BLACK MOUNTAIN EXPLORATION

appea
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THE CANNING BASIN OF WESTERN AUSTRALIA

Petrophysical Analysis of the Unconventional Reservoirs of the Lennard Shelf and Fitzroy Trough in Canning Basin, Australia

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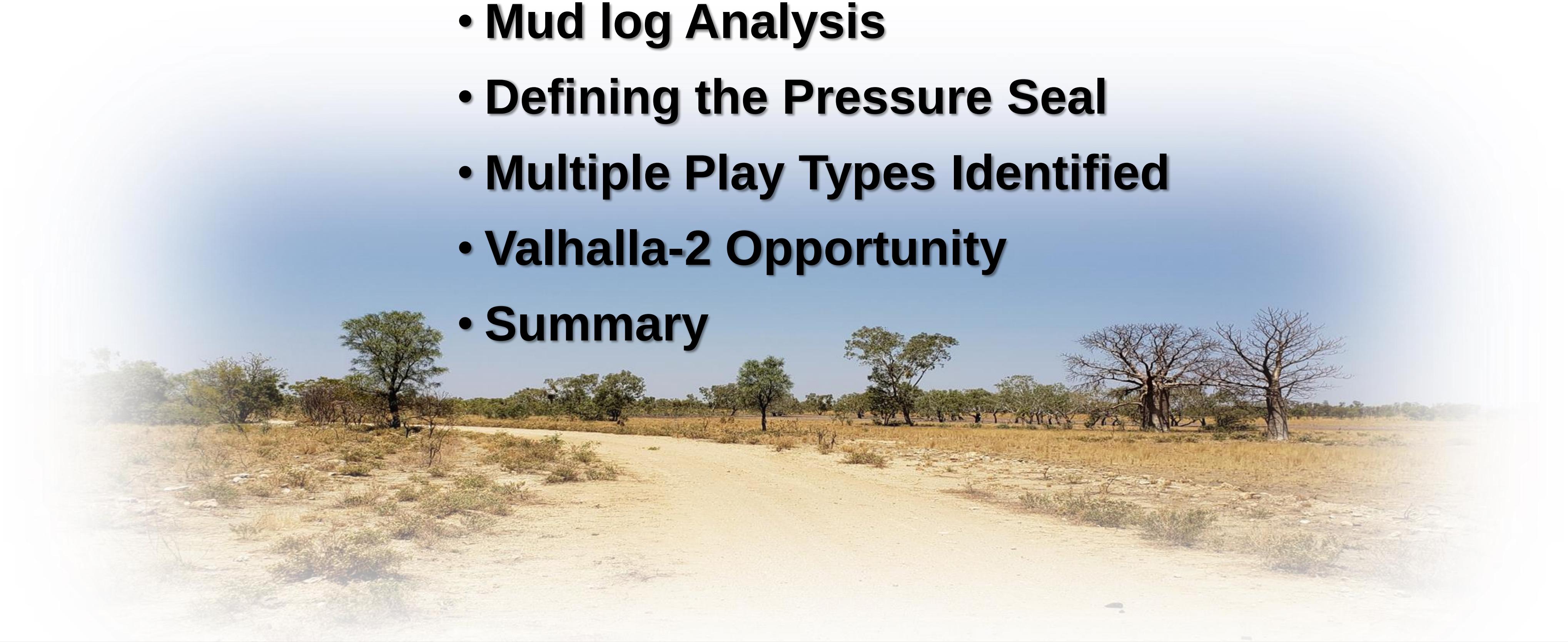
OUTLINE

- Canning Basin Overview
- Petrophysical Hybrid Model Workflow
- Thin beds Analysis and Lithology
- Formation Image Data Observation
- Mud log Analysis
- Defining the Pressure Seal
- Multiple Play Types Identified
- Valhalla-2 Opportunity
- Summary



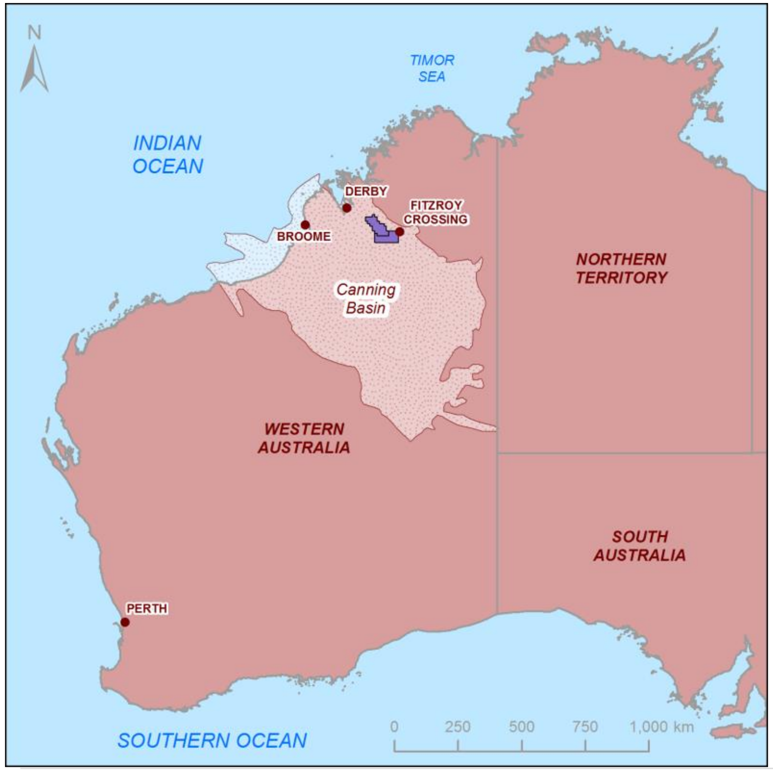
PROJECT AREA

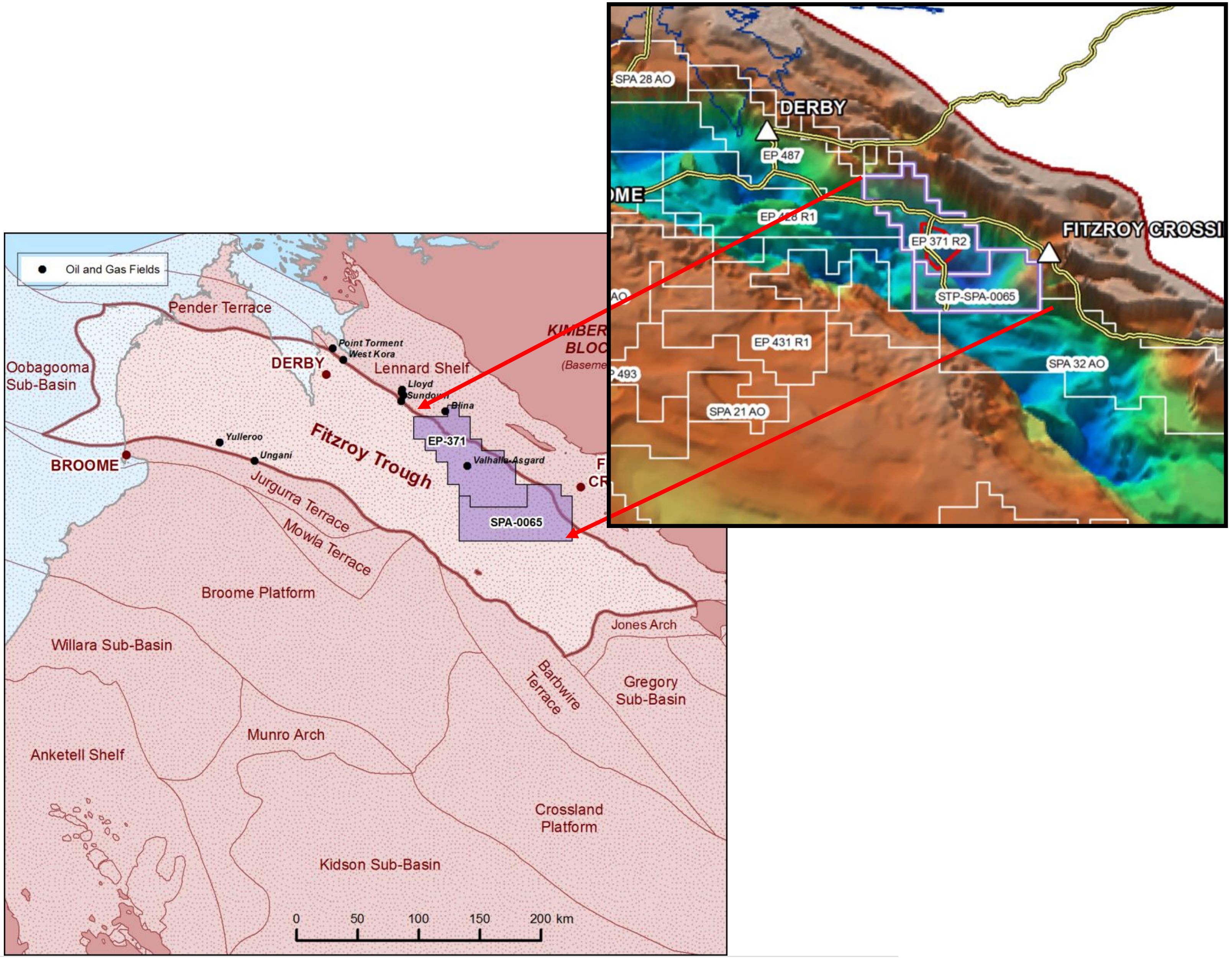
Canning Basin, Western Australia

EP-371 and SPA-0065

~ 2,500 km northeast of Perth

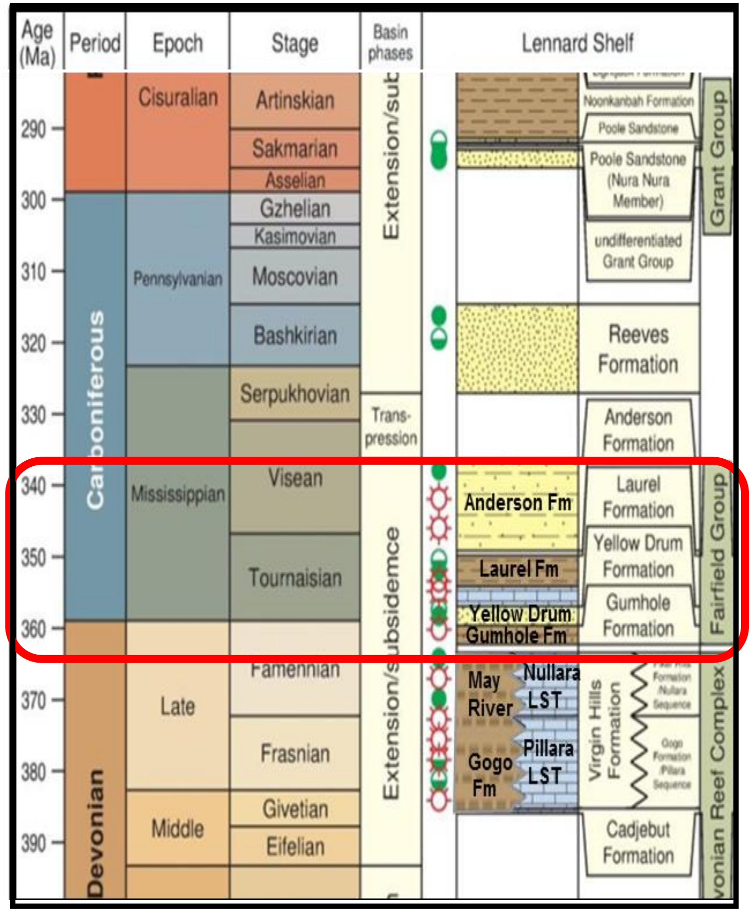
~ 6,767 km^2 Block and SPA





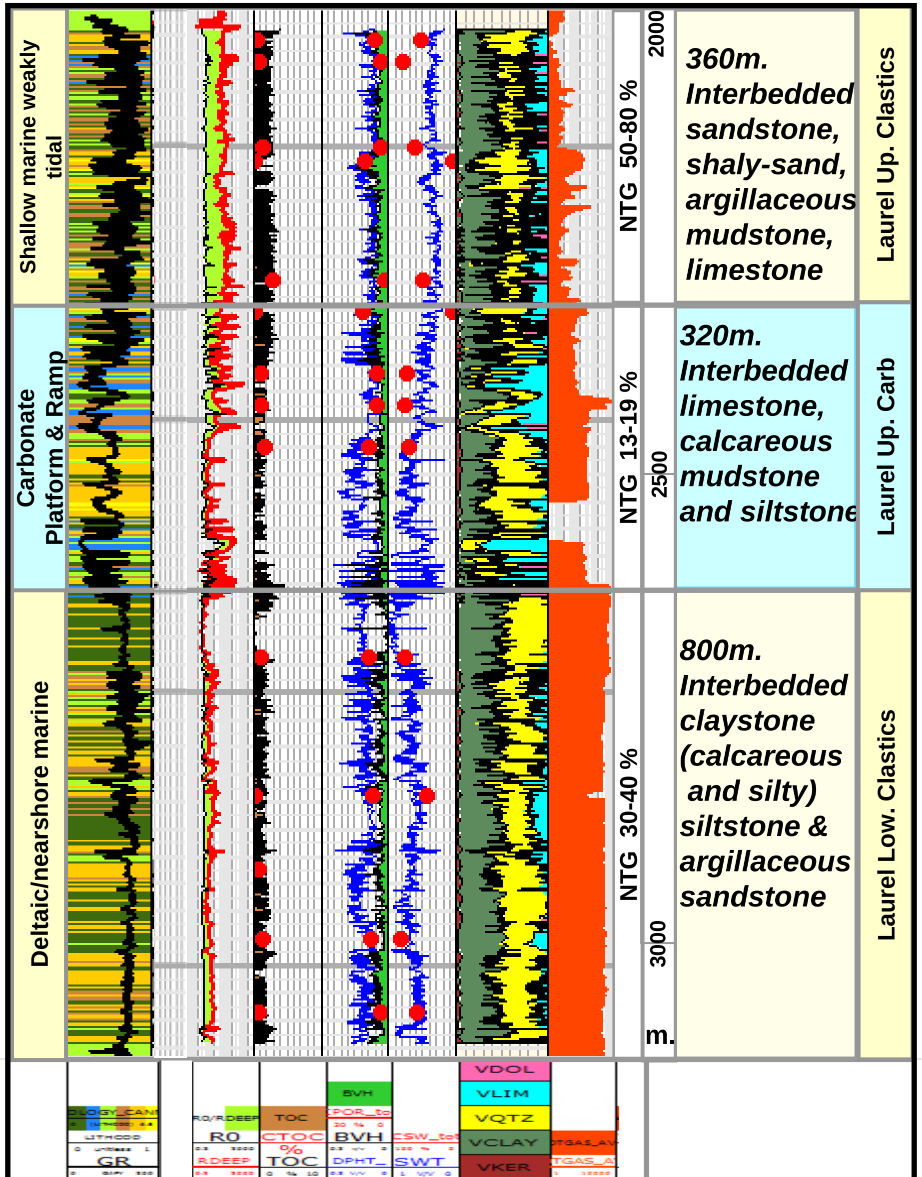
GROSS ROCK PROPERTIES

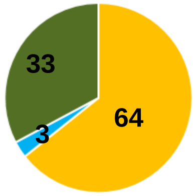
PRESSURE Seal - Unconformity at the Top of Anderson formation, Anderson Shale(Clay 60 - 70%)	
PRESSURE Gradient (psi/ft)	0.55 - 0.65

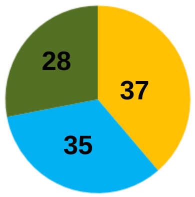


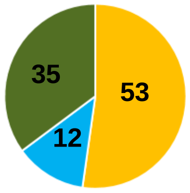
Carboniferous age shallow water SS and Carbonates, 7.8% porosity over 1000m thick

Valhalla-2









FORMATION PROPERTIES	CORE DATA Range	Log Analysis Average (Pay intervals)
POROSITY (%)	2.5 - 11	7.8
PERMEABILITY (mD)	1e-5 - 0.175	0.005
Water Saturation (%)	80 - 18	45
TOC (weight %)	0.5 - 4.45	1.5
QUARTZ (volume %)	up to 80	55
CARBONATE (volume%)	up to 70	12
CLAY (volume%)	up to 48	26
Expandable Clay (Smectite Vol.%)	up to 4.5	N/A

CORE XRD

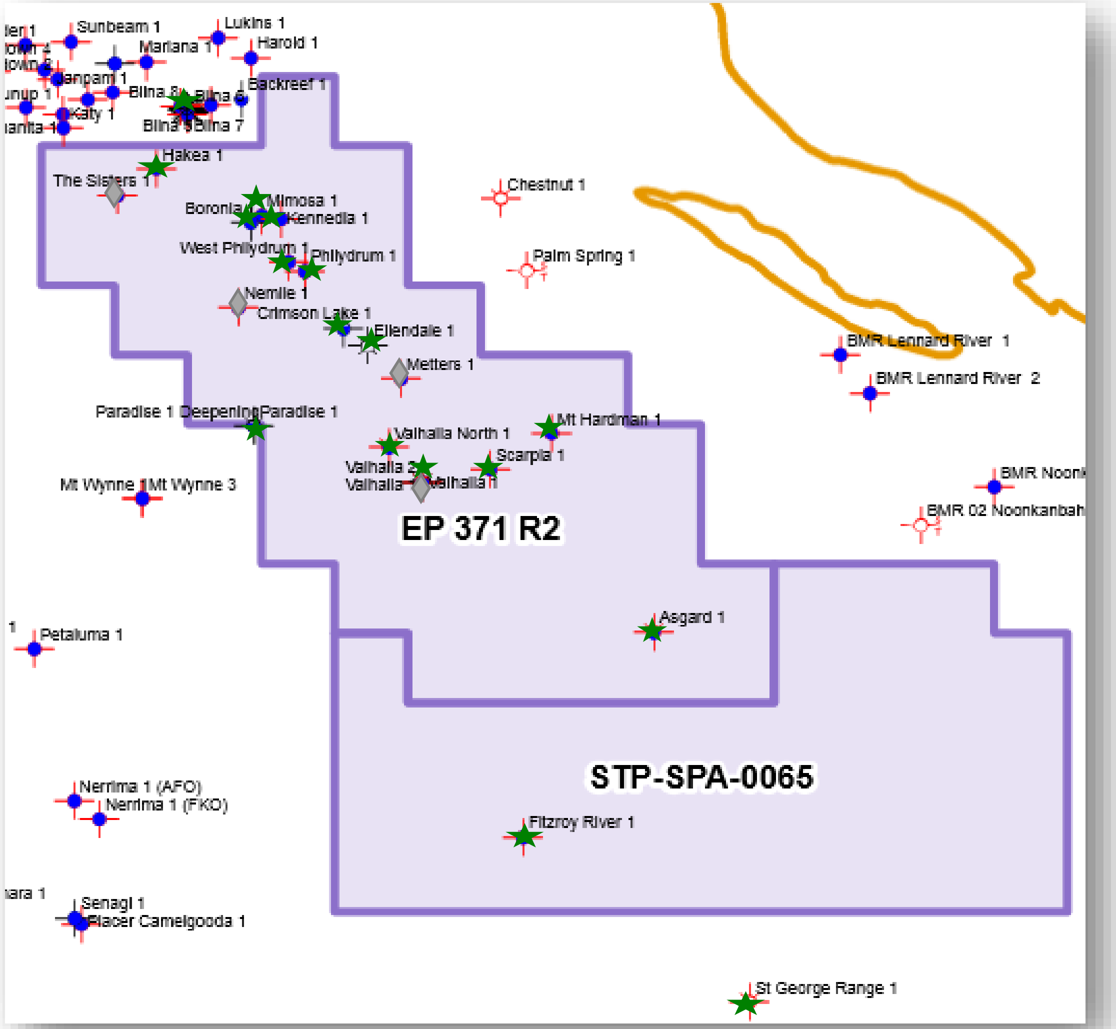
- Quartz + Feldspar + Plagioclase
- Carbonate (Calcite + Dolomite)
- Clay (mostly Illite, minor Kaolinite and Chlorite)

EP-371 LOCATION OF ANALYZED KEY WELLS

Using an unconventional reservoir workflow, assessed 25 key wells in or on the block.

All Laurel wells exhibit multiple hundreds to thousands of meters of gas occurrence.

- ASGARD-1
- BLINA-1
- BORONIA-1
- CRIMSON LAKE-1
- ELLENDALE-1
- FITZROY RIVER-1
- HAKEA-1
- KENNEDIA-1
- KORA-1
- METTERS-1
- MIMOSA-1
- MT HARDMAN-1
- NEMILE-1
- PARADISE-1 DEEPENING
- PHILYDRUM-1
- POINT TORMENT-1
- SCARPIA-1
- ST GEORGE RANGE-1
- THE SISTERS-1
- UNGANI NORTH-1 DEEPENING
- VALHALLA NORTH-1
- VALHALLA-01 ST1
- VALHALLA-2
- WEST PHILYDRUM-1
- YULLEROO-3



Wells with limited or insufficient log data
Analyzed wells with older log data (early 80s)
Analyzed key wells with modern log and Core data data

PETROPHYSICAL ANALYSIS WORKFLOW

- **Petrophysical Hybrid Model:**
  - Integrated petrophysical methods utilized for conventional clastic, carbonate and unconventional tight gas and shale formations
  - Calibrated to core data available on wells: Valhalla-2, Valhalla North-1, Yullero-3
  - Petrophysical analysis was performed using TECHLOG software package,
- **Model Inputs**:

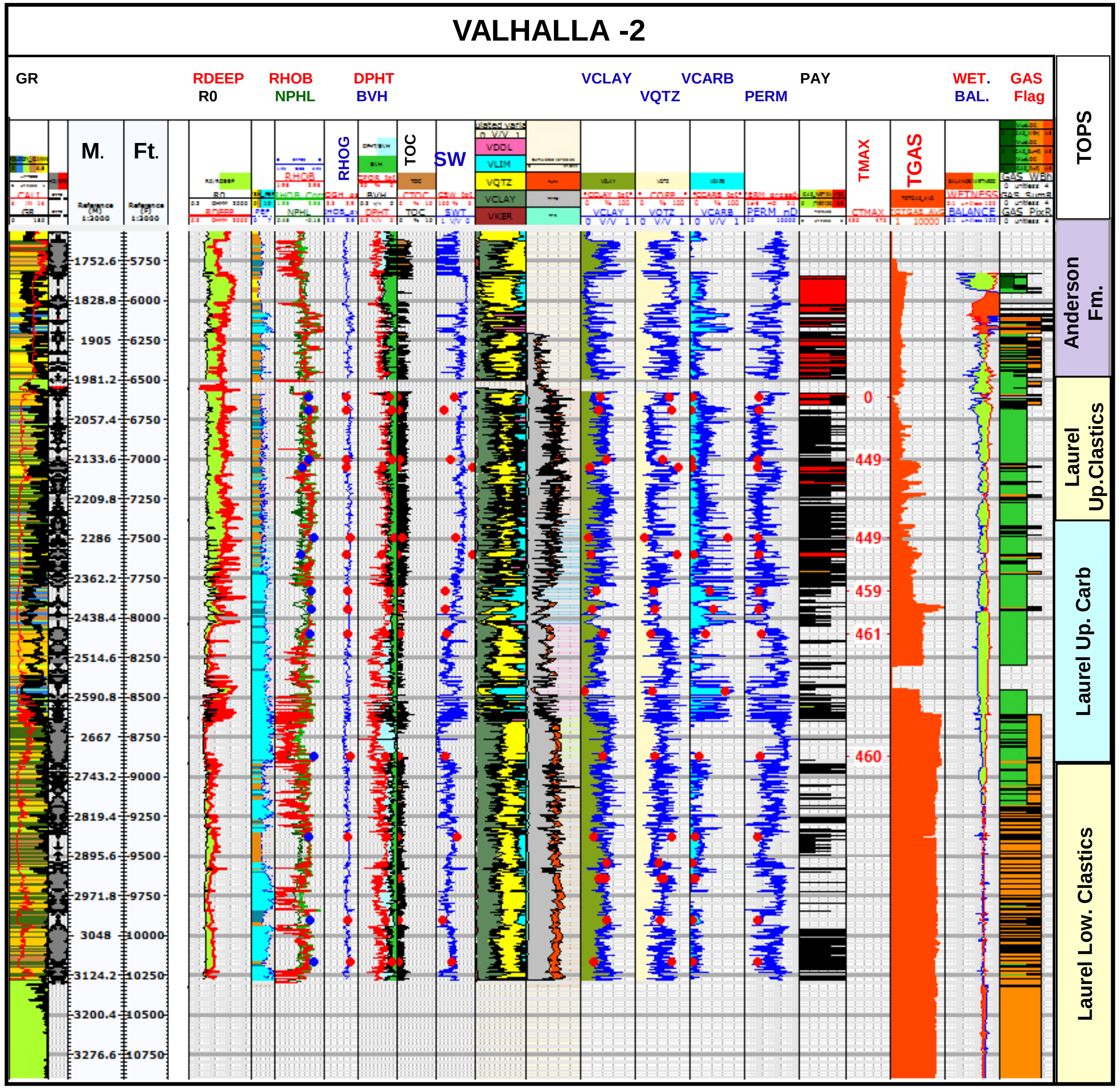
  GR, NPHL, RHOB, RDEEP
- **Model Outputs:**

  Litho-Facies,

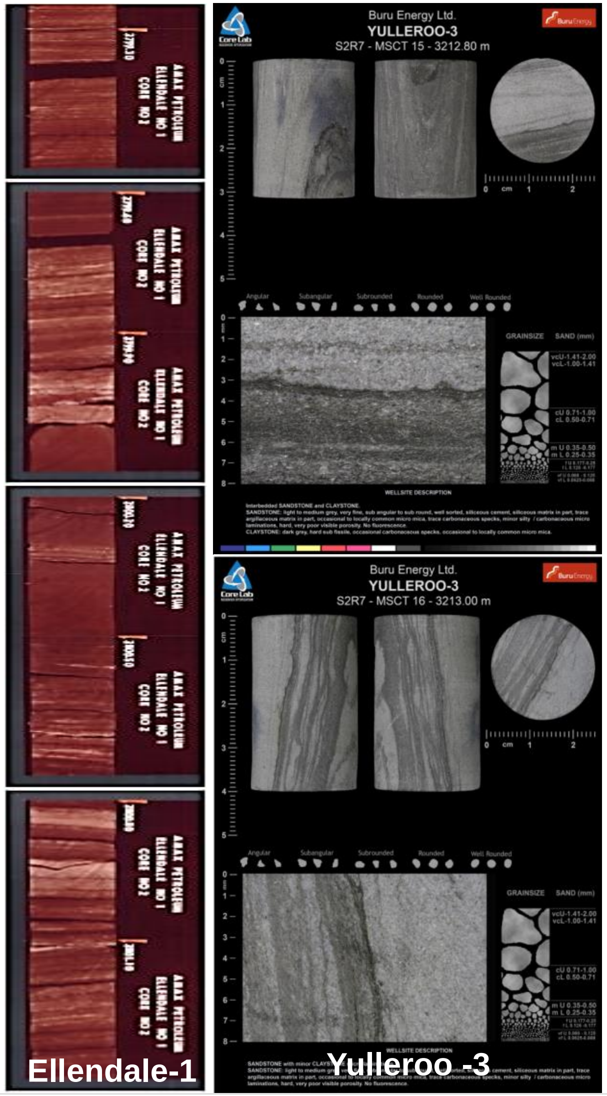
  Volume of minerals(Quartz, Clay, Calcite, Dolomite, Kerogen)

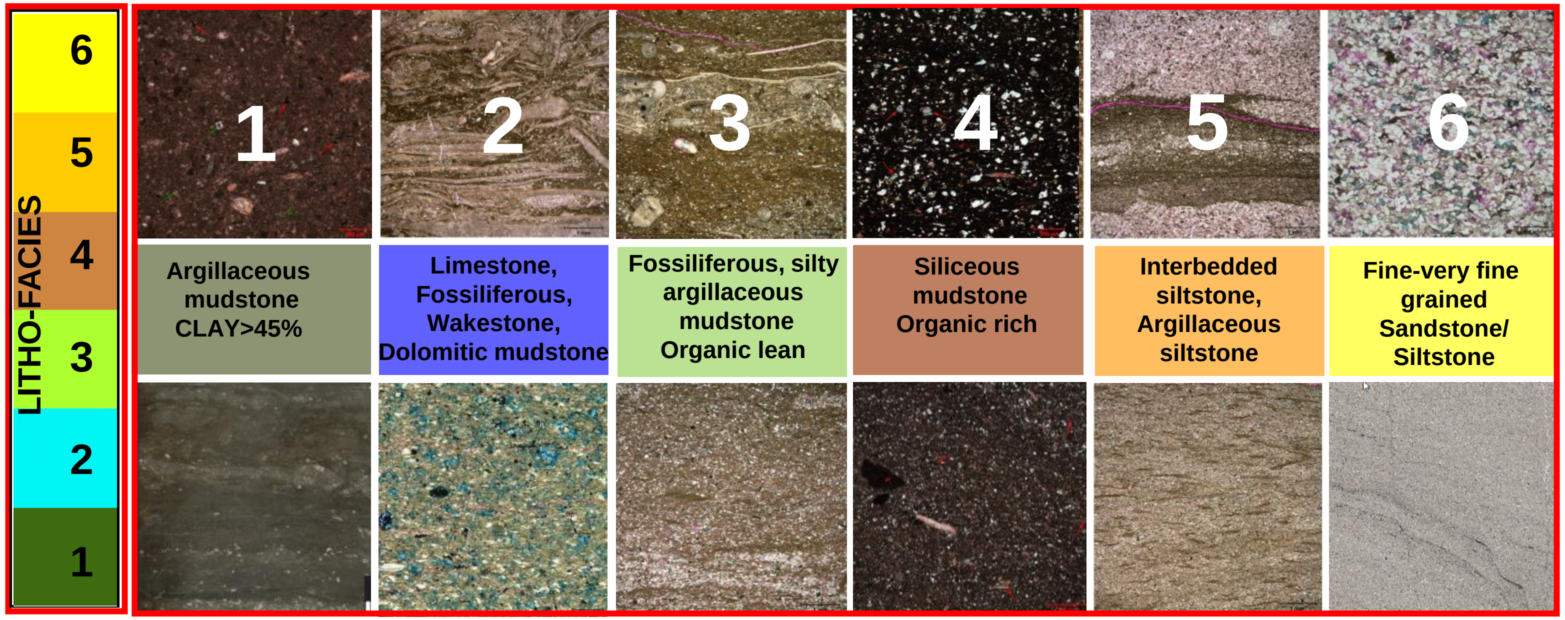
  TOC, DPHT, SWT, BVH, PERM

  PAY-Flag
- **Mud log Analysis:**
  - Integrated descriptive algorithm to define type of hydrocarbons includes Wetness, Balance and Ratios as the hydrocarbons' fingerprints
- **Defining the Pressure Seal:**
  - Sonic data analysis
  - Drilling and Completion data review



THIN BEDS ANALYSIS. LITHOFACIES CALALOG UPSCALED TO LOG RESOLUTION





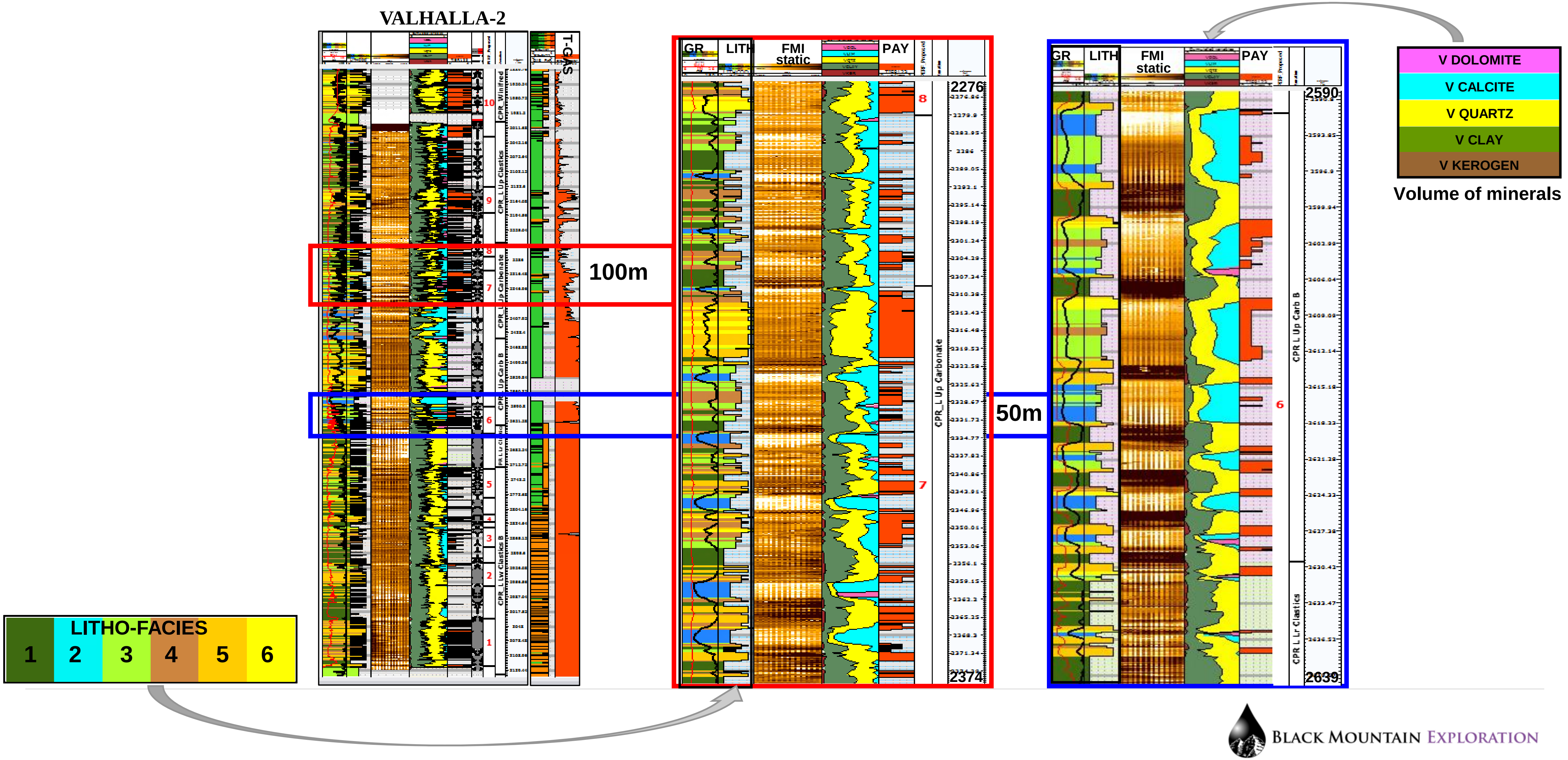
Volumes of five major group of minerals calculated:

- VQTZ (Quartz +Plagioclase)
- VCLAY (predominantly Ilite plus minor amount of Chlorite, Kaolinite and Montmorillonite - less than 3%)
- VDOLOMITE and VCALCITE
- VKEROGEN (converted to volume from TOC weight%)

Six primary lithofacies identified through:

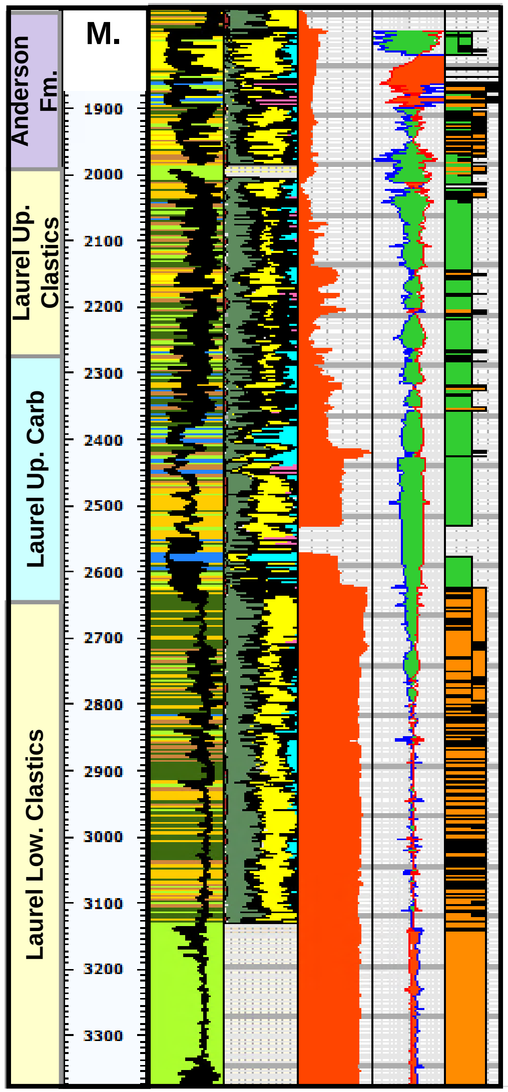
- Integration of thin section analyses, geological core descriptions, log response and petrophysical model results (volume of minerals)
- calibrated to high resolution formation image data

THIN BEDS ANALYSIS. LITHO-FACIES CALIBRATION TO FORMATION IMAGE



MUDLOG ANALYSIS

Valhalla 2



- **Integrated descriptive algorithm to define type of hydrocarbons includes Wetness, Balance and Ratios as the hydrocarbons' fingerprints**
- **All the equations and methodologies listed below have been integrated in Python code to define Hydrocarbon types based on gas compositions from MudLog**
  - ✓ **Model outputs: WETNESS, BALANCE, CHARACTER, FLAG_PixR, FLAG_SumR, FLAG_WBh**

The Haworth *et al.* "wetness" method[3] defines several correlatable ratios: wetness, W_h; balance, B_h; and character, C_h.

$$W_h = \frac{C_2 + C_3 + iC_4 + nC_4 + C_5}{C_1 + C_2 + \ldots + C_5} * 100 \quad \ldots\ldots(5)$$

$$B_h = \frac{C_1 + C_2}{C_3 + iC_4 + nC_4 + C_5} \quad \ldots\ldots(6)$$

$$C_h = \frac{iC_4 + nC_4 + C_5}{C_3} \quad \ldots\ldots(7)$$

Gas dryness = C1/C1+C2+C3+C4+C5

Pixler ratios (C1/C2, C1/C3 and C1/C4)

Wetness (Wh) = 100 * (C2 + C3 + C4 + C5) / (C1 + C2 + C3 + C4 + C5)

Balance (Bh) = (C1 + C2) / (C3 + C4 + C5)

And Character (Ch) = (C4 + C5) / C3

Nomenclature

- B_h = balance ratio
- C_1 = methane
- C_2 = ethane
- C_3 = propane
- C_{4+} = butanes and heavier
- C_{5+} = pentanes and heavier
- C_h = character ratio
- W_h = wetness ratio

Pixler Ratio

Dg	C1/C2 > 35 : dry gas
Cnd	C1/C2 10 - 35 : condensate or light oil
Oil	C1/C2 2 - 10 : productive oil
Roil	C1/C2 < 2 : residual oil

C1/Sum Ratio

C1/Sum > 0.95 : dry gas

C1/Sum 0.85 - 0.95: possible condensate or light oil

C1/Sum 0.6 - 0.85 : Possible productive oil

C1/Sum < 0.6 : residual oil

Wetness vs Balance

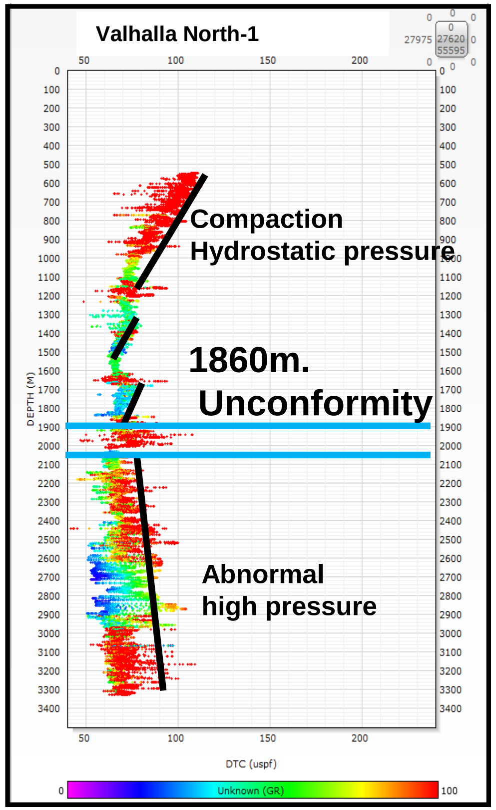
If WH < 0.5 & BH > 100 :
Dry Gas

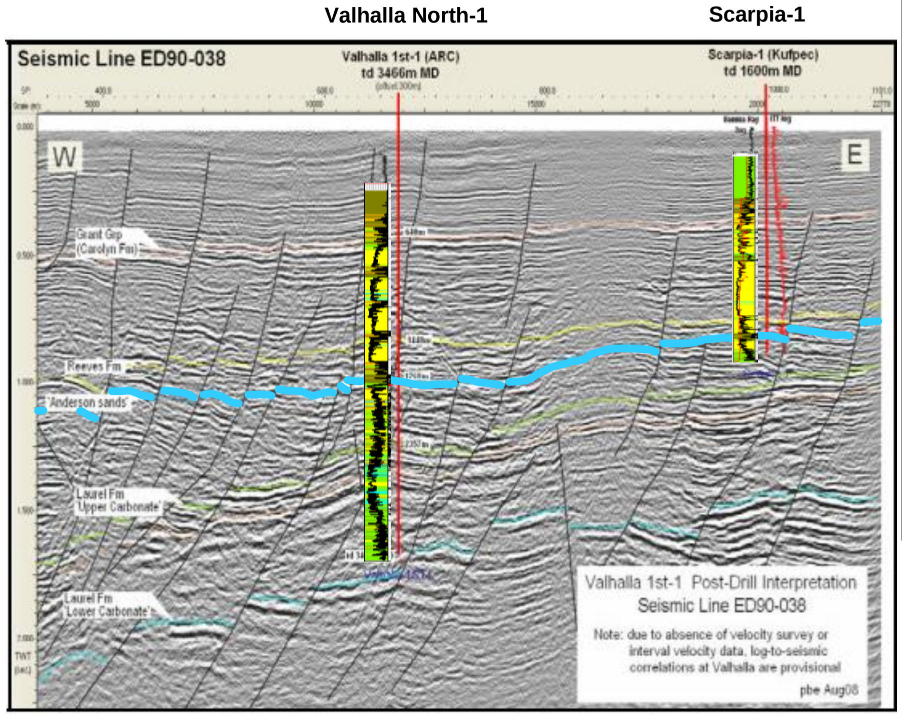
If 0.5 < WH < 17.5 & WH<BH <100 :
Condensate or Light Oil

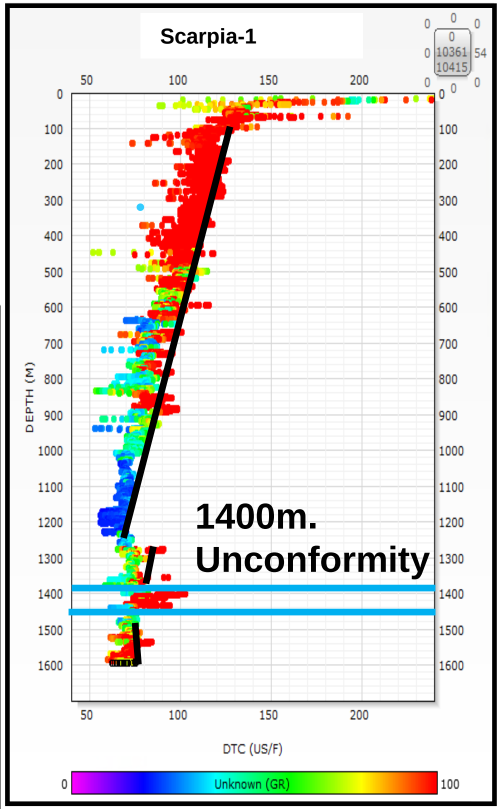
If 17.5 < WH < 40 & WH > BH :
Oil

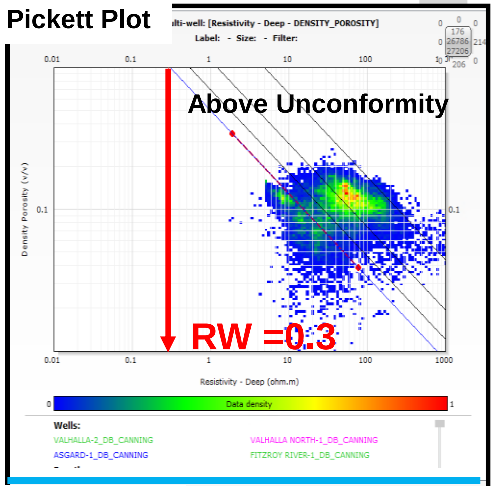
If WH > 40 : Residual Oil or Water

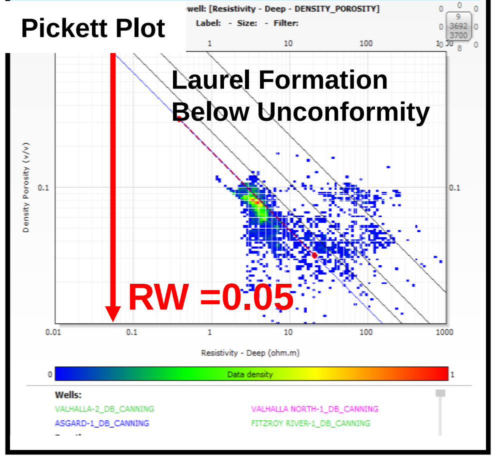
PRESSURE SEAL





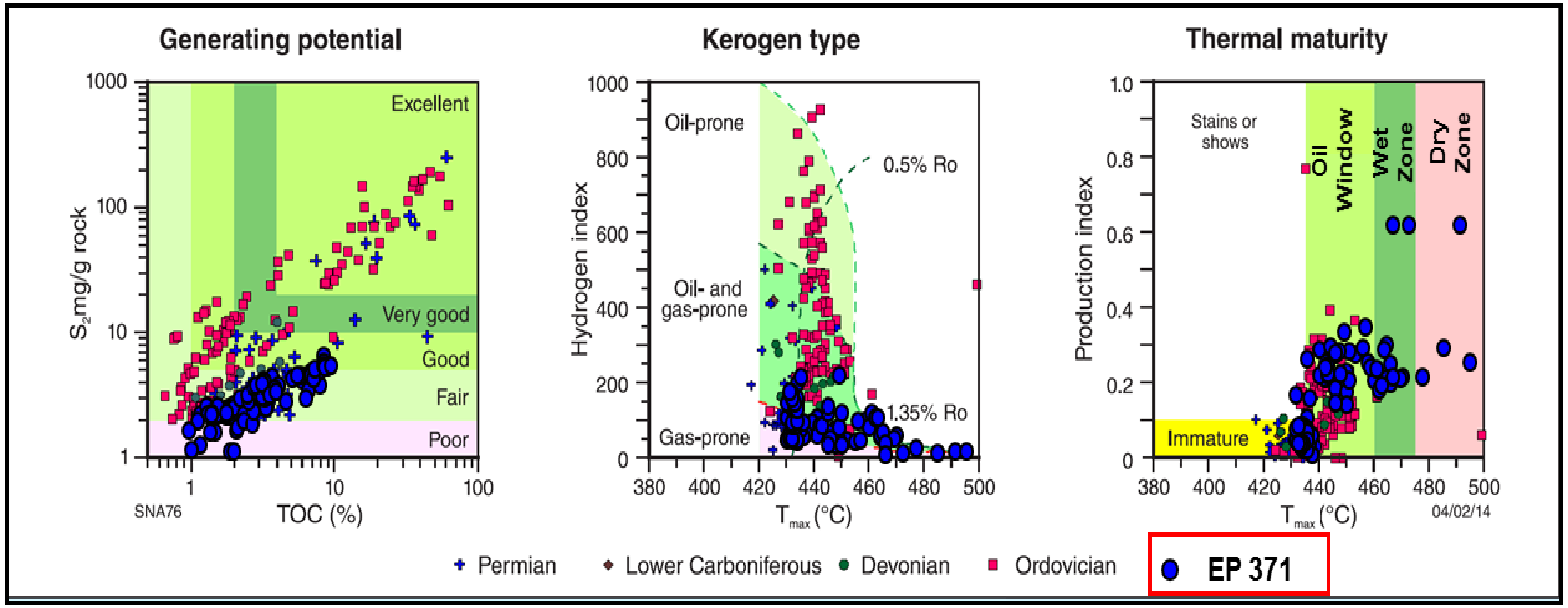


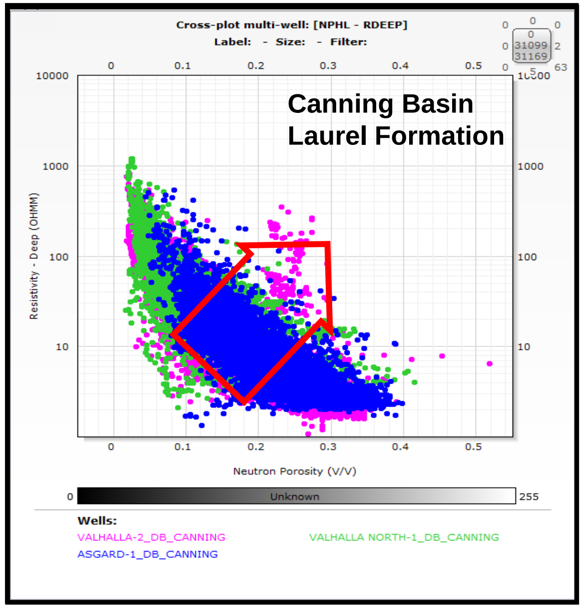




- **Top seal** for the Laurel Formation is the major Unconformity at the top of Anderson Formation
- **Additional seal** - Anderson Shale which is a silty claystone sequence 50-70m. thick with clay content up to 70%
- **Seal Evidence:**
  - Fluorescence with slight increase in gas occurred in an argillaceous sandstone - Anderson Sand, immediately below the Anderson Shale
  - The significant step change of Formation Water salinity and Rw below Unconformity at the top of Anderson Formation
  - Pressure profiles – Depth vs DTC cross-plot shows pressure profile step changes - over pressurized interval below Anderson Shale.

UNCONVENTIONAL SHALE PLAY





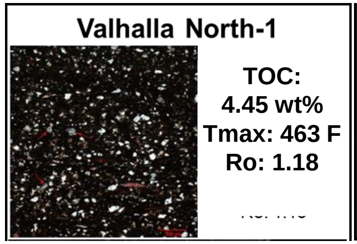
Kerogen type: Mixed (Type II- III) with good/fair generating potential for Wet-Dry gas maturity window below the upper Laurel Carbonates

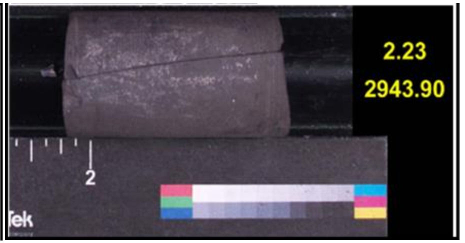
TOC: Organic matter present as dispersed organic particles in carboniferous, siliceous mudstone layers or concentrated in thin, interbedded, silica-rich mudstone beds in both Laurel Clastics and Carbonates

Cuttings and Core – Background presence of TOC 0.5-1.0 (weight %) on entire Laurel Formation, samples with TOC 2 - 4.45% taken from thin, organic-rich, siliceous mudstone beds Log Data - Increase of Excess Resistivity (Delta log R), along with increase in Uranium content (from Spectral GR). Calculated TOC: 0.5-4.5%

Maturity of source rock should be above 1.1% Ro for gas production

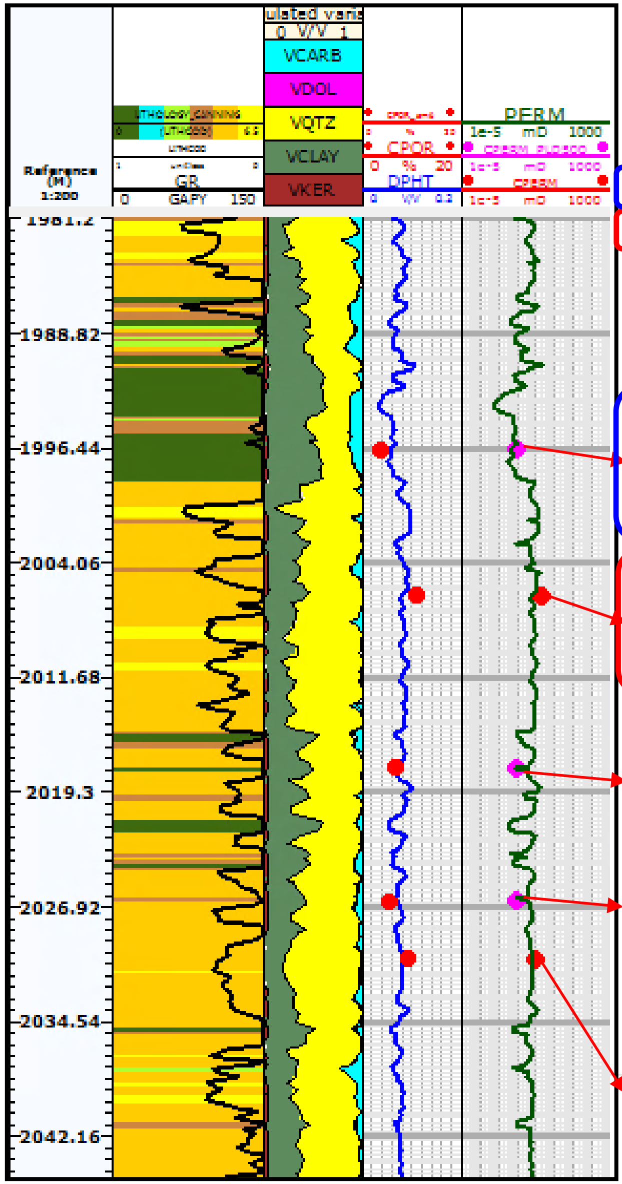
- TMAX > 460 F (Ro equivalent >1.12)
- DST test – 60 API hydrocarbon (Condensate)
- Wetness Balance crossover



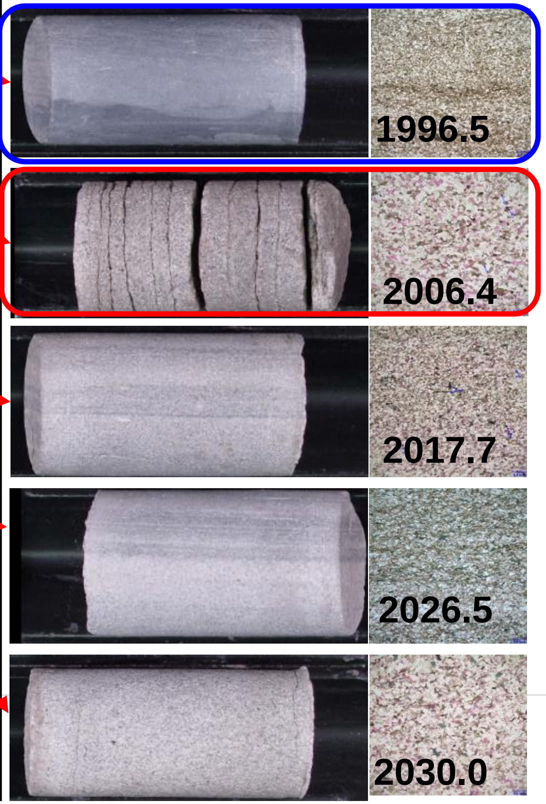


PERMEABILITY/POROSITY/LITHOLOGY RELATIONSHIP

ASGARD-1



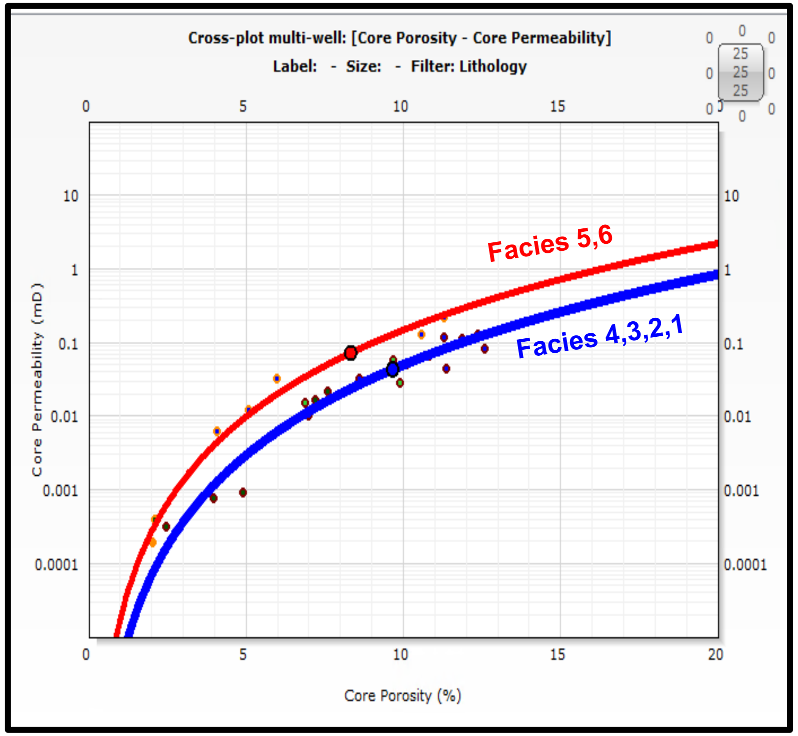
DEPTH	QUARTZ K-Feldspar Plagioclase	CLAY	CALCITE DOLOMITE	PORE tot %	PERM rout. mD
1996.5	59	37	0	2.5	0.0077
2006.4	84	14	0	10.86	0.171
2017.7	71	23	1	5.9	0.0096
2026.5	66	29	1	4.5	0.0097
2030	81	12	1	9.06	0.1



High Permeability trend line Litho-Facies 5 and 6 (Fine-very fine-grained Sandstone/Siltstone, interbedded siltstone)

Lower Permeability trend line Litho-Facies 4,3,2,1

Core Porosity vs Core Permeability Yulleroo-3,Valhalla-1,2 Asgard-1 wells



LITHO-FACIES					
1	2	3	4	5	6

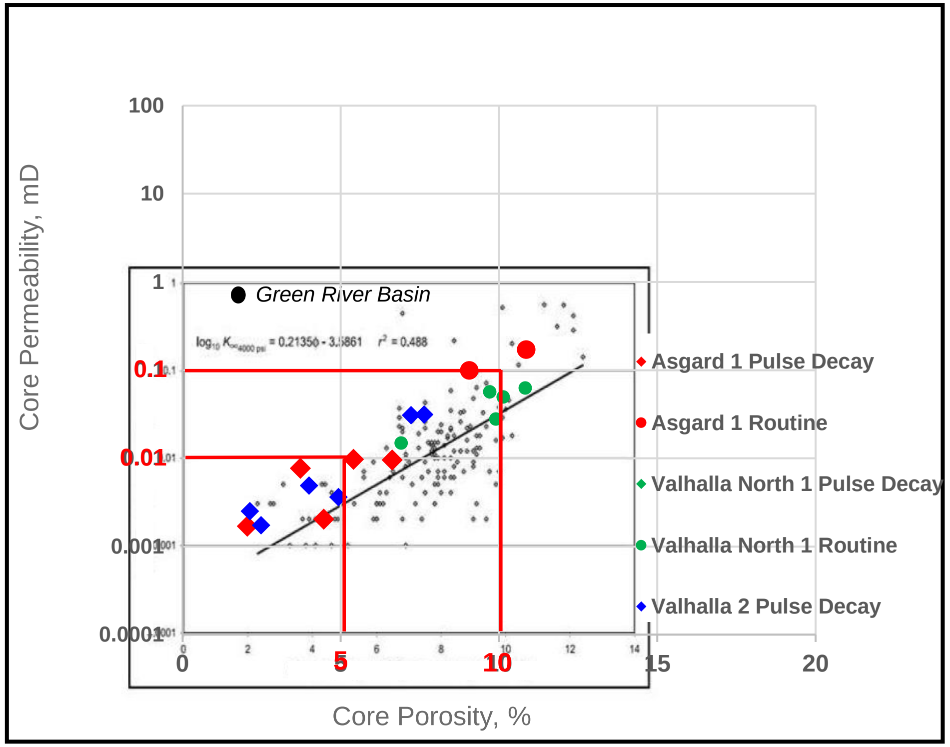
BLACK MOUNTAIN EXPLORATION

CONVENTIONAL BASIN CENTERED TIGHT GAS PLAY

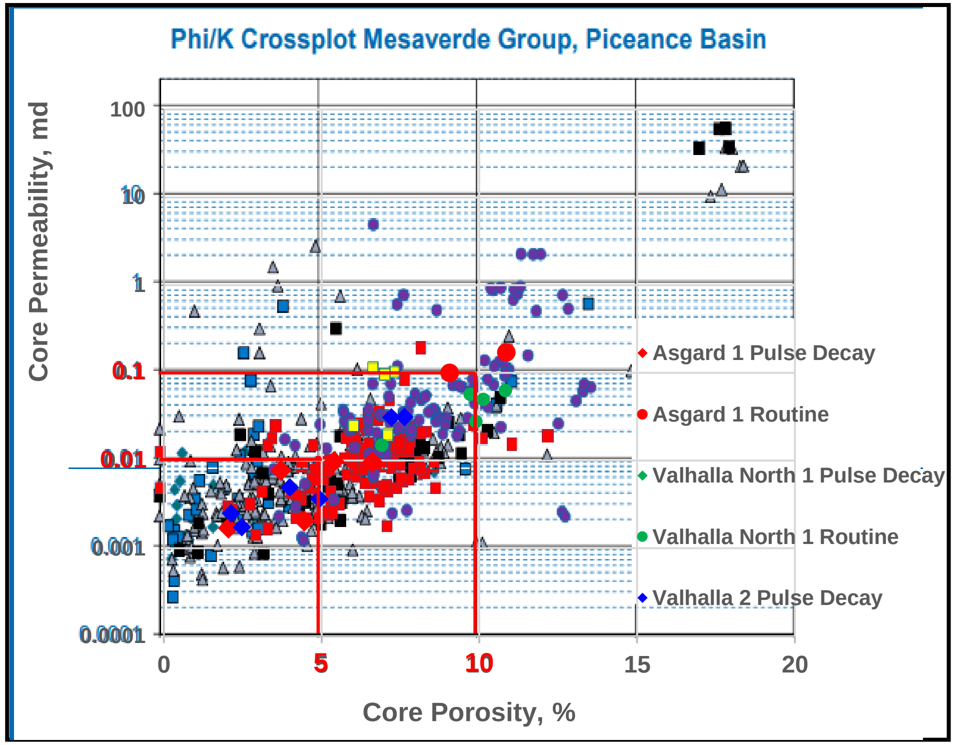
Core Permeability vs Porosity

Green River Basin and Piceance Basin Overlay

EP-371 versus Green River Basin

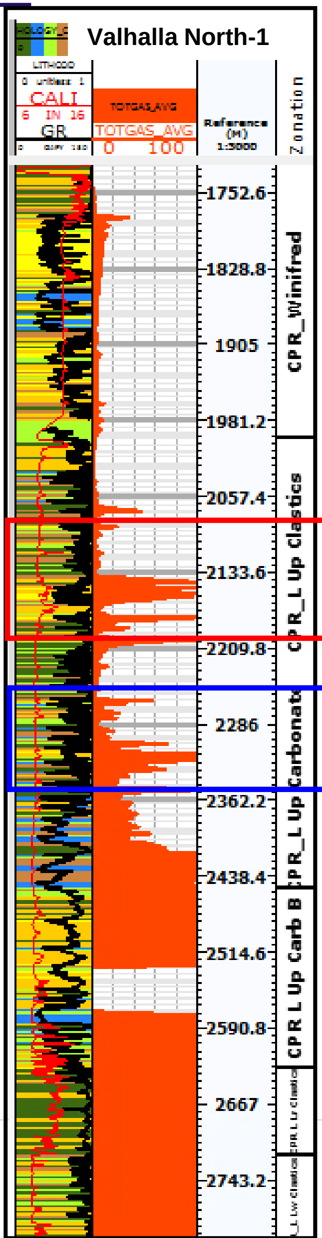


EP-371 versus Piceance Basin

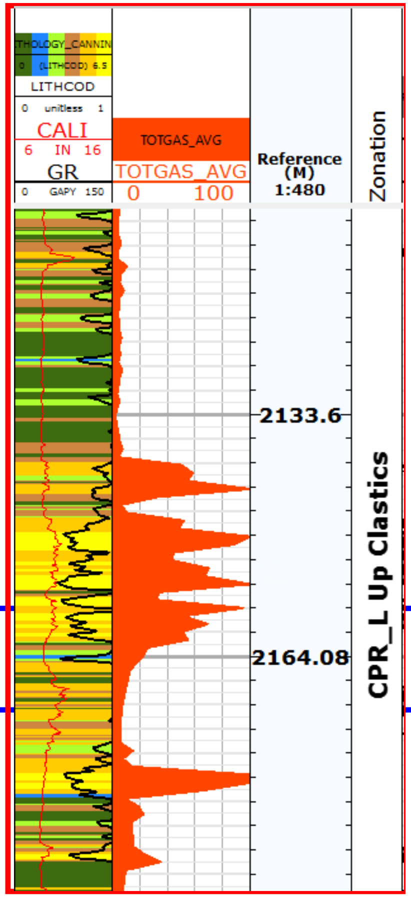


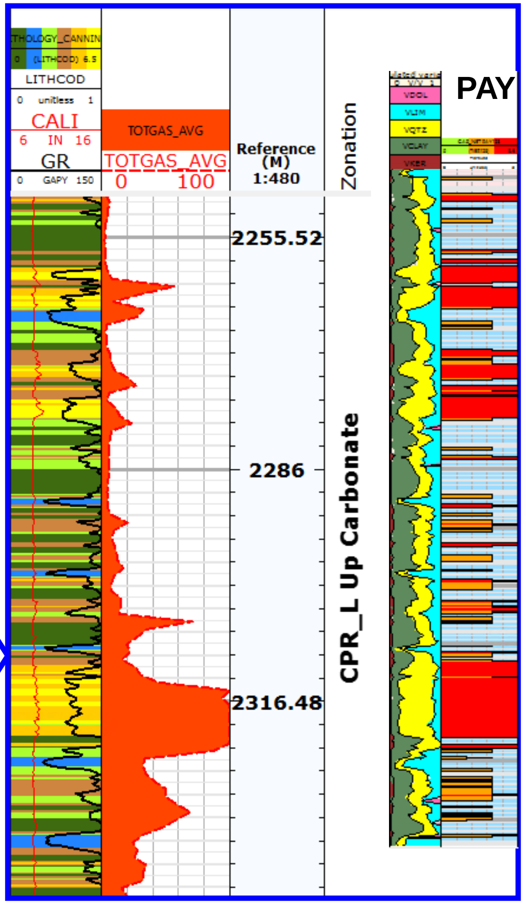
Similar porosity and permeability to U.S. tight gas plays observed

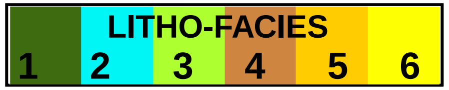
CONVENTIONAL BASIN CENTERED TIGHT GAS PLAY



Higher Permeability Siltstone beds - Conventional Pay.





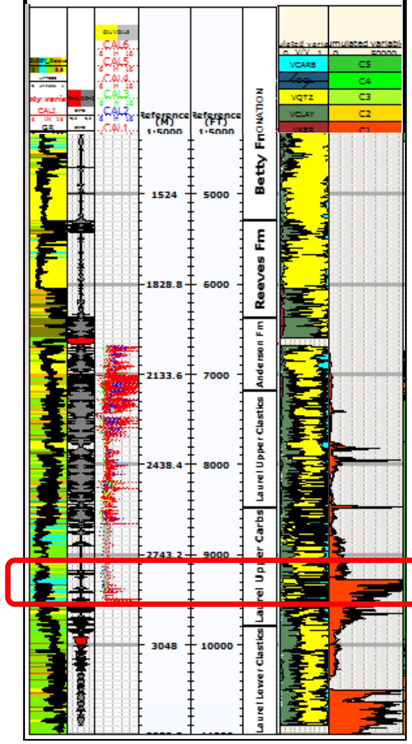


Flare pit at Valhalla North- 1 (2015)

Good correlation of gas influx to Siltstone beds (facies 6 and 5) and calculated Pay Flag

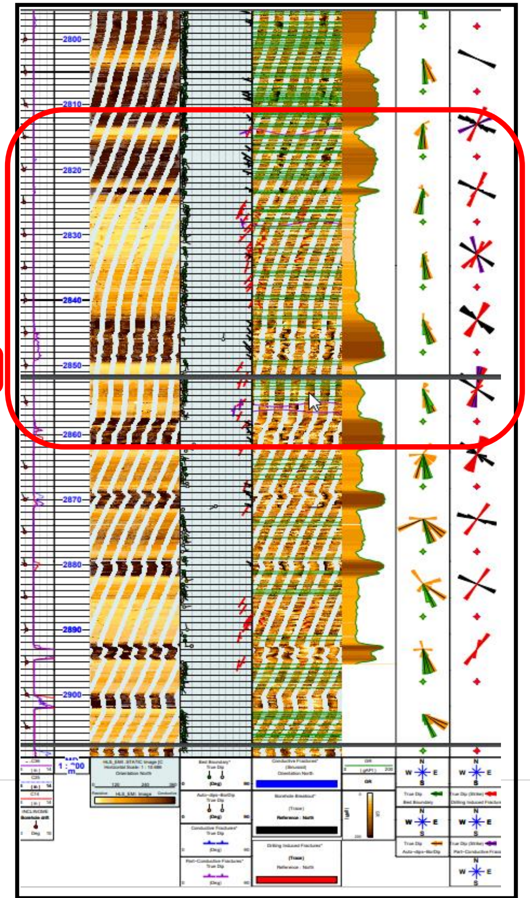
FRACTURED TIGHT GAS RESERVOIR PLAY

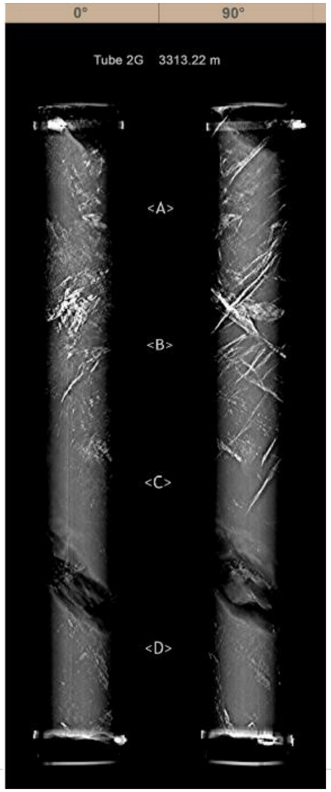
Valhalla North-1



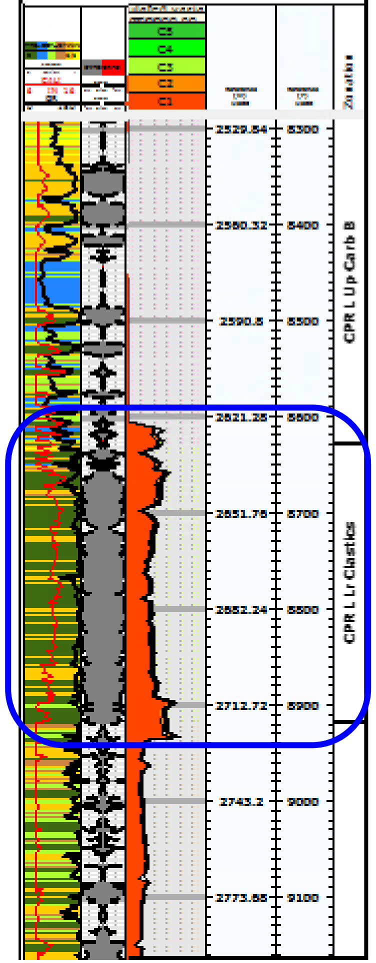
Swarm of fractures Faulted zone 2815m - 2855m

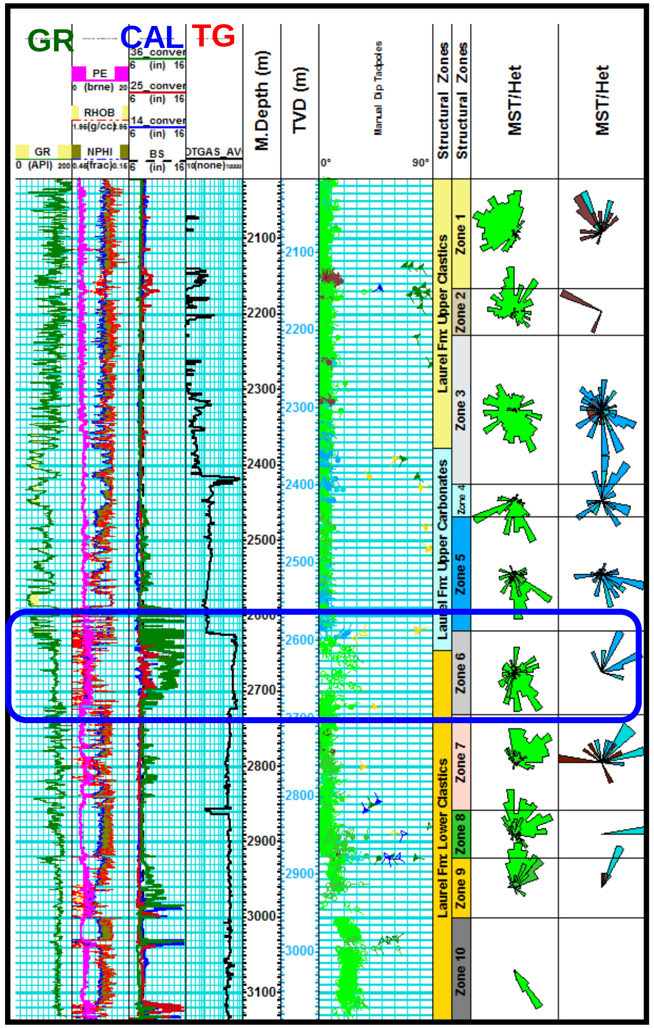
- Structural changes correlate with Mud gas log
- Gas in well increases at major structural breaks
- Most appear associated with faulting
- Some gas increases are associated with hole damage-break-outs coincident with faults





Valhalla - 2

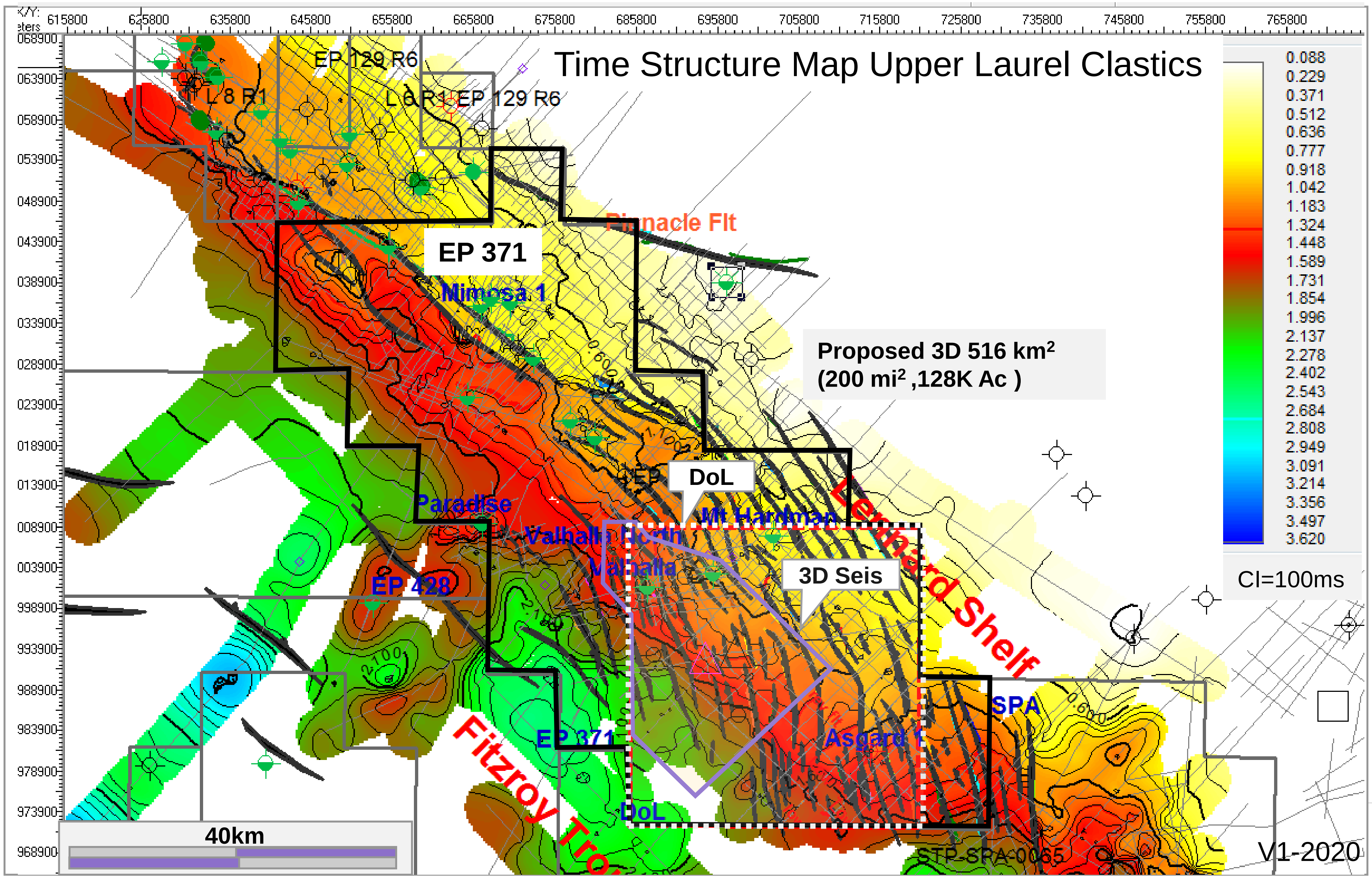




C1 increase from 10,000 to 453,000ppm at faulted interval

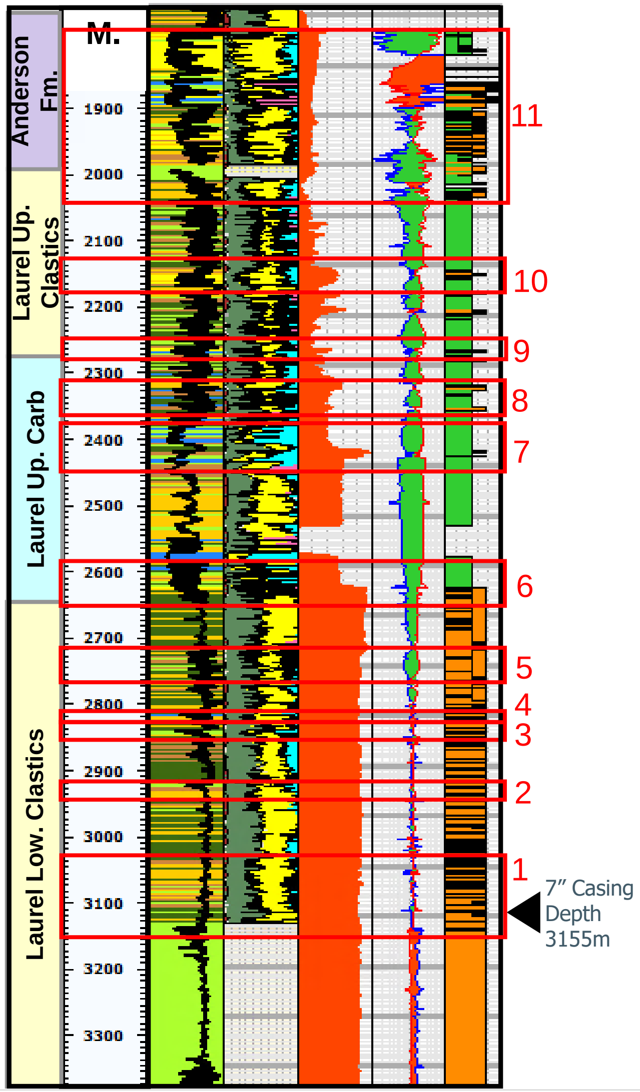
Hybrid Formation

FRACTURED TIGHT GAS RESERVOIR PLAY



- All mapped with 2D seismic data
- Future 3D planned
- 4-6 km spacing between major faults
- Numerous normal downthrown faults parallel to the shelf margin stepping into the trough
- Some Triassic – Jurassic Inversion
- Some faults with noted strike slip offsets

WELL SUMMARY - VALHALLA-2 OPPORTUNITY



Valhalla 2 (not fraced)

Well Summary	
Well Name	Valhalla-2
Spudded	June 6, 2011
Reached TD	July 17, 2011
TD (m)	3390
Fm @ TD	Laurel Lower Clastics
Casing	7" to 3155
Core	53 rotary SWCs
Geology	Deltaic Nearshore marine; at least 3 zones naturally fractured
Drilling & Hole Conditions	Multiple well control events, tight hole, stuck pipe, cavings, couldn't get logging tools down past 3,140 m, took kick while running 7 in production casing, cemented casing high due to hole conditions, had gas and fluid flowing from b-section after cutting casing (well control issue)
Mud Weight	Typically underbalanced while drilling(MW 9.1 -10.3 ppg)
Results	1350m of Gas
Logging Observations	Casing did not reach TD; Set @ 3155
Planned Stimulation	Available for Completion

11 zones identified across 1350 m of section with 795 m of gross reservoir

389 m of net pay with average:

- **Porosity: 7.8%**
  Permeability: 669 Nano Darcy
- **Water Saturation: 0.45**
- **Gas in place: 225 BCF/sec (zones 1-10)**

SUMMARY

- **Petrophysical Hybrid Model:**
  - Integrated petrophysical methods utilized for conventional clastic, carbonate and unconventional tight gas and shale formations and calibrated to core data available
- **Thin beds analysis**
  - Six primary lithofacies identified through: Integration of thin section analyses, geological core descriptions, log response and petrophysical model results (volume of minerals)
  - Litho-Facies calibrated to high resolution formation image data and utilized for defining core pore/perm transforms.
- **Mud log analysis:**
  - Integrated mud log analysis – highlights significant gas influxes at the intervals with high permeable beds(Facies 5-6), at swarms of fractures and faults, also on litho-packages with presence of organic rich beds
  - Presence of Gas condensate below Anderson Shale were confirmed by analysis of Mud Log, Geochemistry and formation test data
- **Formation Image data observation:**
  - Generally shallow bedding
  - The recognized faults dominant NW-SE parallel to regional faults. Some NE-SW parallel to inferred fold hinge
  - Fractures predominantly conductive parallel to inferred Sh-max may indicate that these are open fractures. Also, presence of resistive fractures with variable strike.
  - Maximum horizontal stress has predominant orientation NE-SW
- **Defining the Pressure Seal:**
  - Top seal for the Laurel formation is the major Unconformity at the top of Anderson Formation
  - Additional seal - Anderson Shale which is a silty claystone sequence 50-70m. thick with clay content up to 70%
  - Indication of overpressure below seal
- **Laurel Hybrid formation, Multiple Play Types Identified:**
  - Unconventional Siltstone-Shale Play
  - Conventional Basin Centered Tight Gas Sand Play
  - Fractured Tight Gas Reservoir Play
- **Valhalla-2 Opportunity**
  - 11 zones identified across 1350 m of section with 795 m of gross reservoir and 389 m of net pay
- **Path forward**
  - The tight gas, unconventional opportunity is set for development.
  - To provide increased energy independence for Australia.

ACKNOWLEGMENTS

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Q&A