



# Kalala S-1

*Well Completion Report*

*EP 98*

*Beetaloo Basin  
Northern Territory*

*14<sup>th</sup> July - 25<sup>th</sup> August 2015*

*Origin Energy Resources Ltd*

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# 1 WELL INDEX SHEET

<b>Well Name:</b>	Kalala S-1	<b>Rig Name:</b>	Saxon 185
<b>Basin:</b>	Beetaloo	<b>Spud:</b>	23:30 hrs - 14/07/2015
<b>Permit:</b>	EP98(R)	<b>Reached TD:</b>	18:00 hrs - 25/08/2015
<b>Type:</b>	Vertical Exploration Well	<b>Total Depth:</b>	2619 mMDRT / 2617.14 mTVD (Driller's depth - 2622 mMDRT / 2620.14 mTVD)
<b>Operator:</b>	Origin Energy	<b>Well Suspended:</b>	16:00 hrs - 02/09/2015 (post-Drilling operations) 15:30 hrs - 01/10/2016 (post-DFIT operations)
<b>Ground Level:</b>	239.7 m (above MSL)	<b>Rig Released:</b>	16:00 hrs - 02/09/2015
<b>Rotary Table:</b>	5.35 meters	<b>Total Time:</b>	49.85 days
<b>Latitude:</b>	16° 17' 38.75"S (GDA 94)	<b>Well Status:</b>	Cased and Suspended
<b>Longitude:</b>	133° 36' 44.47"E	<b>Seismic Reference:</b>	East-West Control: 2D Seismic Line - L114. Shot point 7998 - projected ~785 m heading -37.2° from well
<b>Easting:</b>	351 734.909 metres (UTM 53)		North-South Control: 2D Seismic Line - mc92-251. Shot point 4279 - projected ~790 m heading -90° from well
<b>Northing:</b>	8 198 029.423 metres		
1:1M Map Sheet name: SE53 Newcastle Waters - Graticule Block Number 236			
1:250K Map Sheet Name: Tanumbirini - Map Number SE5302			
1:100K Map Sheet Name: Scarlet Hill - Map Number 5665			

## FORMATION TOPS

FORMATION	TOPS			REMARKS/SHOWS
	mMDRT	mTVDSS	THICKNESS PENETRATED (mTVD)	
Undifferentiated Cretaceous	5.35	239.7	68.7	
Anthony Lagoon Formation	74	171.05	27.6	
Gum Ridge Formation	101.6	143.45	109	Partial returns to surface from 105 – 130 mMDRT; Lost returns from 130 – 407 mMDRT
Antrim Plateau Volcanics	210.8	34.29	84.2	No returns to surface 130 – 407 mMDRT Top interpreted from ROP changes and wireline logs
Bukalara Sandstone	295	-49.88	82.5	No returns to surface 130 – 407 mMDRT Top interpreted from ROP changes and wireline logs
Chambers River Formation	377.6	-132.42	454	No returns to surface 130 – 407 mMDRT Top interpreted from ROP changes and wireline logs
Bukalorkmi Sandstone	832	-586.75	80.5	
Kyalla Formation	912.5	-667.25	457	
Moroak Sandstone	1369.2	-1123.89	345	
Velkerri Formation	1714.5	-1469.09	906	Not fully penetrated – Well terminated within the lower Velkerri
Upper Velkerri	1714.5	-1469.09	357	
DOLERITE SILL TOP	2072.1	-1825.85	3.09	
DOLERITE SILL BASE	2075.2	-1828.94		
DOLERITE SILL TOP	2086.2	-1839.89	3.78	
DOLERITE SILL BASE	2090	-1843.67		
DOLERITE SILL TOP	2100.1	-1853.72	4.59	
DOLERITE SILL BASE	2104.7	-1858.31		
Middle Velkerri	2212	-1965.38	361	
Middle Velkerri - C Shale TOP	2212	-1965.38	87.6	
Middle Velkerri - C Shale BASE	2299.7	-2052.97		
DOLERITE SILL TOP	2378.6	-2131.76	6	
DOLERITE SILL BASE	2384.6	-2137.76		
Middle Velkerri - B Shale TOP	2432	-2185.13	52.2	

<b>DOLERITE STILL TOP</b>	2451.4	-2204.53	1.3	
<b>DOLERITE SILL BASE</b>	2452.7	-2205.83		
<b>DOLERITE STILL TOP</b>	2478.6	-2231.72	0.6	
<b>DOLERITE SILL BASE</b>	2479.2	-2232.32		
<b>Middle Velkerri - B Shale BASE</b>	2484.2	-2237.32		
<b>DOLERITE STILL TOP</b>	2529.8	-2282.9	1.7	
<b>DOLERITE SILL BASE</b>	2531.5	-2284.6		
<b>Middle Velkerri - A Shale TOP</b>	2561.6	-2314.7	10.7	
<b>DOLERITE STILL TOP</b>	2566.3	-2319.4	1.1	
<b>DOLERITE SILL BASE</b>	2567.4	-2320.5		
<b>Middle Velkerri - A Shale BASE</b>	2572.3	-2325.4		
<b>Lower Velkerri</b>	2572.8	-2325.9	49.2	Not fully penetrated - well terminated 49.2m into the lower Velkerri
<b>Total Depth</b>	2619	-2372.09		Driller's Depth @ 2622 mMDRT / 2620.14 mTVD

#### FORMATION EVALUATION WHILE DRILLING

Hole Size (mm)	Interval (mMDRT)	Logs Acquired
None Taken		

#### WIRELINE LOGS

Suite #	Run #	Interval (mMDRT)	Logs Acquired
1	1	2619.0 - 0.0	HRLT-HDRS-HGNS-HNGS-EDTC-SP-LEH (PEX)
1	2	2617.0 - 1304.0	PPC-CMR-NEXT-EDTC-LEH (CMR-LithoScanner)
1	3	2617.0 - 15.0	FBST-MAST-PPC-EDTC-LEH (FMI-SonicScanner)
1	9	2618.0 - 1964.0	GTET-DSNTI-SDLTI-DLL-ARCT-GEM-CSNG (Triple Combo/SGT/GEM)

#### CORE- CONVENTIONAL

Core #	Interval (mMD)	Cut (m)	Recovered (m)	Formation
None Taken				

#### CORE - SIDEWALL

Suite#	Run#	Type	Interval (mMDRT)	Cut (units)	Partial Recovery	Recovered	Formation
1	4	CoreVault	2290.0 - 2263.0	9	-	9	Middle Velkerri - C Shale
1	5	CoreVault	Tool Malfunction	-	-	-	
1	6	HRST	No Recovery due to obstruction	-	-	-	
1	7	HRST	2570.0 - 1315.0	30	3	27	Middle & Upper Velkerri; Kyalla Formation
1	8	CoreVault	2475.0 - 2457.0	10	-	10	Middle Velkerri - B Shale

#### HOLE & CASING DETAILS

Hole Size (inch)	Interval (mMDRT)	Casing Size (inch)	Shoe Setting Depth (mMDRT)
20	Surface - 74.0	16	73.85
14 ¾	73.85 - 407.0	10 ¾	367.93
9 ⅞	407.0 - 1305.0	7 ⅞	1304.0
6 ¾	1305.0 - 2622.0 (TD)	4 ½	2617.0

## 2 GENERAL INFORMATION

WELL NAME	Kalala S-1
TYPE OF WELL	Exploration
EXPLORATION PERMIT	EP98(R)
GEOLOGICAL BASIN	Beetaloo Basin
FIELD NAME	Beetaloo North
<b>WELL SURFACE LOCATION</b>	
Northing	8198029.423 m
Easting	351734.909 m
Latitude	16° 17' 38.75" South
Longitude	133° 36' 44.47" East
Australian Map Grid Zone	GDA 94, UTM 53
Map Sheet name	SE53 Newcastle Waters
Graticule Block Number	236
<b>OFFSET REFERENCE WELLS</b>	
Chanin 1 - 15.9 km (heading 65.3° from Kalala S-1)	
Balmain 1 - 36.1 km (heading 174.7° from Kalala S-1)	
Shenandoah 1A - 36.2 km (heading 174.7° from Kalala S-1)	
McManus 1 - 41.5 km (heading 2.4° from Kalala S-1)	
Walton 2 - 42.9 km (heading 4.2° from Kalala S-1)	
Altre 2 - 45.1 km (heading 24.1° from Kalala S-1)	
ELEVATION (GL ABOVE MSL)	239.7 m
RT ELEVATION (ABOVE MSL)	245.05 m
SPUD DATE	14-July-2015 @ 23:30 hrs
REACH TD DATE	25-August-2015 @ 18:00 hrs
TOTAL DEPTH	2619 mMDRT
PBTD - NO TAG PERFORMED INSIDE 4-1/2" CASING	2581.32 mMDRT (top of float collar)
RIG RELEASE DATE	02-September-2015 @ 16:00 hrs
WELL STATUS	Cased and suspended
SUSPENSION DATE	01-October-2016
<b>CONTRACTORS</b>	
Drilling	Saxon
Drilling Fluids	Newpark Drilling Fluids
Mud Logging	Geoservices
Wireline Logging	Schlumberger and Halliburton
Cementing	Halliburton
Casing	Marubeni-Itochu Tubulars Oceania (MITO)
Wellheads	Cactus
Drilling Tools	Schlumberger
Running Casing	Weatherford

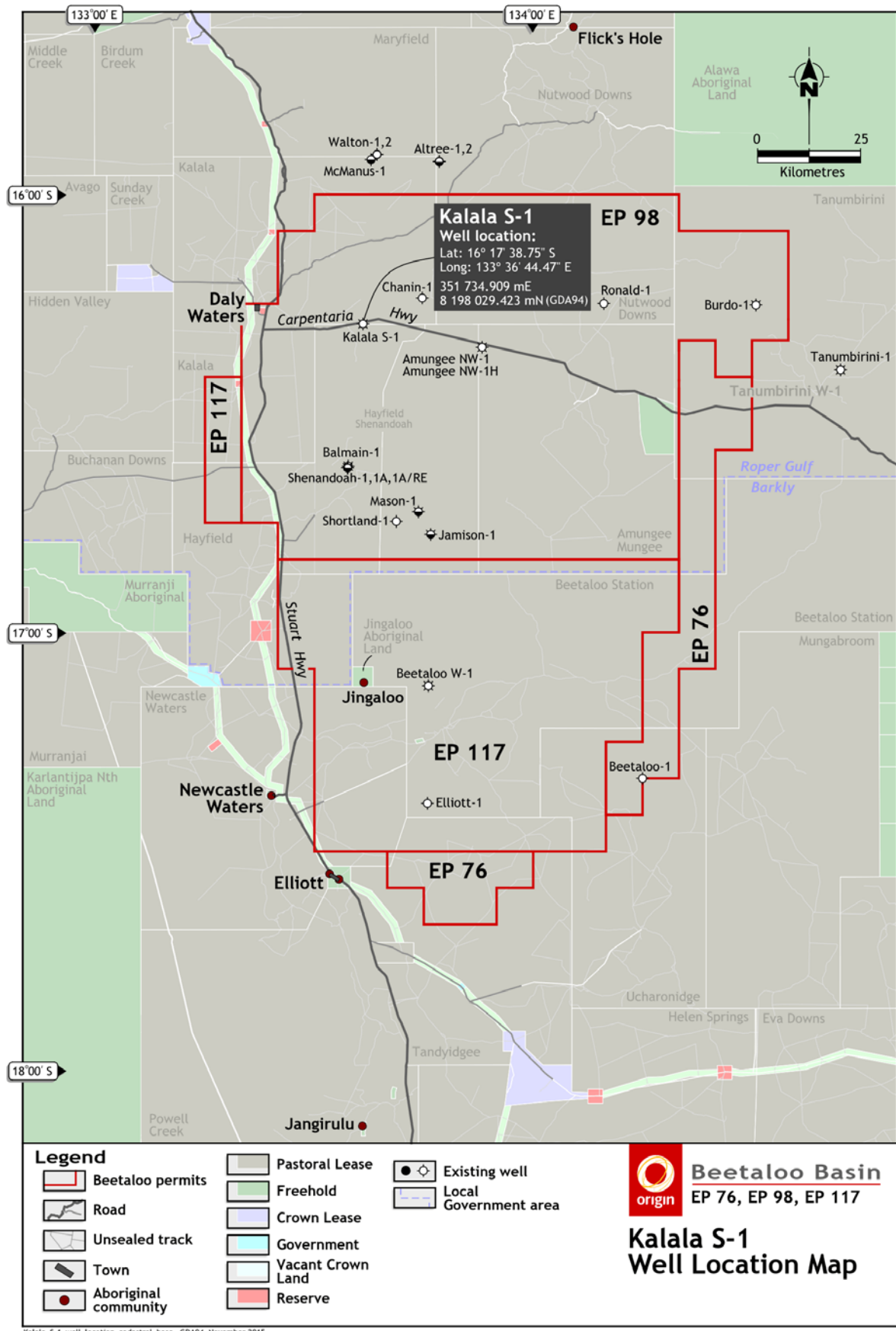


Figure 1 - Kalala S-1 Location

## **3 WELL DESCRIPTION**

### **3.1 INTRODUCTION**

Kalala S-1 was the first well in a two well exploration programme designed to target and test the prospective organic-rich mudstone intervals within the middle member of the Velkerri Formation (middle Velkerri) and Kyalla Formation in the Beetaloo Sub-Basin (Beetaloo Basin), Northern Territory, within onshore exploration permit EP98(R) ('EP98') during Permit Year 2 (2015).

Operations were carried out from the 14<sup>th</sup> July 2015 (well spud) to the 2<sup>nd</sup> September 2015 (rig release) by Origin Energy on behalf of the Beetaloo Joint Venture (JV) (Origin Energy, Sasol and Falcon Oil Gas). The well is located approximately 400 m south of the Carpentaria Highway and 25.4 km east of the town of Daly Waters and the Stuart Highway in the Northern Territory (Figure 1). Kalala S-1 was drilled vertically to a total depth of 2619.0 mMDRT (2622 mMDRT - driller's depth).

### **3.2 LOCATION RATIONALE**

The Kalala S-1 location was selected based on thermal maturity modelling which indicated the organic-rich mudstones of the middle Velkerri were thermally mature for dry gas generation in the area. The well site was optimized between two known penetrations of the organic-rich middle Velkerri to reduce the risk of not encountering the reservoir target and approximately 800 m west of the 2D seismic line mc92-251 which provided north-south seismic control at the target formation depth.

### **3.3 OBJECTIVES**

The Kalala S-1 successfully met all its objectives which included:

1. Assessing the presence, thickness and potential of the middle Velkerri organic-rich mudstones as a regional unconventional source rock play within the northern Beetaloo Basin, with a primary focus on understanding physical reservoir properties through wireline logs and petrophysical analysis.
2. Running a comprehensive wireline log suite to build robust petrophysical, mineralogy and mechanical earth models.
3. Cutting wireline sidewall cores within the middle Velkerri and other targets of opportunity for bulk rock property, rock mechanics, petrographic and geochemical analysis.
4. Performing an extended Diagnostic Formation Injectivity Test (DFIT) to evaluate reservoir pressures of a prospective reservoir interval within the middle Velkerri.

## 4 REGIONAL GEOLOGY AND PROSPECT DESCRIPTION

### 4.1 REGIONAL GEOLOGY

The Beetaloo Basin is an intra-cratonic Proterozoic depression concealed beneath Phanerozoic cover situated approximately 500 km southeast of Darwin, Northern Territory (Figure 2). The Basin stratigraphic sequence (see Section 4.2 - Figure 7) is largely under the cover of the younger Georgina and Carpentaria basins, and primarily defined by gravity and magnetotelluric data (Cull, 1982), deep seismic sounding data (Collins, 1983), and exploratory drilling data (Ahmad et al., 2013) which is well captured in the OZ SEEBASE™ depth-to-basement (Pryer and Loutit, 2005) Proterozoic Basement map (Figure 2).

The Beetaloo Basin is structurally subdivided into three geographical areas and two major structural highs. The north-south trending, structurally complex Daly Waters Arch (west) and structurally benign Arnold Arch (east) divide the area in three major depocenters, referred to here as the Sever Sub-basin, the Core area and the OT Downs Sub-basin from west to east respectively (Figure 3). Early compression and strike-slip movement are thought to be responsible for the development of these structures (Silverman et al., 2007).

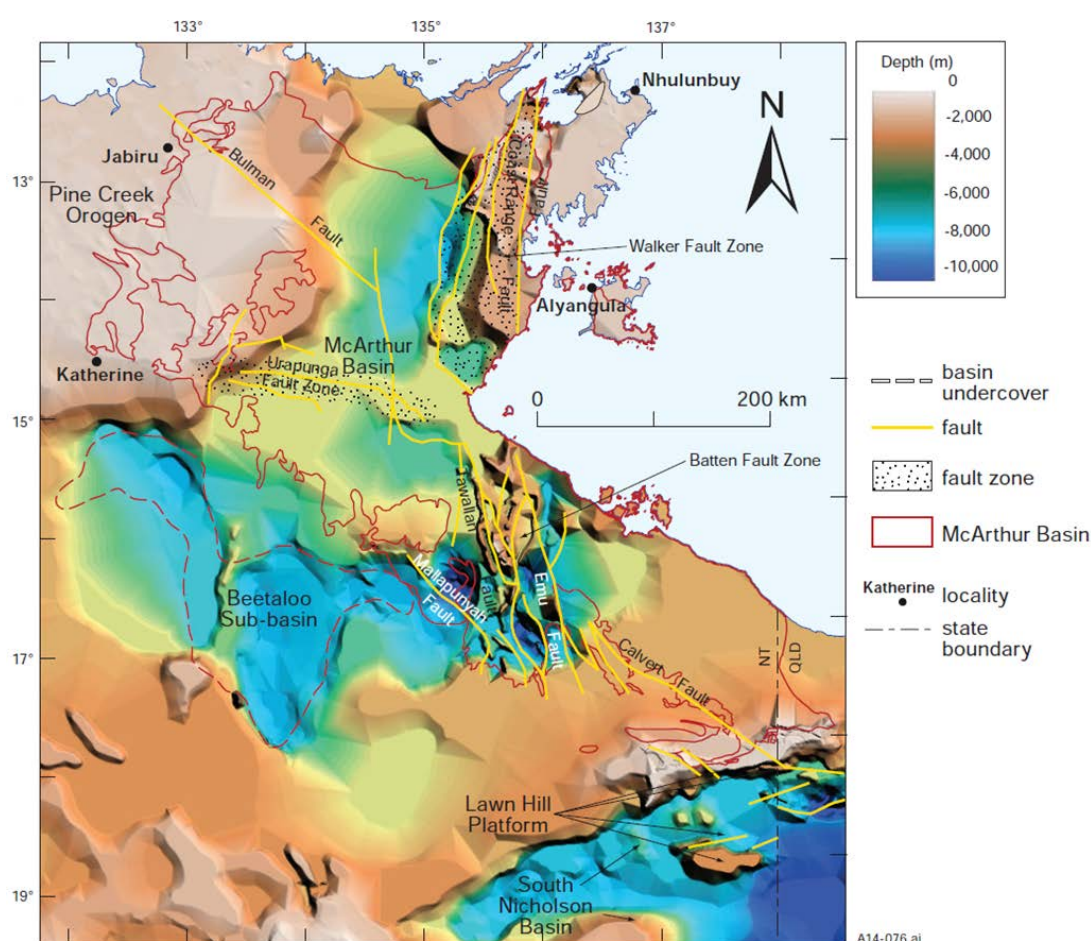


Figure 2 - OZ SEEBASE™ depth-to-basement image (Pryer and Loutit, 2005) showing interpreted location of the McArthur Basin (red solid line) and other associated basins in the Northern Territory. The location of the Beetaloo Basin is outlined in red dashed line (after Munson, 2014)

In the context of the McArthur Basin, the strata within the Beetaloo Basin appear to have undergone only mild tectonism after deposition as evidenced by the flat-lying character of the upper Roper Group in seismic profiles (Figures 4 to 6). The nature and timing of structural events during and post-dating Roper Group deposition appear dominated by two major compressional/transpressional episodes defined by truncation beneath the base of the Bukalorkmi Sandstone and base of the Cambrian Unconformity; the former more evident over structural highs such as the Arnold Arch whereas the latter shows a flatter and regionally extensive character. Truncation at the base of the Bukalorkmi Sandstone followed by the Precambrian/Cambrian unconformity suggests the present day shape of the Beetaloo Basin is a large post-depositional feature which contains the remnant of an original, more extensive basin. Throughout the Phanerozoic, tectonic/structural activity in the area was limited to regional events including broad tilting and relative uplift towards the north of the basin (Lanigan et al., 1994).

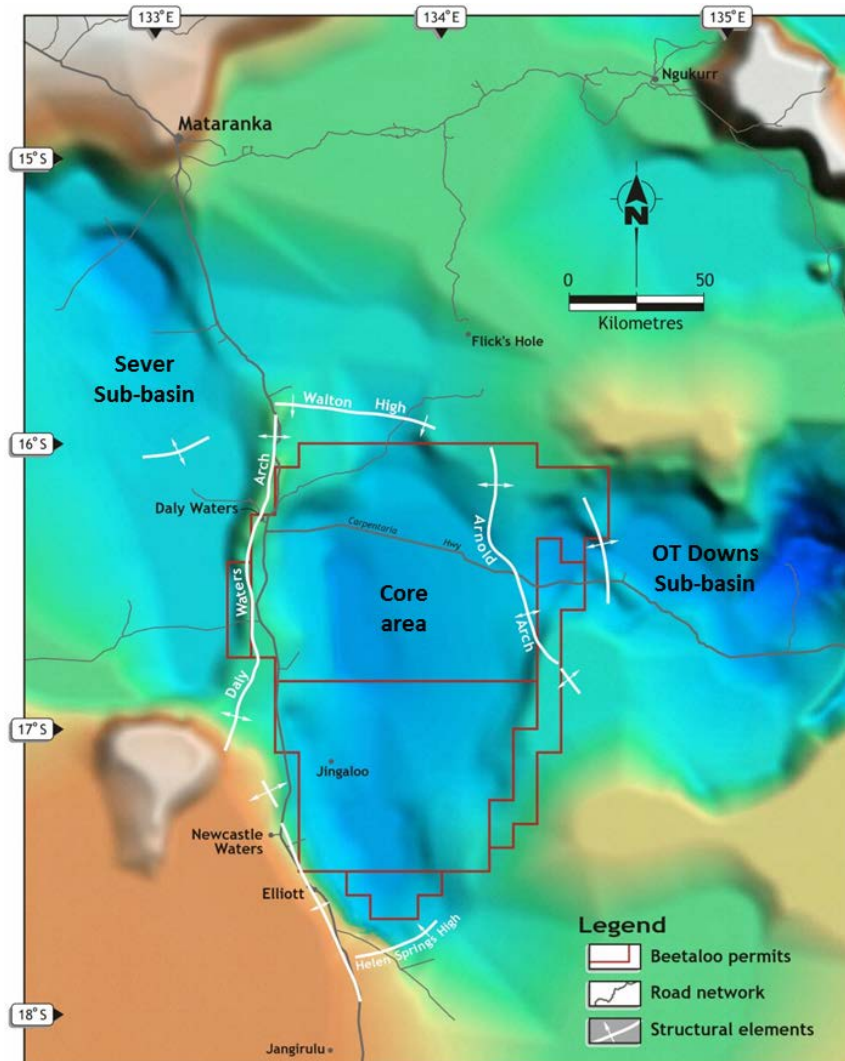


Figure 3 - Structural and tectonic elements of the Beetaloo Basin. The location of the Beetaloo JV permits is outlined in red. Background is OZ SEEBASE™ depth-to-basement image (Pryer and Loutit, 2005)

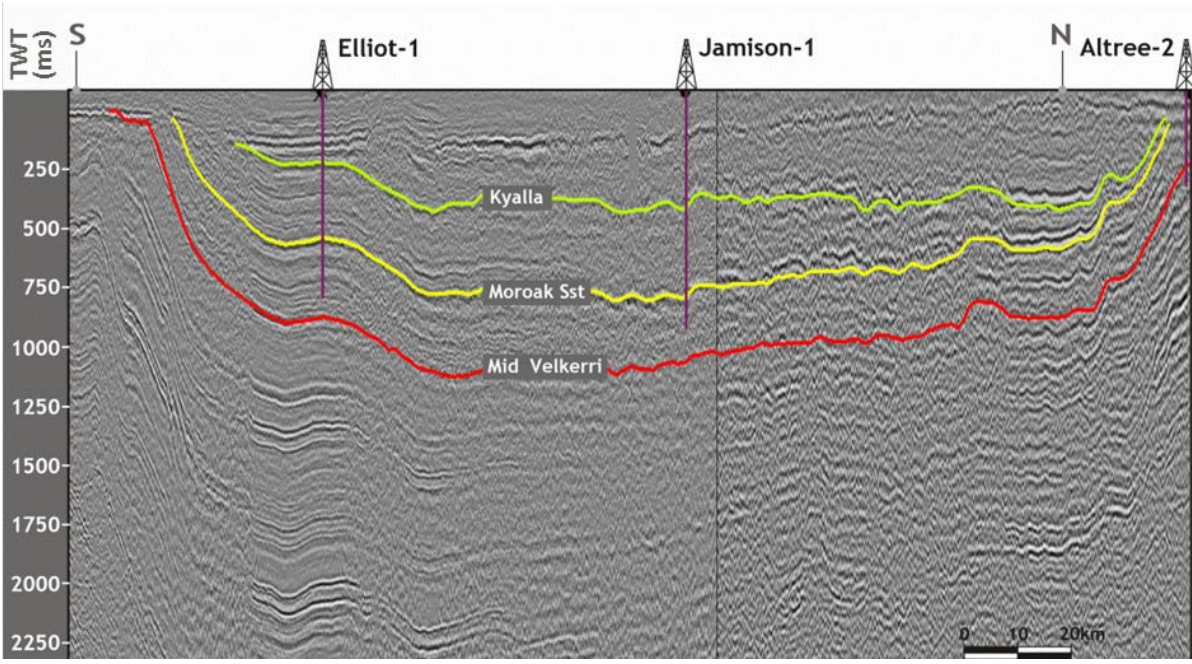


Figure 4 - South to North seismic composite section through the Core area of the Beetaloo Basin. The composite section displays 2D seismic lines ma91-103 and sh90-103 (south to north)

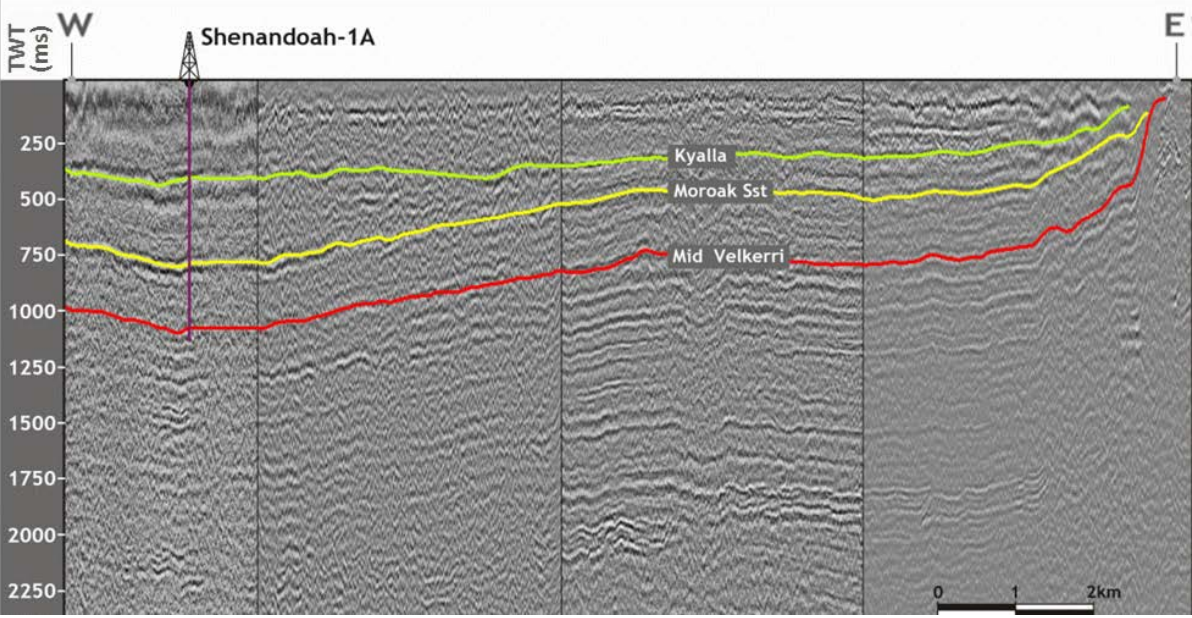


Figure 5 - West to East seismic composite section through the Core area of the Beetaloo Basin. The composite section displays 2D seismic lines md92-250, ma91-250, sh90-100, and mc92-100 (west to east)

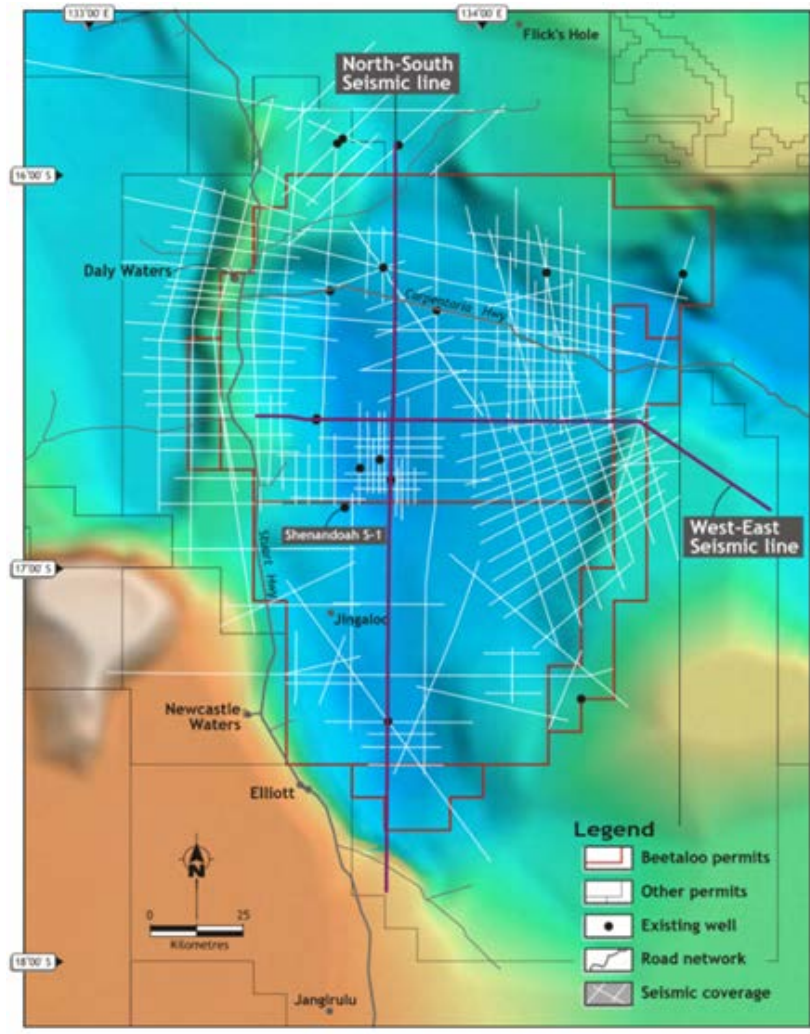


Figure 6 - Map showing location of 2D seismic composite sections from Figures 4 and 5

Faulting and folding occurs primarily within discrete zones up to 10 km wide likely as a result of reactivation of deep-seated faults and subsequent alignment of younger structures. Fault zones largely consist of wrench-related strike-slip and reverse faults producing an echelon, antiformal (positive) flower structures (Lanigan et al., 1994). Due to limited regional tectonic activity during the Cambrian period, the Antrim Plateau Volcanics and Gum Ridge Formation formed a flat-lying drape over the more structured Proterozoic strata. Exceptions occur within the north-western and eastern margins of the Basin where faults extend into the Cambrian sequence (Fulton and Knapton, 2015).

## 4.2 REGIONAL STRATIGRAPHY

The Mesoproterozoic Roper Group comprises progradational cycles of mudstone and sandstone units reaching thickness greater than 3000 m with averages of 1500 m away from major depocenters (Abbott and Sweet, 2000). Even though the succession has yet to be fully penetrated in the deepest depocenters, individual formations can be traced across the basin showing remarkable thickness consistency and lateral continuity in seismic profiles (Figure 4 to 6) (Munson, 2014). The first detailed stratigraphic study of the Roper Group was presented by Jackson et al. (1988) and furthered by detailed investigations from Jackson and Raiswell (1991) and Warren et al. (1998) who supplemented the pre-existing framework with additional regional and local stratigraphic, sedimentological and geochemical information. The Roper Group succession was deposited in a variety of settings within shallow-marine, and nearshore to shelf environments (Powell et al., 1987; Jackson et al., 1988; Abbott and Sweet, 2000) with organic enrichment confined to the Velkerri and Kyalla formations. The sequence has been recognised as having excellent exploration potential.

The Velkerri Formation, comprising green, grey and black mudstone and siltstone sits conformably on the Bessie Creek Sandstone, often showing a gradational contact with the overlying Moroak Sandstone (Figure 7). The formation is subdivided into three informal units - lower, middle and upper Velkerri. The prospectivity of the Formation is greatest in the organic-rich mudstones of the middle Velkerri - informally subdivided by Origin into 'A', 'B', and 'C' Shales (from oldest to youngest). These organic-rich mudstones are typically separated by organic-lean siltstones. Dolerites intruding the Roper Group at various stratigraphic levels have collectively been named the Derim Derim Dolerite. U-Pb SHRIMP dating of baddeleyite from a sample of the dolerite has yielded an age of  $1324 \pm 4$  Ma (Abbott et al., 2001), however ages of 1280 Ma have also been reported (Dutkiewicz et al., 2007). These typically intrude laterally along boundaries of mechanical weakness in the north and west of the Beetaloo Basin, reaching maximum thickness of 120 m to the west before thinning and terminating towards the centre of the basin. Planes of mechanical weakness often include the boundary between the Bessie Creek Sandstone and the Velkerri Formation and laminated intervals throughout the Velkerri Formation.

The Kyalla Formation, dominated by grey and black siltstone and mudstone sits conformably on the Moroak Sandstone (Figure 7). The Formation is subdivided into an upper and lower unit with organic richness generally confined to the lower section. Historic drilling has seen multiple oil shows and gas bleeds in the lower Kyalla section supporting its potential as an unconventional play. The Formation exhibits a sharp, erosional and disconformable contact with the overlying Bukalorkmi Sandstone, a thin to medium bedded, trough cross-stratified, fine grained, quartz sandstone. Dating of detrital zircons from the Bukalorkmi Sandstone indicates a maximum depositional age of  $1106 \pm 22$  Ma and  $1086 \pm 47$  Ma, however it has been suggested to be as young as Neoproterozoic on the basis of stratigraphic correlations (Lanigan et al., 1994).

Conformable a top of the Bukalorkmi Sandstone is the thin to medium bedded, laminated, micaceous, brown to grey, oxidised red and reduced green claystone and siltstone of the Chambers

River Formation. Interbeds of fine grained, feldspar-rich sandstone are also present but generally limited in abundance and thickness throughout the interval. In the Beetaloo Basin, this formation represents the youngest unit of the Roper Group as a significant downward erosional unconformity typically separates the Chambers River Formation from the Cambrian Barkly Group sediments of the Georgina Basin. This unconformity variably erodes the Bukalorkmi Sandstone, Kyalla Formation, Moroak Sandstone and Velkerri Formation depending on location within the Basin.

The Cambrian Barkley sediment succession begins with the basal Bukalara Sandstone. The regional distribution and thickness of the unit is uncertain, however it is sporadic based on well penetrations.

Sitting conformably on the Bukalara Sandstone are the tholeiitic basalt flows of the mid-late Cambrian Kalkarindji Large Igneous Province (Kalkarindji Province). Where absent, the basalt flows sit uncomfortably on top of Roper Group sediments. The flows are known as the Antrim Plateau Volcanics in the Beetaloo Basin (Munson, 2014).

The Gum Ridge Formation sits conformably on the basalt and grades upwards as interfingering limestone and brown to oxidised red claystone into the Anthony Lagoon Formation. Where absent, the unit sits uncomfortably on top of the Bukalara Sandstone or the Roper Group.

An Undifferentiated Cretaceous section caps the regional stratigraphy of the Beetaloo Basin. The sequence forms a continuous veneer across the Basin with the exception of the south-west margin. Recent palynological studies have dated the base of the Cretaceous unit between ~100 - 113 Ma.

A generalised north to south cross-section showing the distribution of the stratigraphic sequence in the Beetaloo Basin is provided in Figure 8.



The Kyalla Formation displays a thick sequence of predominantly silty and micaceous mudstone with thin planar interbeds of siltstone and sandstone. The most perspective interval within the Kyalla Formation, informally referred to as the lower Kyalla resides between the top of the Moroak Sandstone and a regionally extensive sandstone unit previously referred to as the “Kyalla Sandstone” (Lanigan et al., 1994). The lower Kyalla represents an interval of increased organic richness which through thermal maturation has led to a prospective, gas saturated, unconventional reservoir.

## Beetaloo Basin Stratigraphy

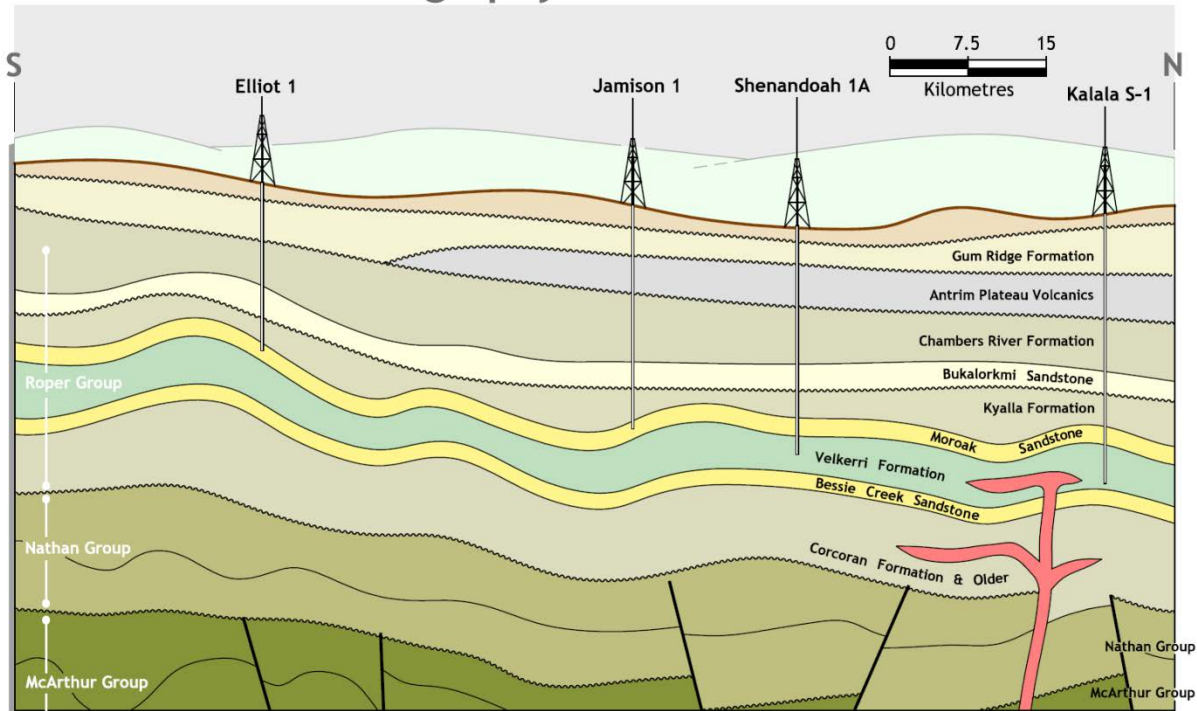


Figure 8 - Generalised north to south cross-section through the Beetaloo Basin

## 5 ENGINEERING DATA

### 5.1 DRILLING OPERATIONS SUMMARY

Saxon 185 rig and equipment were mobilised and installed at the Kalala S-1 well location between the 25<sup>th</sup> June and 14<sup>th</sup> July 2015. Approximately one month prior to Rig 185 arriving on location, a smaller mineral style rig set a 16" conductor to approximately 73.85 mMDRT in preparation for drilling activities. Kalala S-1 was officially spudded on the 14<sup>th</sup> July 2015 @ 23:30 hrs.

A 14-3/4" tri-cone tooth bit was used to drill out the cement at the base of the 16" conductor. Drilling fluid losses were experienced whilst drilling new hole in the surface section from 75 mMDRT to 80 mMDRT approximately. At this point, the bottom hole assembly (BHA) was tripped out and replaced with a 14-3/4" tri-cone insert bit (IADC Code 515) to proceed with drilling activities.

Air/mist drilling continued to 106 mMDRT at which point total losses were experienced. Drilling proceeded with no returns down to 145 mMDRT, when the rig's main generators overloaded and shut the rig down. Once power was restored, the drill string had become stuck taking numerous attempts over a period of nine hours to free it up. Additional 6-1/2" drill collars and a set of 6-1/2" drilling jars were picked up before drilling ahead. After some washing and reaming to bottom, air/mist drilling continued to 287 mMDRT at which point ROP was too low to proceed. A new 14-3/4" tri-cone insert bit (IADC Code 515) was run in with minimum washing and reaming. Drilling continued without returns to section TD at 407 mMDRT.

A survey run at 372 mMDRT indicated a hole inclination of 2½ degrees.

The 10-3/4" casing was rig in hole (RIH), but held up at 95 mMDRT. A second attempt removing the centralisers was unable to pass below 98 mMDRT. A clean out trip to 197 mMDRT in preparation for a third attempt required significant washing and reaming from 98 mMDRT to 131 mMDRT with no returns to surface. A third attempt with a modified casing shoe only reached a depth of 110 mMDRT. The fourth, and final attempt resulted in casing getting to 280 mMDRT by washing and reaming through numerous tight spots. Pass this point, the casing was run without difficulty to 385 mMDRT. At this depth, the casing became stuck. Attempts to wash down were unsuccessful due to 'packing off' in the annulus. Significant over pulls, application of torque, attempts to circulate and other techniques failed to free the casing only pulling the shoe back to 367.93 mMDRT. The conductor was cemented at this depth.

Without the ability to circulate, the cement was pumped into the annulus and let fall under gravity. A total of 76 bbls of 16 lb/gal slurry were pumped in nine batches over an eight hour period until cement was observed at surface with no slurry fall back.

The 10-3/4" casing slips were installed in the cellar and the casing cut. The wellhead A-Section was then installed on the surface casing and the blow out preventer (BOP) stack installed on the A-Section. A successful BOP test was achieved prior to picking up the 9-7/8" intermediate hole BHA.

A 9-7/8" drill out BHA and tooth bit were run in hole drilling out the float collar at 344 mMDRT, followed by the float shoe cleaning to the previous section TD at 407 mMDRT. A diagnostic leak-off test proved lack of integrity at this depth requiring additional cement plugs to be squeezed at the shoe. A 4" drill pipe was run and ~44 bbls of cement spotted with ~5 bbls squeezed into the formation. A 9-7/8" drill out assembly was then run in to 258 mMDRT and the casing pressured tested. Results indicated the pressure was slowly leaking off. A test plug was run confirming surface equipment was not the source of the leak. The drill out assembly was run in to 325 mMDRT drilling cement to 363 mMDRT where the casing was successfully pressure tested allowing operations to continue. Drilling cement progressed to 371 mMDRT (~3 meters below the casing shoe). Three attempts to get a satisfactory leak-off test were unsuccessful hence the need run a second cement plug over the shoe. A drill pipe was run in open ended and ~12 bbls of slurry spotted with less than 1 bbl squeezed into the formation prior to POOH. A 9-7/8" drill out assembly tagged the second plug at 332 mMDRT and drilled down to 371 mMDRT. An attempt to perform an FIT to 560 psi was

unsuccessful. After adjusting the programmed intermediate casing shoe depth, approvals were obtained to drill ahead.

Cement was drilled to 407 mMDRT and 3 meters of new formation penetrated before unloading the hole with air. At this depth, water influx occurred at measured rates of ~225 bbls per hour. The compressors were shut down and no flows to surface were observed over ~2 hours.

The well was displaced with 8.6 ppg mud before drilling of the 9-7/8" intermediate hole proceeded to section TD at 1305 mMDRT. The mud weight was gradually increased to 9.5 ppg as drilling progressed over the interval. Drilling fluid losses of ~7-15 bbls per hour commenced from ~1140 mMDRT. The 7-5/8" intermediate casing was run in the hole to 1281 mMDRT and washed down to 1304 mMDRT before cemented with returns to surface. A successful pressure test to 5000 psi was conducted before lifting the BOP, slipping the casing, setting the seal assembly and cutting the casing for the B-Section installation. A broken seal was identified and replaced prior to lowering the B-section over the casing stub and A -section and re-installing the BOP. A test plug was run but initial pressure testing on the annular and HCR valve failed to get above 800 psi. The decision was made to inspect the test plug but initial attempts to pull the test plug with 30 klbs were unsuccessful. All the lock screws were checked for proper positioning and the annular closed to ensure the test plug was properly positioned in the BOP. The plug came free, retrieved and the seal found broken. A significant amount of cuttings were also washed and jetted off the plug. The BOP was then successfully pressure tested.

The 6-3/4" production hole polycrystalline diamond compact (PDC) bit and drill out BHA were run in hole. The shoe track and 3 meters of new formation were drilled to 1308 mMDRT and an extended leak-off test pumped. The test was pumped with 9.5 ppg mud with the formation breaking down at 2900 psi (~15.3 ppg EMW). A wireline survey returned a hole inclination of 1 degree at 1294 mMDRT. Drilling progressed through 162 m of formation before low ROP (~1.3 m/hr) forced a bit trip at 1470 mMDRT. A 6-3/4" tri-cone insert style bit (IADC code 627) was then RIH resuming drilling to 1558 mMDRT.

Prior to tripping out, the hole was circulated to air and checked for water influx from the Moroak Sandstone. Measured influx rates were approximately 151 bbls per hour. The compressors were shut down and the well circulated to 9.9 ppg mud.

A new 6-3/4" PDC bit was RIH and the production hole drilled from 1558 mMDRT to 2383 mMDRT with high ROPs (> 7 m/hr). Mud weight was progressively increased to 10.6 ppg in preparation for wireline logging operations. The run was terminated following very slow ROP (< 1.0 m/hr) while drilling a dolerite sill. The BOP was pressure tested after the bit was tripped.

A re-run 6-3/4" PDC was RIH and the production hole drilled from 2383 mMDRT to 2481 mMDRT before being pulled on low ROP. A new standard 6-3/4" PDC bit with motor drilled the remaining production hole to well TD at 2622 mMDRT. Kalala S-1 reached TD the 25<sup>th</sup> August 2016 @ 18:00hrs. The well was displaced to a low salinity logging pill prior to pulling out of hole for wireline activities.

Schlumberger wireline was rigged up to run the following logs:

1. HRLT-HDRS-HGNS-HNGS-EDTC-SP-LEH (PEX)
2. PPC-CMR-NEXT-EDTC-LEH (CMR/LithoScanner)
3. FBST-MAST-PPC-EDTC-LEH (FMI/SonicScanner)

Schlumberger wireline was rigged down and Halliburton wireline rigged up to run three additional logging runs. Due to operational difficulties the final logging programme was as follows:

4. CoreVault™
5. CoreVault™
6. HRSCCT (Rotary Sidewall Cores) - unable to pass 1544 mMDRT
7. HRSCCT (Rotary Sidewall Cores)
8. CoreVault™
9. GTET-DSNTI-SDLTI-DLL-ARct-GEM-CSNG (Triple Combo/SGT/GEM)

While RIH with Run#6, the string was unable to pass 1544 mMDRT and the decision was made to conduct a wiper trip. A 6-3/4" wiper trip BHA was ran in hole to 2622 mMDRT washing and reaming from 2567 mMDRT to 2622 mMDRT. The mud system was circulated and conditioned, restoring mud weight 10.6 ppg before POOH to continue with wireline operations. Halliburton wireline was rigged up again successfully completing the wireline program (Run#7 to #9).

Halliburton wireline was rigged down and the rig floor prepared to run casing.

A 4-1/2" production casing was run landing out at 2617 mMDRT. The casing was cemented in place with cement slurry evident at surface on displacement. The casing was pressure tested to 5000 psi after successfully 'bumping' the plug. The wellhead and BOPs were flushed clean and the pack off installed and tested. The BOPs were nipped down, removed and the tubing spool and master valve installed and tested as per program. The rig was released from Kalala S-1 the 2<sup>nd</sup> of September 2016 @ 16:00hrs.

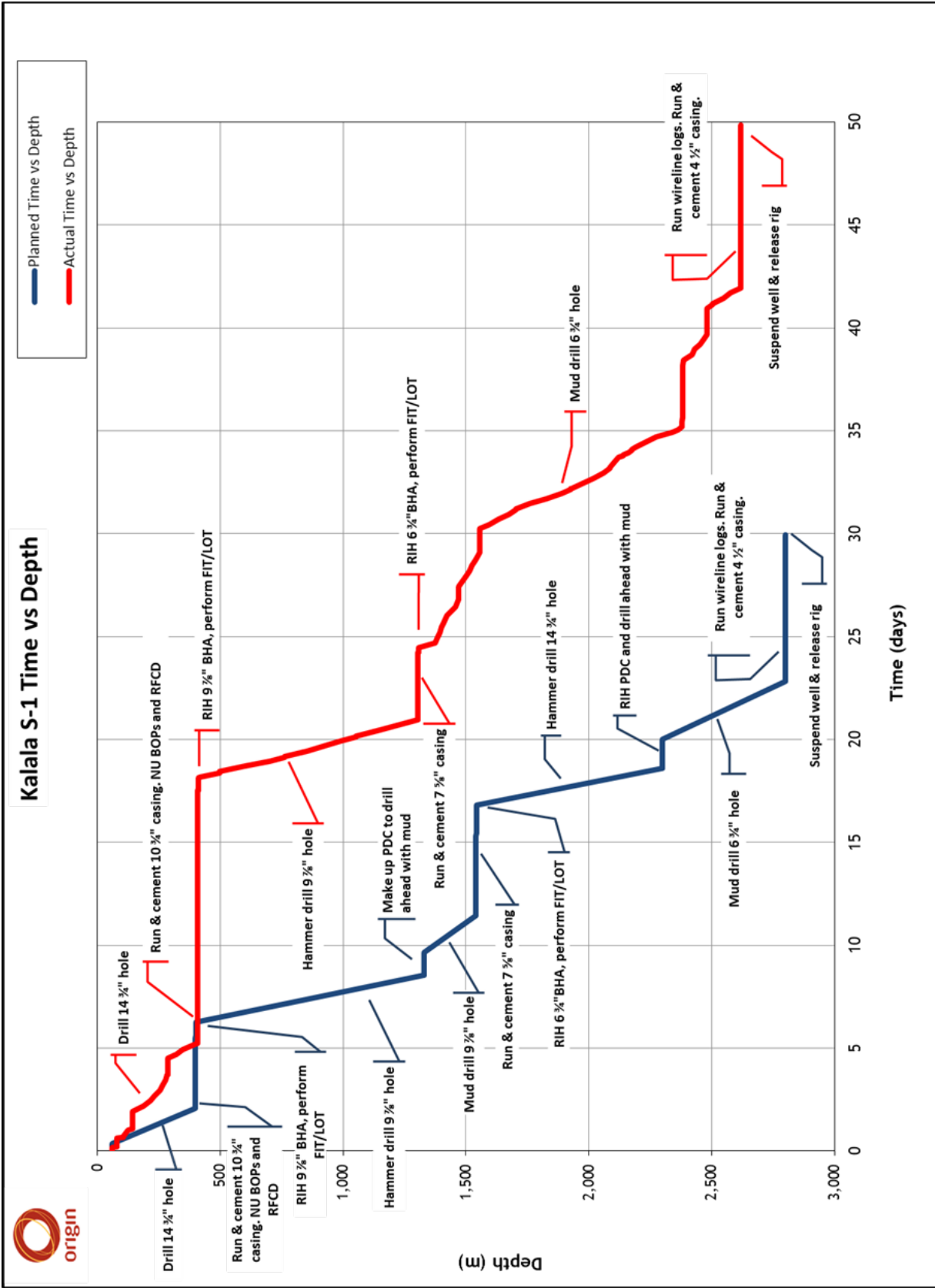


Figure 9 - Kalala S-1 Time vs Depth Chart

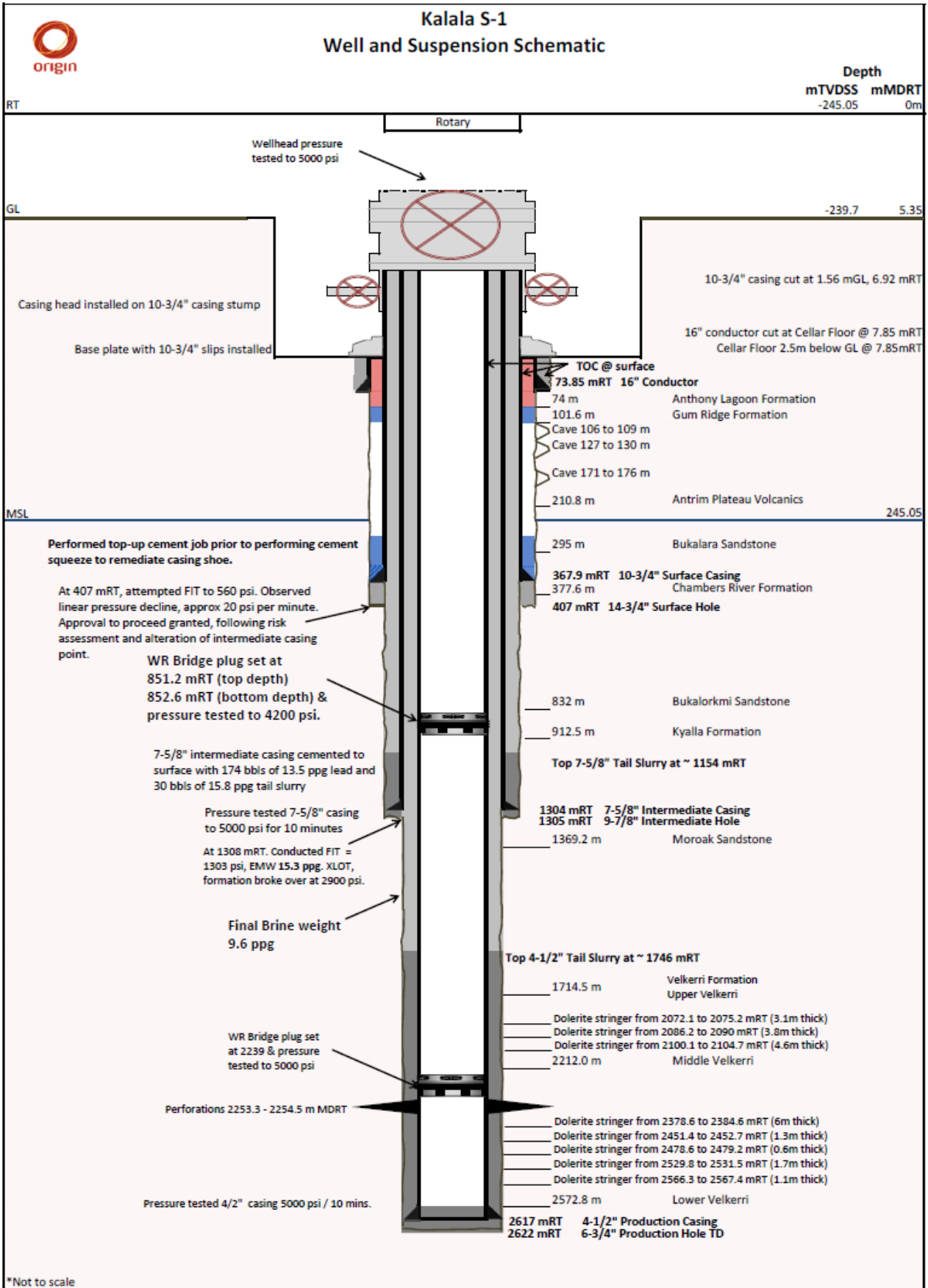


Figure 10 - Kalala S-1 Well Schematic

## 5.2 DRILLING RIG

The Saxon Energy Services Australia Rig 185 was used to drill Kalala S-1. This rig is a 1200 hp AC hydraulic drive rig with a 178,000 daN (400,000 lbf) pull capacity. The rig has two AC/VFD HongHua HHF-1000 triplex pumps powered by AmeriMex Dominator 1150 hp AC electric motors. An air package consisting of two screw compressors rated for 1400 CFM at 350 psi and a booster unit capable of 2800 CFM at 1600 psi. The mud system consists of three trailer mounted mud tank units rated for 767 bbl capacity complete with two Derrick FLC 504 shale shakers, a Derrick Vac-Flo 500 vacuum degasser and a Derrick DE-1000 FHD centrifuge. The BOP system comprises a 2M Drill Master Elite RFCD-2000, a 5M T3-Energy 11" Annular, a 5M T3-Energy Double Gate Ram (Blind & VBR), a 5M Drilling Spool with 3-1/8" Choke Line and 2-1/16" Kill Line, a 5M Cameron Choke Manifold, and a Control Technology 7 Station 14 Bottle Accumulator.

## 5.3 HOLE SIZES AND DEPTHS

Details of hole sizes and depths in Kalala S-1 are provided in Table 1. Kalala S-1 as drilled schematics showing hole size and depths is provided in Figure 10.

Type	Size (")	Depth (mMDRT)	Rig
Conductor #1	24	16.85	DDH-1
Conductor #2	20	73.85	DDH-1
Surface	14 3/4	407	Saxon 185
Intermediate	9 7/8	1305	Saxon 185
Production	6 3/4	2622	Saxon 185

Table 1. Hole Sizes and Depths

## 5.4 CASING

Details of the various casing runs in Kalala S-1 are given in Table 2. Kalala S-1 as drilled schematics showing casing details and depths is provided in Figure 10.

Type	Size (")	Weight (ppf)	Grade	Thread	Depth (mMDRT)
Conductor	16	42	X42	Plain End	73.85
Surface Casing	10 3/4	40.5	K55	BTC	367.93
Intermediate Casing	7 5/8	29.7	P110	JFE FOX	1304.0
Production Casing	4 1/2	11.6	P110	JFE FOX	2617.0

Table 2. Casing details

## 5.5 DRILLING MUD

Newpark Drilling Fluids were contracted to supply and maintain drilling fluids in Kalala S-1. A daily summary of drilling fluids operations and the EOWR can be found in Appendix 9. A Polymer Spud and Pre-hydrated Bentonite (Gel) mud was made up to commence operations on Kalala S-1. Initially while drilling the 16" conductor shoe track, rat hole and new formation down to 80 mMDRT a 'short' circulating mud system was used with Polymer Spud Mud. After changing the bit, BHA and resuming drilling pass 80 mMDRT total lost circulation occurred. The interval was air drilled to a depth of 407 mMDRT.

The mud properties in the 14-3/4" surface hole section ranged as follows:

Mud weight (ppg)	8.4 - 8.74
Plastic viscosity (cP)	1 - 20
Yield point (lbs/100ft <sup>2</sup> )	0 - 22
API Filtrate (ml/30 min.)	n/c - 9.4
Total Hardness (mg/lit.)	80 - 280
pH	8.5 - 9.5
Sulphites (mg/lit.)	40 - 200
Funnel Viscosity (sec./qt.)	27 - 61
Flow line temperatures (°C)	19 - 21
KCL (by weight %)	n/a
PHPA (ppb)	0.01 - 0.61

A water based Polymer Mud drilling fluid was utilized for drilling of the 9-7/8" Intermediate hole section. The mud properties during this interval ranged as follows:

Mud weight (ppg)	8.6 - 9.5
Plastic viscosity (cP)	7 - 12
Yield point (lbs/100ft <sup>2</sup> )	15 - 25
API Filtrate (ml/30 min.)	9.0 - 22.5
HTHP Filtrate at 250°F (ml./30min.)	n/a
Total Hardness (mg/lit.)	160 - 400
pH	9.0 - 9.5
Sulphites (mg/lit.)	100 - 180
Funnel Viscosity (sec./qt.)	51 - 65
Flow line temperatures (°C)	33 - 47

The drilling fluid utilized for the 6-3/4" production hole was water based NaCl Polymer Mud system. During the production section the mud properties ranged as follows:

Mud weight (ppg)	9.5 - 10.6
Plastic viscosity (cP)	10 - 15
Yield point (lbs/100ft <sup>2</sup> )	22 - 28
API Filtrate (ml/30 min.)	5.0 - 6.8

Hardness (Ca <sup>++</sup> & Mg <sup>++</sup> ) (mg/l)	184 - 400
Chlorides (mg/l)	113,000 - 182,000
pH	9.0 - 10.0
SO <sub>3</sub> (ppm)	10 - 180
Funnel Viscosity (sec./qt.)	42 - 52
Flow line temperatures (°C)	48 - 66

After reaching TD the hole was circulated clean and a 10.6 ppg low salt pill spotted on bottom aiming at covering the hole from 2000 mMDRT down to 2622 mMDRT (driller's TD). The purpose of this pill was to ensure a low salt brine over the primary and secondary targets to allow proper functioning of wireline logging tools and improve data quality. The low salt pill aimed to contain < 40,000 mg/l chloride concentration and was weighted up predominantly with Barite with all other polymers added as they had been for the drilling phase. The final low salt pill was ultimately unsuccessfully spotted with chlorides estimated from wireline logs at ~90,000 mg/l.

After completion of the wireline logging program a 4-1/2" production casing string was run and cemented in place at a depth of 2617 mMDRT. The cement was displaced with a 9.6 ppg NaCl Inhibited completion brine before removing the BOP and setting a well suspension assembly to complete operations.

## 5.6 WATER SUPPLY

Water supply for this well was sourced from the NTG Roads and Highways Department water supply bore No RN5942 located in the Kalala Station nearby the rig site and trucked in at a rate that maintained sufficient water levels for camp activities and drilling purposes. The field analysis of this water produced the following results:

Density (sg)	1.006
Pf / Mf	0.01 - 0.41
Chlorides (mg/L)	75
Hardness (mg/L)	240
Sand	Trace
pH	7.5

## 5.7 BIT AND DEVIATION RECORDS

### 5.7.1 BIT RECORDS

The bit records and drilling parameters are provided in Appendix 3.

### 5.7.2 DEVIATION SURVEY

Kalala S-1 wireline deviation survey was run by Schlumberger during wireline Run#3 with measurements acquired from well TD to surface. The field wireline deviation survey is provided in Appendix 5.

### 5.8 TIME DISTRIBUTION

A daily summary of drilling operations can be found in Appendix 9 and the drilling progress depth vs time chart for the well is provided in Figure 9. The overall time breakdown for Kalala S-1 activities is summarized below:

Time Breakdown	Days	Percentage
Productive Time	39.26	78.75%
Saxon NPT	0.36	0.73%
All other NPT	10.23	20.52%
<b>Total Time on Kalala S-1</b>	<b>49.85</b>	<b>100.00%</b>

## 6 COMPLETION OPERATIONS

### 6.1 COMPLETIONS SUMMARY

Completion operations commenced at Kalala S-1 on the 16<sup>th</sup> October 2015, approximately one month after the drilling rig was released. The scope of the completion work included wireline drift and cement bond log (CBL), perforations targeting the middle Velkerri C Shale interval and a diagnostic fracture injection test (DFIT) to obtain critical reservoir and geomechanical data. Daily DFIT operation reports are enclosed in Appendix 9.

A Vause wireline unit and Halliburton cementing unit were mobilised to Kalala S-1 on 16<sup>th</sup> October 2015. The wellbore was drifted with a 3-7/8" gauge ring down to 2545 mMDRT. A CBL was subsequently run down to 2545 mMDRT and logged back to surface. Results indicated good cement from TD to 1305 mMDRT. The 4-1/2", 11.6 ppf, P-110 production casing was pressure tested to 500 psi for 5 minutes and 8500 psi for 20 minutes. The production casing was then perforated targeting the middle Velkerri C Shale between 2253.3 - 2254.48 mMDRT with the following perforating gun details:

Perforation Information										
Top	Bottom				Perf Dia.	Gun Size			Charge Size	MD - TVD
(mMD)	(mMD)	SPF	Holes	Phasing	(in)	(in)	Gun Type	Charge Type	(g)	(m)
2253	2254	6	20	60°	0.36	3-3/8"	Other	SCP-3375-411NT4	25	0

A DFIT was pumped on 19<sup>th</sup> October 2015. The main objectives of the operation included the determination of breakdown pressures and fracture gradients. A 9.65 ppg inhibited completion brine was pumped for the operations. The formation broke down at 5790 psi(a). After break down, a 6.6 bpm injection rate was achieved prior to shutting down with an instantaneous shut in pressure (ISIP) of 4160 psi on surface and 7505 psi bottom hole observed. Breakdown and fracture gradients of 1.28 psi/ft and 1.06 psi/ft respectively were calculated based on the DFIT data. The well was shut in post-DFIT operations and pressure leak-off monitored until the 8<sup>th</sup> September 2016. Pressures observed at the wellhead were approximately 4500 psi. All objectives of the DFIT were met with the test providing estimates of breakdown pressures, fracture gradient, closure pressure.

## 6.2 PRODUCTION SUSPENSION

Schlumberger wireline and pumping units were mobilised to location to perform well suspension operations on the 30<sup>th</sup> September 2016. The well was displaced to a 9.6 ppg inhibited brine with a total of 150 bbls of fluid displaced into the wellbore. A wireline retrievable bridge plug was set at 2144.96 mMDRT on the 1<sup>st</sup> October 2016 and pressure tested against the wellhead to 5000 psi for 5 minutes. Pressures were bled off at surface and an inflow test was successfully conducted and monitored for 60 minutes. The wellhead was secured and tested to 5000 psi to finalize the wellbore suspension leaving two tested mechanical barriers in place. Suspension activities finalize on 1<sup>st</sup> October 2016.

Following the initial suspension a build-up in pressure was observed on the wellhead. The pressure was bled off and monitored. A Vause wireline unit was mobilized to location to perform a remedial well suspension operation on the 24<sup>th</sup> November 2016. A second wireline retrievable bridge plug was set at 852 mMDRT and tested to 4100 psi for 20 minutes.

All daily completion reports are enclosed in Appendix 9.

## 7 GEOLOGICAL DATA

### 7.1 GEOLOGICAL SUMMARY

Kalala S-1 was spudded in the unconsolidated to poorly consolidated and weathered Undifferentiated Cretaceous sediments and drilled to a depth of 73.85 mMDRT where a 16" deep

conductor was set (Figure 10). X-ray Fluorescence (XRF) analysis on drill cuttings indicated penetration of the Anthony Lagoon Formation within the interval from 75 to 80 mMDRT following an increase in Calcium element concentrations. The top of the Anthony Lagoon Formation was picked at 74 mMDRT following wireline interpretation.

The 14-3/4" surface hole was drilled through the Anthony Lagoon Formation, Gum Ridge Formation and Antrim Plateau Volcanics before terminating 29.4 m into the Chambers River Formation at 407 mMDRT. The top of the Gum Ridge Formation was interpreted at a depth of 101.6 mMDRT following the wireline regional correlation established from offset wells and water bores. Partial returns were recorded from 105 mMDRT to 115 mMDRT and total losses encountered at 130 mMDRT persisting until the end of the 14-3/4" hole section at 407 mMDRT. The top of the tholeiitic basalt flows of the Antrim Plateau Volcanics were initially interpreted at 210.8 mMDRT based on relative changes in ROP and subsequently confirmed after a small but sharp increase in the gamma ray log run through casing. The top of the Bukalara Sandstone was interpreted at 295 mMDRT following a significant drilling break shortly after a drill bit change. Wireline logs supported the interpretation in the form of a small but sharp decrease in gamma ray over the interval. Despite wireline indicators, the boundary remains ambiguous due to lack of drill cuttings to confirm the lithology change along with a renewed decrease in ROP from 330 mMDRT to 350 mMDRT. Stratigraphic correlation between Kalala S-1 and the recently drilled offset Amungee NW-1 well, which had full returns throughout the Bukalara section suggests 295 mMDRT as the best pick for the top Bukalara Sandstone in Kalala S-1. Below 377.6 mMDRT, a sharp gamma ray increase defined the transition from the clean sandstones of the Bukalara Sandstone to the clay and mica-rich mudstone and siltstone of the Chambers River Formation. The 14-3/4" hole section was terminated 29.4 m past the top of the Chambers River Formation to a depth of 407 mMDRT. The 10-3/4" casing was hung up at 367.93 mMDRT and cemented in place not far above the interpreted top of the Chambers River Formation.

The Chambers River Formation was fully penetrated in the 9-7/8" hole section with trace to minor dry gas shows over sandier and siltier intervals. A short-lived, dull yellow fluorescence show was observed in cuttings sampled at 685-690 mMDRT. The top of the Bukalorkmi Sandstone was intersected at 832 mMDRT after a clear change in cuttings lithology from primarily mudstone and siltstone (Chambers River Formation) to very fine to medium grained, moderately well sorted sandstone. The contact shows a similar conformable and gradational nature characteristic of this boundary across the Beetaloo Basin. While drilling the Bukalorkmi Sandstone minor gas shows were observed at the top of the formation with peak gas (2 - 2.7 %) over a porous sandstone bed between 854 mMDRT and 856 mMDRT. Moderately bright yellow fluorescence was also observed in drill cuttings from 850-890 mMDRT.

Wet gas shows were observed upon penetration of the Kyalla Formation at 912.5 mMDRT persisting and generally increasing through the formation. Gas peaked at 8.4 % before dropping to 2.3 - 4 % upon penetration of a sandier interval known informally as the Kyalla Sandstone at 1158.2 mMDRT. Past the base of the sandstone (1215.1 mMDRT) gas increased progressively from 4.4 % to a peak of

10.7 % while drilling the dark, organic-rich mudstones of the lower Kyalla Formation before terminating the 9-7/8" hole section at 1305 mMDRT.

The 6-3/4" hole section resumed drilling in the lower Kyalla Formation down to a depth of 1369.2 mMDRT. First evidence of sandstone in drill cuttings at 1340-1345 mMDRT was interpreted as the beginning of a conformable boundary, expressed in the interfingering of mudstone from the overlying Kyalla and the cemented sandstone of the underlying progradational Moroak Sandstone. Sandstone percentage in drill cuttings continued to increase until the Moroak Sandstone was fully penetrated.

The top Moroak Sandstone was interpreted from open hole logs at 1369.2 mMDRT. Total gas dropped from trace to nil upon entering the Sandstone suggesting any remaining porosity not occluded by cement was likely saturated with brine. This interpretation was confirmed by open hole logs following a sharp drop in resistivity in zones of cleaner and more porous sandstone beds in the upper section of the unit. From 1447.5 mMDRT, the unit transitioned from massive sandstone to interfingering sandstone and siltstone/mudstone beds. This change was interpreted as a progressive shift from high-energy, shallow water environments to a relatively deeper, low-energy marine settings with possible intermittent periods of fluctuating depositional energy conditions.

The top of the upper member of the Velkerri Formation, a finely interbedded, variably organic-rich, mudstone and siltstone sequence was defined at the base of the last of the clean progradational sandstone units at 1714.5 mMDRT. Three closely spaced dolerite sills were intersected in the upper Velkerri at 2072.1 - 2075.2 mMDRT, 2086.2 - 2090 mMDRT and 2100.1 - 2104.7 mMDRT. Brief but strong total gas shows were recorded directly before and after drilling the central dolerite sill, with gas peaking briefly at 15 %. Petrophysical evaluation along with thin section and argon-ion milled SEM image characterization of the interval indicated gas was likely retained within very fine to fine grained, calcite cemented sandstone and liberated while drilling. Thermal alteration induced by the intrusion are thought to have enhanced reservoir properties resulting in the anomalously high gas content observed.

The first of three prospective organic-rich shale targets, the middle Velkerri C Shale was intersected at 2212 mMDRT as shown by darkening of the interval from very dark grey to black drill cuttings coupled with a sharp increase in diagnostic element concentrations (e.g. Molybdenum, Vanadium, Uranium, and Thallium). Darkening of drill cuttings along with increase in diagnostic element concentrations and drill gas were used as indicators of organic richness. High sulphur content in conjunction with increased anoxic to euxinic sensitive trace elements (e.g. Vanadium, Molybdenum, Nickel, and Uranium) in drill cuttings suggested the interval was like deposited under anoxic to euxinic bottom water conditions. Pyrite bands and nodules were also common as defined by thin, high density and conductive spikes in wireline logs (e.g. FMI log). Drill gas peaked at 9.8 % towards the bottom of the C Shale coinciding with the highest gamma ray log value. A distinct drop in mud gas, diagnostic element concentrations, and resistivity coupled with an increase in bulk density defined the base of C Shale at 2299.7 mMDRT.

A section dominated by organic-lean, finely interbedded claystone and siltstone started at 2299.7 mMDRT and persisted down to 2432 mMDRT where the top of the second prospective target, the B Shale was intersected. A dolerite sill was penetrated from 2378.6 - 2384.6 mMDRT. Similar to the C Shale, the B Shale was dominated by finely laminated, dark, organic-rich mudstones displaying increased mud gas, diagnostic element concentrations, as well as an increase in resistivity and gamma ray and a decrease in bulk density values. Pyrite bands were also abundant throughout the interval as interpreted from wireline logs. Two, thin dolerite sills were intersected within the B shale at 2451.4 - 2452.7 mMDRT and 2478.6 - 2479.2 mMDRT. Petrophysical analysis indicated that the thicker sill from 2451.7 - 2452.7 mMDRT has enhanced the reservoir, resulting in higher total porosity and greater gas saturations directly adjacent to the dolerite sill. This enhanced reservoir zone quickly decreases away from the dolerite sill to background levels within 1.5 m, suggesting a limited extent of thermal alteration. The base of the B Shale was interpreted at 2484.2 mMDRT following a decrease in mud gas, increase in bulk density and a decrease in resistivity. The top remains somewhat ambiguous due to the gradational nature of the transition to the underlying finely interbedded claystone and siltstone unit. Very little colour or morphology changes were observed in drill cuttings over the boundary.

Down from 2484.2 mMDRT to 2561.6 mMDRT the lithology was dominated by thinly laminated, variably organic-rich mudstone. Mud gas was relatively high but remained below the trend observed previously in the C and B shales suggesting a decrease in reservoir quality over the section. Petrophysical evaluation supported this observation. A decrease in diagnostic element concentrations associated to anoxia and euxinia suggested bottom water conditions were relatively more oxygenated compared to those present during the B and C shale deposition. A dolerite sill was penetrated from 2529.8 - 2531.5 mMDRT with adjacent sediments showing indications of thermally enhanced reservoir quality similar to those observed previously.

The top of the A Shale was penetrated at a depth of 2561.6 mMDRT as indicated by a sharp increase in mud gas, increase diagnostic element concentrations, increase gamma ray values, and decrease bulk density. Lithology was dominated by laminated organic-rich mudstone, similar to that observed in the C and B shales. Diagnostic element concentrations and sulphur content indicated oxygen deficient conditions at the time of deposition which favour preservation of organic matter. The interpreted base of the A Shale coincided with the appearance of a regional carbonate rich marker at the base of the middle Velkerri from 2572.3 - 2572.8 mMDRT. Whereas the marker is generally thick in some parts of the Beetaloo Basin (e.g. 3.8 m in McManus-1), it was significantly less developed at Kalala S-1 (0.5 m). While absent in drill cuttings, except for a few fragments of carbonate material the bed was evident from wireline logs. A dolerite sill was penetrated within the A Shale from 2566.3 - 2567.4 mMDRT with adjacent sediments showing indications of thermally enhanced reservoir quality.

The top lower Velkerri was interpreted at 2572.8 mMDRT following a colour transition from dark to medium grey in drill cuttings, a sharp drop in diagnostic element concentrations and decrease in mud gas. Changes in colour were interpreted as a decrease in organic richness. The 6-3/4"

production hole section was terminated 49.2 m below the top lower Velkerri at a drillers depth of 2622 mMDRT and TD of 2619 mMDRT as defined by wireline.

## 7.2 PROGNOSED VS ACTUAL WELL STRATIGRAPHY

The prognosed and actual intersected stratigraphy of Kalala S-1 is shown in Table 3 and illustrated in the Composite Well Log (Appendix 1).

FORMATION	Prognosed Depth		Actual Depth		Difference (mTVDSS)	COMMENTS
	(mMDRT)	(mTVDSS)	(mMDRT)	(mTVDSS)		
Undifferentiated Cretaceous	5.35	239.7	5.35	239.7	0	
Anthony Lagoon Formation	-	-	74	171.05	-	No initial prognosis as it was absent in offset wells
Gum Ridge Formation	78	161	101.6	143.45	17.55 Low	
Antrim Plateau Volcanics	200	39	210.8	34.29	4.71 Low	No returns to surface. Interpreted from Wireline logs though casing and drilling parameters
Bukalara Sandstone	457	-218	295	-49.88	168.12 High	No returns to surface. Interpreted from Wireline logs through casing and drilling parameters
Chambers River Formation	495	-256	377.6	-132.42	123.58 High	No returns to surface down to 407m. Interpreted from Wireline logs and drilling parameters
Bukalorkmi Sandstone	971	-732	832	-586.75	145.25 High	
Kyalla Formation	1045	-806	912.5	-667.25	138.75 High	<b>Secondary Target</b>
Moroak Sandstone	1535	-1296	1369.2	-1123.89	172.11 High	
Velkerri Formation	2007	-1768	1714.5	-1469.09	298.91 High	
Upper Velkerri	2007	-1768	1714.5	-1469.09	298.91 High	
DOLERITE SILL TOP	-	-	2072.1	-1825.85	-	3.1 m thick unit
DOLERITE SILL BASE	-	-	2075.2	-1828.94	-	
DOLERITE SILL TOP	-	-	2086.2	-1839.89	-	3.8 m thick unit
DOLERITE SILL BASE	-	-	2090	-1843.67	-	
DOLERITE SILL TOP	-	-	2100.1	-1853.72	-	4.6 m thick unit
DOLERITE SILL BASE	-	-	2104.7	-1858.31	-	
Middle Velkerri	2179	-1940	2212	-1965.38	25.38 Low	<b>Primary Target</b>
Middle Velkerri – C Shale TOP	-	-	2212	-1965.38		organic-rich mudstone
Middle Velkerri – C Shale BASE	-	-	2299.7	-2052.97		
DOLERITE SILL TOP	-	-	2378.6	-2131.76		6 m thick unit
DOLERITE SILL BASE	-	-	2384.6	-2137.76		

Middle Velkerri – B Shale TOP	-	-	2432	-2185.13		organic-rich mudstone
DOLERITE STILL TOP	-	-	2451.4	-2204.53		1.3 m thick unit
DOLERITE SILL BASE	-	-	2452.7	-2205.83		
DOLERITE STILL TOP	-	-	2478.6	-2231.72		0.6 m thick unit
DOLERITE SILL BASE	-	-	2479.2	-2232.32		
Middle Velkerri – B Shale BASE	-	-	2484.2	-2237.32		
DOLERITE STILL TOP	-	-	2529.8	-2282.9		1.7 m thick unit
DOLERITE SILL BASE	-	-	2531.5	-2284.6		
Middle Velkerri – A Shale TOP	-	-	2561.6	-2314.7		organic-rich mudstone
DOLERITE STILL TOP			2566.3	-2319.4		
DOLERITE SILL BASE	-	-	2567.4	-2320.5		
Middle Velkerri – A Shale BASE	-	-	2572.3	-2325.4		
Lower Velkerri	2700	-2461	2572.8	-2325.9	135.1 High	
Total Depth	2800	-2561	2619	-2372.09	185.91 High	Driller TD @ 2622m

Table 3 - Prognosed vs actual intersected well stratigraphy of Kalala S-1

### 7.2.1 LITHOLOGY DESCRIPTION

(For complete sample by sample detailed drill cuttings lithology descriptions see Appendix 2).

#### Undifferentiated Cretaceous - 5.35 to 74 mMDRT (68.65 meters thick)

Moderate to dark reddish brown, argillaceous siltstone grading to moderate reddish orange with intervals of white to light grey claystone, presumably kaolinite. Soft, sticky and plastic claystone below 30 m and paling to yellowish orange over the lowermost 20 m.

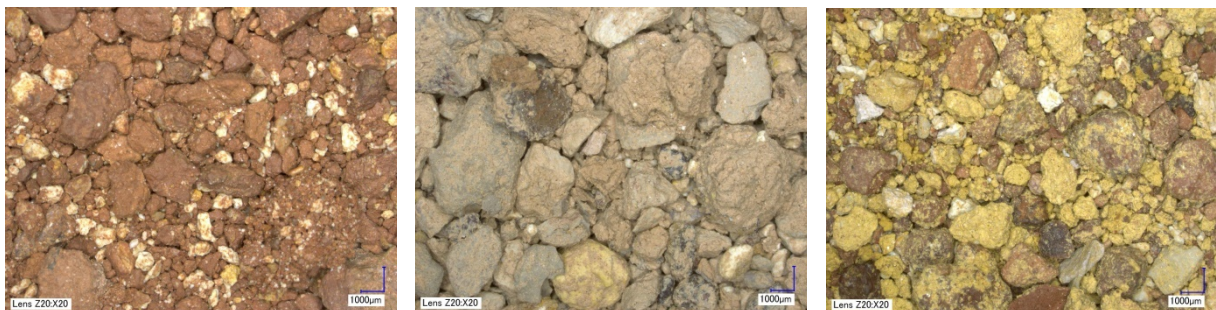


Figure 11 - Undifferentiated Cretaceous sediments in Kalala S-1 well at 10-15 mMDRT (left), 35-40 mMDRT (centre), and 55-60 mMDRT (right)

#### Anthony Lagoon Formation - 74 to 101.6 mMDRT (27.6 meters thick)

The section comprises moderate yellow orange, silty in part, soft, sticky, plastic and blocky claystone interbedded with clear, translucent, fine to medium grained, moderately sorted, sub angular to predominantly sub rounded sandstone becoming increasingly calcitic towards the base of the formation. Trace limestone was noted in drill cuttings at 85-90 mMDRT.



Figure 12 - Anthony Lagoon Formation in Kalala S-1 well at 85-90 mMDRT

**Gum Ridge Formation - 101.6 to 210.8(?) mMDRT (109.2(?) meters thick)**

Off white to white grading to light yellowish brown, translucent, lutitic to finely arenitic, microcrystalline, moderately hard to hard limestone. Possible Undifferentiated Cretaceous(?) cavings or silty claystone interbeds within the interval contain minor interbedded yellow orange, yellow brown, silty in part, firm, occasionally moderately hard, blocky claystone and translucent, white, clear, very fine to fine, trace medium grained, sub angular to sub rounded, trace siliceous cement, predominantly loose quartz grain sandstone.

Limited sample available from 115 m with no returns to surface from 130 m. The base of the Formation was interpreted from wireline logs and changes in drilling parameters.



Figure 13 - Gum Ridge Formation in Kalala S-1 well at 125-130 mMDRT.  
Last drill cuttings sample recovered before returns were lost

**Antrim Plateau Volcanics - 210.8(?) to 295(?) mMDRT (84.2(?) meters thick)**

No returns to surface. Top and base of the interval interpreted from wireline logs and changes in drilling parameters.

**Bukalara Sandstone - 295(?) to 377.6(?) mMDRT (82.6(?) meters thick)**

No returns to surface. Top and base of the interval interpreted from wireline logs and changes in drilling parameters. While drilling out the 10-3/4" casing shoe, rare, coarse grained, well rounded, loose sand grains were recovered. These were taken as an indication of positive penetration of the Bukalara Sandstone by 407 mMDRT (Figure 14).



Figure 14 - Hole fill from 407 mMDRT indicative of positive penetration of the Bukalara Sandstone

**Chambers River Formation - 377.6(?) to 832 mMDRT (454.4(?) meters thick)**

No returns to surface down to 407 m.

From 407 to 495 mMDRT the section comprises light to medium grey, light greenish grey, silty in part, firm to moderately hard, sub blocky to occasionally sub fissile claystone interbedded with medium red brown, dusky red siltstone, argillaceous in part, grading to claystone with traces of micro mica, moderately hard, blocky to sub fissile grains.

From 495 to 705 mMDRT the formation displays local increase in white, very light grey, very fine to occasionally fine grained, well sorted, sub angular to occasionally sub rounded and strong siliceous sandstone interbedded with, and grading to siltstone with abundant light to medium greenish grey, light grey and red brown claystone.

A regional calcitic marker bed was identified from cuttings in the form of minor calcite cemented sandstone. The base of the marker was interpreted from wireline logs at 597.5 mMDRT.

In general, the section contains traces of very fine lithic grains moderately hard to hard and displays tight visual porosity. Trace of dull yellow spotted, no cut or crush fluorescence was observed in sandstones within 685-690 mMDRT.

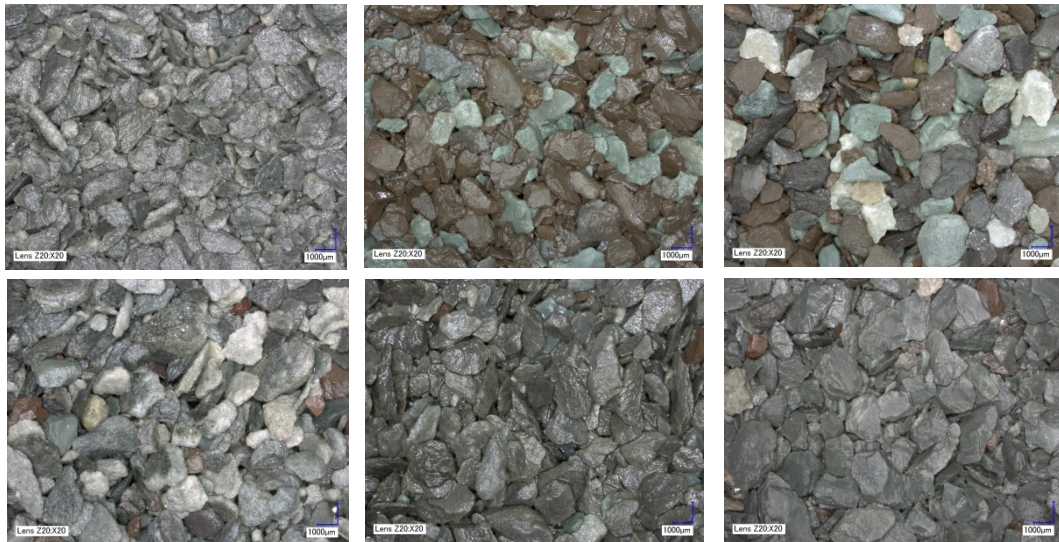


Figure 15 – Chambers River Formation sediments in Kalala S-1 well at 445-450 mMDRT (top left), 585-590 mMDRT (top centre), 595-600 mMDRT (top right), 685-690 mMDRT (bottom left), 745-750 mMDRT (bottom centre) and 810-815 mMDRT (bottom right)

**Bukalorkmi Sandstone - 832 to 912.5 mMDRT (80.5 meters thick)**

Dominantly white, translucent, fine to predominantly medium grained, trace coarse, moderately sorted, sub angular to sub rounded sandstone with minor interbedded light to medium grey, light greenish grey, trace dusky red, moderately hard to hard, sub blocky to sub fissile claystone. Sandstones display weak to moderately strong siliceous cement, rare white argillaceous matrix, friable to moderately hard grains, loose in part with generally poor to fair visual porosity. Trace of moderately bright yellow spotted, no direct cut, faint white crush cut, thin yellow green ring residue fluorescence was observed in sandstones within 850-890 mMDRT.



Figure 16 – Bukalorkmi Sandstone in Kalala S-1 well at 845-850 mMDRT (left), 870-875 mMDRT (centre) and 890-895 mMDRT (right)

**Kyalla Formation - 912.5 to 1369.2 mMDRT (456.7 meters thick)**

Down to 1158 mMDRT the formation is characterised by medium dark grey, dark brownish grey, silty in part, moderately hard to hard, sub blocky to sub fissile claystone with minor interbedded fine grained, very light grey, light brownish grey sandstone and light to dark grey, very fine to fine, argillaceous, soft to firm, sub fissile to blocky siltstone. Trace amounts of carbonaceous flecks and laminae, micro mica and lithics are generally present.

From 1158 to 1255 mMDRT, the sandstone content increases showing translucent, very light grey to white, trace clear, very fine to fine grained, trace medium, moderately sorted, sub angular to sub rounded, moderately strong siliceous cement in very fine to fine grained aggregates, loose medium quartz grains, minor light grey argillaceous matrix, moderately hard with tight visual porosity in fine grained aggregates.

From 1255 mMDRT, lithology is dominated by very dark grey to dark grey black, minor micro mica, common carbonaceous fragments, trace nodular pyrite, moderately hard to hard, blocky to sub fissile claystone. An increase in sandstone content from trace to 40% starting from 1340 down to 1369.2 mMDRT marks the fast, conformable transition to the high energy shoreface facies of the progradational Moroak Sandstone. The transition contains sandstone that is typically light grey, translucent, light brownish grey, very fine to medium, angular to sub rounded, fair sorting, moderately strong siliceous cement, minor light brown argillaceous matrix, friable to predominantly moderately hard, with tight to very poor visual porosity.

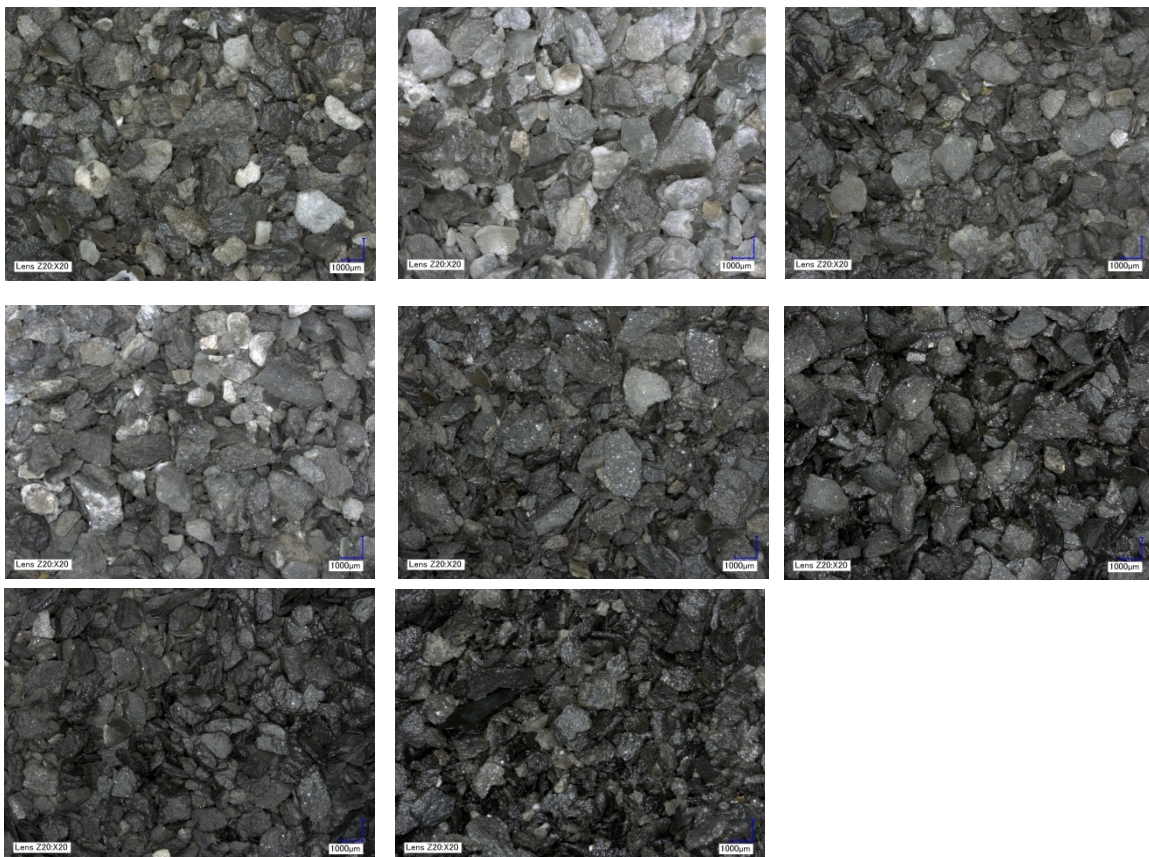


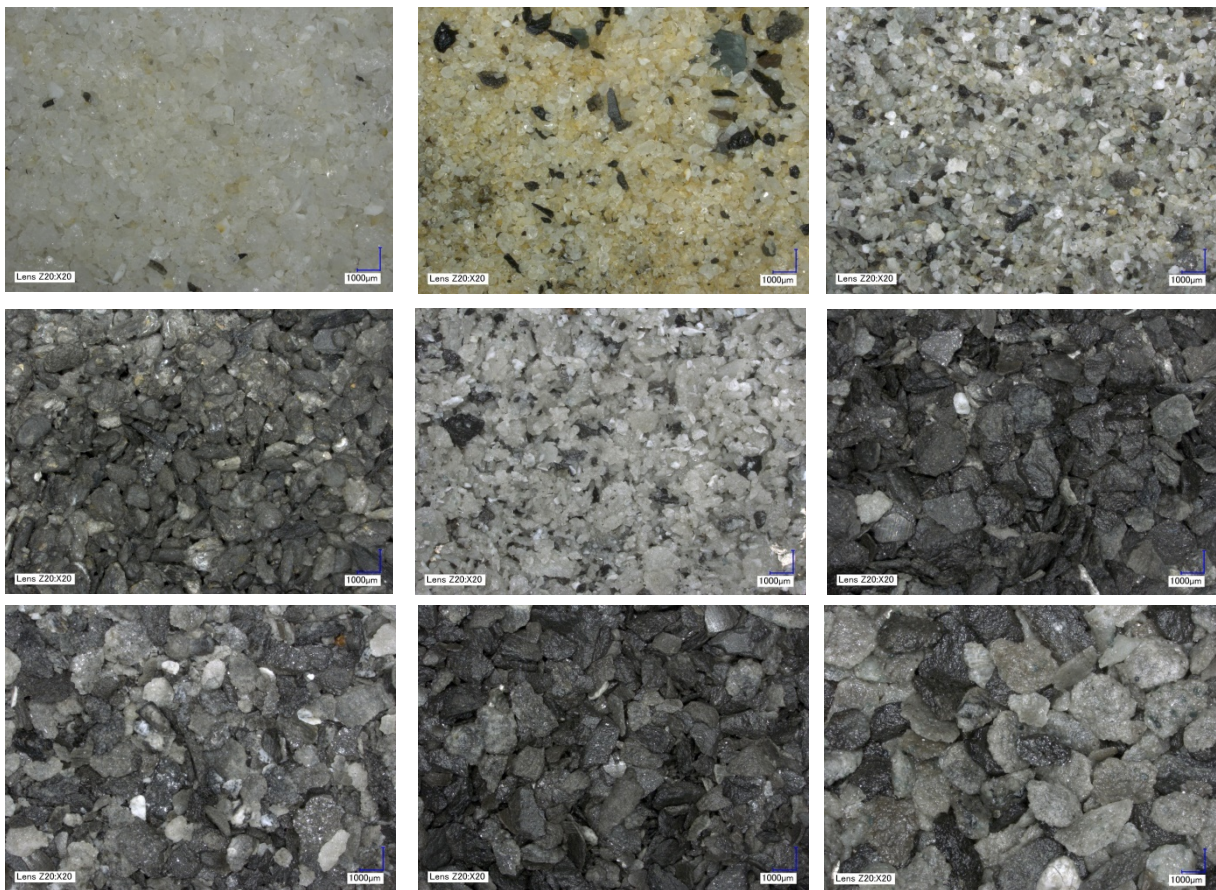
Figure 17 – Kyalla Formation cuttings in Kalala S-1 well at 945-950 mMDRT (top left), 1005-1010 mMDRT (top centre), 1120-1125 mMDRT (top right), 1190-1195 mMDRT (centre left), 1255-1260 mMDRT (centre centre), 1300-1305 mMDRT (centre right), 1315-1320 mMDRT (bottom left), 1345-1350 mMDRT (bottom right)

**Moroak Sandstone - 1369.2 to 1714.5 mMDRT (345.3 meters thick)**

Down to 1440 mMDRT the unit is dominated by sandstone, translucent, white, clear, frosted, very fine to coarse, poor sorting, angular to sub angular displaying siliceous shards, disaggregated,

siliceous cement, common white argillaceous matrix, moderately hard to hard aggregates and tight visual porosity.

A progressive increase in claystone and siltstone interbedded with sandstone is evident from 1440 mMDRT to 1714.5 mMDRT. Claystone is typically medium dark grey, dark grey black, carbonaceous in part, slightly silty with trace carbonaceous specks, trace micro mica, moderately hard, blocky to sub fissile whereas siltstone is medium dark grey to dark grey, arenaceous grading to very fine sandstone, carbonaceous specks, common disseminated pyrite, moderate hard, occasionally hard, sub blocky to sub fissile. When present sandstone is very light to light grey, off white, fine to medium, moderate sorting, sub angular to sub rounded with local common siliceous cement, common white argillaceous matrix, carbonaceous specks, common micaceous flecks, trace glauconite, trace micro micaceous, moderately hard to dominantly hard with tight visual porosity. This interval has been interpreted as a downward transition from nearshore to shallow marine depositional environments.



**Figure 18 – Moroak Sandstone cuttings in Kalala S-1 well at 1380-1385 mMDRT (top left), 1425-1430 mMDRT (top centre), 1450-1455 mMDRT (top right), 1525-1530 mMDRT (centre left), 1570-1575 mMDRT (centre centre), 1595-1600 mMDRT (centre right), 1635-1640 mMDRT (bottom left), 1665-1670 mMDRT (bottom centre), 1705-1710 mMDRT (bottom right)**

## Velkerri Formation

### Upper Velkerri - 1714.5 to 2212 mMDRT (497.5 meters thick)

Predominantly siltstone finely interbedded with very thin sandstone beds. Siltstone is dark grey, minor dark grey brown, rare medium grey, arenaceous to rare argillaceous, occasionally grading to very fine sandstone, commonly siliceous, common micro micaceous, rare disseminated pyrite, hard, sub blocky to occasionally blocky. Sandstone is typically light grey, minor off white, very fine, well sorted, sub angular to occasionally sub rounded, moderate to strong siliceous cement, occasional off white to light grey argillaceous matrix, micro micaceous in part with trace lithics, hard to moderately hard showing tight to very tight visual porosity.

Trace claystone appears at 2148 mMDRT becoming more common downwards towards the contact with the middle Velkerri at 2212 mMDRT. Claystone displays dark grey to greyish black, common to abundant disseminated pyrite, occasional to common micro mica, firm to rare hard, sub-blocky to sub-fissile and partly fissile characteristics.

Three dolerite sills were intersected in the lower section of the upper Velkerri at 2072.1 - 2075.2 mMDRT, 2086.2 - 2090 mMDRT, and 2100.1 - 2104.7 mMDRT. Dolerites were visually described as very tight sandstones while drilling but later confirmed as dolerites sills after wireline log evaluation.

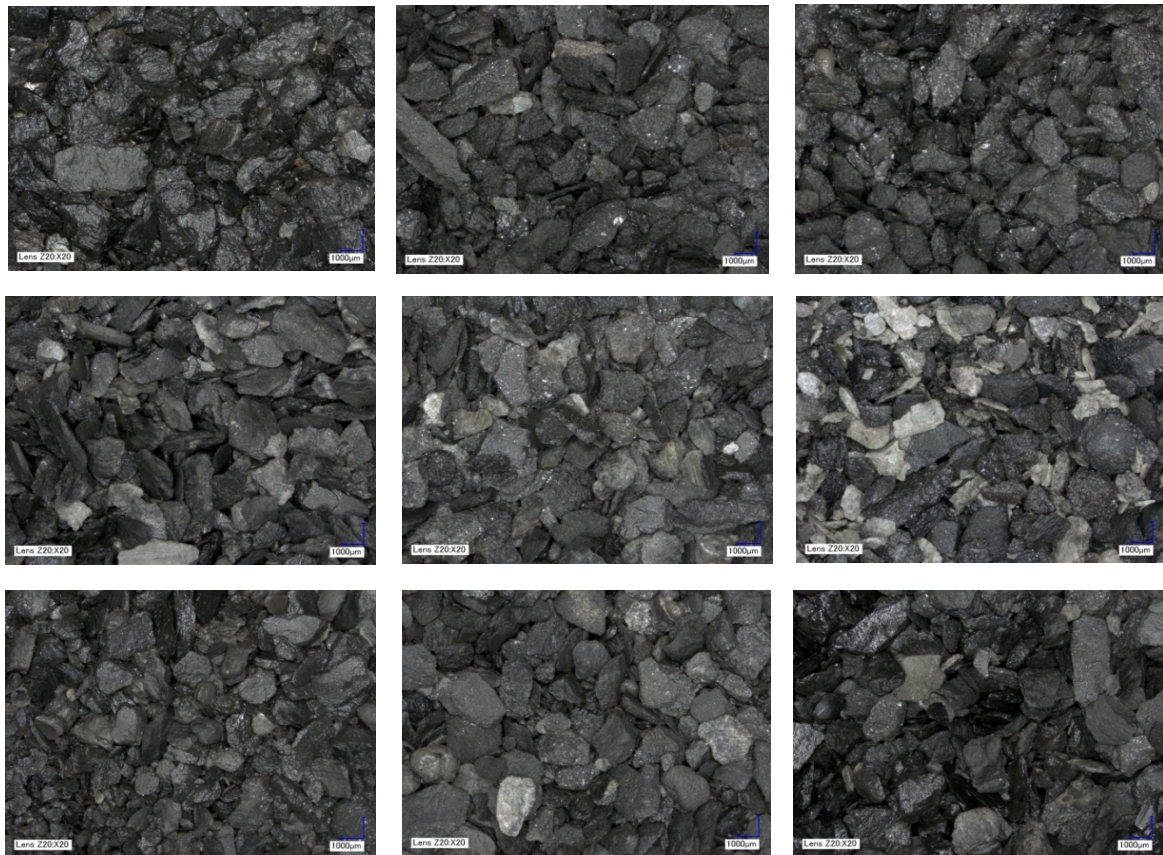


Figure 19 – Upper Velkerri cuttings in Kalala S-1 well at depths of 1735-1740 mMDRT (top left), 1820-1825 mMDRT (top centre), 1915-1920 mMDRT (top right), 1998-2001 mMDRT (centre left), 2028-2031 mMDRT (centre), 2085-2088 mMDRT (centre right), 2142-2145 mMDRT (bottom left), 2184-2187 mMDRT (bottom centre) and 2193-2196 mMDRT (bottom right)

**Middle Velkerri - 2212 to 2572.8 mMDRT (360.8 meters thick)**

The interval is dominated by carbonaceous-rich claystone with minor siltstone over three prospective target intervals known as the A, B and C shales. At Kalala S-1 these units were separated by organic-lean siltstones.

From 2212 - 2299.7 mMDRT (C Shale) gamma ray values show an increase in the clay and organic content. Typical cuttings descriptions in the interval include claystone, very dark grey, occasionally very dark grey black, micro micaceous, occasional disseminated pyrite, occasional nodular pyrite, hard to moderately hard, sub fissile to sub blocky, minor fissile and minor siltstone, dark grey, occasionally medium grey, commonly arenaceous, minor argillaceous in part, dominantly micro micaceous, occasional nodular pyrite, hard to very hard, sub blocky to dominantly sub fissile, rare blocky.

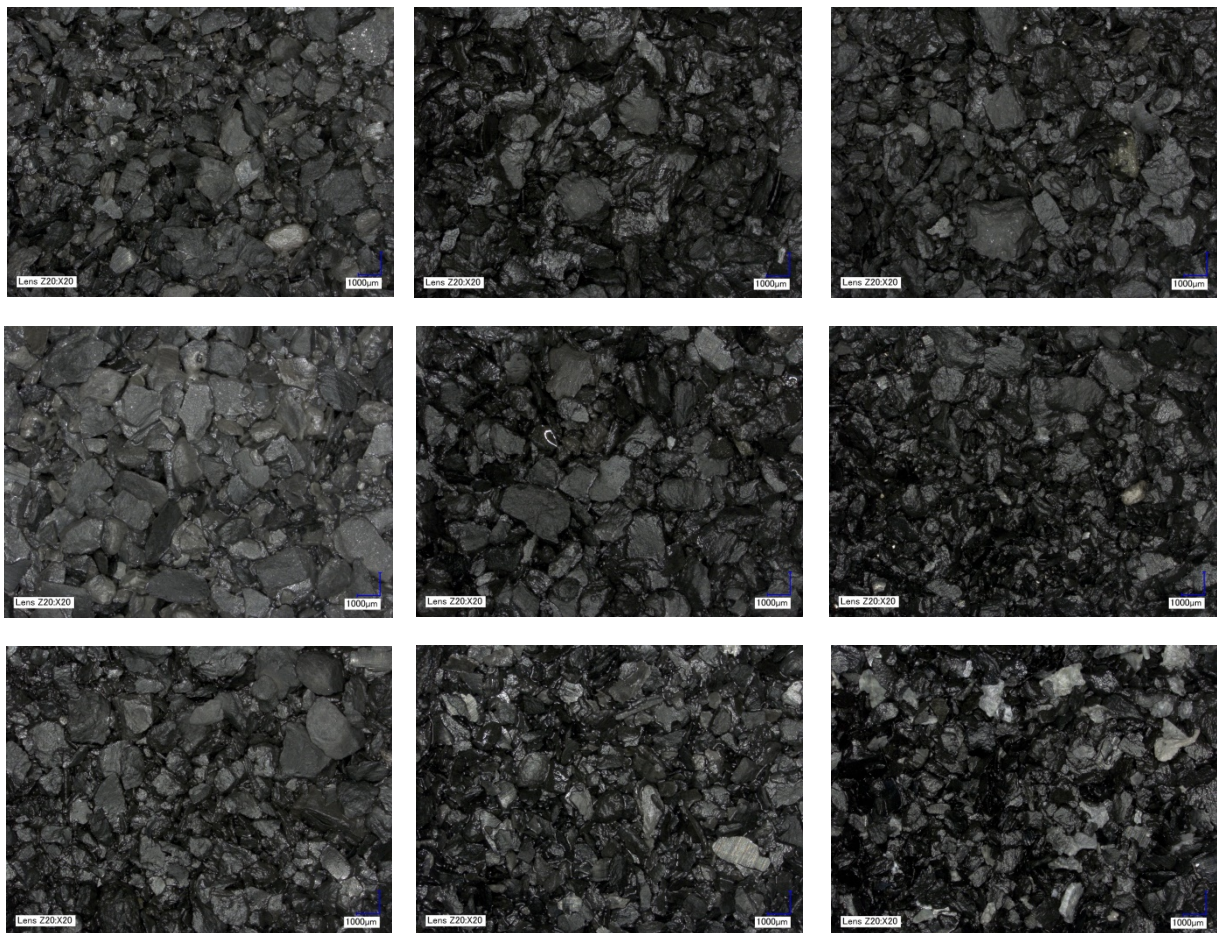
A transition from organic-rich claystone to organic-lean, finely interbedded claystone and siltstone commenced at 2299.7 mMDRT and persisted down to 2432 mMDRT. General descriptions were siltstone, dark grey, medium grey in part, arenaceous, argillaceous in part, common micro mica, occasional disseminated pyrite, hard to locally very hard, sub-blocky to sub-fissile and claystone, light to medium brown grey, dark to very dark grey in part, rare silty, micro micaceous in part, occasional disseminated pyrite, soft and dispersive, firm in part, amorphous, sub fissile to sub blocky in part.

A 6 m thick dolerite sill, very dark grey to black, crystalline to micro crystalline, common pyrite nodules and veins with occasional calcite inclusions and veins, hard to dominantly very hard was intersected from 2378.6 - 2384.6 mMDRT.

From 2432 - 2484.2 mMDRT (B Shale) gamma ray values displayed a renewed increase in the clay and organic content. This interval was described from drill cuttings as primarily claystone, dark to very dark grey, occasionally very dark grey brown to black, minor silty, micro micaceous, rare disseminated and occasional nodular pyrite, hard to occasionally moderately hard, sub fissile to occasionally sub blocky and minor siltstone, medium to dark grey, argillaceous to occasionally arenaceous, minor siliceous, common micro micaceous, moderately hard to hard, sub fissile, minor sub blocky to blocky.

From 2484.2 down to 2561.6 mMDRT the lithology consisted of finely interbedded siltstone and claystone with variably organic content. The general siltstone description was medium mottled grey, occasionally light grey to dark, dominantly arenaceous, commonly siliceous, calcareous in part, occasional calcite inclusions, occasional pyrite nodules and veins, localised disseminated pyrite, common dark lithics, hard to minor very hard, sub blocky to blocky. The claystone was described as dark to very dark grey brown, dark grey, commonly silty, commonly micro micaceous, minor pyrite nodules, hard to occasionally very hard, minor moderately hard, sub blocky, occasionally sub fissile to blocky.

A renewed increase in gamma ray occurred from 2561.6 - 2572.3 mMDRT (A Shale). Cuttings were described as primarily claystone, dark to very dark grey, dark grey brown, commonly silty, commonly micro micaceous, minor nodular pyrite, hard to very hard, sub blocky, occasionally sub fissile to blocky and minor siltstone, medium to occasionally light grey, minor dark grey, dominantly arenaceous, siliceous in part, weakly calcareous in part, minor pyrite nodules, localised disseminated pyrite, hard to minor very hard, sub blocky to blocky. A thin but regional carbonate marker bed defined the base of the middle Velkerri (2572.3 - 2572.8 mMDRT). The marker was easily recognized in wireline logs, but difficult to interpret from drill cuttings. Differences in log and cuttings interpretation resulted from discrepancies in the resolution of the techniques with drill cuttings sampling rate (3 metres) being too coarse to resolve the 0.5 m marker bed. When present, limestone was described as off white, minor light grey, micritic to dominantly lutitic, argillaceous, occasional lithics, microcrystalline, firm to hard.



**Figure 20 – Middle Velkerri cuttings in Kalala S-1 well at 2223-2226 mMDRT (top left), 2274-2277 mMDRT (top centre), 2289-2292 mMDRT (top right), 2352-2355 mMDRT (centre left), 2436-2439 mMDRT (centre), 2472-2475 mMDRT (centre right), 2487-2490 mMDRT (bottom left), 2542-2547 mMDRT (bottom centre) and 2565-2568 mMDRT (bottom right)**

### Lower Velkerri - 2572.8 to 2622 mMDRT (TD driller's depth)

The lower Velkerri was intersected at 2572.8 mMDRT and drilled 49.2 m before terminating the well at 2622 mMDRT. Cuttings descriptions defined the unit as primarily claystone, medium to light grey, occasionally very mottled light grey to off white, rare silty, locally common calcareous, commonly siliceous, occasionally localised micro micaceous, hard to occasionally very hard, minor moderately hard to firm, sub fissile to fissile, minor sub blocky.



Figure 21 – Lower Velkerri cuttings in Kalala S-1 well at 2571-2574 mMDRT (left), 2592-2595 mMDRT (centre) and 2616-2619 mMDRT (right).

## 8 WELL EVALUATION

### 8.1 MUD LOGGING

Geoservices provided mudlogging services for the drilling of Kalala S-1. This included conventional mudlogging, formation evaluation, real time data monitoring, drilling analysis, as well as high resolution imaging and X-Ray fluorescence (XRF) on drilling cuttings over the interval from 75.35 to 2622 mMDRT. A record of the mudlogging data, drill cutting XRF raw values, HDRM drill cutting photos, drill cutting lithology descriptions, mudlog and XRF log displays and Geoservices End of Well Report can be found in Appendix 2.

### 8.2 WIRELINE LOGGING

A total of nine wireline runs, including five rotary sidewall coring runs were attempted at Kalala S-1 over the 6-3/4" hole section (three by Schlumberger, six by Halliburton). A summary of runs is provided in Table 4. Raw and processed Wireline logs are included in Appendix 5.

LOGGING					
RUN #	Depth (mMDRT)		Description	Operator	Remarks
	From	To			
1	2619	Surface	HRLT-HDRS-HGNS-HNGS-EDTC-SP-LEH (PEX)	SLB	GR to Surface
2	2614.4	1304	PPC-CMR-NEXT-EDTC-LEH (CMR-Lithoscanner)	SLB	
3	2616.9	14.8	FBST-MAST-PPC-EDTC-LEH (FMI-Sonicscanner)	SLB	FMI - 2614 - 1312m Sonic Scan - 2619 - 900m
4	2290	2263	CoreVault™	HAL	9 cores cut and pressurized
5	Cancelled	Cancelled	CoreVault™	HAL	Cancelled after rock fragment from collapsing hole entered tools cavity preventing tilting bit box in and out of tools
6	Surface	1544	HR SCT (Rotary Sidewall Cores)	HAL	No recovery. Unable to pass 1544m
7	2570	1315	HR SCT (Rotary Sidewall Cores)	HAL	30 cores cut, 30 recovered
8	2475	2457	CoreVault™	HAL	10 cores cut, 10 recovered but no pressurized
9	2620.4	1964	GTET-DSNT-I-SDLT-I-DLL-ACRt-GEM-CSNG-I (Triple Combo-SGT-GEM)	HAL	

Table 4 - Kalala S-1 Summary of Wireline log runs

Note - The coring log files from Halliburton indicate coring tools were run from Run#3 to Run#7. This is incorrect. Coring runs were Run#4 to Run#8 as shown in Table 4.

## 9 FORMATION SAMPLING

### 9.1 CUTTINGS SAMPLING

Cuttings in Kalala S-1 were collected, washed and described at 5-10 metre intervals from 5.35 mMDRT down to 407 mMDRT, 5 metre intervals from 407 mMDRT to 1950 mMDRT, and at 3 metre intervals from 1950 mMDRT to TD (driller depth - 2622 mMDRT) as per Table 5. The lithology and composition of the cuttings are summarised in Appendix 2.

Cuttings Interval (mMDRT)	Sample Rate (m)	Comments
5.0 - 75.35	5	
75.35 - 407.0	5 - 10	Variable sampling intervals based on ROP (No returns from 130-407mMDRT)
407.0 - 1950.0	5	
1950 - 2622 (TD)	3	

Table 5. Drill Cuttings Interval and Sampling Rate Summary

## 9.2 CORING

### 9.2.1 ROTARY SIDEWALL CORING

Two unpressurized rotary sidewall coring runs (Run#6 and Run#7) using Halliburton's hostile rotary sidewall coring tool (HR SCT™, 1.5" diameter by 2" length idealised core cutting size) were attempted at Kalala S-1 (Table 4).

The first run (Run #6) was aborted after the tool failed to pass below 1544 mMDRT.

Following a wiper trip a second rotary sidewall coring run attempt (Run #7) recovered a total of 30 rotary sidewall cores from the interval 1315 to 2570 mMDRT. Depths and size measurements are summarized in Table 6.

Sidewall core photographs in natural light with size scales are enclosed in Appendix 4. Note: RSWC numbers as per the official wireline records in Table 6 do not match those in the RSWC photos in Appendix 4. Also note that an exception to the submission of UV light photographs of sidewall cores was submitted and granted by the Department of Mines and Energy due to minimal evidence of fluorescence in drill cuttings. RSWC recovered lengths for Run #7, are as per wellsite geologist measurements (Table 6).

Wireline Run No.	Core Number	Depth (mMDRT)	Diameter (mm)	Length Cut (mm)	Length Recovered (mm)	Supplementary Information
7	1	2570	38.1	57.7	53	
7	2	2563	38.1	57.2	54	
7	3	2550	38.1	53.6	53	
7	4	2523	38.1	46.7	45	Oval shaped core
7	5	2513	38.1	55.9	51	
7	6	2482	38.1	52.8	52	
7	7	2470	38.1	52.3	53	
7	8	2462	38.1	53.6	53	Different coloured wedge in core
7	9	2444	38.1	50.3	70	Rubble
7	10	2436	38.1	58.9	43	
7	11	2430	38.1	56.6	54	
7	12	2394	38.1	36.8	29	
7	13	2376	38.1	36.8	40	
7	14	2350	38.1	53.8	48	
7	15	2325	38.1	48.3	47	Rubble 4x pieces
7	16	2308	38.1	52.3	52	
7	17	2257	38.1	51.3	51	
7	18	2250	38.1	51.3	51	
7	19	2237	38.1	52.8	53	
7	20	2228	38.1	51.3	51	
7	21	2190	38.1	52.1	53	

7	22	2179	38.1	52.8	54	
7	23	2143	38.1	52.3	52	
7	24	2119	38.1	53.6	53	
7	25	2091	38.1	50.8	51	
7	26	2080	38.1	56.1	57	
7	27	1357	38.1	53.6	54	
7	28	1329	38.1	52.1	54	
7	29	1315	38.1	51.6	52	
7	30	2381	38.1	32.0	30	Rubble, most likely not from this core depth?

Table 6 - Rotary Sidewall Coring Depth and Size measurement Summary

### 9.2.2 PRESSURIZED ROTARY SIDEWALL CORING

Three pressurised rotary sidewall coring runs were attempted at Kalala S-1 using Halliburton's Hostile Rotary Coring Tool with the attached CoreVault™ System (HRSC-T-B, 1.5" diameter by 2" length idealised core cutting size with Corevault™).

The first run (Run #4) was successful in cutting and pressure-sealing downhole a total of nine rotary sidewall cores.

The second run (Run #5) was aborted after a rock fragment entered the tool cavity, preventing the tilting of the bit box in and out of the tool.

A third attempt (Run #8) was run following rotary side wall coring runs Run #6 and Run#7. Run #8 was successful in cutting 10 sidewall cores, but the CoreVault™ pressure chamber failed to seal downhole.

A summary of the pressurised rotary sidewall coring runs is provided in Table 7. Sidewall core photographs in natural light with size scales are enclosed in Appendix 4. Note: RSWC numbers as per the official wireline records in Table 7 do not match those in the RSWC photos in Appendix 4. Also note that an exception to the submission of UV light photographs of sidewall cores was submitted and granted by the Department of Mines and Energy due to minimal evidence of fluorescence in drill cuttings. RSWC recovered lengths for Run #8, are as per wellsite geologist measurements. RSWC recovered lengths for Run #4 were recorded by Weatherford Labs once the tool was safely unpressurized in their laboratory in Brisbane.

Wireline Run No.	Core Number	Depth (mMDRT)	Diameter (mm)	Length Cut (mm)	Length Recovered (mm)	Supplementary Information
8	1	2475	38.1	77.5	53	Not pressurized
8	2	2473	38.1	57.2	52	Not pressurized
8	3	2471	38.1	50.0	49	Not pressurized
8	4	2469	38.1	52.1	50	Not pressurized

8	5	2467	38.1	46.0	42	Not pressurized
8	6	2465	38.1	51.6	49	Not pressurized
8	7	2463	38.1	43.9	41	Not pressurized
8	8	2461	38.1	53.3	50	Not pressurized
8	9	2459	38.1	50.5	49	Not pressurized
8	10	2457	38.1	49.8	48	Not pressurized 3x Pieces
4	1	2290	38.1	96.3	41	
4	2	2287	38.1	56.9	39	
4	3	2284	38.1	81.8	41	
4	4	2281	38.1	52.1	41	
4	5	2278	38.1	50.8	42	
4	6	2275	38.1	49	43	
4	7	2271	38.1	49.3	44	
4	8	2267	38.1	50.8	44	
4	9	2263	38.1	51.3	40	

Table 7 - Pressurized Rotary Sidewall Coring Depth and Size measurement Summary

### 9.3 HYDROCARBON SUMMARY

Total hydrocarbon gas ('mud gas'), including chromatographic breakdown of the gas from C1 to C5 is displayed on the Mud Log and provided in raw data form in Appendix 2. The recording of mud gas including chromatographic breakdown, commenced at a depth of 75.5 mMDRT below the top of the Anthony Lagoon Formation at 74 mMDRT.

Mud gas was not detected or any fluorescence observed in drill cuttings through the Gum Ridge Formation, Antrim Plateau Volcanics or Bukalara Sandstone. Mud gas first appeared while drilling through the Chambers River Formation at a depth of 545 mMDRT at 10 ppm, rising progressively through the formation until stabilising at around 1000-3000 ppm (0.2 - 0.3 % Total Gas (TG)) between 673 mMDRT and the base of the formation at 832 mMDRT. Gas throughout the Chambers River Formation was dry, dominated by methane. Trace dull yellow spotted fluorescence was observed from cuttings between 685 - 690 mMDRT.

While drilling the Bukalorkmi Sandstone from 832 to 912.5 mMDRT, gas remained at a background level of 0.2 - 0.4 % TG, progressively becoming drier towards the bottom of the formation. Two short lived gas peaks were observed at 838.6 and 855.4 mMDRT at 1.2 and 2.7 % TG respectively with the latter correlating with a cleaner sandstone interval identified by a cleaner gamma ray log response. Chromatographic breakdown of the gas over the peak at 855.4 mMDRT indicated C1 - 19500ppm, C2 - 2000ppm, C3 - 1000ppm, C4 - 650ppm, C5 - 370ppm. Trace, moderately bright yellow spotted fluorescence with no direct cut, faint white crush cut, and thin yellow green ring residue was described from drill cuttings in the Bukalorkmi Sandstone between 850 to 890 m.

Upon intersecting the Kyalla Formation at 912.5 mMDRT, total gas increased gradually first to a peak of 1.6 % at 947 mMDRT followed by a gradual increase to a peak of 8.4 % from 1032.5 to 1158 mMDRT. Pass the informal Kyalla Sandstone at 1216 mMDRT gas increased gradually to a peak of 10.7 % at 1303 mMDRT before terminating the 9-7/8" hole section at 1305 mMDRT. Following the beginning of the 6-3/4" hole section, TG remained within the range of 3 - 5 % before declining gradually towards the base of the Kyalla Formation as the thin, interfingering sands of the Moroak Sandstone became increasingly common. Gas composition over the Kyalla Formation was generally 'wet'. Chromatographic breakdown of the gas over the peak at 1158 mMDRT (8.4 % TG) indicated C1 - 27500ppm, C2 - 11380ppm, C3 - 7540ppm, C4 - 3520ppm, C5 - 1520ppm; The composition over the gas peak at 1303 mMDRT (10.7 % TG) indicated C1 - 53630ppm, C2 - 11400ppm, C3 - 5320ppm, C4 - 2440ppm, C5 - 1220ppm. **No fluorescence was observed from drill cuttings within the Kyalla Formation.**

Mud gas fell following penetration of the upper Moroak Sandstone at 1369.2 mMDRT indicating the unit was predominantly water saturated. Gas remained low throughout the interpreted shoreface facies and into the lower shoreface interfingering sandstone and siltstone/mudstone section down to 1572 mMDRT. Gas within the interval ranged from trace to 0.6 % TG (generally 0.2-0.3 %). Between 1574.2 mMDRT and the interpreted top upper Velkerri at 1714.5 mMDRT a total of eight clean, tight sands were penetrated with gas peaks of 2.7 %, 1.7 %, 1.4 %, 4.2 %, 1.1 %, 3.3 %, 3.1 %, and 2 % downhole respectively. The highest gas peak of 4.2 % had a chromatographic breakdown of C1 - 34410ppm, C2 - 2250ppm, C3 - 280ppm, C4 - 45ppm, C5 - 10ppm. **No fluorescence was observed from drill cuttings.**

Background gas remained between 0.7 and 1 % TG while drilling the upper Velkerri. Short lived gas peaks occurred over intervals with relatively higher net siltstone and sandstone content ranging from 2 to 4.6 % TG. The chromatographic breakdown of the gases indicated progressive drier gas composition with depth as per the Haworth gas wetness ratio. Additional short lived gas peaks were also observed while drilling rocks adjacent to thin dolerite sills (2072.1 to 2075.2 mMDRT, 2086.2 to 2090 mMDRT and 2100.1 to 2104.7 mMDRT) from 2068 down to 2105.9 mMDRT. The best gas peaks occurred immediately before and after penetration of the second dolerite sill (2086.2 to 2090 mMDRT) with gas peaking at 15 % TG (C1 - 139050ppm, C2 - 5280ppm, C3 - 600ppm, C4 - 90ppm, C5 - 10ppm) and 13.1 % respectively. Cutting descriptions over the adjacent sill strata identified the lithology as primarily calcareous cemented sandstone. Lithology was later confirmed from XRD results and supported by thin section analysis (see Appendix 7). **No fluorescence was observed from drill cuttings.**

Total gas increased gradually upon penetrating the top of the C Shale at 2212 mMDRT to a peak 9.8 % at 2281 mMDRT (C1 - 94690ppm, C2 - 3670ppm, C3 - 190ppm, C4 - 20ppm, C5 - 3ppm) before decreasing to background levels of 1.2 - 2 % from 2299.7 to 2432 mMDRT. Small gas peaks were observed while drilling through a dolerite sill (2378.6 to 2384.6 mMDRT) and adjacent strata. TG values of 3.6 and 6.1 % were observed at the top and base of the sill unit respectively. Gas peaks

had a similar chromatographic breakdown to those from adjacent dolerite sill strata intersected in the upper Velkerri. **No fluorescence was observed over this interval.**

Total gas increased gradually upon intersecting the top of the organic-rich B Shale at 2432 mMDRT to values between 2.5 to 5 % TG with a peak of 7.6 % TG reached at 2466.6 mMDRT (C1 - 71285ppm, C2 - 2875ppm, C3 - 140ppm, C4 - 15ppm, C5 - 3ppm). This peak was centred over a few metres of relatively higher quality source rock mudstone reservoir as interpreted from wireline logs. An additional gas peak centred at 2451.6 mMDRT and spanning over a few metre interval before a dolerite sill, recorded a maximum value of 7.4 % TG (C1 - 70630ppm, C2 - 2420ppm, C3 - 110ppm, C4 - 10ppm, C5 - 3ppm). Gas within the B Shale became slightly but not materially drier deeper within the unit as estimated from the Haworth gas wetness ratio calculations. A noticeable drier gas signature was observed directly adjacent to a dolerite sill (2451.4 - 2452.7 mMDRT). This variation was interpreted as the result of a local increase in thermal maturation of organic matter triggered by the dolerite sill intrusion. **No fluorescence was observed from drill cuttings.**

From the base of the B Shale (2484.2 mMDRT) to the top of the A Shale (2561.6 mMDRT) mud gas generally ranged from 2.2 to 4 % TG. An 8 m interval of relatively higher quality source rock reservoir centred at 2515.9 mMDRT displayed a gas peak of 5.4 % (C1 - 50845ppm, C2 - 1505ppm, C3 - 55ppm, C4 - 7ppm, C5 - 2ppm). Mud gas increased and stabilised at 4 - 5.2 % TG past the top of the A Shale (C1 - 49710ppm, C2 - 1400ppm, C3 - 60ppm, C4 - 7ppm, C5 - 2ppm). **No fluorescence was observed from drill cuttings.**

Gas fell to 0.7 - 0.3 % TG upon penetration of the lower Velkerri at 2572.8 mMDRT and remained low to well TD. This was taken as an indication of the poor source and reservoir potential of the Lower Velkerri at Kalala S-1. **No fluorescence was observed from drill cuttings.**

## 10 RESERVOIR EVALUATION

### 10.1 PETROPHYSICAL ANALYSIS

Three prospective intervals were identified in the Velkerri Formation; the A, B and C shales (from oldest to youngest). All zones were found to be gas bearing and have high quartz content. A summary of the average total porosity (PHIT), total organic content (TOC), clay volume (VCLAY), quartz content (VOL QTZ), and total water saturation (SWT) is provided in Table 8. The average gas saturation for the three zones is 36 %.

The petrophysical interpretation utilised a mineral and fluid volume balance model that incorporated only the triple-combo and Lithoscanner logs. Resulting mineral volumes, TOC, dry matrix density, total porosity and *as received* water saturation aligned with core data derived from X-ray diffraction (XRD), X-ray Fluorescence (XRF), pyrolysis and Shale Rock Properties (SRP) analyses.

Velkerri Formation Total								
Formation	Top	Base	Gross/ Net	PHIT	TOC	VCLAY	VOL QTZ	SWT
	mRT	mRT	m	%	wt%	%	%	%
C Shale	2225.9	2297	71.1	5.7	2.9	30	49	62
B Shale	2428.6	2483.4	54.8	5.4	3.9	28	52	66
B Shale (base)	2483.4	2561.6	78.2	4	1.9	29	55	76
A Shale	2561.6	2572.3	10.7	5.5	3.3	30	49	61
Velkerri Total	2225.9	2572.3	214.8	5	2.8	29	52	68

Table 8. Summary statistics for gas bearing zones in the Velkerri Formation in Kalala S-1. Porosity (PHIT), Total Organic Content (TOC), clay volume (VCLAY), quartz content (VOL\_QTZ), total water saturation (SWT).

A detailed petrophysics report is included in Appendix 6.

## 10.2 ROTARY SIDEWALL CORE AND DRILL CUTTING ANALYSIS

To calibrate the petrophysical work done on Kalala S-1 a total of 49 RSWCs, including nine CoreVault™ system pressure sealed RSWC's and 35 drill cuttings samples were sent to Weatherford Laboratory and Terratek for various rock property, geochemical, petrographic, and rock mechanics analysis.

For gas analysis a total of 33 Isojars™, 47 Isotubes™, 40 RSWC Isobags™ and 20 CoreVault™ blowdown, desorbed and crushed gas samples were sent to Isotech Labs in Perth, Australia for bulk gas and carbon and deuterium isotope analysis.

A summary of the analyses undertaken and all laboratory results are included in Appendix 7.

Note: RSWC Isobags™ gas samples represent primarily the desorbed component of gas diffused from RSWC's while enroute to Weatherford from the wellsite. A gas sample was extracted from each of the Isobags™ using a hypodermic needle and sent to Isotech Labs for compositional analysis.

## 10.3 COREVAULT™ TOTAL GAS CONTENT ANALYSIS

The total gas content from the CoreVault™ was estimated by summing the CoreVault™ gas content released during the depressurisation process, the measurable canister gas content, and the remaining gas content liberated from the crushed sample at the end of desorbed gas analysis. The gas volume measurements were corrected for canister and ambient temperature and ambient pressure variations. The total gas content estimate was based upon the sample mass. The gas content summary for CoreVault™ samples are summarized in Table 9.

Top Depth	Bottom Depth	No. of Samples	AR Sample Weight	CoreVault Gas Content	Canister Gas Content	Crushed Gas Content	Total Gas Content
mMDRT	mMDRT		g	scc/g	scc/g	scc/g	scc/g
2263	2290	9	1304.5	0.908	1.1319	0.7511	2.791

Table 9 - CoreVault™ Gas Content Data summary

A detailed CoreVault™ report including a summary of operations and methodology are included in Appendix 7 (see Desorption).

## 10.4 FMI INTERPRETATION

A high-resolution formation micro-image of the Kalala S-1 borehole was acquired from the intermediate casing shoe to well TD (1312 - 2614 mMDRT) using the Schlumberger FMI tool. A copy of the Interpretation report, processed logs and supporting material can be found within Appendix 5.

Interpretation by Origin Energy indicates the mean maximum horizontal stress ( $Sh_{max}$ ) orientation is in the direction  $48.89^\circ N$  whereas the mean minimum horizontal stress ( $Sh_{min}$ ) orientation is in the direction  $25.03^\circ N$  over the middle Velkerri interval. Interpretation was determined from observations of 103 drilling induced tensile failure (DITF) and 3 borehole breakout (BHBO) interpreted fracture count respectively (Figure 22).

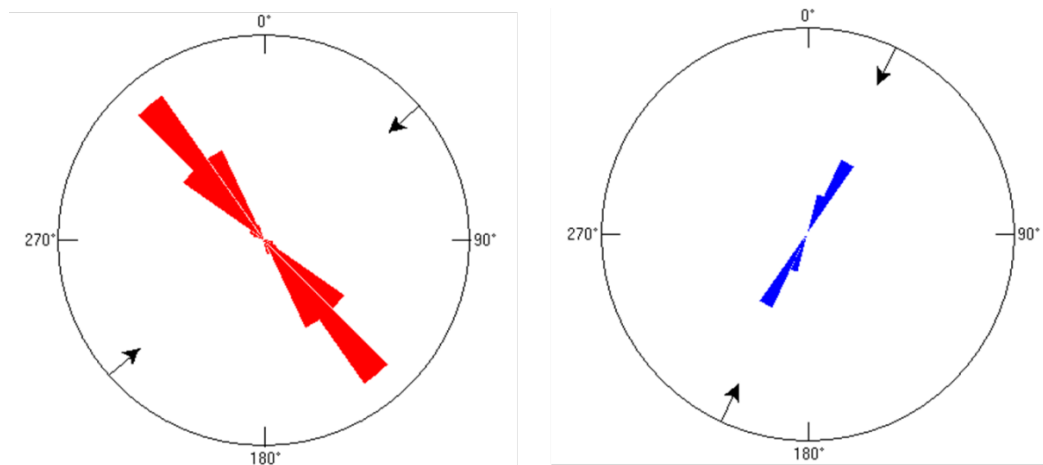


Figure 22 - Stress Interpretation Rose Diagrams: mean  $Sh_{max}$ :  $48.89^\circ N$ , SD:  $10.38^\circ N$  (Fracture Count: 103) (left) and mean  $Sh_{min}$ :  $25.03^\circ N$ , SD:  $4.41^\circ N$  (Fracture Count: 3) (right)

Total FMI analysis yielded 386 interpreted fractures with a distinct bimodal distribution (Figure 23).

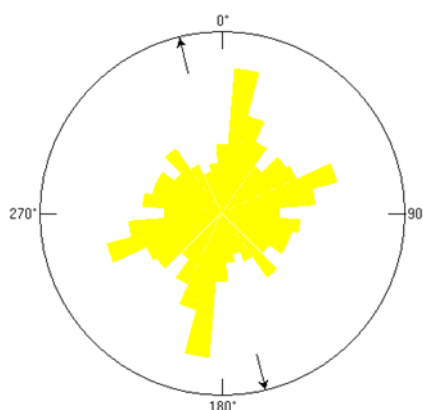


Figure 23 – Total Wellbore FMI Fracture Interpretation Rose Diagram: 47.43°N, Fracture Count: 386

## 11 FORMATION TESTING

### 11.1 FORMATION PRESSURE TESTING

A post-drilling, cased-hole Diagnostic Formation Injectivity Test (DFIT) was performed in Kalala S-1 over the middle Velkerri C Shale within the interval from 2253.3 - 2254.48 mMDRT. The test commenced on the 19<sup>th</sup> October 2015 with pressure leak-off monitored until 8<sup>th</sup> September 2016. All objectives of the DFIT, including evaluation of reservoir and fracture related properties were successfully met with the test providing robust estimates of breakdown pressure, fracture gradient and closure pressure.

The DFIT confirmed the C Shale is overpressured within a primarily normal to strike slip stress environment. The breakdown, leak-off storage and fissure leak-off analysis supported a transverse fracture storage mechanism consistent with image log interpretations. The analysis shows uncertainty around the closure pressure suggesting values may be artificially high as the result of 1) fracture reactivation in the direction of the minimum horizontal stress or 2) stress shadowing effect driven by fractures oriented in the minimum horizontal stress direction. DFIT results also confirmed the C Shale has very low permeability in the nano-darcy range.

Daily activity reports, raw data and DFIT report are enclosed in Appendix 8.

### 11.2 FLUID SAMPLING

No fluids from DST or downhole formation test tools were recovered during the drilling of Kalala S-1.

A total of 12 water samples were collected while air drilling Kalala S-1 and sent to ALS Laboratories in Darwin for compositional analysis including ionic species determination. Samples were taken from the BLOOIE line and stored in plastic bottles at ambient conditions. A summary of samples depths is included in Table 10. Compositional analysis results are shown in Appendix 7 (Water Analysis).

Standard data quality checks indicated all samples presented ionic imbalance exceeding 5 %, the cut-off for a reliable sample analysis (e.g. Appelo and Postma, 2005). Ion imbalance usually results from a major ionic component of the water not being analysed (e.g. silica or organic material). As a result, caution was exercised when using the data in interpreting the in-situ formation fluid properties. Analysis of fluid samples from a suite of historical DST's throughout the Beetaloo Basin were used.

No	ALS Sample Name	Depth (mMDRT)	Sample Type	Sample Volume	Sampling Location	Comments
1	1_W_KS1	410	Water	1000ml	BLOOIE line	3.252ohmm @ 75°F
2	N/A	410	Water	1000ml	BLOOIE line	3.252ohmm @ 75°F
3	2_W_KS1	410	Water	1000ml	BLOOIE line	3.252ohmm @ 75°F
4	N/A	410	Water	1000ml	BLOOIE line	3.252ohmm @ 75°F
5	3_W_KS1	410	Water	1000ml	BLOOIE line	3.252ohmm @ 75°F
6	4_W_KS1	1558 (Unloading Well)	Water	1000ml	BLOOIE line	0.040ohmm @ 75°F
7	N/A	1558 (Unloading Well)	Water	1000ml	BLOOIE line	0.040ohmm @ 75°F
8	5_W_KS1	1558 (Unloading Well)	Water	1000ml	BLOOIE line	0.040ohmm @ 75°F
9	N/A	1558 (Unloading Well)	Water	1000ml	BLOOIE line	0.040ohmm @ 75°F
10	6_W_KS1	1558 (Unloading Well)	Water	1000ml	BLOOIE line	0.040ohmm @ 75°F
11	7_W_KS1	1558 (Unloading Well)	Water	1000ml	BLOOIE line	0.040ohmm @ 75°F
12	8_W_KS1	1558 (Unloading Well)	Water	1000ml	BLOOIE line	0.040ohmm @ 75°F

Table 10 – Summary of water samples collected at Kalala S-1

### 11.3 PRODUCTION TESTING

No production tests were run in Kalala S-1.

## 12 CONTRIBUTIONS TO GEOLOGICAL KNOWLEDGE

Kalala S-1 reached its TD of 2619 mMDRT in the lower Velkerri having met all of its technical objectives and confirming the presence and regional extent of the primary target, the middle Velkerri south of known penetrations (e.g. McManus 1, Atree 2, Walton 2) as well as the presence and prospectivity of the secondary target, the Kyalla Formation within the northern region of the Beetaloo Basin.

The middle Velkerri in Kalala S-1 was very similar in log character and thickness to the middle Velkerri intersected in Amungee NW-1 (~29.5 km offset) indicating regionally consistent reservoir units across the northern edge of the Beetaloo Basin.

Petrophysical evaluation showed that the prospective intervals of the middle Velkerri, the organic-rich A, B, and C shales had good gas saturations and porosity. Combined petrophysics and core analysis confirmed the best middle Velkerri source rock reservoir target interval intersected in Kalala S-1 was the organic-rich C Shale.

Compositional analysis of gas recovered from the primary and secondary targets indicated the prospective middle Velkerri contained dry gas (363 - 94690 C1; 77 - 23955 C2+ (ppm)) whereas the Kyalla Formation contained primarily wet gas (788 - 53904 C1; 27 - 3879 C2+ (ppm)). Both displayed low inerts content (CO<sub>2</sub>/N<sub>2</sub>/H<sub>2</sub>S).

Increased concentrations of anoxic and euxinic diagnostic element concentrations (i.e. Vanadium, Molybdenum, Nickel and Uranium) over the A, B and C shales indicated these were deposited under anoxic, and possibly sulfidic bottom water conditions.

A post-drill extended leak-off test within the middle Velkerri C Shale indicated that the target organic-rich mudstones are over-pressured and have matrix permeability in the nano-darcy range.

Penetration of a number of dolerite sills within the Velkerri Formation confirmed the lateral extent of the Derim Derim Dolerites into the northern Beetaloo Basin at Kalala S-1.

## REFERENCES

- Abbott S.T. and Sweet I.P., 2000, Tectonic control on third-order sequences in a siliciclastic ramp-style basin: an example from the Roper Superbasin (Mesoproterozoic), northern Australia. *Australian Journal of Earth Sciences* 47(3), p637-657.
- Abbott, S.T., Sweet, I.P., Plumb, K.A., Young, D.N., Cutovinos, A., Ferenczi, P.A., Brakel, A., Pietsch, B.A., 2001, Roper Region: Urapunga and Roper River Special, Northern Territory (Second Edition), Sheets SD 53-10, SD53-11, 1:250 000 Geological Map Series Explanatory Notes Northern Territory Geological Survey, 100p.
- Ahmad, M., Dunster, J.N., Munson, T.J., 2013, McArthur Basin IN 'Geology and mineral resources of the Northern Territory', Ahmad M. and Munson T.J. (compilers) Northern Territory Geological Survey. Special Publication 5, 15:1-72.
- Appelo, C.A.J. and Postma, D., 2005, *Geochemistry, Groundwater and Pollution*, 2<sup>nd</sup> Edition, CRC Press, 688p.
- Collins, C.D.N., 1983, Crustal structure of the southern McArthur Basin, northern Australia, from deep seismic sounding. *BMR Journal of Australian Geology and Geophysics* 8(1), p19-34.
- Cull J.P., 1982, Magnetotelluric profiles in the McArthur Basin of northern Australia. *BMR Journal of Australian Geology and Geophysics* 7(4), p275-286.

- Dutkiewicz, A., Volk, H., Ridley, J., George, S.C., 2007, Precambrian inclusion oils in the Roper Group: a review. IN Munson, T.J. & Ambrose G.J. (eds) ' Proceedings of the Central Australian Basins Symposium', Alice Springs 16-18 Aug 2005. Northern Territory Geological Survey. Special Publication 2, p326-348.
- Fulton S. and Knapton A., 2015, Beetaloo Basin Hydrogeological Assessment. Cloud GMS Report (unpublished propriety report Origin Energy on behalf of Beetaloo Joint Venture), 66p.
- Jackson, M.J., Sweet, I.P., Powell, T.G., 1988, Studies on petroleum geology and geochemistry, Middle Proterozoic, McArthur Basin northern Australia I: Petroleum potential. APEA Journal 28(1), p283-302.
- Jackson M.J. and Raiswell R., 1991, Sedimentology and carbon-sulphur geochemistry of the Velkerri Formation, a mid-Proterozoic potential oil source in northern Australia. Precambrian Research 54(1), p81-108.
- Lanigan, K., Hibbird, S., Menpes, S., Torkington, J., 1994, Petroleum Exploration in the Proterozoic Beetaloo Sub-basin, Northern Territory. APEA Journal 34(1), p674 -691.
- Munson, T.J., 2014, Petroleum geology and potential of the onshore Northern Territory, 2014. Northern Territory Geological Survey, Report 2014-022, 242p.
- Powell, T.G., Jackson, M.J., Sweet, I.P., Crick, I.H., Boreham, C.J., Summons, R.E., 1987, Petroleum geology and geochemistry, Middle Proterozoic McArthur Basin. Bureau of Mineral Resources, Geology and Geophysics, Record 1987/48, 286p.
- Pryer L. and Loutit T., 2005, OZ SEEBASE™ structural GIS 2005 version 1. FrogTech Pty Ltd, Canberra.
- Silverman, M.R., Landon, S.M., Leaver, J.S., Mather, T.J., Berg, E., 2007, No fuel like an old fuel: Proterozoic oil and gas potential in the Beetaloo Basin, Northern Territory, Australia. IN Munson, T.J. & Ambrose G.J. (eds) ' Proceedings of the Central Australian Basins Symposium', Alice Springs 16-18 Aug 2005. Northern Territory Geological Survey. Special Publication 2, p205-215.
- Warren, J.K., George, S. C., Hamilton P.J & Tingate P., 1998, Proterozoic source rocks: sedimentology and organic characteristics of the Velkerri Formation, Northern Territory, Australia. American Association of Petroleum Geologists Bulletin 82(3), p442-463.