IADC Bit Forensics Presentation

Case Study: *Motor Back-drive Dynamics*

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17th November 2021

Agenda

- **Run Summary and Information**
  - County
  - Formations (Gamma, UCS, etc)
- **Bit Photos**
  - Photos
  - Bit Damages (Damaged Areas)
  - Stick Slip Cases
- **Downhole and Surface Data**
  - Downhole Sensor Location
  - Downhole Data
  - Motor Back-drive Dynamics
  - Surface Data and Control System (Setpoint)
- **Summary and Conclusions** (recommendation for mitigation)

Run Summary and Information

Run Summary (Steerable Motor BHA)

Time and Depths (This BHA)	
Date In:	07-17 @ 11:15
Date Out:	07-19 @ 01:15
Hours In Hole:	38.00
Start Depth:	10071
End Depth:	11198
Total Drilled:	1127
Avg. Total ROP:	69.64
Circ. Hrs: Tot/only:	20.93 / 4.70
Percent Slide:	4.0%
Percent Hrs:	16.5%
Slide Hours:	2.67
Total Sliding:	45
Average Slide ROP:	16.87
Percent Rotary:	96.0%
Percent Hours:	83.5%
Rot/Total Hours:	13.52 / 16.18
Rotary Drilled:	1082
Avg. Rotary ROP:	80.05
Reason POOH:	TD

Motor Data			
Desc:	Adj 1.50° 7/8 5.9 w/ 9 3/8" NBS		
MFG:			
BHA Circ/All BHA:	4.70 / 20.93		
Motor SN:			
Pad OD:	8 5/16	NB Stab:	0
Bit to Bend:	6.71		
Bent Hsg/Sub:	1.5 / 1.5		
Lobe/Stage	7/8 / 5.9		
Revs/Gal:	0.16		
Rotor Jet:	16.19		
Proposed BUR:	0		
Actual BUR:	0		
Stator Clearance:			
Lower Stab OD:	9-3/8		
UpperStabOD:			
Extended Motor?	No		
Number of Stalls:	0		
Stalls Duration:			

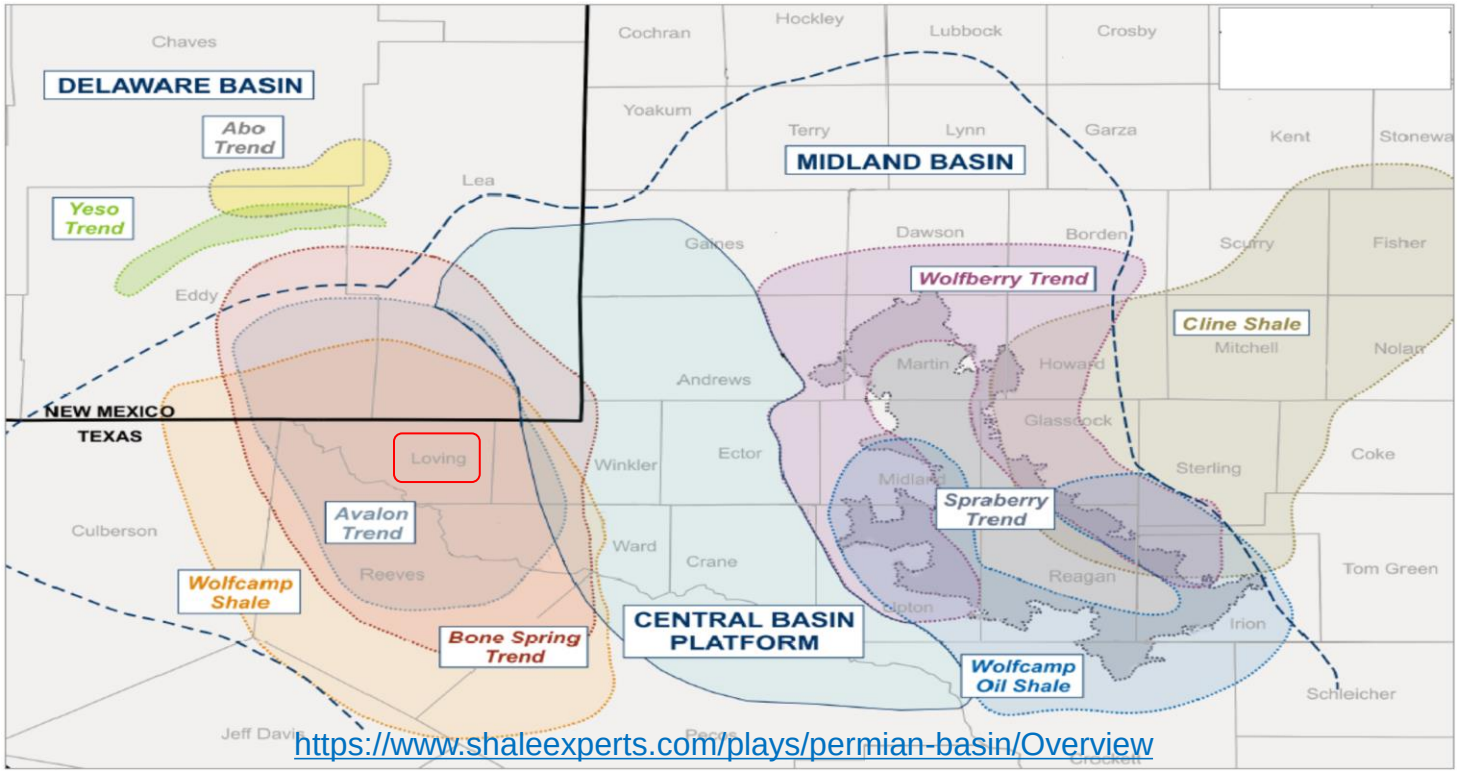
Drilling Parameters	
WOB	30-50
Torque	9500-16000
SPP	4400-5131
Motor RPM:	111.2-112
Rotary RPM:	0-75
Flow Rate:	695-700
Avg Differential:	400
Stall Pressure	1335
Off Bot. Pressure:	0

Bit Record			
Run #:	3		
Type Bit:	PDC`		
IADC#:		TFA:	0.84
Jets:	9-11		
P Drop:	643 @ 700		
	9 7/8" Hole		

695 gpm * 0.16 rpg = 111.2 rpm

700 gpm * 0.16 rpg = 112.0 rpm

Loving County, Texas



https://www.shaleexperts.com/plays/permian-basin/Overview

Formations (Delaware Basin)

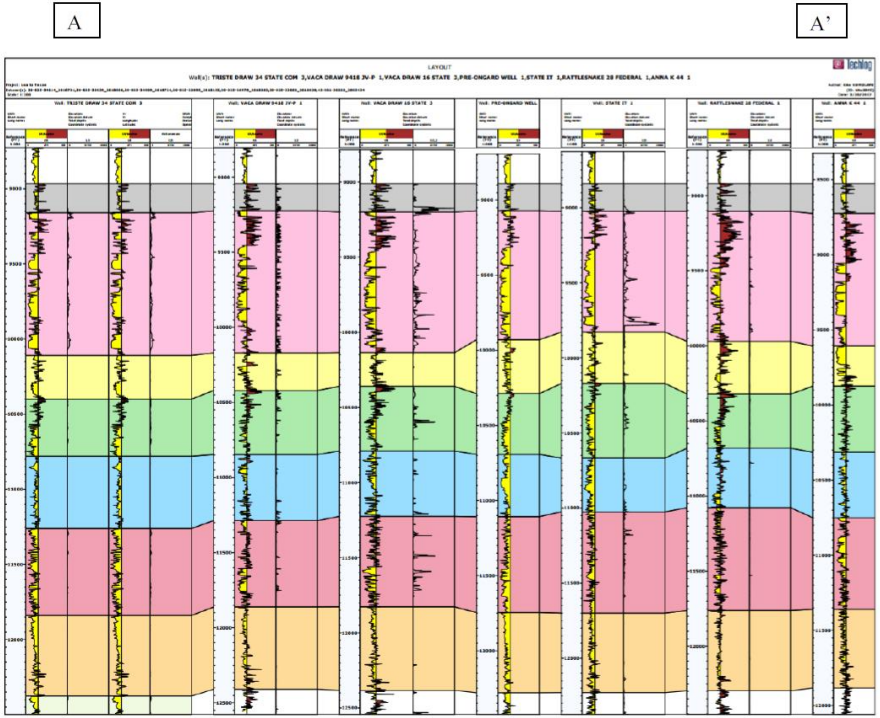


Figure 2. Wireline logs running from Lea County, NM to Loving County, TX

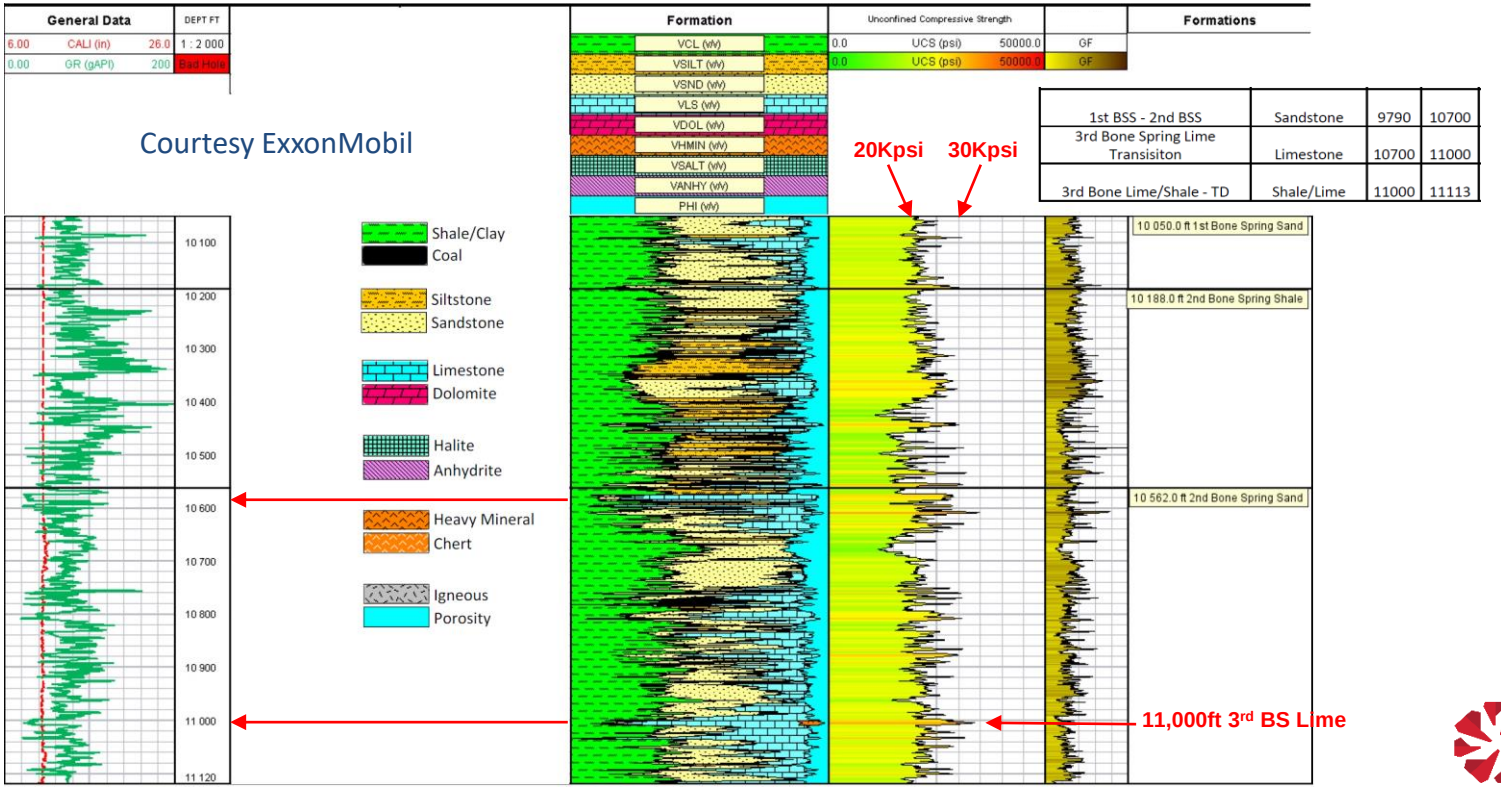
- Cutoff
- Bone Spring (1st Carbonate)
- 1st BS SS
- 2nd BS Carbonate
- 2nd BS SS
- 3rd BS Carbonate
- 3rd BS SS

SYSTEM	SERIES OR EPOCH	DELAWARE BASIN		NORTHWEST SHELF	CENTRAL BASIN PLATFORM
PERMIAN	OCHOA	Dewey Lake		Dewey Lake	Dewey Lake
		Rustler		Rustler	Rustler
		Salado		Salado	Salado
		Castile			Castile
	GUADALUPE	Delaware Mtn. Group	Lamar Bell Canyon	Tansill	Tansill
				Yates	Yates
			Cherry Canyon	Seven Rivers	Seven Rivers
				Queen	Queen
				Grayburg	Grayburg
			Brushy Canyon	San Andres	San Andres
				Glorieta	Glorieta
	LEONARD	Bone Spring Fm.	Cutoff Formation		
			1st Bone Spring Carbonate	Clear Fork Yeso	Clear Fork
			1st Bone Spring Sand		
			2nd Bone Spring Carbonate	Wichita Abo	Wichita
			2nd Bone Spring Sand		
			3rd Bone Spring Carbonate		
			3rd Bone Spring Sand		
	WOLFCAMP	Wolfcamp		Wolfcamp	Wolfcamp

https://core.ac.uk/download/pdf/147122179.pdf

1st BSS - 2nd BSS	Sandstone	9790	10700
3rd Bone Spring Lime Transisiton	Limestone	10700	11000
3rd Bone Lime/Shale - TD	Shale/Lime	11000	11113

1st and 2nd BS: Gamma, UCS, Formations



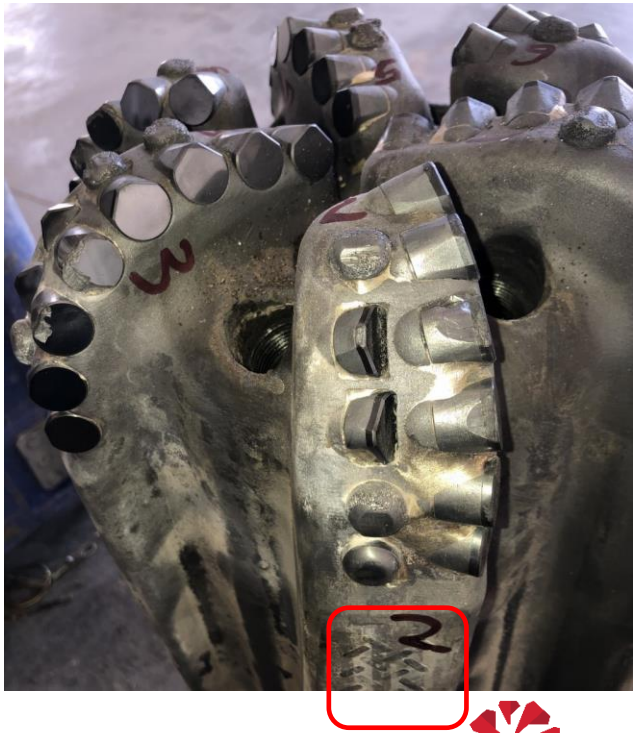
Bit Photos

Bit Photos (Side and Top)

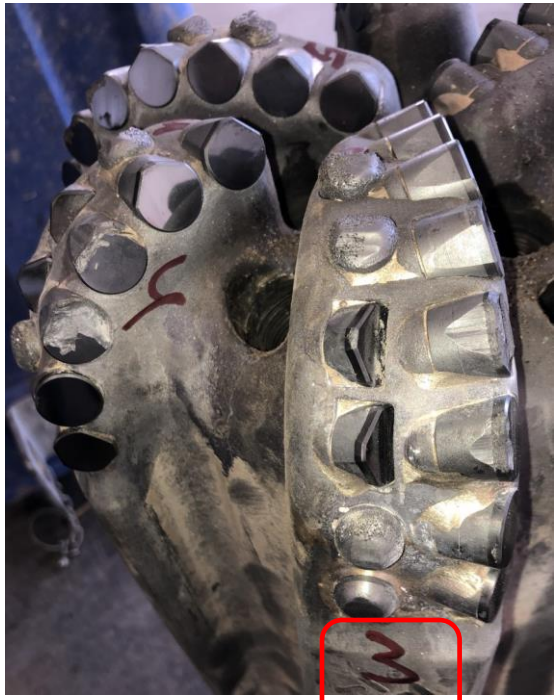
Bit Type	Icon	Size	Connection Size	Connection Thread	Make	Depth In	Depth In (TVD)	Depth Out	Depth Out (TVD)	Depth Drilled This Job	Hours Drilled This Job	Hours Circ This Job	Date In	Date Out	Tripping Time	Other Time	Circ+Trip+Other	IADC Bit Dull Out
PDC	Bit - Diamond	9.87	6.63	REG	R	1,220.0	1,219.9	10,071.0	10,053.0	8,851.00	92.25	10.50	7/12/ 6:00	7/17/ 7:00	16.75	1.25	28.50	3-3-WT-S-X-0-BT-DMF
PDC	Bit - Diamond	9.87	6.63	REG	R	10,071.0	10,053.0	11,198.0	11,179.8	1,127.00	16.50	3.00	7/17 8:00	7/19/ 2:00	19.00	9.50	31.50	1-1-WT-S-X-0-WO-TD

Bit Photos (Blade 1)

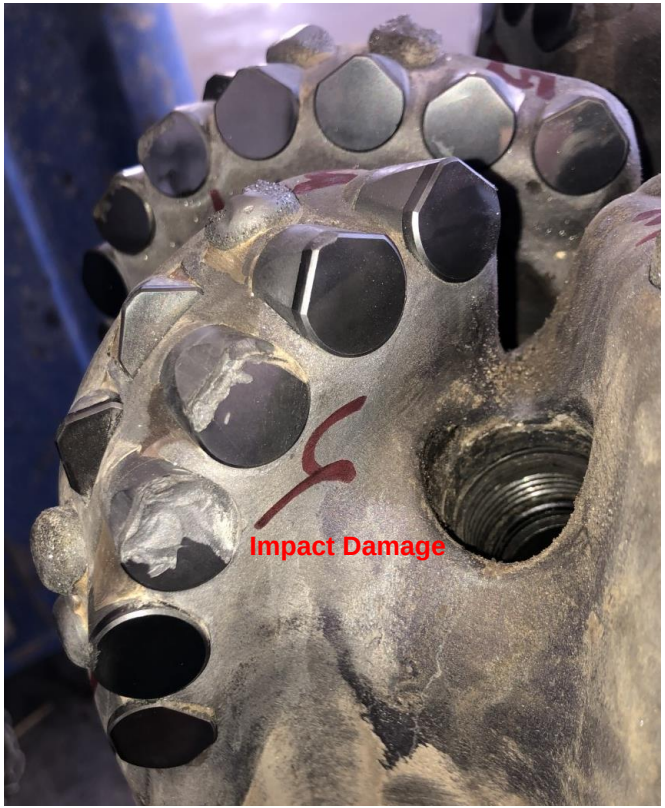
Bit Photos (Blade 2)

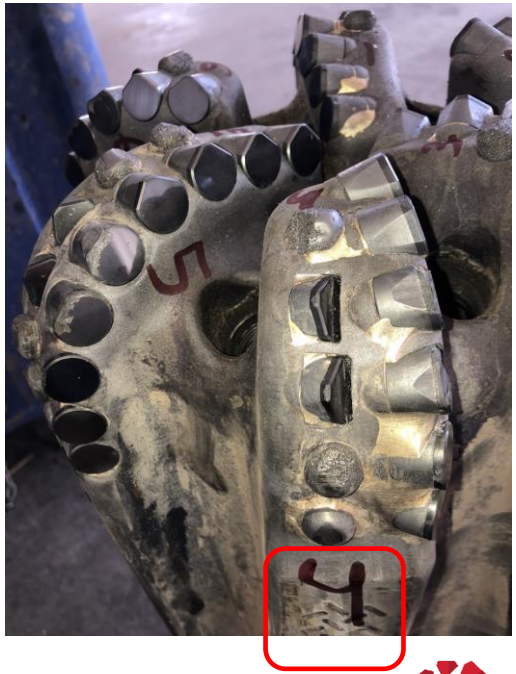


Bit Photos (Blade 3)



Bit Photos (Blade 4)



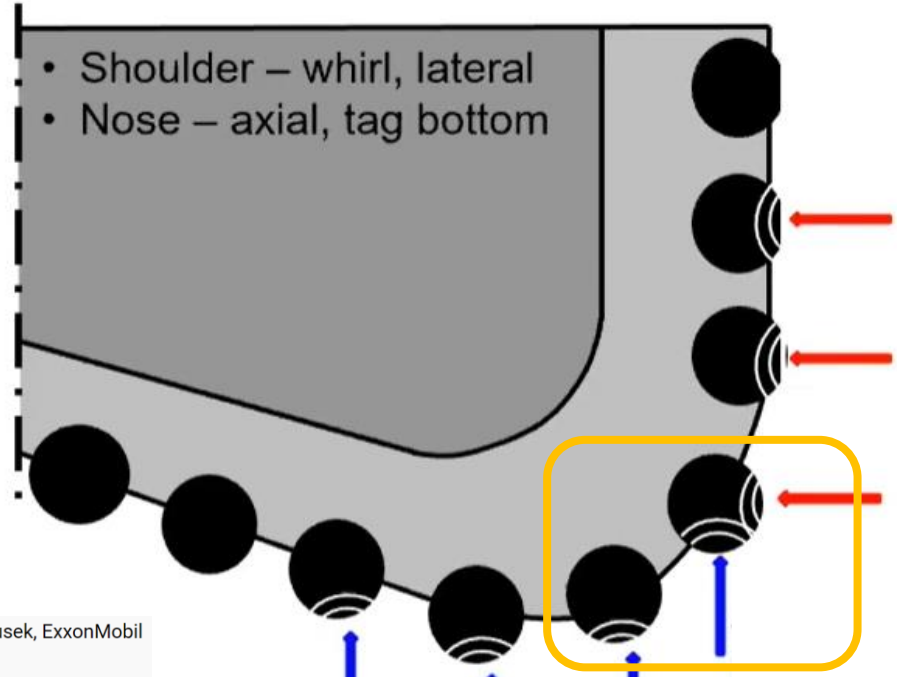


Bit Photos (Blade 5)

Bit Photos (Blade 6)

Bit Damage Analysis

Damaged Area



Lateral Shocks/ Vibrations

DC VPD - Drill Bit Forensics with Paul Pastusek, ExxonMobil

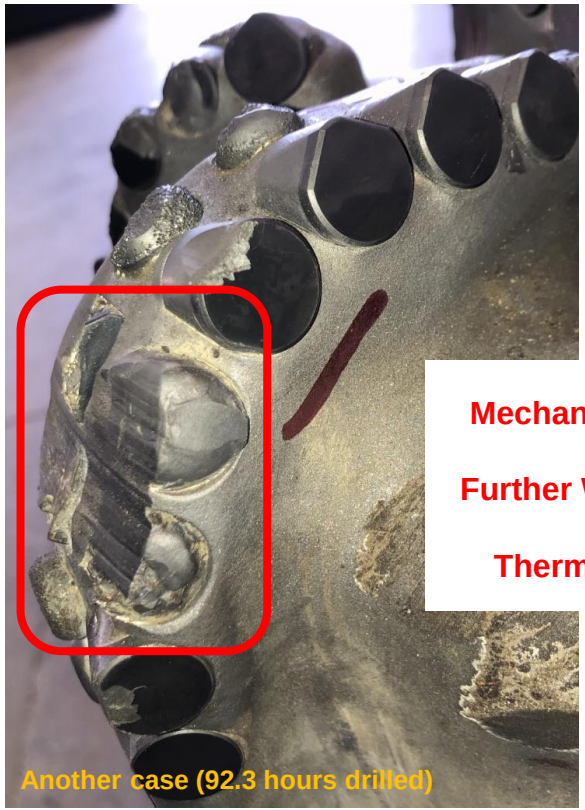
507 views • Apr 12, 2021

https://www.youtube.com/watch?v=3MLBAAh21nk&t=1002s

Damages were on the shoulder cutters

Axial S&V

Damage Progression



Mechanical Damage
↓
Further Wear/Friction
↓
Thermal Damage

Some Similarities?

Not smooth cutter wear!

Damage Caused by Stick Slip

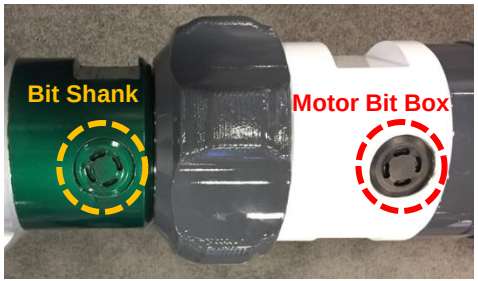
This case (16.5 hours drilled)

Location	Cone	Nose	Shoulder	Gauge
Average damage	0	0	3.41	0

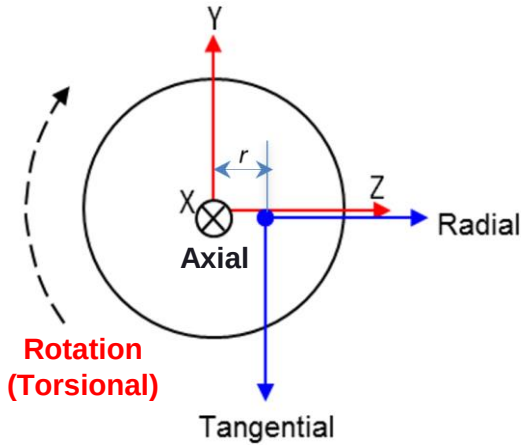
Figure 16—Damage cause classified as stick slip.

Downhole and Surface Data (Digital Data Forensics)

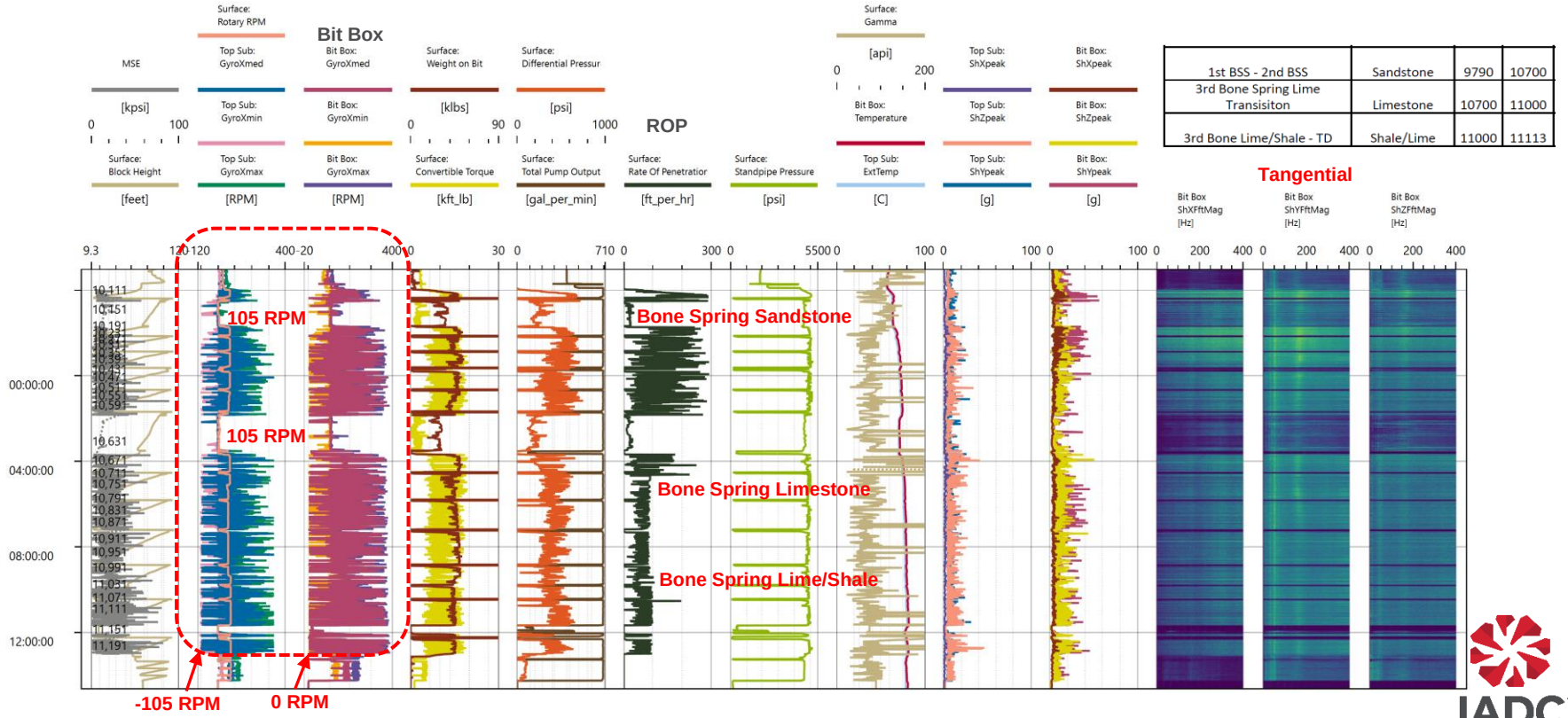
Downhole Sensor Locations



Sensor in a bit box



Downhole Data Overview (3 parts)



1st BSS - 2nd BSS	Sandstone	9790	10700
3rd Bone Spring Lime Transisiton	Limestone	10700	11000
3rd Bone Lime/Shale - TD	Shale/Lime	11000	11113

Motor Back-drive Dynamics (SPE-204032-PA)

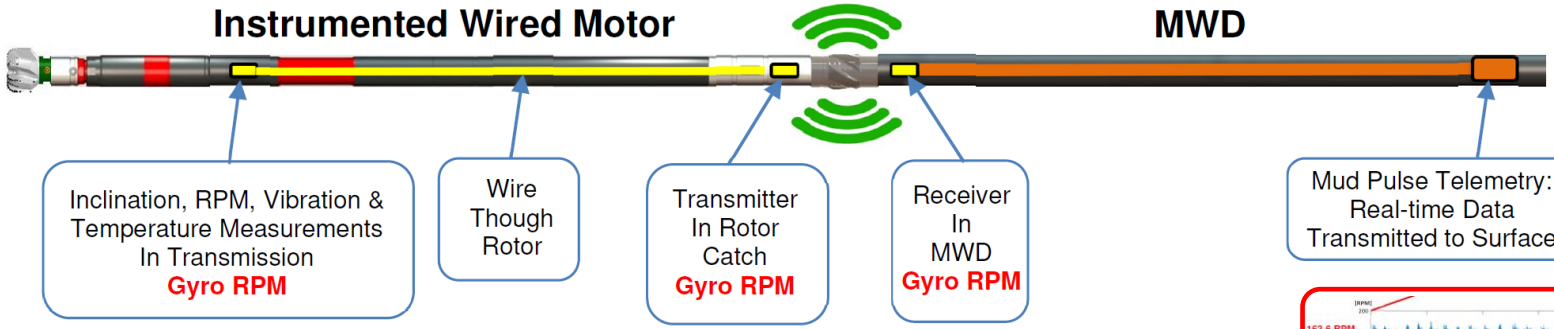
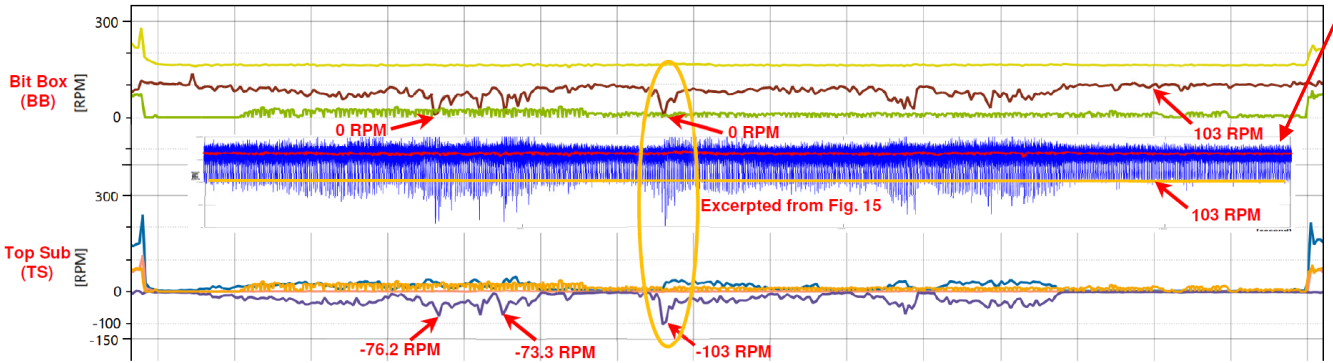
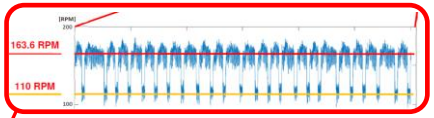


Fig. 24—Instrumented wired motor BHA (modified from Jones and Sugiura, 2020).





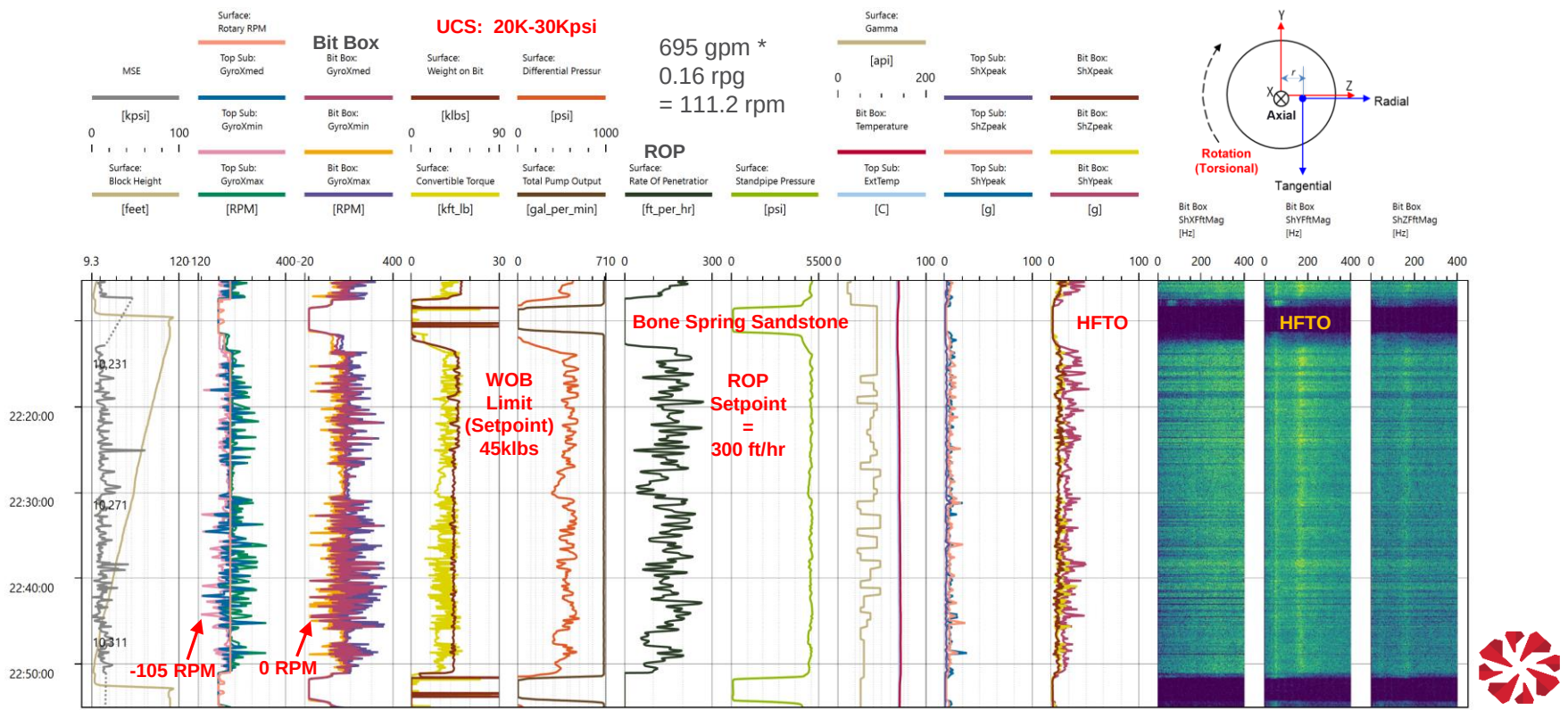
Bit Min. RPM

BB 100hz_GX-HSmin

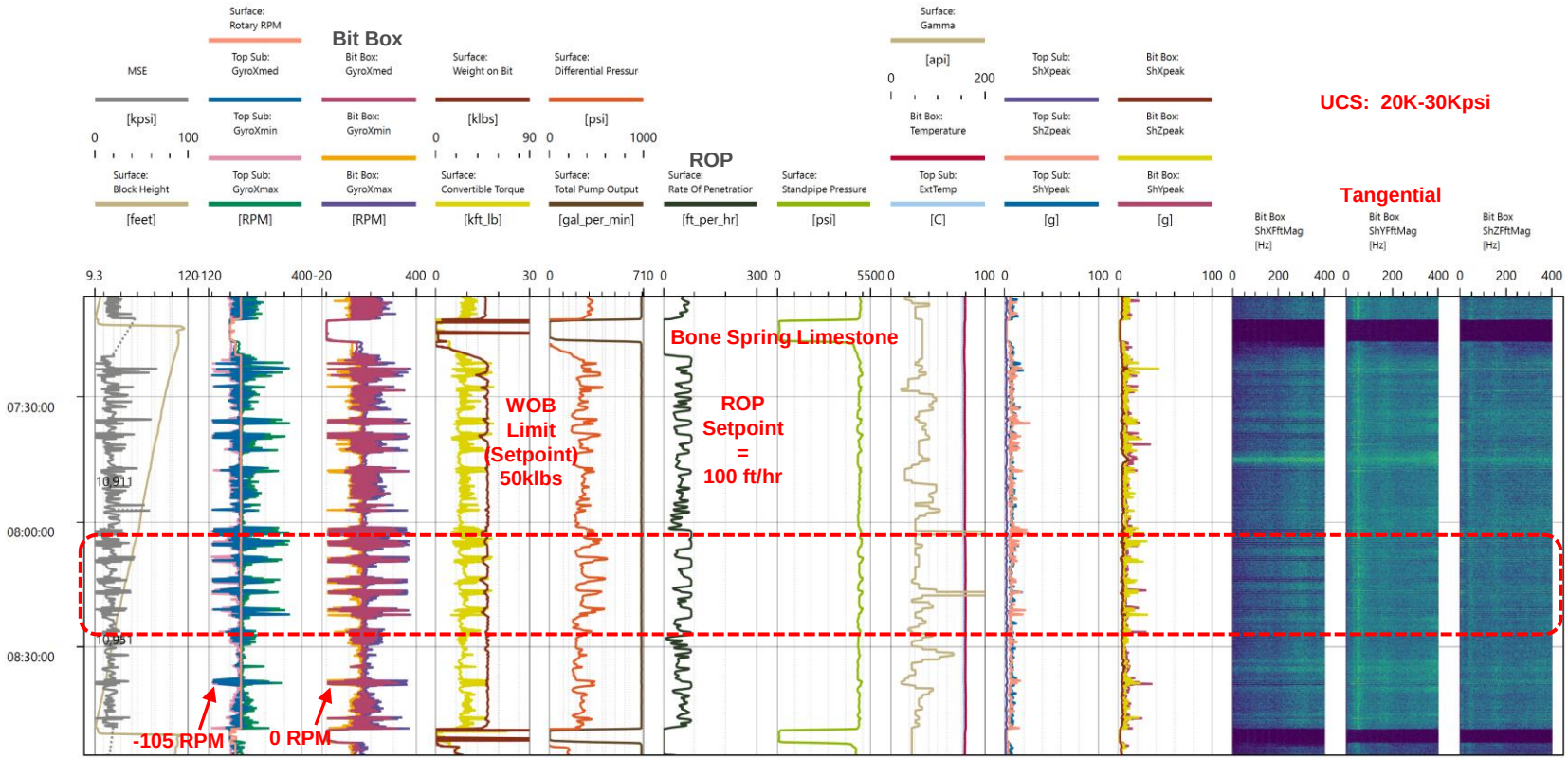
String Min. RPM

TS 100hz_GX-HSmin

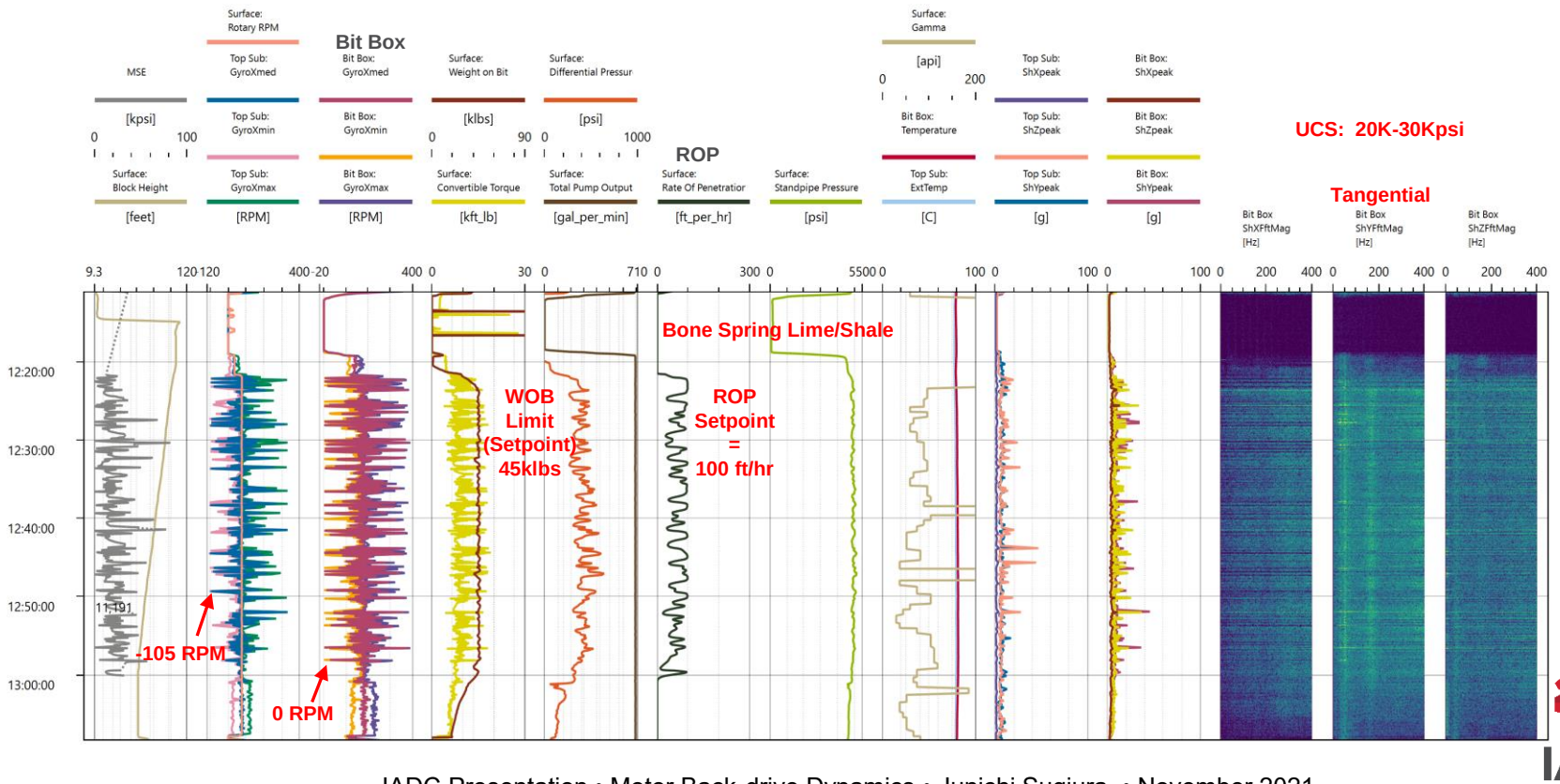
Downhole Data (Bone Spring Sandstone)



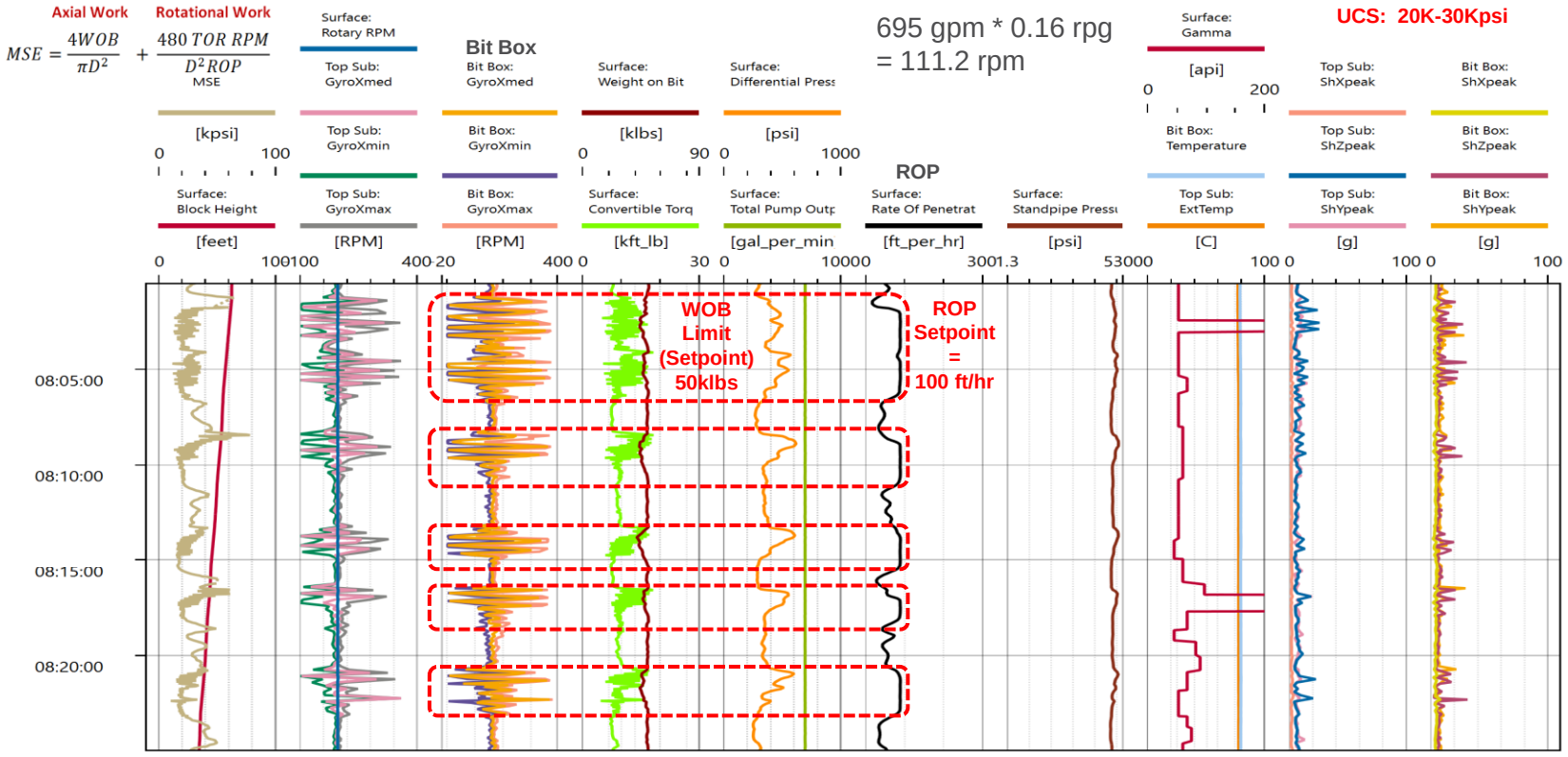
Downhole Data (3rd Bone Spring Limestone)



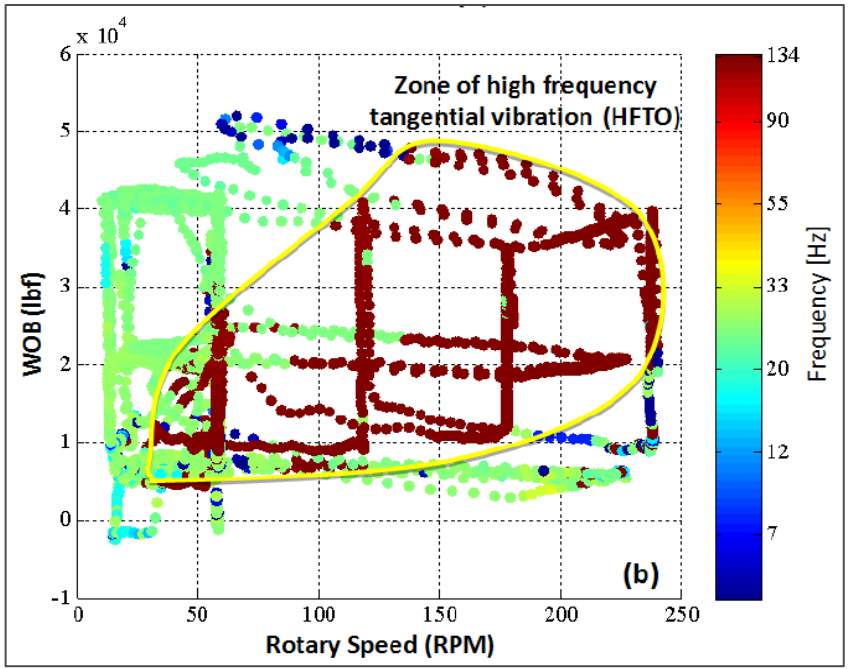
Downhole Data (3rd Bone Spring Lime/Shale)

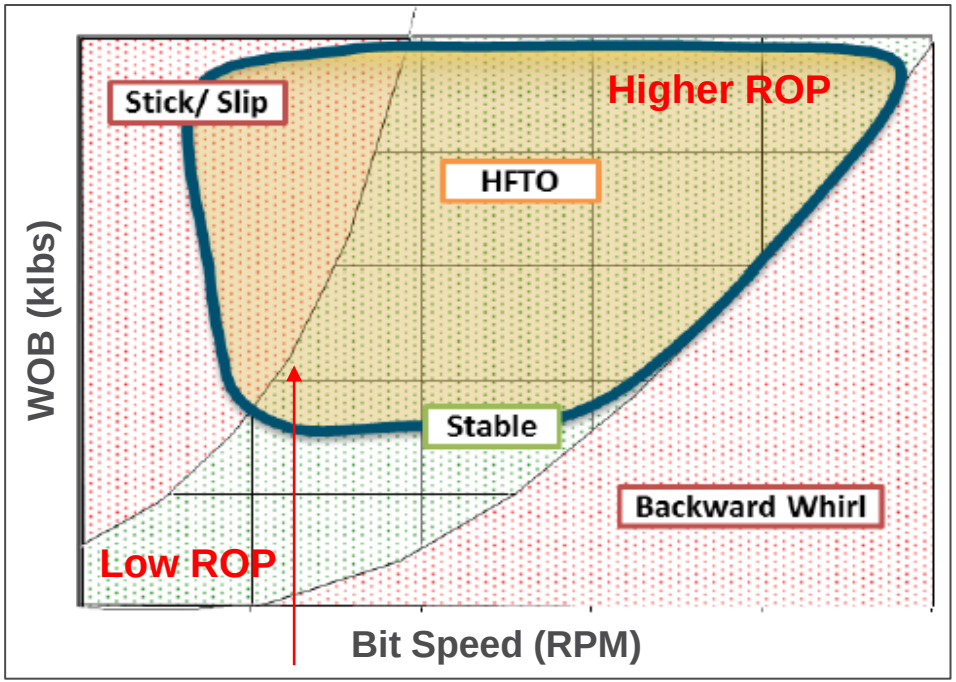


Surface Data (Zoomed) in 3rd BS Limestone



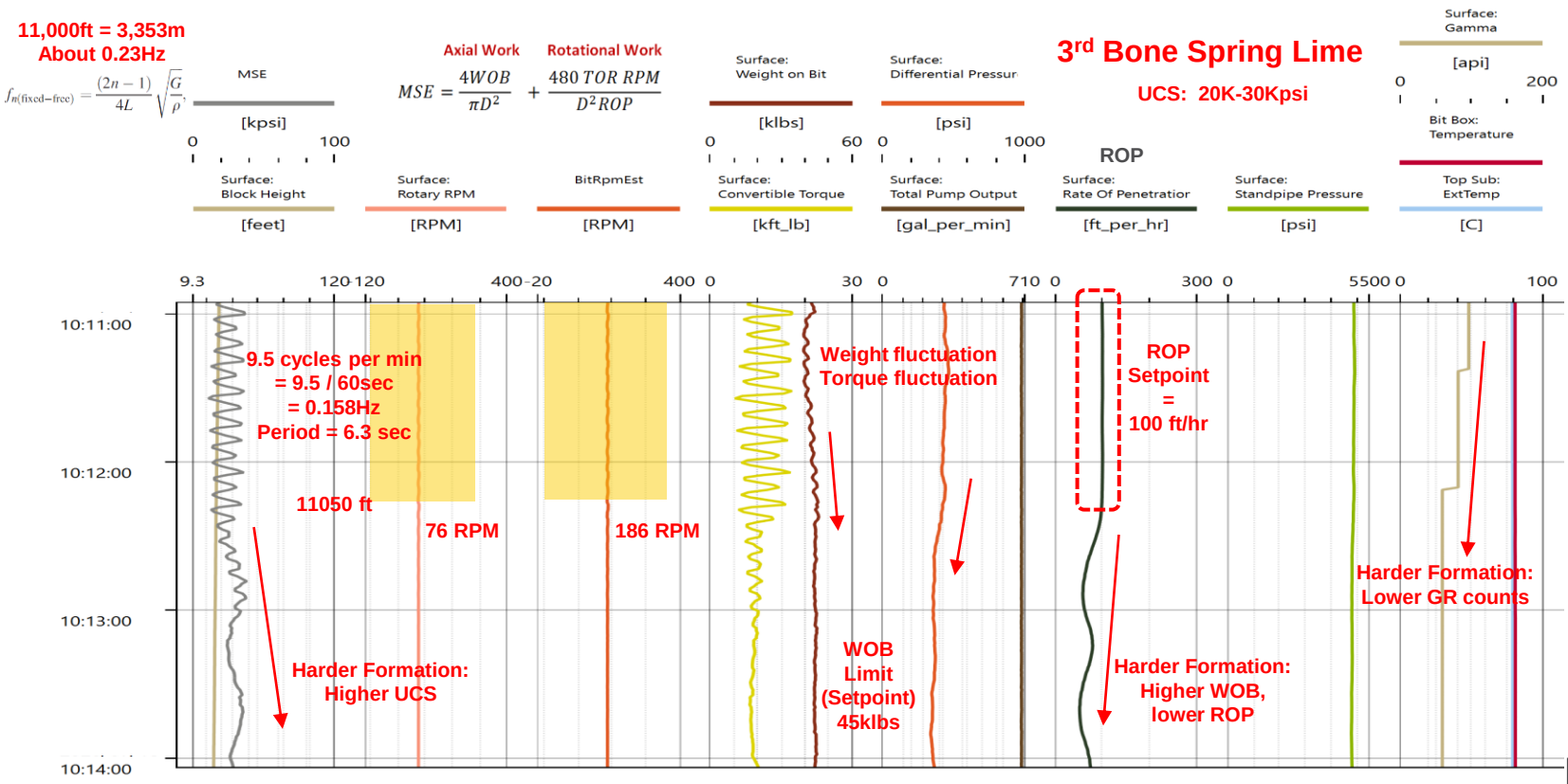
Stick Slip and Surface Parameters



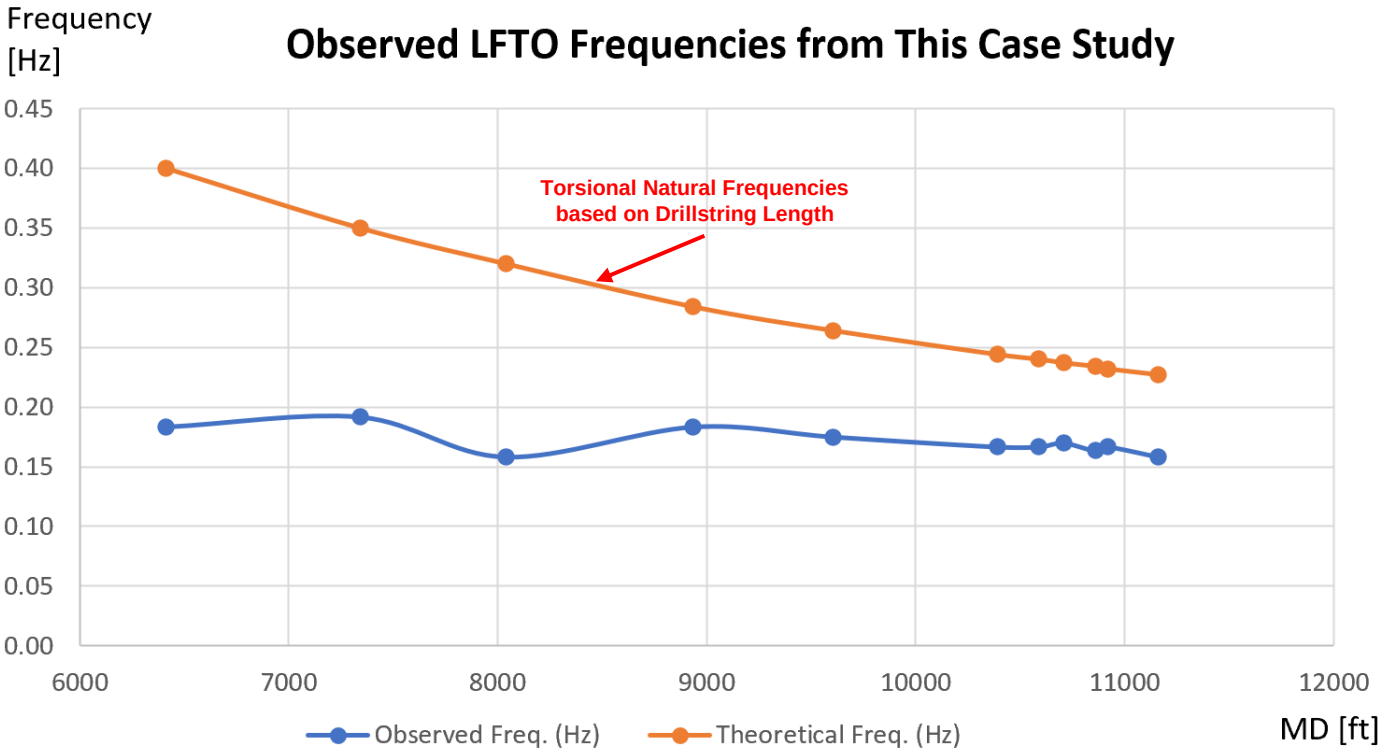


SPE-166212-MS

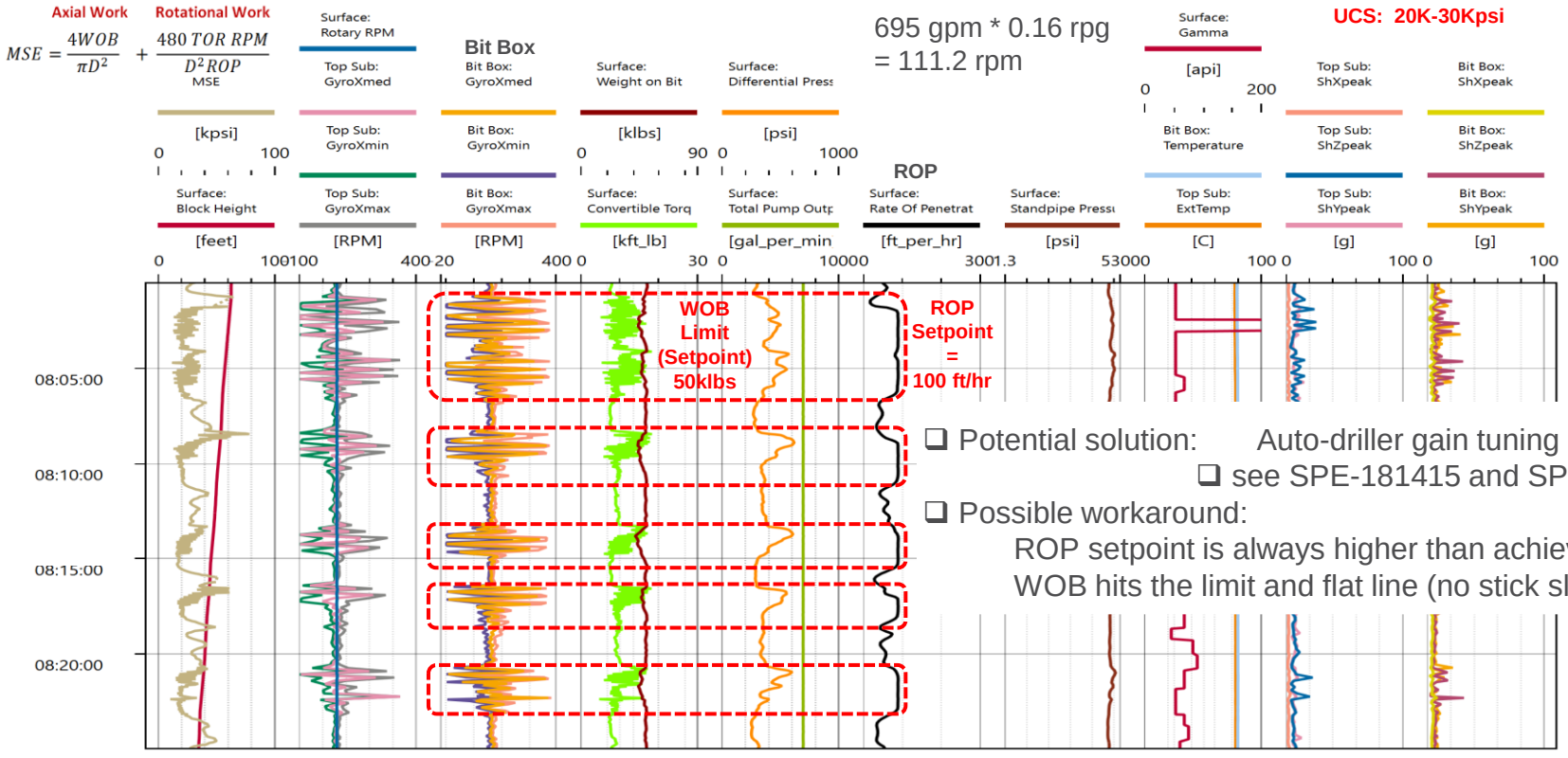
Surface Data (Zoomed) in 3rd BS Lime



Back-up Slide (Observed LFTO Frequencies)



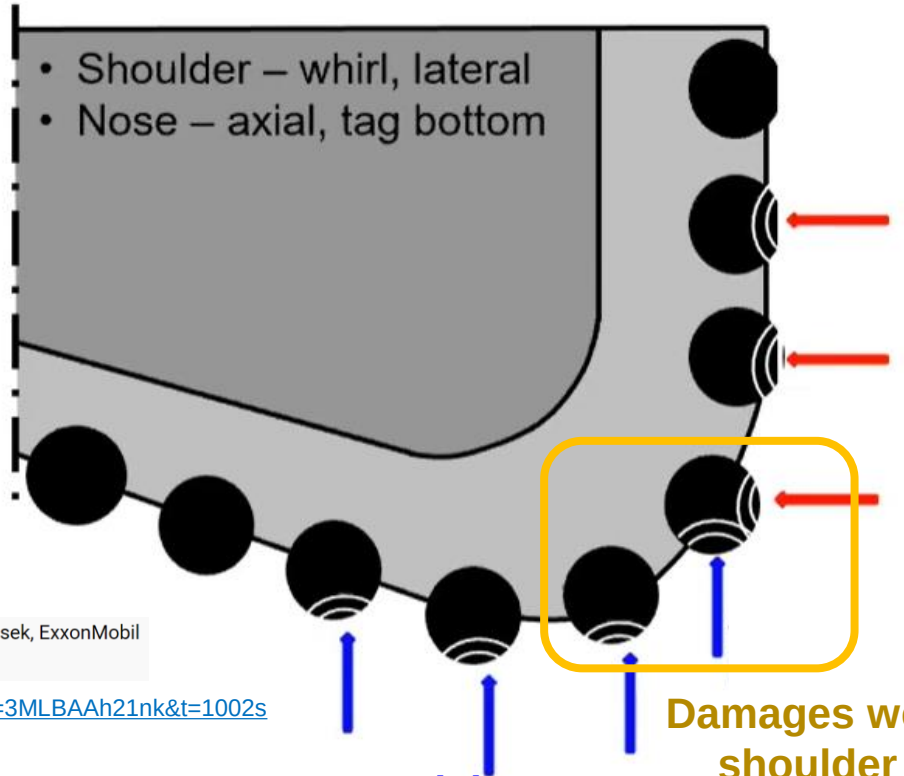
Surface Data (Zoomed) in 3rd BS Limestone



- Potential solution: Auto-driller gain tuning
  - see SPE-181415 and SPE-191417
- Possible workaround:
  - ROP setpoint is always higher than achievable ROP
  - WOB hits the limit and flat line (no stick slip)

Drill Bit Forensics (Review)

Damaged Area (Torsional Vibration Damage)



Lateral Shocks/ Vibrations

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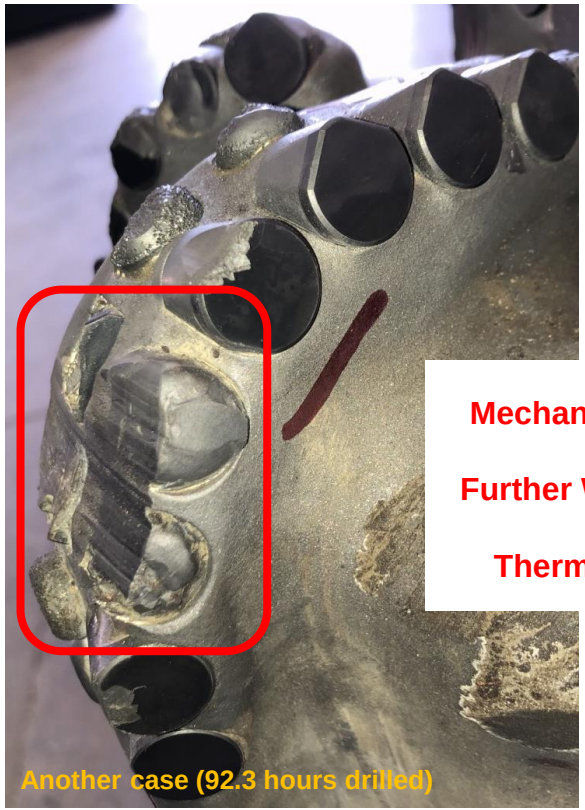
Damages were on the shoulder cutters

Axial S&V

Damage Progression



Mechanical Damage
↓
Further Wear/Friction
↓
Thermal Damage

Bit Damage from Motor Back-drive

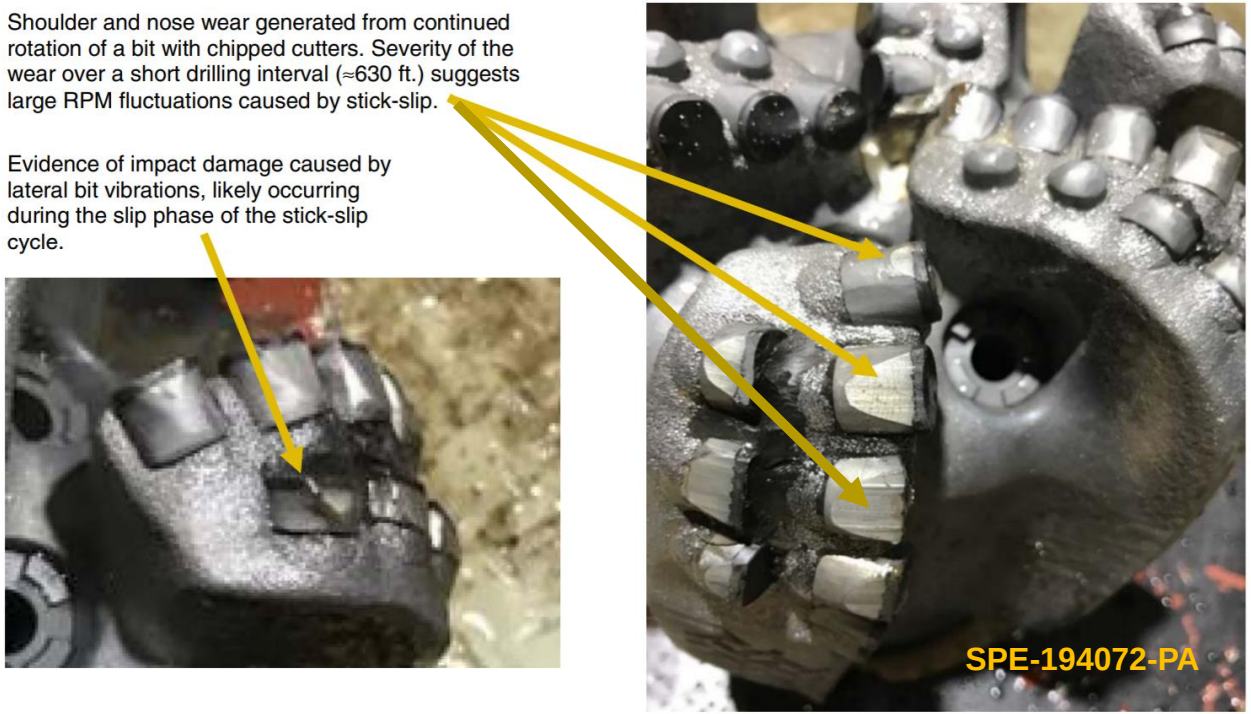
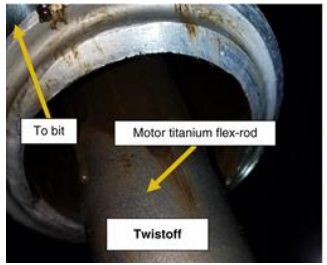
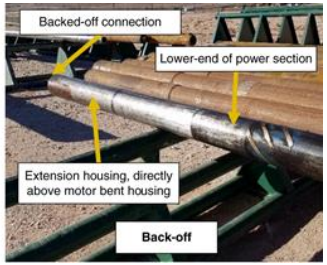


Fig. 4—Post-run pictures of the bit for the run that resulted in the twistoff.

Possible Damages from Back-drive Dynamics

- **SPE-194072-PA (Wilson et al. 2019)**
  - Motor connection twist-offs
  - Motor connection back-offs
  - Accelerated bit wear
  - Bending stress on the motor bend





- **SPE-204032-PA (Sugiura and Jones 2021)**
  - Drillstring twist-offs (1,000 - 2,000ft from the bit)
  - Drillstring back-offs (1,000 - 2,000ft from the bit)
  - 7-8Hz torsional oscillations at 3,000, 9,000 and 20,000 ft MD

- **Other field observations**
  - Motor transmission failure
  - Motor stator damage (cracks, bending fatigue)
  - Motor kick-pad damage
  - MWD rubber fin damage
  - MWD failure

Summary and Conclusions

Summary (Part 1)

- **Severe stick-slip and motor back-drive dynamics were observed in 1st, 2nd, and 3rd Bone Spring in the Delaware Basin**
  - Bit RPM = 0 and string RPM = -105 (near the motor output RPM in reverse)
  - Severe drilling dynamics were observed in Sandstone, Limestone, and Lime/Shale
  - Severe drilling dynamics regardless of ROP (between 50-300 ft/hr)
  - Some HFTO, but overall low axial and lateral shocks at bit and top-sub of the motor
- **Examination of drilling dynamics data indicates a possible problem with surface control system**
  - Surface WOB fluctuation ←→ torque fluctuation (f = 0.158Hz or T = 6.3 sec)
  - Surface torque fluctuation was correlated with downhole stick slip and motor back-drive dynamics (up to 11,200 ft MD)

Summary (Part 2)

- **Post-run bit photos show (primarily) damaged shoulder cutters**
  - Shoulder cutters were worn or damaged
  - Bit damages and damaged cutter positions are consistent with stick-slip damages reported in literature
  - As the run was short (16.2 drilling hours), no equipment damages were reported

- **Possibly, the root cause of severe downhole dynamics might have come from the surface control system (control gain issue and mis-tuned auto-driller)**
  - When the actual ROP was around the ROP setpoint, WOB fluctuation was observed
  - When the formation became harder, the actual ROP became lower (than the setpoint) and WOB was slightly increased to hit the WOB limit. When the surface WOB hit the limit, WOB fluctuation disappeared.
  - Surface WOB and torque fluctuation occurred at 0.158Hz (Period = 6.3 seconds)
  - Potential solution: Auto-driller gain tuning
  - Possible workaround: ROP setpoint is always higher than achievable ROP

References

- Wilson, J. K., Whitacre, T.. , and G.. Heisig. "High-Frequency At-Bit Measurements Provide New Insights Into Torsional Dynamics When Drilling With Steerable Mud Motors in Unconventional Horizontal Wells." *SPE Drill & Compl* 34 (2019): 414–425. doi: https://doi.org/10.2118/194072-PA

- Sugiura, Junichi, and Jones, Steve. "Measurement of Mud Motor Back-Drive Dynamics, Associated Risks, and Benefits of Real-Time Detection and Mitigation Measures." *SPE Drill & Compl* 36 (2021): 628–646. doi: https://doi.org/10.2118/204032-PA

- Robnett, E.W., Hood, J.A., Heisig, G., and J.D. Macpherson. "Analysis Of The Stick-Slip Phenomenon Using Downhole Drillstring Rotation Data." Paper presented at the SPE/IADC Drilling Conference, Amsterdam, Netherlands, March 1999. doi: https://doi.org/10.2118/52821-MS

- Ledgerwood, L.W.. W., Jain, Jayesh R., Hoffmann, Olivier J., and Reed W. Spencer. "Downhole Measurement and Monitoring Lead to an Enhanced Understanding of Drilling Vibrations and Polycrystalline Diamond Compact Bit Damage." *SPE Drill & Compl* 28 (2013): 254–262. doi: https://doi.org/10.2118/134488-PA

- Oueslati, Hatem , Jain, Jayesh R., Reckmann, Hanno , Ledgerwood, L. W., Pessier, Rolf , and Sridharan Chandrasekaran. "New Insights into Drilling Dynamics through High-Frequency Vibration Measurement and Modeling." Paper presented at the SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, USA, September 2013. doi: https://doi.org/10.2118/166212-MS

It may be dull

…….but its never boring

or

It should be boring

…….and never dull

You Decide ☺