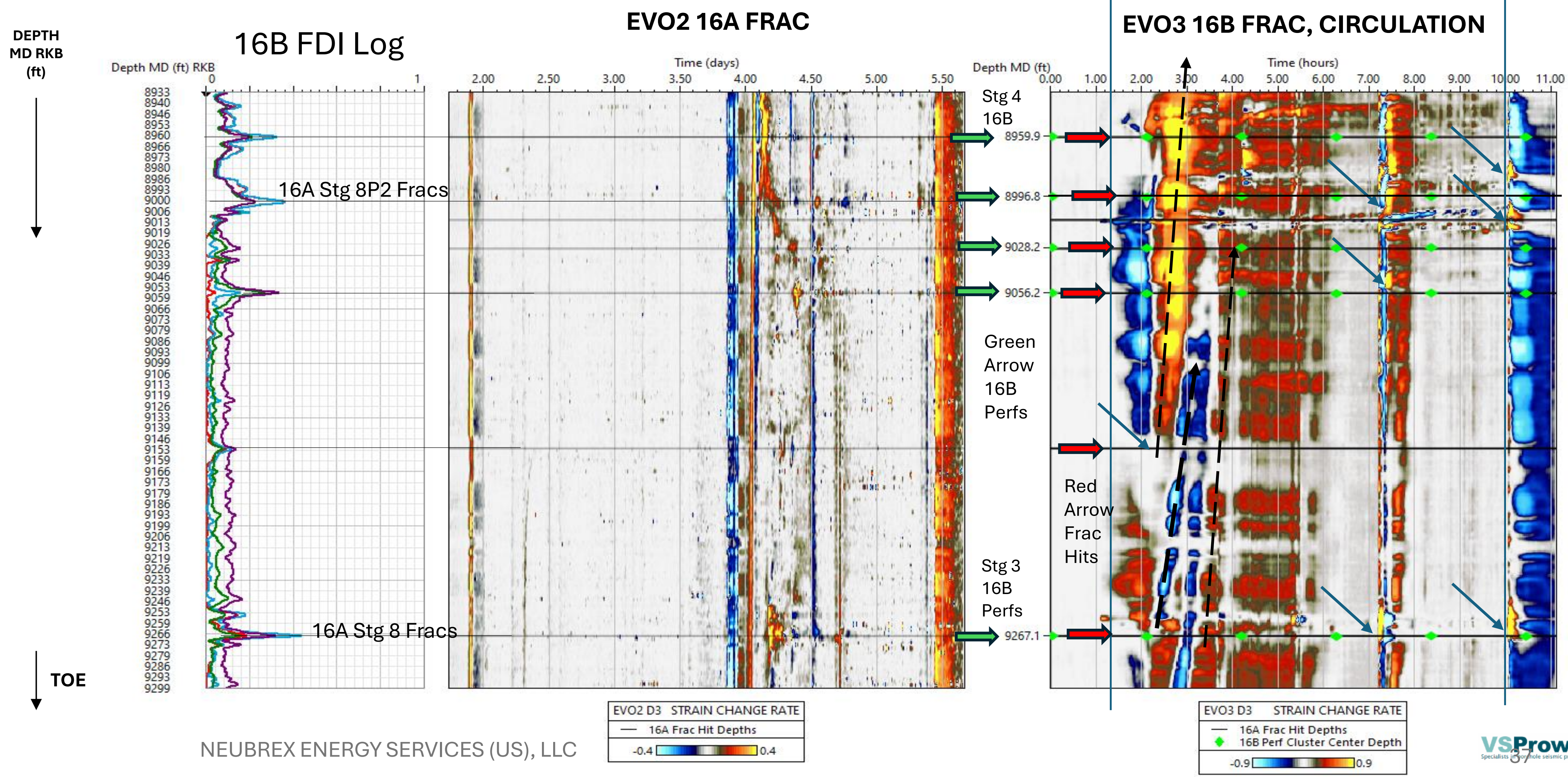
EVO2 - 16A FRAC, EVO3 - 16B FRAC & CIRCULATION

16B RFS DSS Strain Change Rate

All Depths
MD (ft) RKB
KB = 30.5 ft

Depth Range:
8933 - 9299 ft (MD RKB)

Strain change rate
On 16B Circulation Test



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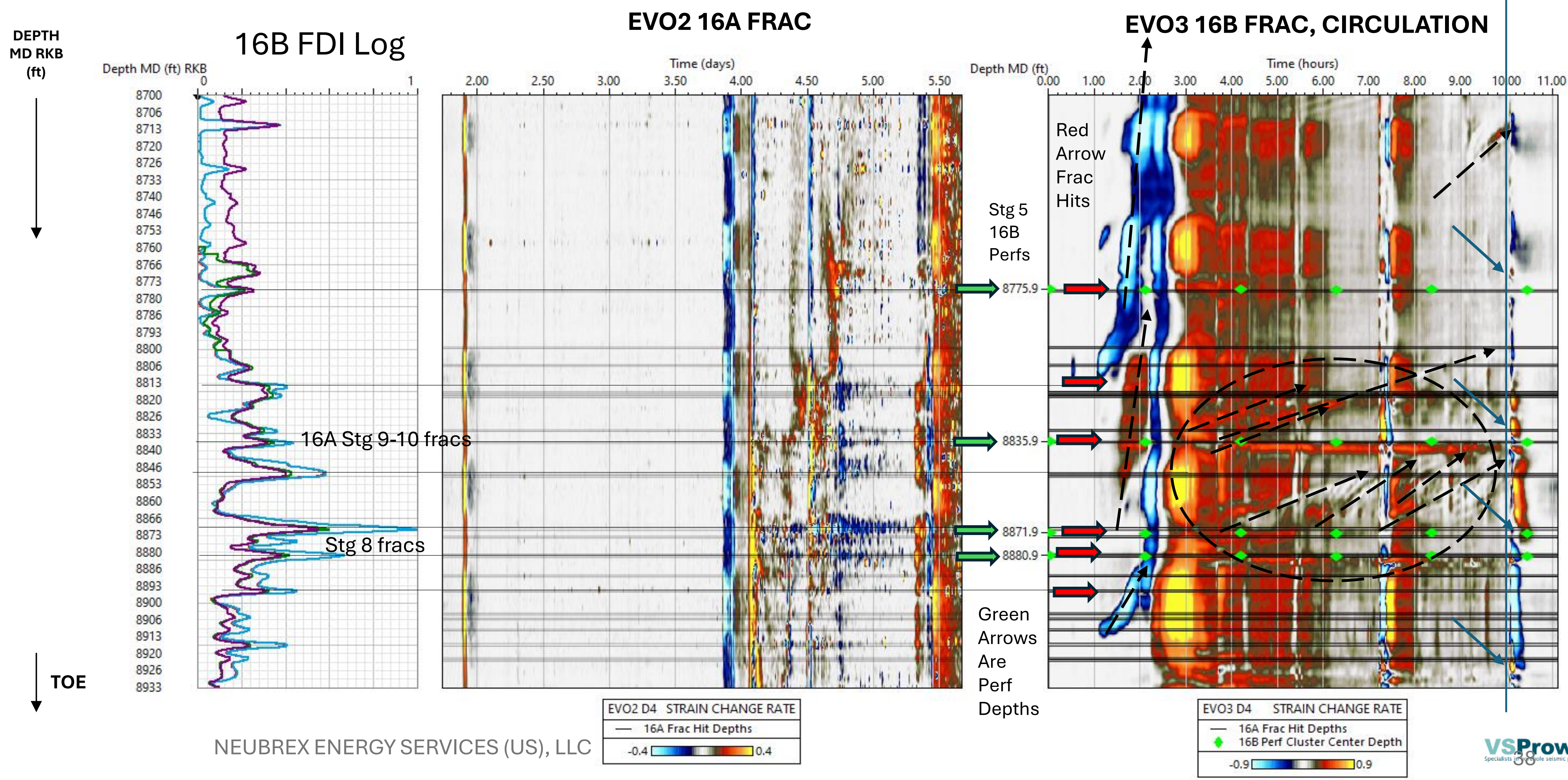
EVO2 - 16A FRAC, EVO3 - 16B FRAC & CIRCULATION

16B RFS DSS Strain Change Rate

All Depths MD (ft) RKB KB = 30.5 ft

Depth Range: 8700 - 8933 ft (MD RKB)

Strain change rate On 16B Circulation Test



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EVO2 - 16A FRAC & EVO3 – 16B CIRCULATION

April 27, 2024

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KB = 30.5 ft

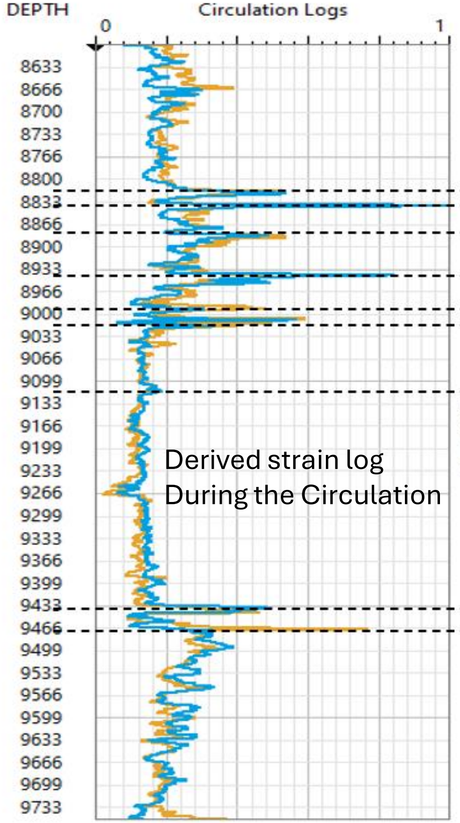
April 2024
Thermal Circulation
Logs FORGE

Local time Zone Coordinates = UTC -6 Hours

16B Circulation Log

DEPTH MD RKB (ft)

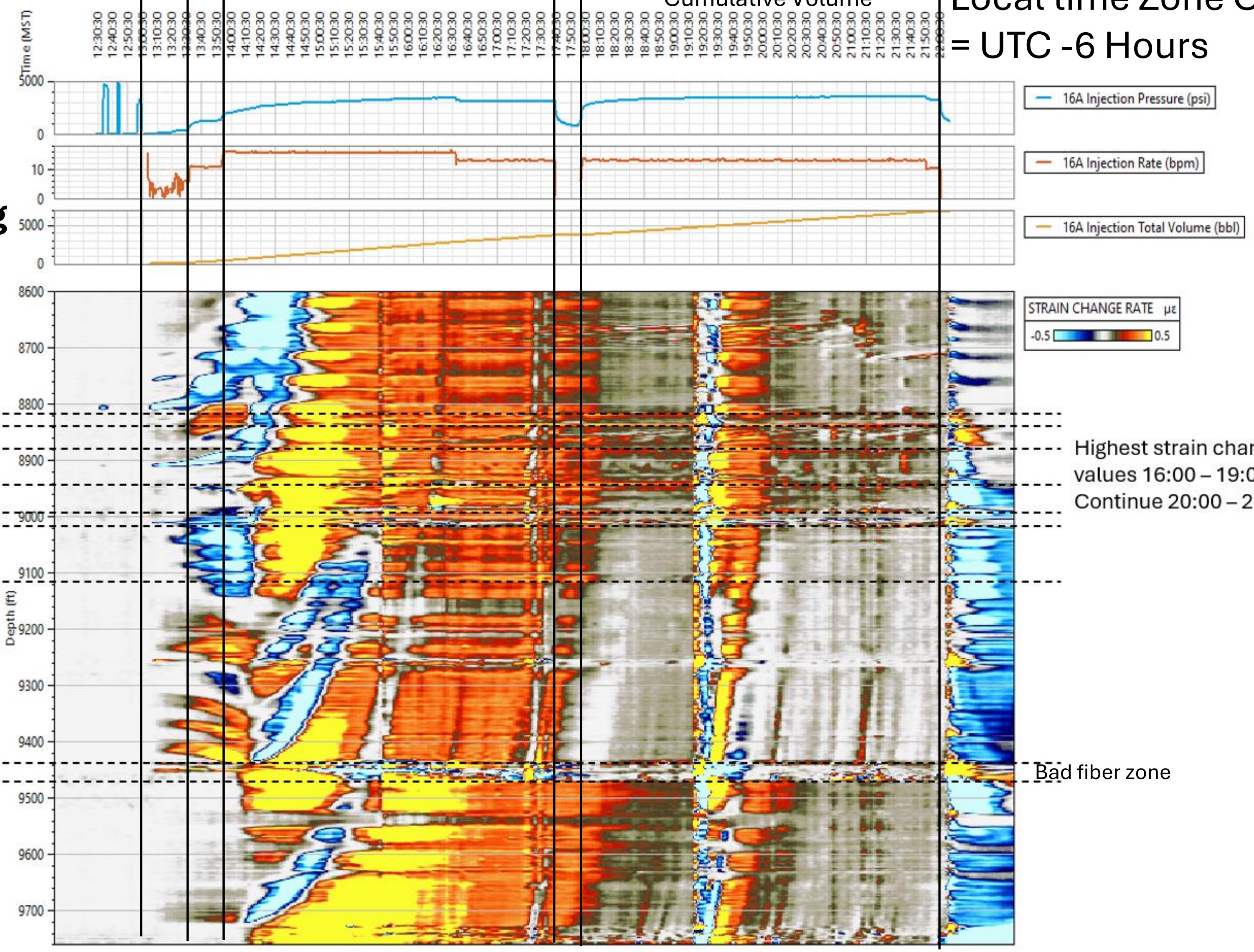
TOE



EVO3 - 16B RFS DSS Strain Change Rate

16B Circulation

16A Injection Pressure
Injection Rate &
Cumulative Volume



Highest strain change rate values 16:00 – 19:00
Continue 20:00 – 22:00

Bad fiber zone

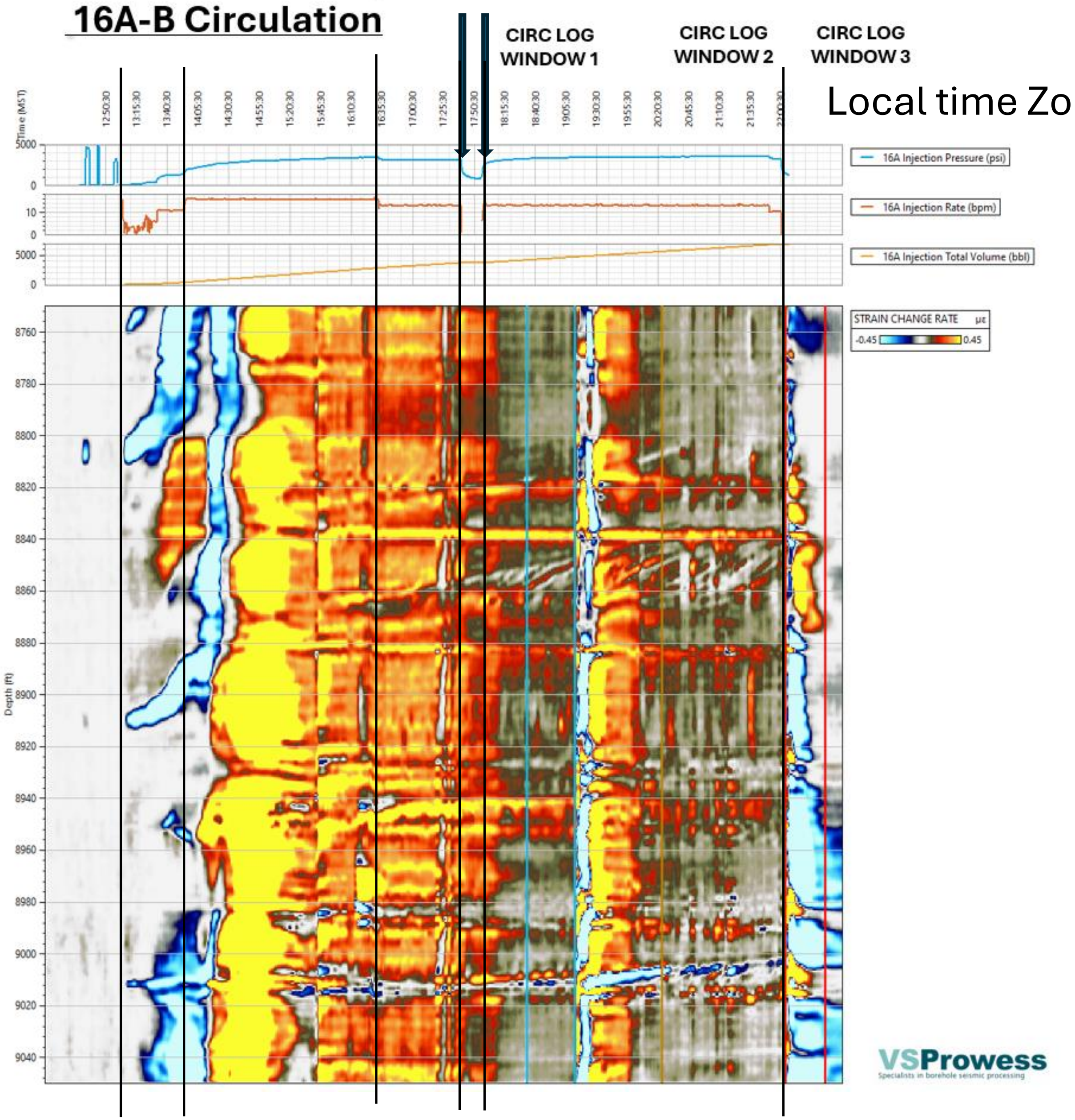
Zoom from 8700 to 9050 MD

16A Injection Pressure
Injection Rate
Cumulative Volume

Summary
Waterfall Plot
Depth (Y)
Time (X)
DSS Strain Rate
(Color)

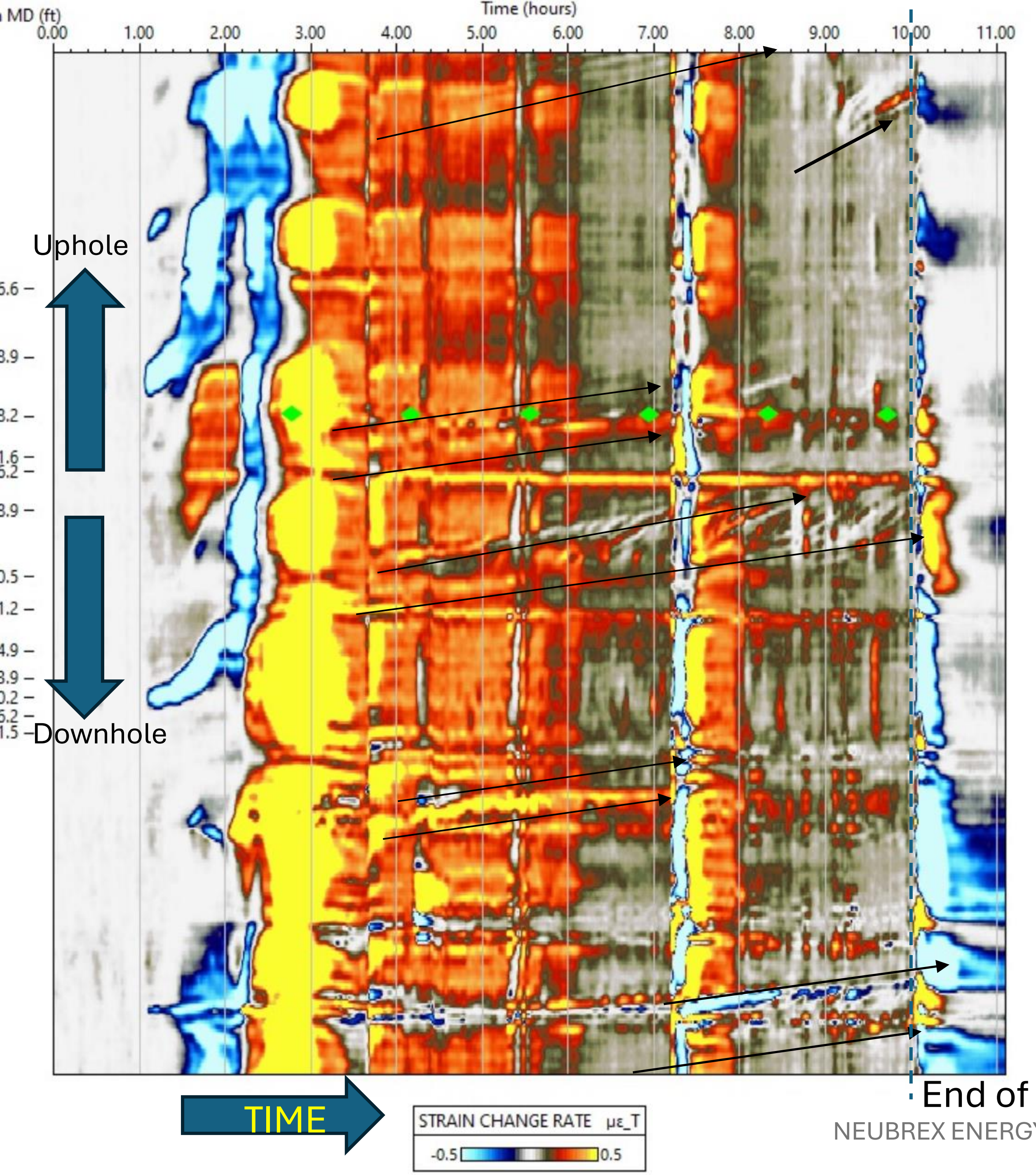
Blue = Neg Change
Yellow – Red =
Positive Strain
Change Rate

EVO3 - 16B RFS DSS Strain Change Rate



Local time Zone Coordinates

Energy Se



End of 16A pumping

Circulation Period – Example of Upgoing Thermal Slugs From a region of 16B (Green Diamonds are Perf Locations)

Arrow indicate slugs

End of Technical Report and Contact Information

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Backup Detail on Data Processing

Measurement Units

The time zone and unit system

Measurement units

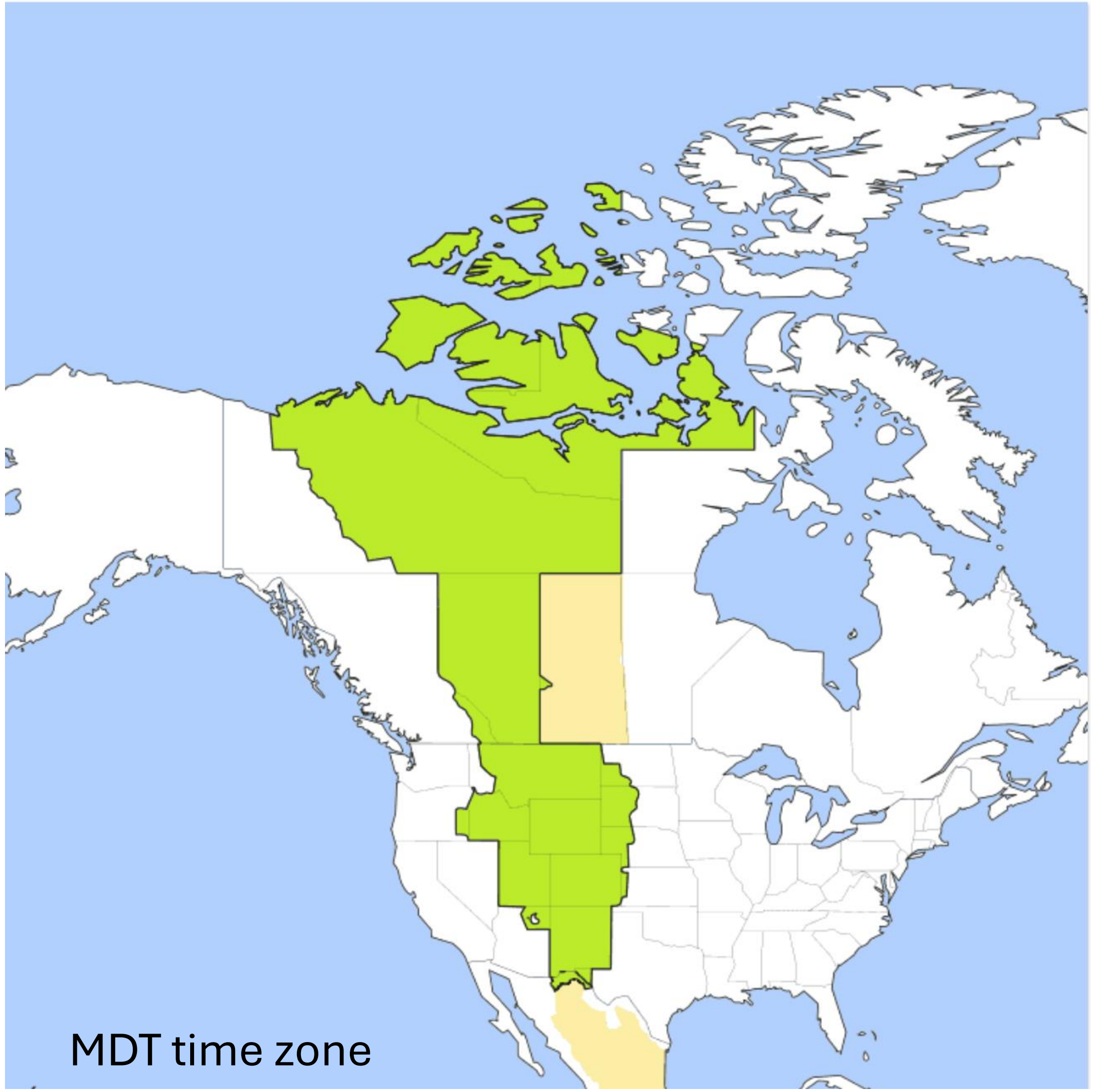
- Imperial (US) units are used in the report
  - Distance – foot, ft
  - Temperature – Fahrenheit degree, °F
  - Pressure – pound per square inch, psi

- Values of strain reported as micro-strain, $\mu\epsilon$
  - Unless stated otherwise

Time zone

- Results reported in this document are in ***Coordinated Universal Time (UTC)***

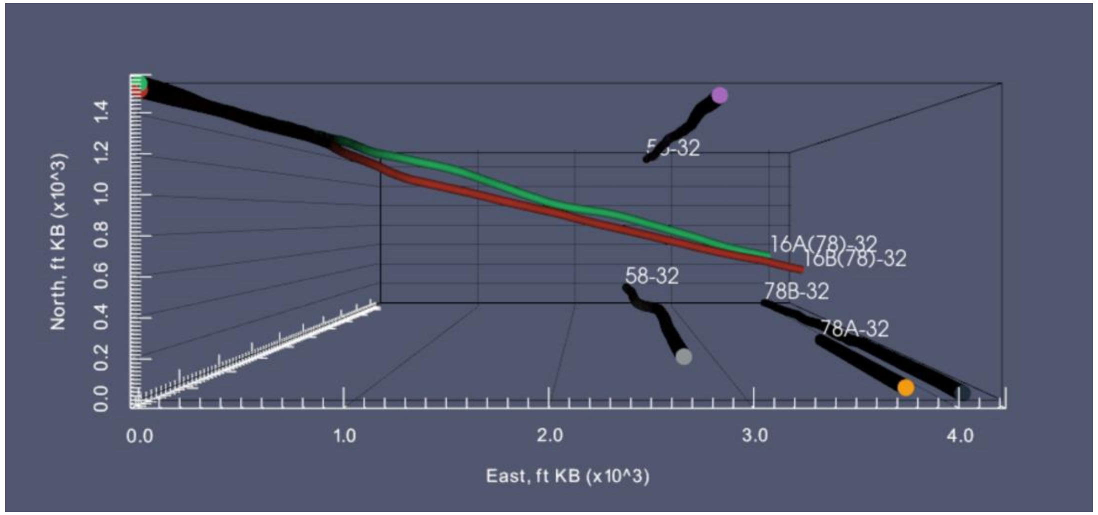
- Local time zone was ***Mountain Daylight Time (MDT)***
  - **UTC Offset: UTC −6**

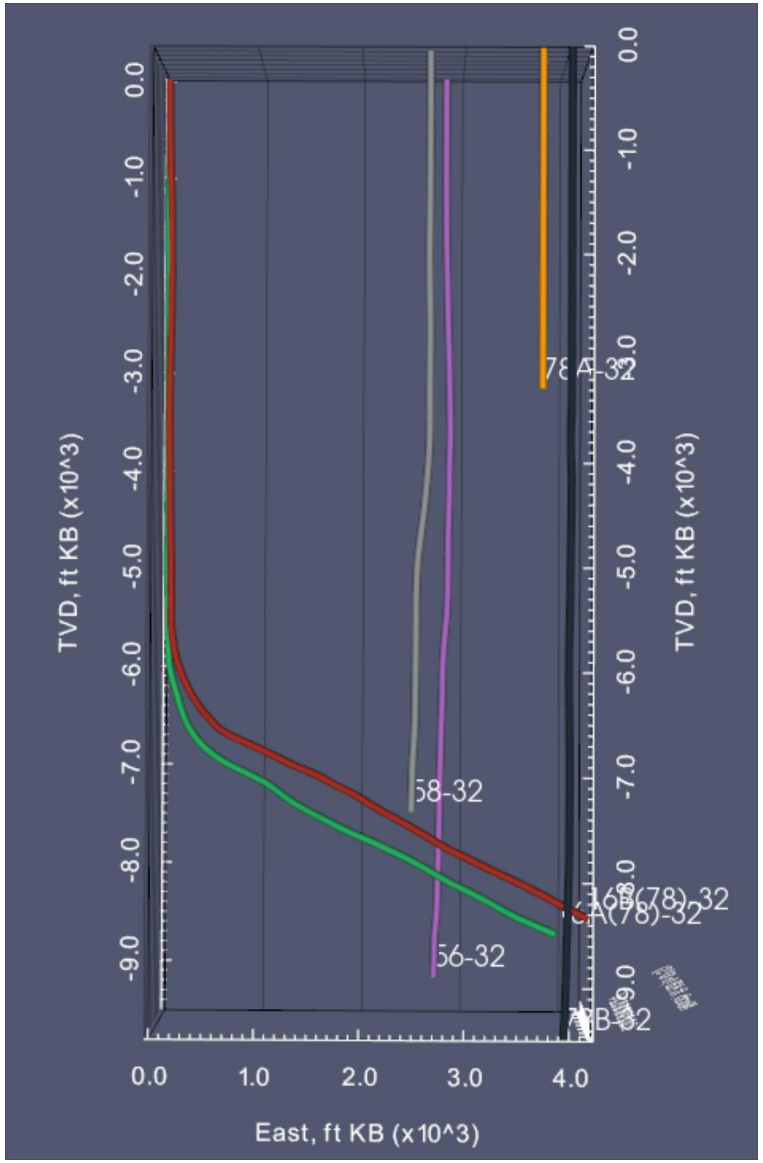


Well Survey Renderings

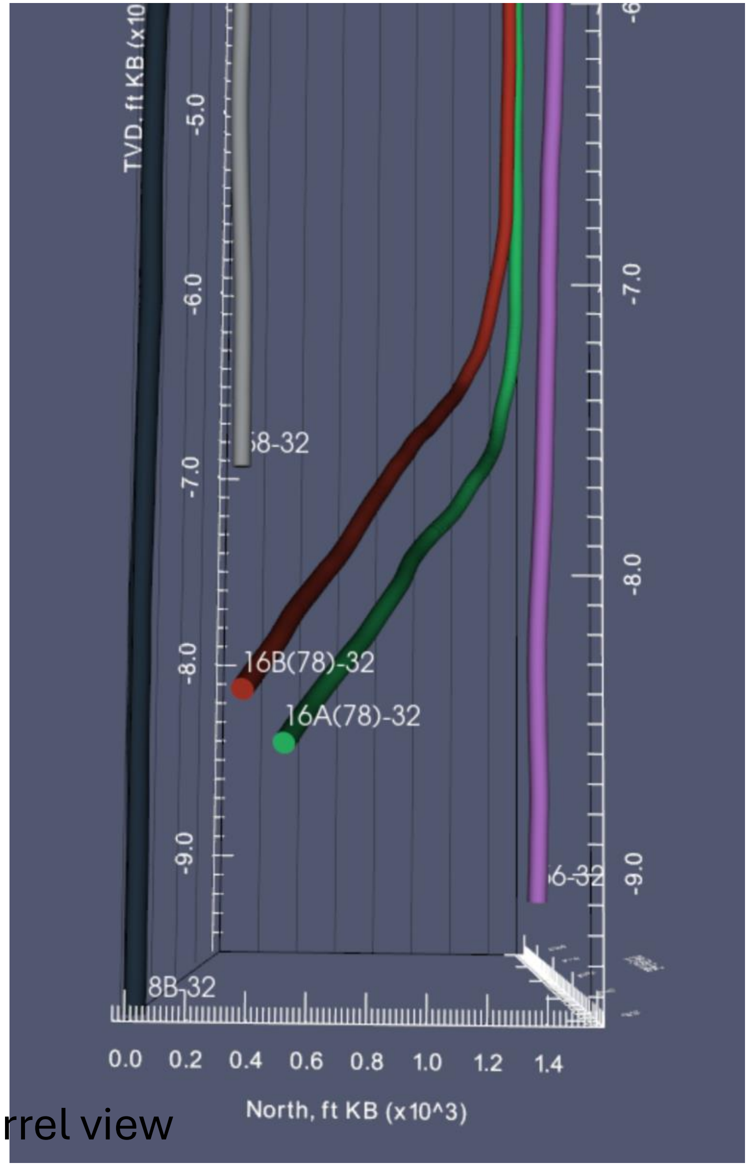
Based on schematics and deviation survey data provided by Operator

Monitored well

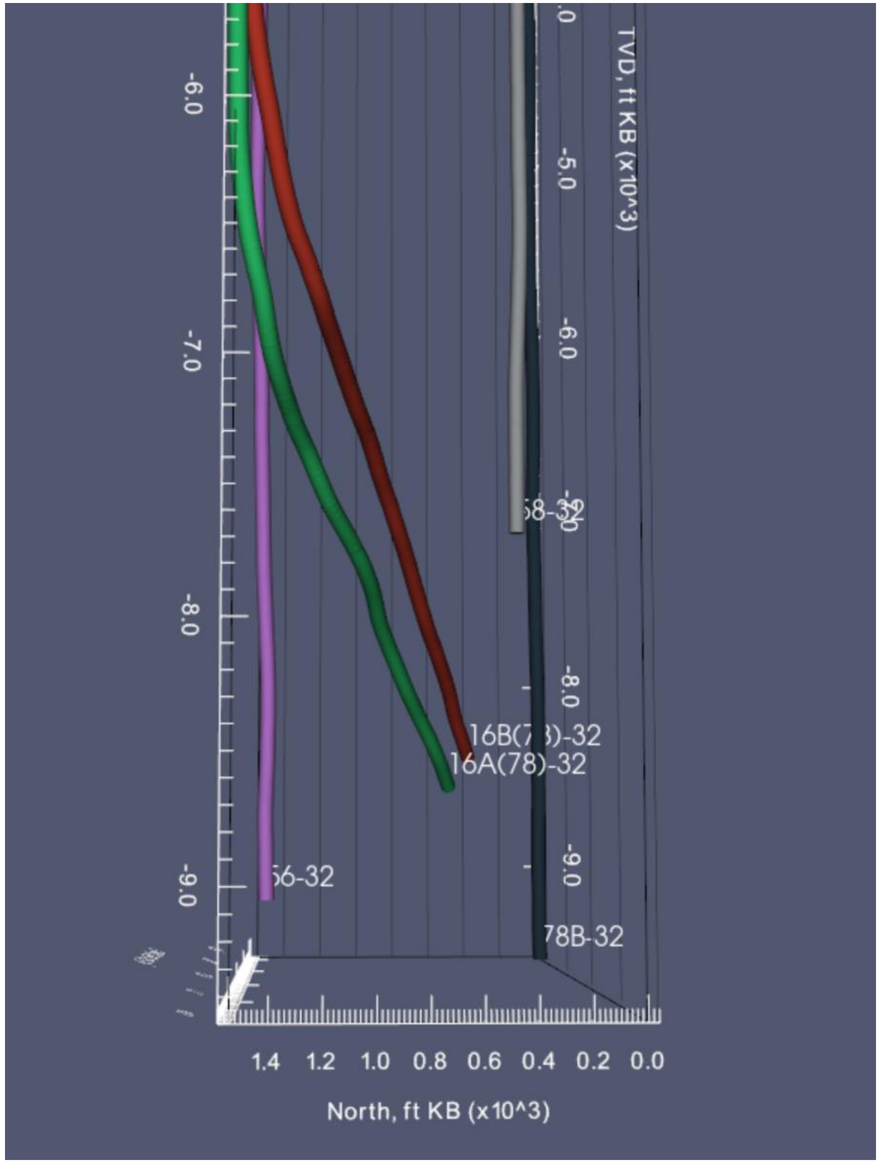




Monitored well



Gun barrel view



Depth calibration

This Section contains depth mapping of the fiber optics on monitored wells.

Depth calibration between fiber optic measurements and well measured depth features is an essential and critical component of fiber optic data processing.

Depth calibration findings from Neubrex workflow and data

- Final measured depth of the fiber termination = **10,108.46 MD, ft KB**
- KB = **31.0 ft MD**
  - Casing tally report
  - Reference location: GL
- **Depth Contraction coefficient (SMF 2/MMF 2):**
  - RFS = 1.0000
  - BCF = 1.0000
  - DTS = 1.0042
- **Offset Correction Distances (SMF 2/MMF 2):**
  - RFS: 648.94 ft
  - BCF: 825.57 ft
  - DTS: 419.96 ft

End