Preston New Road-2:
LJ/06-08
HFP Report

Preston New Road-2 HFP Report					
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Version	**Section**	**Revision Information**		**Date**	**Reviser**
Procedures are reviewed as per proposed review date, or sooner if a significant change to the operation has taken place, to ensure relevance to the systems and process that they define.					

Contents

1 OPERATIONS SUMMARY

Preston New Road-2 (PNR-2, LJ/06-8) was drilled from the Preston New Road site. The surface location of the well is located within EXL 269, the bottom hole location is within PEDL165. Both licences lie within the Bowland Basin, Lancashire, North West England. The well is located within a 100km^2 3D seismic survey in the same structural fairway as the shale gas discovery well Preese Hall-1. It is located approximately 3.9km south of Preese Hall-1.

The lateral section was completed with a 4.5" to 5.5" tapered production string to surface. 47 mechanically manipulated multi-cycle frac sleeves were placed approximately every 14.5m within the production string and cemented in place. During hydraulic fracturing operations the sleeves were shifted open selectively using 2" coiled tubing assembly. A choice of "slickwater" and/or "hybrid" hydraulic fracture design consisting of mains water, recycled flowback water, 100 mesh and/or 40/70 mesh sand, and a friction reducer to reduce pumping pressures was used to stimulate PNR-2. The over-riding objective was to complete hydraulic fracturing operations in full accordance with planning consent conditions and regulatory requirements, and with zero safety, environmental or community related incidents. Pumping operations took place during the period 13th August – 23rd August 2019. All operations were conducted under the seismicity limits of the Traffic Light System (TLS) set out in the Hydraulic Fracture Plan (HFP). This report is drafted and submitted in accordance with Section F.13 of the Consolidated Onshore Guidance Version 2.2, June 2018. No wireline image logs or coring were undertaken in the stimulated section of PNR-2.

Due to the seismic limitation not all the stages were stimulated with the designed frac fluid and proppant of 400m^3 and 50 tonnes per stage. Table 1 shows the total volumes pumped at each sleeve and the sequence in which they were pumped.

Date	Sleeve #	Activity	Volume (m^3)	Proppant (mT)	10% HCl (m^3)	FR (kg)
13-Aug	1	DFIT	2.5	0.0		
15-Aug	1	Mini/Main	303.5	30.4		96.0
16-Aug	2	Mini/Main	411.0	52.5		106.0
17-Aug	3	Mini/Main	422.8	55.0		107.0
19-Aug	4	Mini/Main	370.2	55.0		90.0
20-Aug	5	Mini/Main	401.3	55.0		140.0
21-Aug	6	Mini/Main	432.0	37.2	3.0	305.0
22-Aug	7	Mini/Main	142.0	3.7	2.0	134.0
		Total	**2485**	**288.8**	**5.0**	**978.0**

Table 1 Summary on injected volumes in each sleeve

2 WELL INTEGRITY

A pressure test was carried out after each casing string was installed to ensure the integrity of that barrier. The pressure testing limit was within a safety margin of the maximum burst rating of the casing, which was not exceeded during hydraulic fracturing operations. The annulus outside the main production string was continually monitored to ensure there was no leakage from the inner barrier. On the 25th August 2019 a pressure test was carried out on the casing above sleeve 7 at 3021m MD and successfully tested to 365 bar for 10 minutes. Following the completion of hydraulic fracturing all well annuli have been continually monitored and no well integrity issues have been identified.

3 PNR-2 CASING DIAGRAM

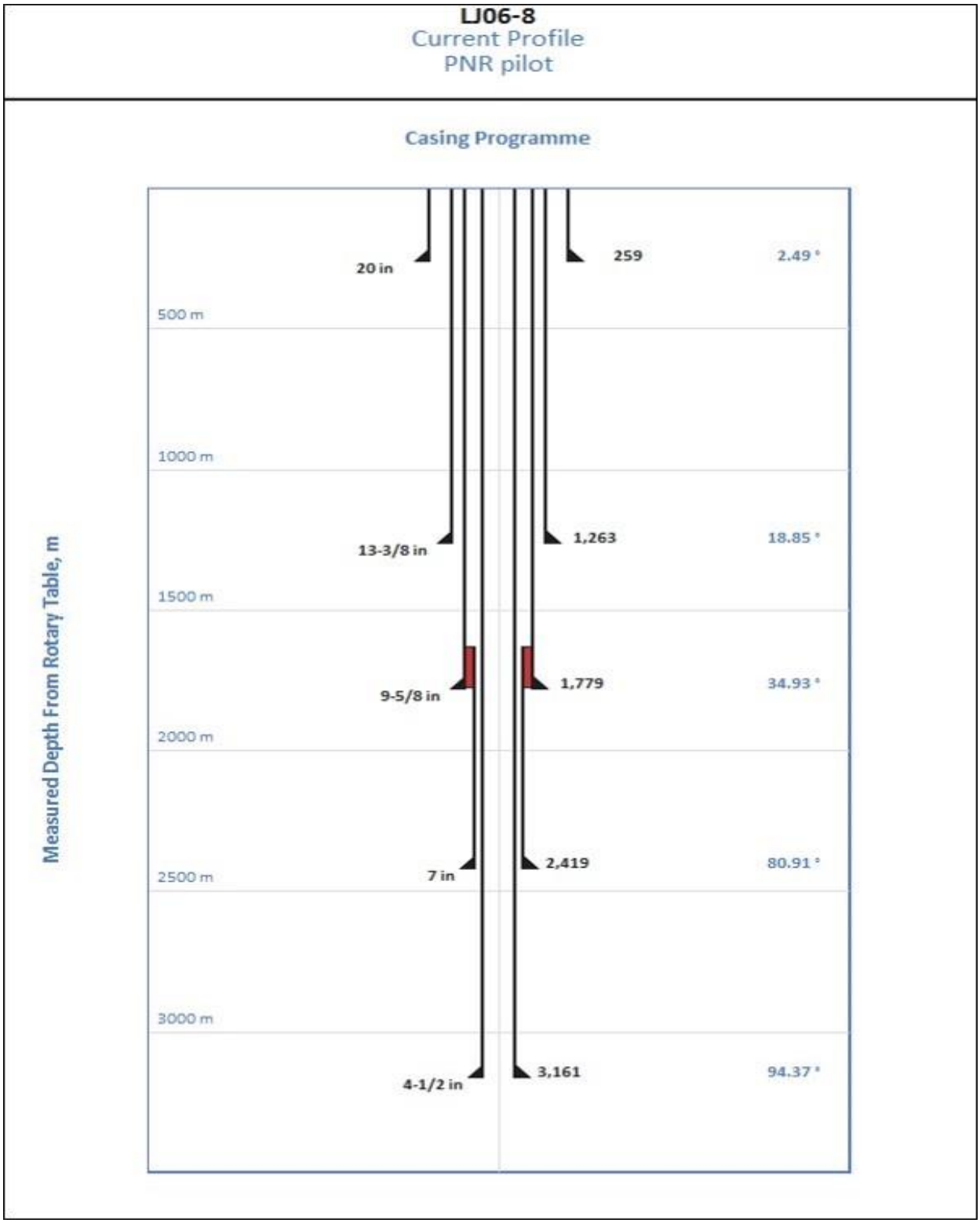

Figure 1: PNR-2 Casing Diagram

4 WELLBORE DIAGRAM WITH LOCATION OF FRACTURE SLEEVES ON SEISMIC DISPLAY

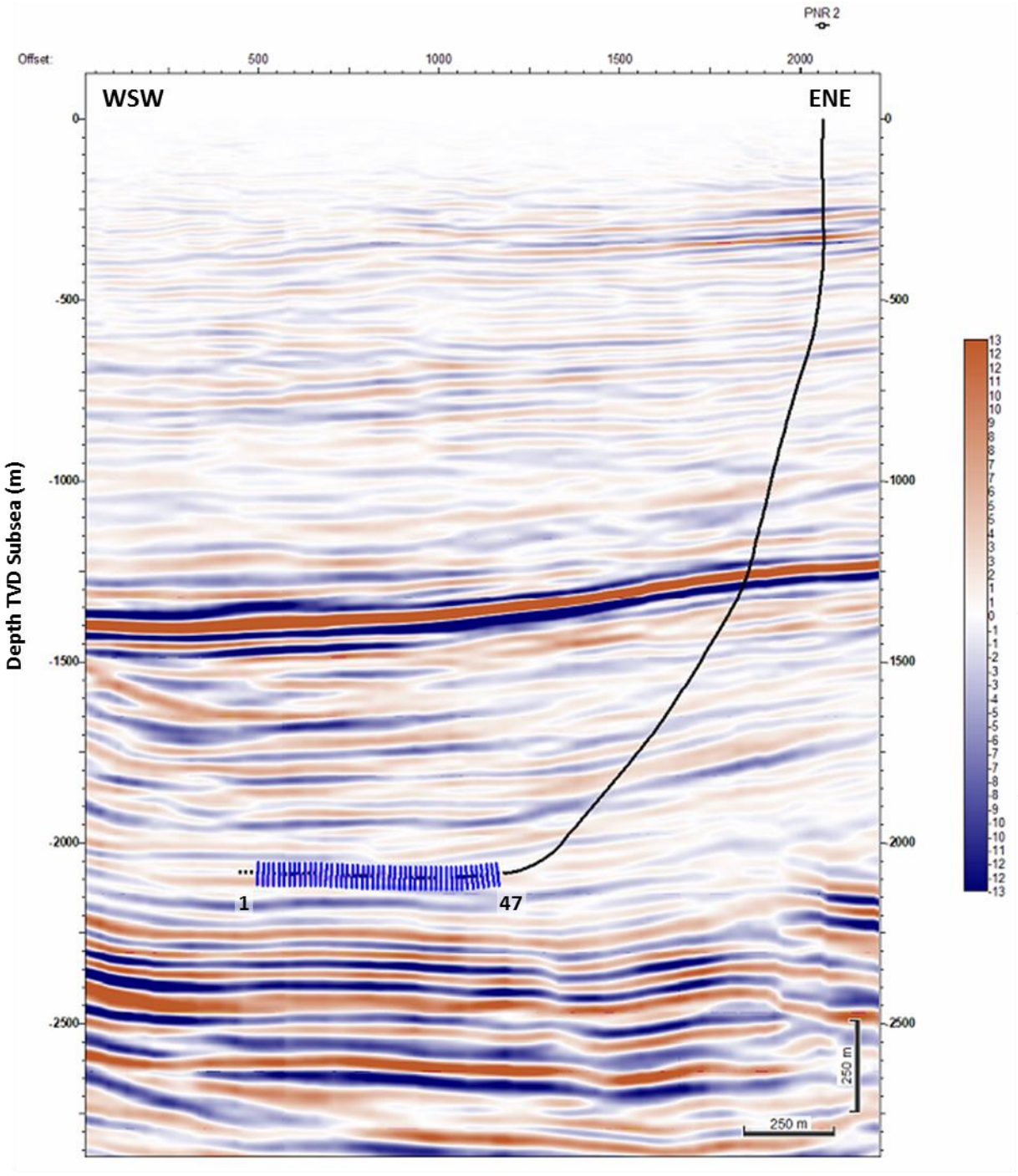

Figure 2 PNR-2 wellbore diagram and fracture zones projected onto 3D seismic inline

5 GEOLOGICAL CROSS SECTION

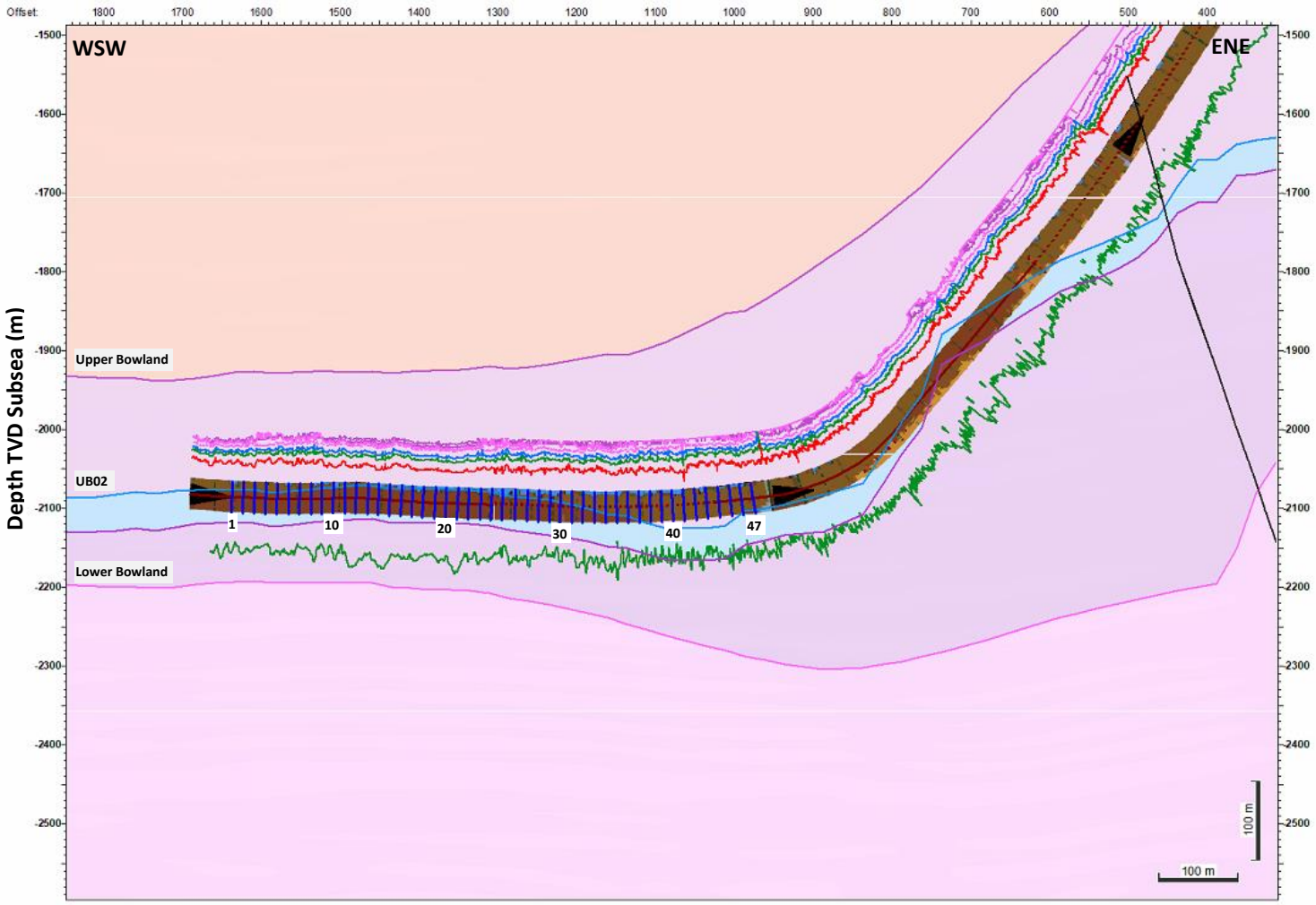

Figure 3 *Geological cross section of PNR-2. Well profiles projected onto arbitrary line following PNR-2 azimuth. Gas chromatograph (left hand side of wellbore): C1 - red, C2 - green, C3 – blue, IC4 - pink (solid), NC4 - pink (hashed), IC5 - purple (solid), NC5 - purple (hashed). Gamma Ray (GR) (right hand side of wellbore): green. Frac sleeves shown in blue. Lithology track colours: dark brown - claystone, light brown - siltstone, blue - carbonate*

6 WIRELINE IMAGES OF ZONES

No wireline log images were collected within the stimulated section of PNR-2

7 GAS CHROMATOGRAPH LOG

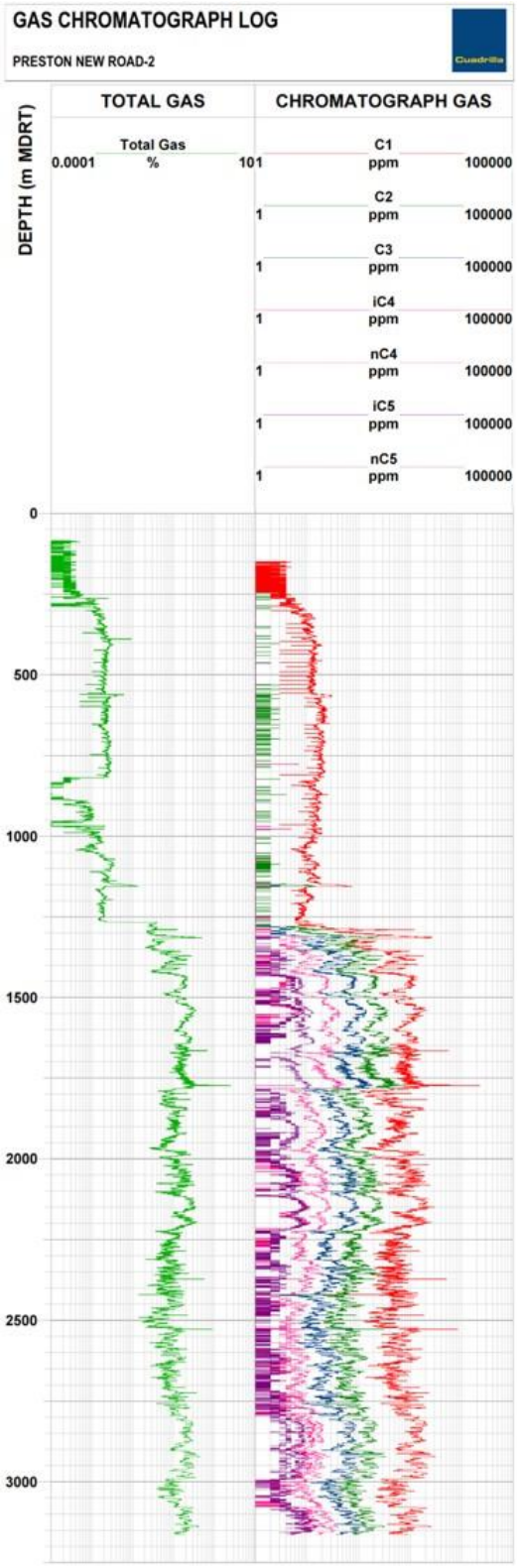

Figure 4 PNR-2 gas chromatograph

8 GAS COMPOSITION

No gas samples were taken during this period.

9 MINEROLOGY FROM CUTTINGS (XRD)

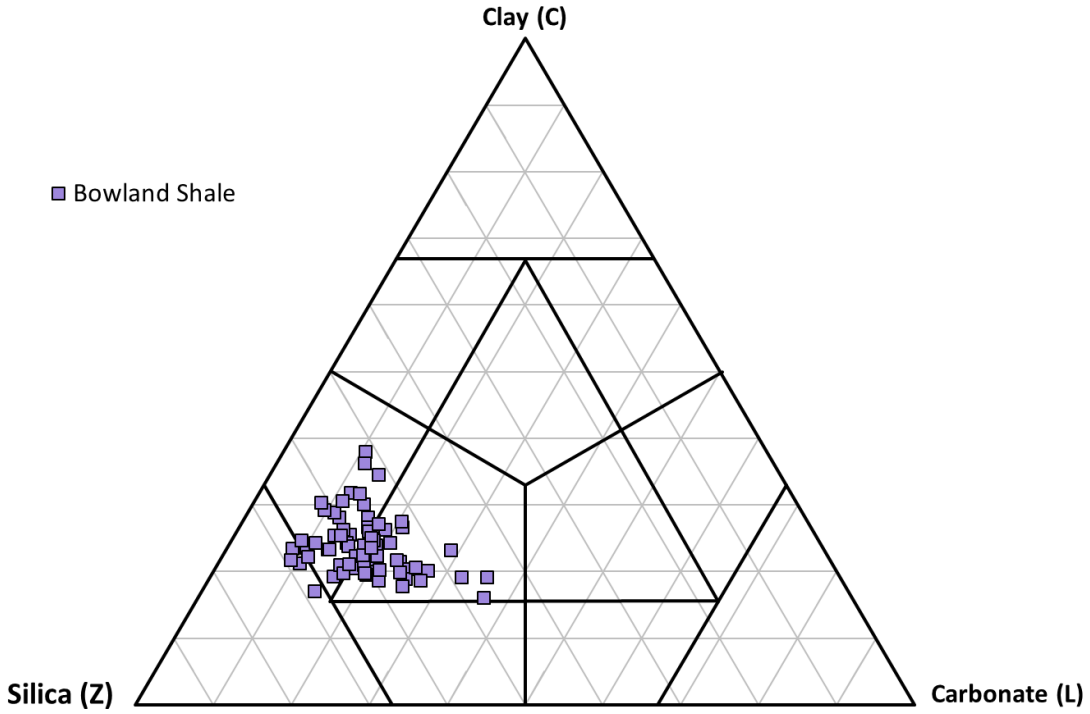

Figure 5. Ternary plot of PNR-2 cuttings XRD

10 ROCK PROPERTIES

Hall-1	Bulk Density (g cm-3)	Total Porosity (%)	Effective Porosity (%)	Matrix Perm (mD)	Water Saturation (sw)	TOC (%)	Maturity (Tmax)	Desorbed gas content scf/ton	Quartz	Carbs	Clay
Upper Bowland	2.62	3.70	2.82	1.50 x 10^{-5}	25.5	2.32	476.9	27.0	58.7	19.1	22.1

Table 2 Preese Hall-1 Average Lower Bowland Rock Properties, Clarke et al 2018

11 STRESS INTERPRETATION

SHmin = 0.67 psi/ft

SHmax azimuth = 350°N (estimated from fracture growth detected by microseismic)

12 VISUALISATION OF FRACTURE EXTENT ON MICROSEISMIC

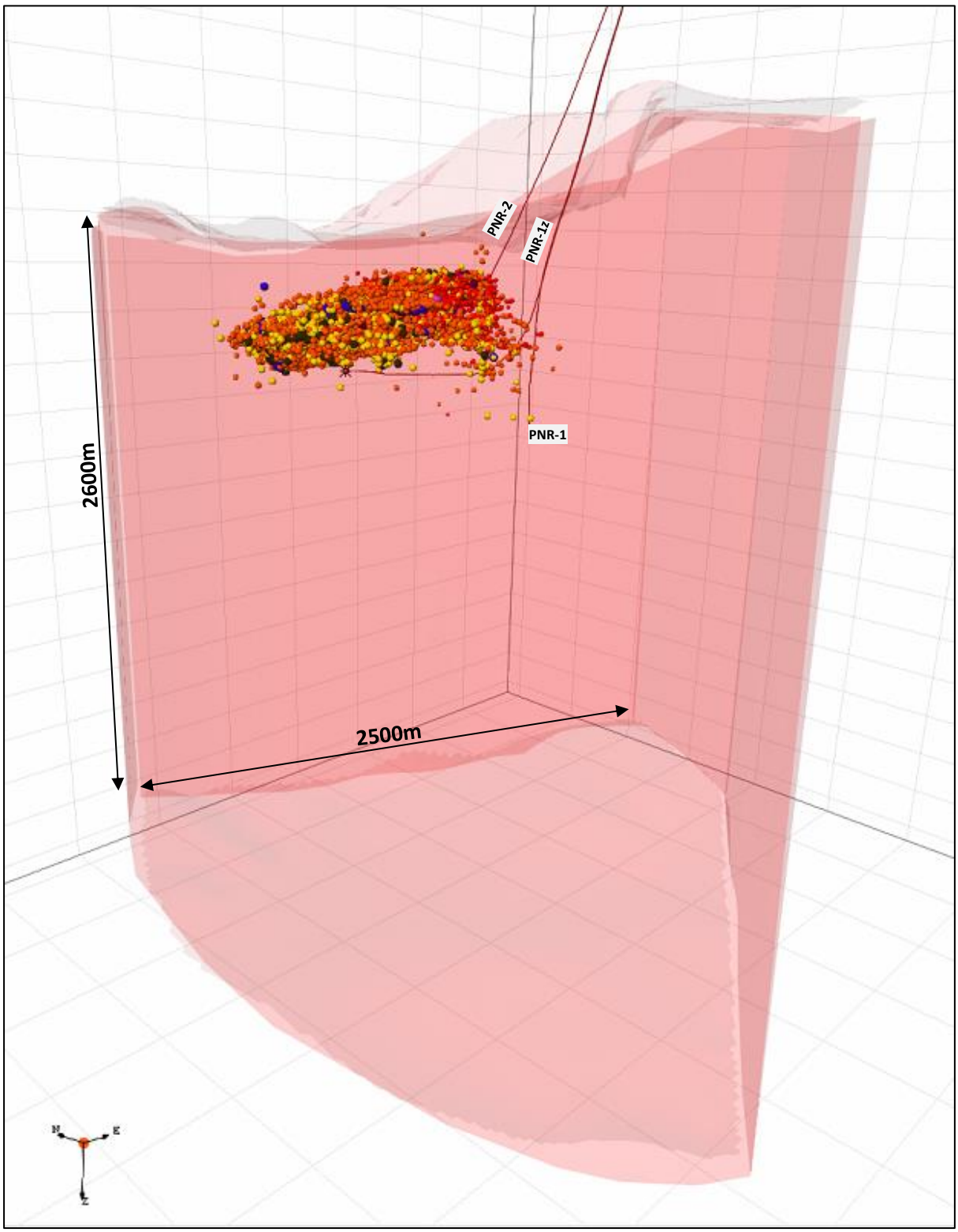

Figure 6 Microseismic event cloud with respect to EA redline permit boundary shown in red. Upper and Lower boundary Upper Bowland and Top Clitheroe Limestone respectively. Microseismic events coloured via magnitude (Mw). Red -2.6, Purple 1.1

13 MODELLED VS ACTUAL STIMULATED RESERVOIR MODEL

Kinetix 3D fracture simulation model of high density discrete fracture network (DFN) based on PNR2 geology						
Sleeve #	**Pre job Modelled Propped Width (mm)**	**Post job Modelled Avg Propped Width (mm)**	**Pre job Modelled Avg Fracture Height (m)**	**Post Job Modelled Fracture Height (m)**	**Pre Job Modelled Avg Fracture Half Length (m)**	**Post Job Modelled Fracture Half Length (m)**
1	1.6	0.54	64	106	254	177
10	2	N/A	65	N/A	162	N/A
19	1.9	N/A	77	N/A	138	N/A
35	1.7	N/A	73	N/A	289	N/A
47	2.9	N/A	46	N/A	556	N/A

Table 3 Summary of modelled vs actual (post job modelled) stimulated reservoir volume. NB/ Pre Job numbers shown are 1 Centipoise "Slickwater" cases

14 TRAFFIC LIGHT SYSTEM MONITORING

DD/MM/YYYY hh:mm:ss	TLS M_L	PUMPING / TRAILING	ACTIONS TAKEN
19/08/2019 10:35:50	**0.04**	Pumping	Informed regulators event amber event occurred during pumping, verified well integrity
19/08/2019 11:06:14	**0.09**	Pumping	Informed regulators event amber event occurred during pumping, verified well integrity
21/08/2019 20:46:33	**1.55**	Trailing	Informed regulators event red event occurred post pumping, verified well integrity
21/08/2019 22:42:00	**0.87**	Trailing	Informed regulators event red event occurred post pumping, verified well integrity
22/08/2019 16:23:33	**1.03**	Trailing	Informed regulators event red event occurred post pumping, verified well integrity
23/08/2019 23:22:08	**1.05**	Trailing	Informed regulators event red event occurred post pumping, verified well integrity

DD/MM/YYYY hh:mm:ss	TLS M_L	PUMPING / TRAILING	ACTIONS TAKEN
24/08/2019 05:01:07	**0.53**	Trailing	Informed regulators event red event occurred post pumping, verified well integrity
24/08/2019 23:01:35	**2.1**	Trailing	Informed regulators event red event occurred post pumping, verified well integrity
26/08/2019 08:30:47	**2.9**	Trailing	Informed regulators event red event occurred post pumping, verified well integrity
26/08/2019 22:18:29	**1.0**	Trailing	Informed regulators event red event occurred post pumping, verified well integrity
27/08/2019 07:55:12	**0.6**	Trailing	Informed regulators event red event occurred post pumping, verified well integrity

Table 4 Summary of reported TLS seismicity and action taken. Events colour coded via TLS. Event time shown in BST/GMT

15 INJECTION/FLOWBACK VOLUME

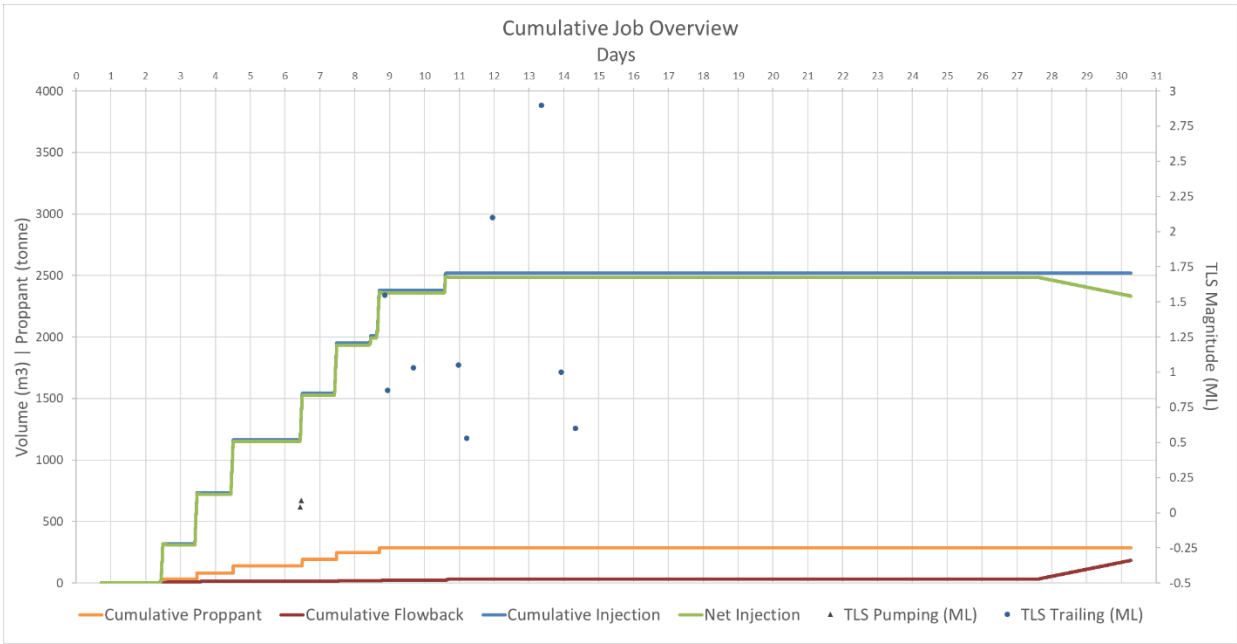

Figure 7 Plot summarising injection / flowback volumes in addition to seismicity related to Traffic Light Mitigation System

16 KEY LEARNINGS

The data collected within the Bowland Shale during drilling and hydraulic fracturing operations reveal it to have excellent reservoir and completion properties. When considering hydraulic fracturing operations, the microseismic data collected demonstrates a relationship between injection activities and induced micro-seismicity. A total of 55,556 microseismic events were detected within the redline permit boundary at Preston New Road, (Figure 6), in addition to this a total of eleven events were reported to regulators as part of the Traffic Light Mitigation System (see Table 4). Interpretation of the microseismic data identified one additional feature, MSPNR2_i.

Of the planned 45 injection sleeves (400m_3 and 50mT), only 7 were hydraulically stimulated (mini and /or main frac), 7 of which placed proppant, (ranging from 4 to 55mT). Two of the eleven TLS events occurred during pumping, none of which resulted in the premature termination of the associated frac jobs. This resulted in just 13% of the intended proppant being injected into the formation.

17 REFERENCES

Clarke, H, Turner P., Bustin. R.M., Riley, N. and Besly, B. (2018) Shale gas resources of the Bowland Basin, NW England: a holistic study. *Petroleum Geoscience*, Vol 24, pp. 287-322

APPENDIX 1 – OGA CONSOLIDATED ONSHORE GUIDANCE – JUNE 2018 – HFP REPORT DATA REQUIREMENT

The HFP report required (in .pdf format) should include:

- operations summary including result of well integrity monitoring
- well diagram with perf stages
- deviation survey
- wireline log images of zones
- gas chromatograph
- core intervals
- mineralogy from cuttings
- summary of stress interpretation
- location of frac stages posted on seismic display
- visualisation of fracture extent on micro-seismic and/or optical fibre data
- plot containment within permitted boundary
- comparison of modelled vs actual Stimulated Reservoir Volume
- summary of Traffic Light System seismicity monitoring and actions taken
- injection/flowback volume plotted vs induced seismicity over time
- summary of key learnings

Digital file (in .xls format) should include the following profile data over time:

- Bottom Hole pressure
- Injection rate
- Well Head pressure
- Proppant concentration
- Injection volume
- Flowback volume

APPENDIX 2 – RELEASED DATA

In accordance with Section F.13 of the Consolidated Onshore Guidance Version 2.2, June 2018 the following data is publicly available:

- PNR-2 Definitive Deviation Survey
- Frac Sleeve Depths
- Pumping Data
- Pumping charts
- Microseismic events
- Daily Water Summary

APPENDIX 3 – SLEEVE DEPTHS

Frac Sleeve #	Top Location Z m (TVDMSL)	Bottom Location Z m (TVDMSL)	Mid Location Z m (TVDMSL)
1	-2085.27	-2085.18	-2085.23
2	-2085.92	-2085.83	-2085.88
3	-2086.59	-2086.5	-2086.55
4	-2087.21	-2087.13	-2087.17
5	-2087.7	-2087.63	-2087.67
6	-2088.02	-2088.01	-2088.02
7	-2087.95	-2087.97	-2087.96
8	-2087.8	-2087.82	-2087.81
9	-2087.61	-2087.64	-2087.63
10	-2087.25	-2087.31	-2087.28
11	-2086.86	-2086.9	-2086.88
12	-2086.91	-2086.88	-2086.90
13	-2087.26	-2087.18	-2087.22
14	-2088.13	-2088	-2088.07
15	-2089.1	-2088.96	-2089.03
16	-2089.88	-2089.79	-2089.84
17	-2090.69	-2090.55	-2090.62
18	-2091.76	-2091.76	-2091.76
19	-2092.69	-2092.59	-2092.64
20	-2093.29	-2093.22	-2093.26
21	-2093.78	-2093.72	-2093.75
22	-2094.18	-2094.13	-2094.16
23	-2094.53	-2094.49	-2094.51
24	-2094.86	-2094.82	-2094.84
25	-2095.19	-2095.14	-2095.17
26	-2095.63	-2095.59	-2095.61
27	-2096.06	-2096.06	-2096.06
28	-2096.89	-2096.77	-2096.83
29	-2097.58	-2097.49	-2097.54
30	-2098.06	-2098.01	-2098.04
31	-2098.26	-2098.24	-2098.25
32	-2098.55	-2098.52	-2098.54
33	-2098.74	-2098.72	-2098.73
34	-2098.89	-2098.87	-2098.88
35	-2098.76	-2098.79	-2098.78
36	-2098.55	-2098.57	-2098.56
37	-2098.47	-2098.5	-2098.49
38	-2098.18	-2098.23	-2098.21
39	-2098.23	-2098.23	-2098.23
40	-2097.17	-2097.24	-2097.21

41	-2096.53	-2096.63	-2096.58
42	-2095.58	-2095.73	-2095.66
43	-2094.27	-2094.47	-2094.37
44	-2092.81	-2092.81	-2092.81
45	-2091.26	-2091.48	-2091.37
46	-2089.56	-2089.81	-2089.69
47	-2087.87	-2088.12	-2088.00

APPENDIX 4 – NOMENCLATURE

10% HCl	10% Concentration Hydrochloric acid
AN_B	B annulus Pressure
Azi	azimuth
bbl/min	Barrels per minute
BH	Bottom Hole
BHP	Bottom Hole Pressure
C1	Methane
C2	Ethane
C3	Propane
IC4	Isobutane
NC4	Normal-Butane
NC5	Normal-Pentane
IC5	Isopentane
C6	Hexane
C7	Heptane
C8	Octene
C9	Nonene
C10	Decene
C11	Undecane
C12	Dodecane
C13	Tridecane
C14	Tetradecane
C15	Pentadecane
CO2	Carbon dioxide
calc	Calculated
Circ Press	circulating pressure
CON	concentration
CT	coil tubing
dd:mm:yy	Day:month:year
DLS	Dog leg severity
E.	Eastings
EXL	Exploration Licence
FR	Friction Reducer
H2	Hydrogen
He	Helium
HFP	Hydraulic Fracture Plan
hh:mm:ss	hours:minutes:seconds

hrs	hours
in	inches
Inc	inclination
INJ	Injection
ISIP	Instantaneous Shut-in Pressure
kgPA	kilogram per cubic meter
km^2	square kilometre
lbf	pound force
m	meter
m^3	cubic meter
m^3/min	cubic meter/minute
max	maximum
mD	Millidarcy
MD RT	Measured depth from Rotary Table
min	minute
ML	Local magnitude
mm	millimetre
mol%	Mole percentage
MPa	Megapascal
MPa/m	Megapascals per meter
MSL	Mean sea level
mT	metric tonne
Mw	Moment magnitude
N.	Northing
N2	Nitrogen
PEDL	Petroleum Exploration Development Licence
PNR	Preston New Road
PROP	proppant
RT	Rotary Table
Scf/ton	Standard cubic feet per Imperial ton
SLUR	Slurry
TLS	Traffic Light System
Tmax	Indicator of thermal maturity
TOC	Total organic content
TVD	True vertical depth
VS	Vertical section
wt %	weight %
X	Eastings
XRD	X-ray diffraction
Y	Northings
Z	Depth

APPENDIX 5 – PUMPING AND MICROSEISMIC HEADING ABBREVIATIONS/UNITS

Abbreviation	Meaning	Unit
JobTime	Job time in British Summer Time (BST) Microseismic data uses same time format	day:month:year:hours: minutes:seconds
UTC Time	Coordinated Universal Time	day:month:year:hours: minutes:seconds
TR_PRESS	Frac Pressure down the annulus	Bar
CIRC_PRESS	Circulating Pressure in the coiled tubing	Bar
An_B_PNR2	B Annulus Pressure, Outside 5.5" casing	Bar
BHP_CALC	Calculated Bottom Hole Pressure, Using Coil as dead string	Bar
SLUR_RATE	Slurry rate, (proppant and water) fluid rate down the annulus	M^3/min
PROP_CON	Proppant concentration, surface measurement	Kg/m^3 water
BH_PROP_CON	Proppant concentration, Downhole measurement	Kg/m^3 water
INJ_RATE	Total Injection rate (total fluid rate coil and annulus)	M^3/min
JOB_INJ	Cumulative total injected volume	M^3
CT_RATE	Water rate injected down coil	M^3/min
CT WEIGHT	Weight of the coil	LBF
CIRC_PRESS	Pressure in the coil. This includes the frictional pressure as it is the pressure required to pumped the fluid down the coil tubing string	Bar
JOB_SLUR	Cumulative fluid volume pumped down annulus	M^3
JOB_PROP	Cumulative Proppant pumped in weight at surface	Kg
JOB_BH_PROP	Cumulative Proppant pumped in weight downhole (into formation)	Kg
Sleeve No	Number of frac sleeve injected	
Frequency	Number of microseismic events per minute	Per minute
QC_LOC_X	Qc'd eastings of microseismic event	m
QC_LOC_Y	Qc'd northings of microseismic event	m
QC_LOC_Z	Qc'd subsea depth subsea of microseismic event	m
SP_MAGNITUDE	Magnitude of microseismic event	M_w
MS_SNR	Signal to noise ratio	

N.B. Due to an extended interruption in the power supply to the wireline unit, the following data gap is present in the microseismic data:

Start Time day:month:year:hours:minutes:seconds	17:08:19:08:17:27
End Time day:month:year:hours:minutes:seconds	17:08:19:10:31:43

During a routine project reset, a file corruption led to the following short data gap

Start Time day:month:year:hours:minutes:seconds	21:08:19:00:38:16
End Time day:month:year:hours:minutes:seconds	21:08:19:01:42:39

Due to intermittent data acquisition on the downhole array, c.1/3 of the acquisition was lost between the following times:

Start Time day:month:year:hours:minutes:seconds	26:08:19:01:03:00
End Time day:month:year:hours:minutes:seconds	26:08:19:09:20:40

No data gaps or intermittent data loss occurred during any period of pumping.

APPENDIX 6 – PNG PUMPING FILES

PNG files of each sleeve show microseismic events overlain on injection charts. Job time is in British Summer Time (BST).