Organic Rich Facies in the Lewis Shale as an Oil and Gas Source Rock, Greater Green River Basin, Wyoming, United States*

Ligia Carolina Mayorga-Gonzalez[1], Roger M. Slatt[2], and David Pyles[3]

Search and Discovery Article #51280 (2016)**
Posted August 8, 2016

*Adapted from oral presentation given at AAPG 2016 Annual Convention and Exhibition, Calgary, Alberta, Canada, June 19-22, 2016

[1]Geology, The University of Oklahoma, Norman, Oklahoma, United States (ligia.c.mayorga.gonzalez-1@ou.edu)
[2]Geology, The University of Oklahoma, Norman, Oklahoma, United States (rslatt@ou.edu)
[3]Geology, EOG, Denver, Colorado, United States (david.r.pyles@gmail.com)

Abstract

The Lower Maastrichtian Lewis Shale is a series of sediment gravity flow (turbidite plus hyperpycnite) deposits of sandstones interbedded with shales in the Greater Green River basin in Colorado and Wyoming. It has been informally divided into three members with varying amounts of shale, siltstone, and very fine to medium grained sandstone. Large volumes of gas and some oil have been produced from the formation. The Asquith Marker, in the lower Lewis Shale, is an organic-rich shale easily recognizable on GR log. This third order condensed section has a maximum thickness of 100 ft. All the previous analyses indicate that the Lewis Shale is generating gas; however, it has never been studied as a potential oil prone source or reservoir rock. Geochemical analysis from Champlin 276 Amoco D well indicates Asquith Marker has a “high potential” to generate hydrocarbons and type II kerogen which can generate oil and gas. Also there is an oil field in the basin producing from the Lewis Shale that supports the idea of oil potential. Structural and stratigraphic maps were used to identify the areas where the Asquith Marker is thickest and is in the oil window. Samples of the Asquith interval taken from 5 well cuttings, 6 well cores, and 8 outcrop samples were analyzed for Rock-Eval, vitrinite reflectance, XRD, and biomarker geochemistry from which the composition, maturity, oil potential, and kerogen type is determined. The results from the analysis are integrated to determine the potential to generate oil from the Asquith Marker.

References Cited

Blakey, R.C., 2014, Paleogeography: Colorado Plateau Geosystems, Phoenix, AZ.

Hart, B.S., and A.S. Steen, 2015, Programmed Pyrolysis (Rock-Eval) Data and Shale Paleoenvironmental Analyses: A Review: Interpretation, v. 3/1, p. SH41-SH58.

Jarvie, D.M., 1991, Total Organic Carbon (TOC) Analysis: Chapter 11: Geochemical Methods and Exploration, *in* R.K. Merrill (ed.), Source and Migration Processes and Evaluation Techniques: AAPG Special Volumes, p. 113-118.

Pasternack, I., 2005, The Weimer Marker Bentonite - A Regionally Persistent Correlation Horizon Within the Upper Cretaceous Lewis Shale, Eastern Greater Green River Basin, Wyoming and Colorado: The Mountain Geologist, v. 42/2, p. 67–84.

Peters, K.E., 1986, Guidelines for Evaluating Petroleum Source Rock Using Programmed Pyrolysis: AAPG Bulletin, v. 70/3, p.318-329.

Philp, R.P., and C.A. Lewis, 1987, Organic Geochemistry of Biomarkers: Annual Review of Earth and Planetary Sciences, v. 15, p. 363-395.

Pyles, D.R., 2000, A High-Frequency Sequence Stratigraphic Framework for the Lewis Shale and Fox Hills Sandstone, Great Divide and Washakie Basins, Wyoming: Master's Thesis, Colorado School of Mines, Golden, Colorado, 261 p.

Pyles, D.R. and R.M. Slatt, 2007, Stratigraphy of the Lewis Shale, Wyoming, USA: Application to Understanding Shelf Edge to Base-of-Slope Changes in Stratigraphic Architecture of Prograding Basin Margins, *in* T.H. Nilsen, R.D. Shew, G.S. Steffens, and J.R.J. Studlick, (eds.), Atlas of Deep-Water Outcrops: American Association of Petroleum Geologists Studies in Geology, v. 56, p. 1-19.

Pyles, D.R., and R.M. Slatt, 2000, A High-Frequency Sequence Stratigraphic Framework for Shallow Through Deep-Water Deposits of the Lewis Shale and Fox Hills Sandstone, Great Divide and Washakie Basins, Wyoming, *in* P. Weimer, R.M. Slatt, J. Coleman, N.C. Rosen, H.C. Bouma, M.J. Styzen, and D.T. Lawrence (eds.), Deep-Water Reservoirs of the World (CD-ROM): Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Foundation, 20th Annual Bob F. Perkins Research Conference, Houston, TX, p. 836–861.

The UNIVERSITY of OKLAHOMA
Mewbourne College of Earth and Energy
ConocoPhillips School of Geology and Geophysics
ConocoPhillips

Organic Rich Facies in the Lewis Shale as an Oil and Gas Source Rock, Greater Green River Basin, Wyoming, United States

Ligia Carolina Mayorga-González[1], Roger M. Slatt[2], David Pyles[3].

June, 2016

*lcmayorgag@hotmail.com, ligia.c.mayorga.gonzalez-1@ou.edu, rslatt@ou.edu, david.r.pyles@gmail.com

OUTLINE

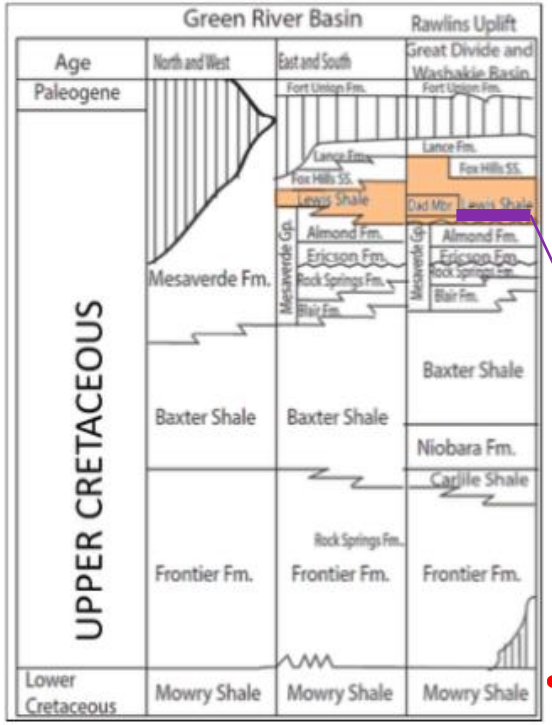
- Objective
- Lewis Shale and Asquith Marker Outline
- Study area
- Geology
- Results
  - Data
  - Thickness and structure in the basin
  - Structural and Isochore maps
  - Geochemical Analysis
    - TOC
    - Rock-Eval
    - Biomarkers
- Potential areas

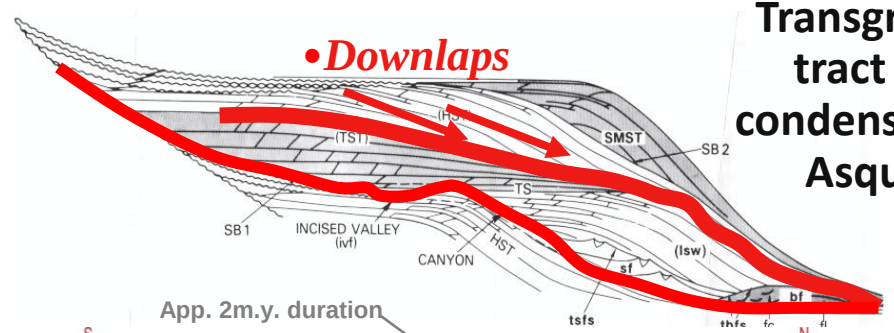
Objectives

- To define the potential to generate oil from the Organic rich interval named Asquith Marker.
- To identify potential areas to develop the Asquith Marker as an unconventional play.

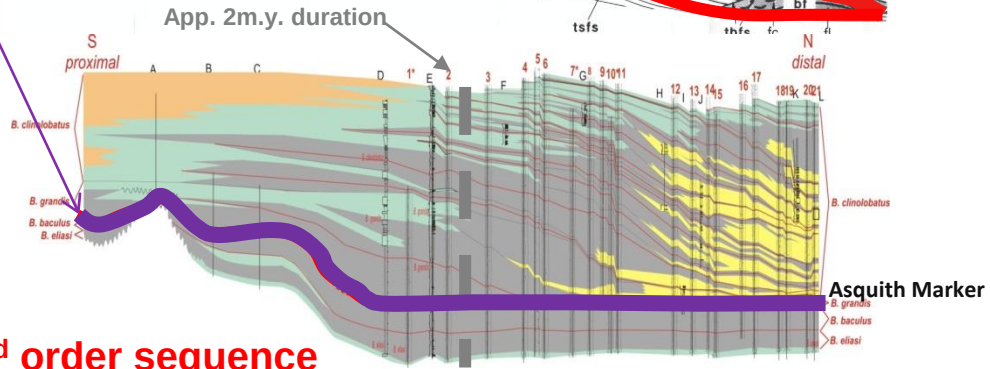
Lewis Shale and Asquith Marker outline

- **Lewis Shale Sequence Stratigraphy**





Transgressive System tract capped by a condensed section; the Asquith Marker.

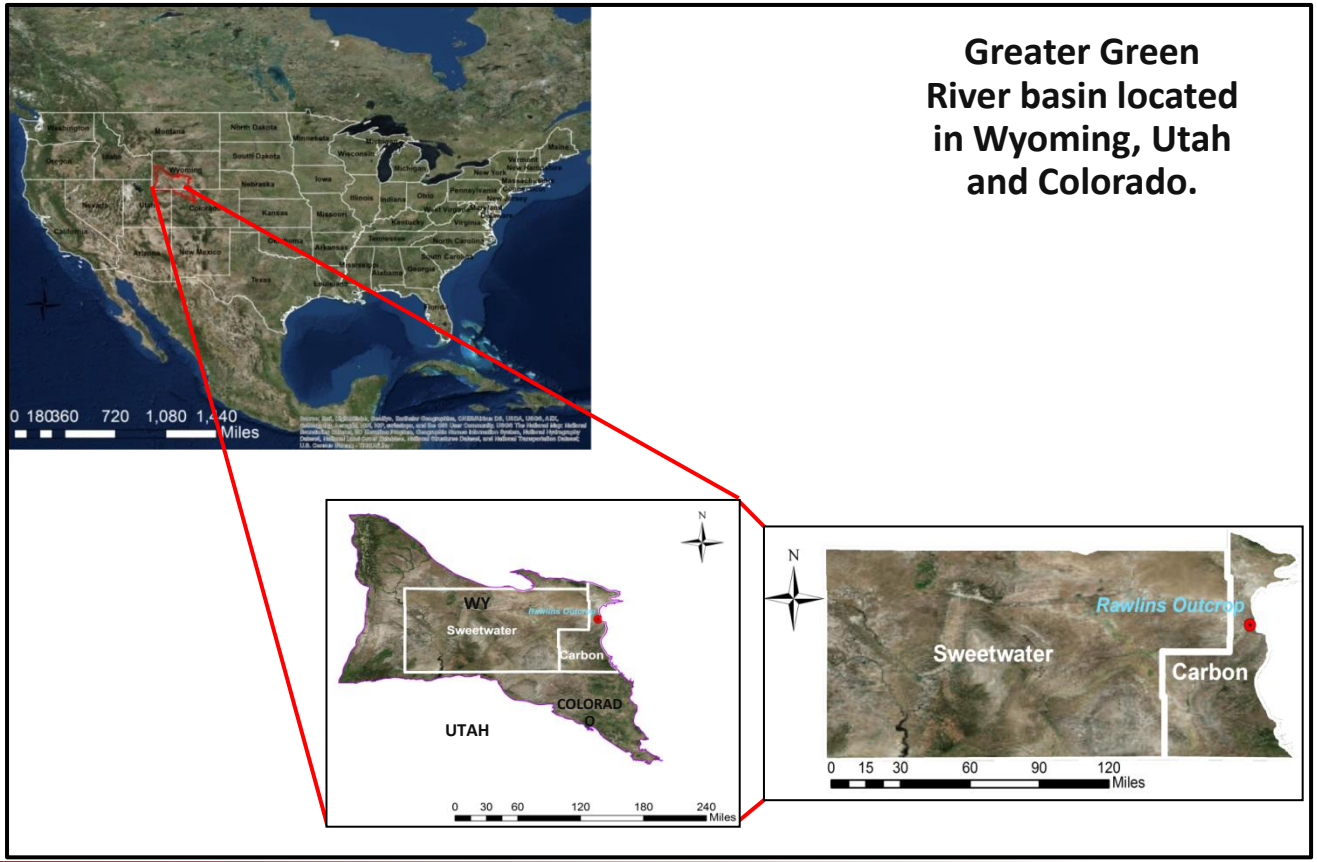


•3rd order sequence

Pyles and Slatt, 2007

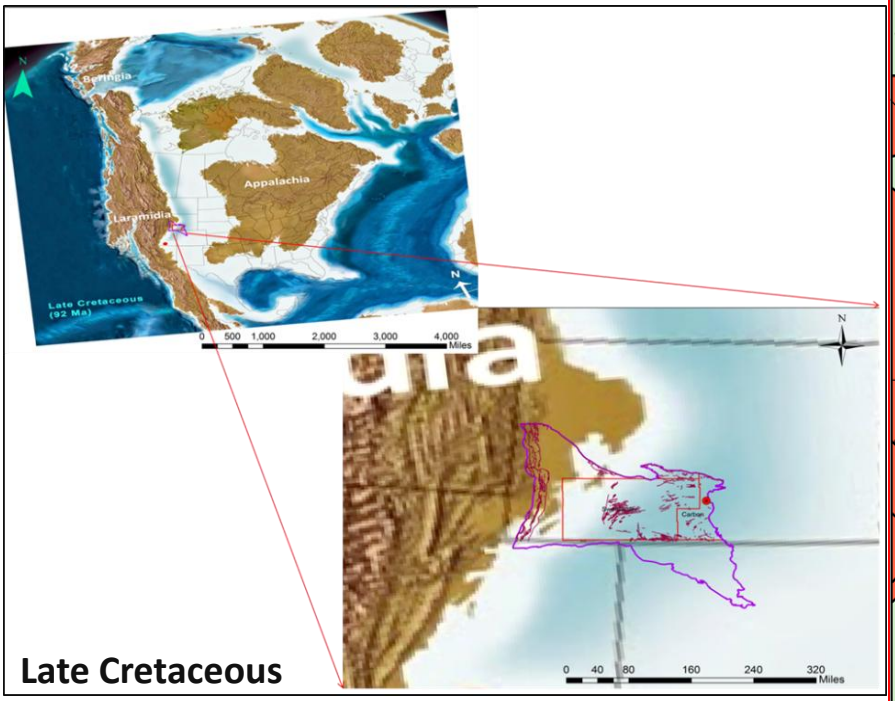
Study Area

- **Location**

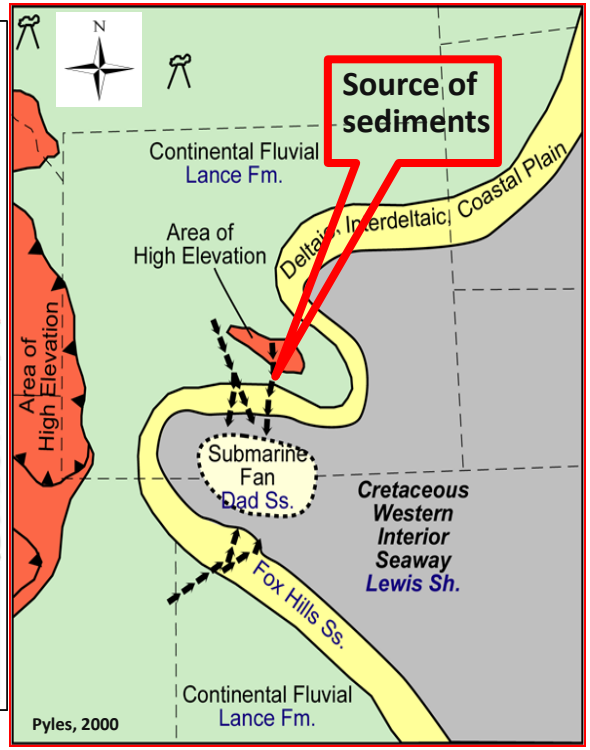


Geology

Cretaceous Seaway during Late Cretaceous



Paleomap from Colorado Plateau Geosystems



The Lewis was deposited in an embayment in the seaway

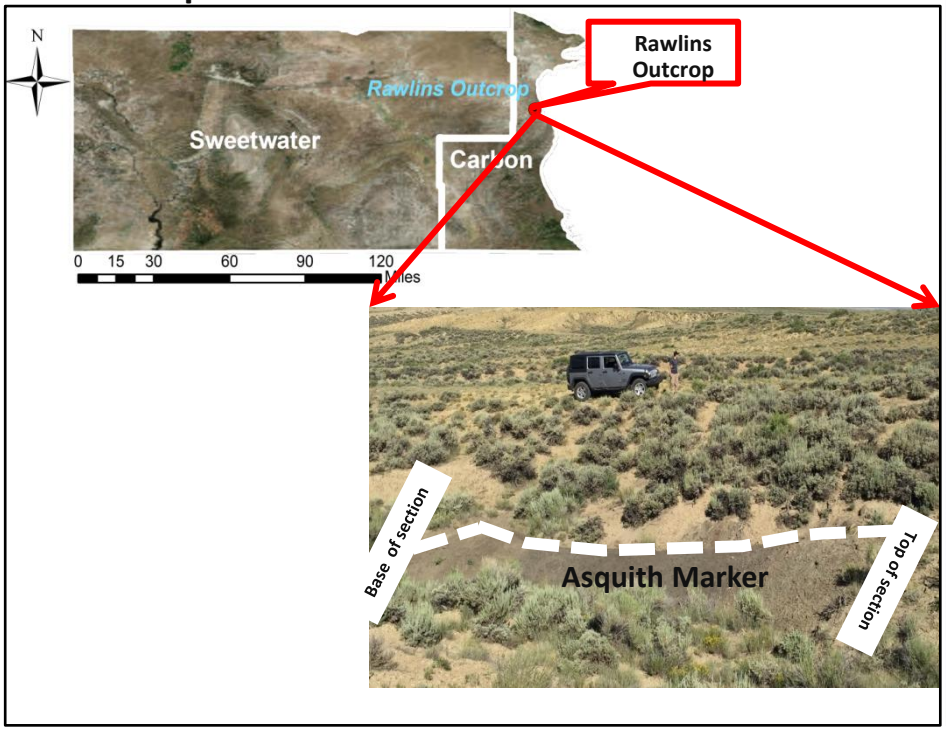
The embayment was formed by rock uplift in the area of the present day Wind River Uplift, Granite Mountains, and Lost Soldier anticline

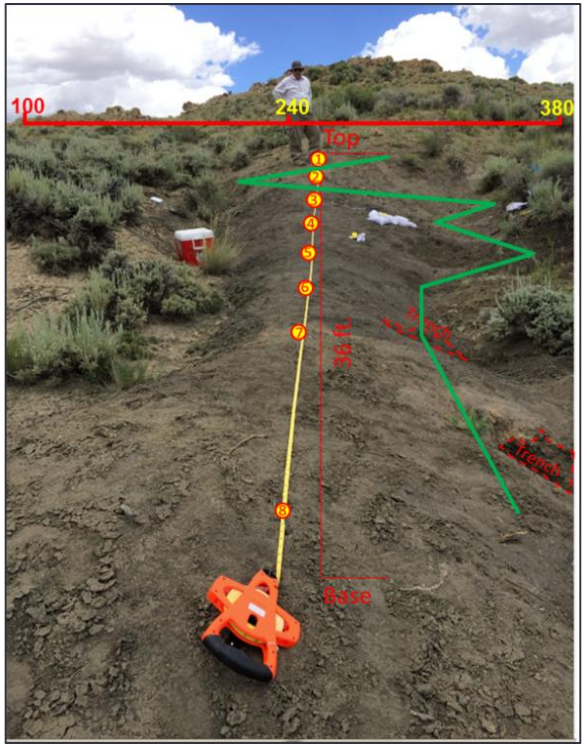
At least two major rivers systems drained into the embayment

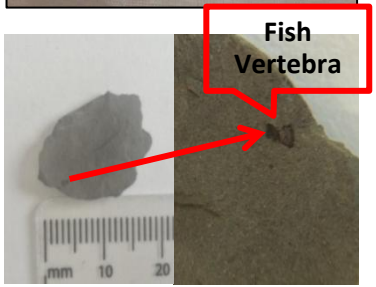
Submarine-fan sediments locally accumulated in the center of the embayment

Data

- **Outcrop**



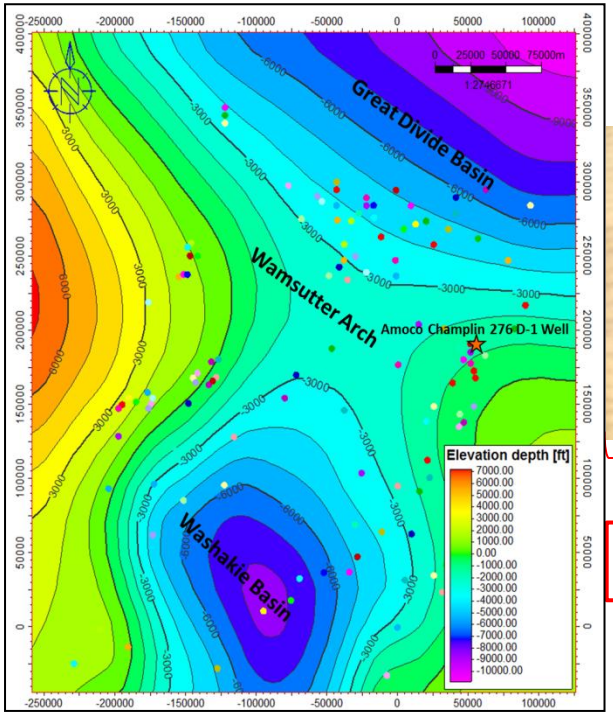




Outcrop sample from the Asquith Marker

Data

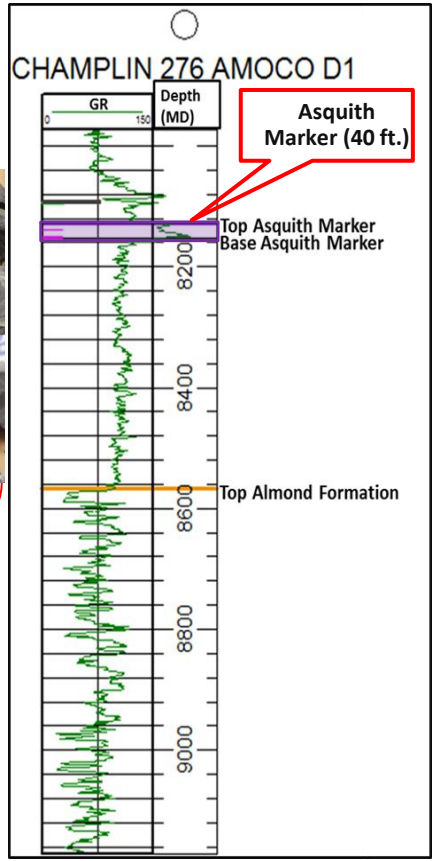
- **Well Data**



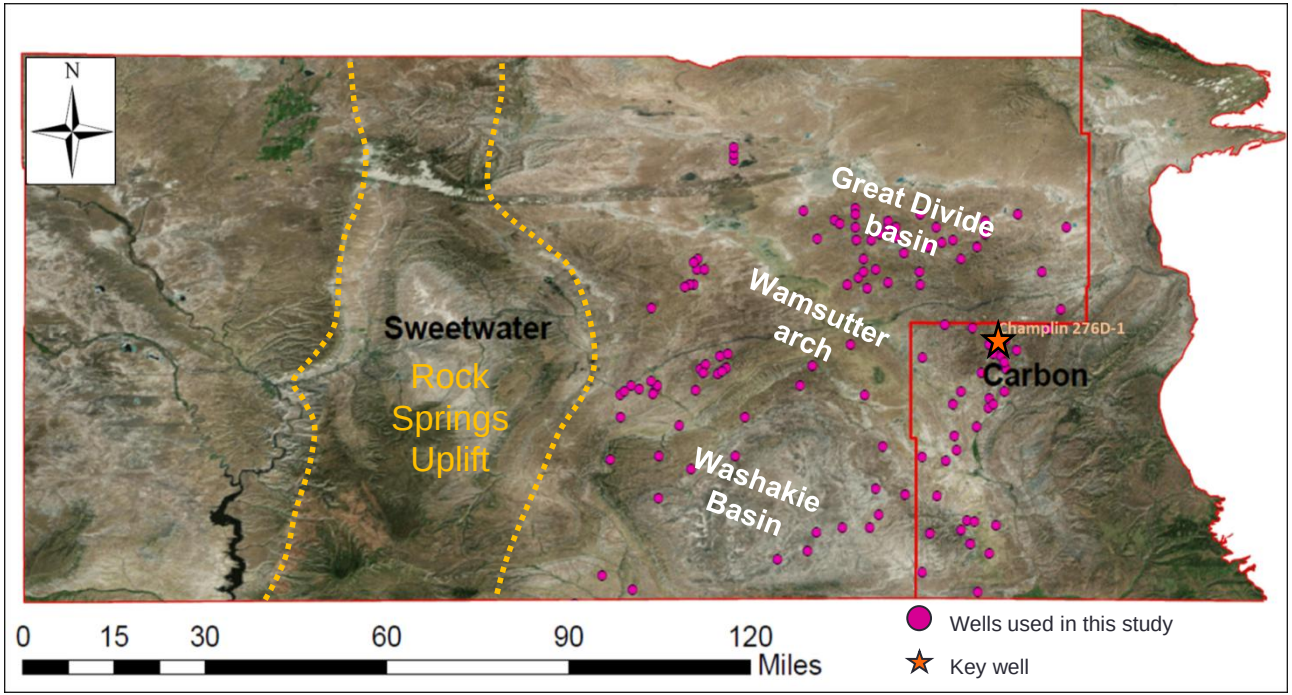
Dark grey shale. Very fissile.
With fossil parts.

Asquith Marker

Amoco Champlin 276
Amoco D-1 Well core



Structural cross section of the Asquith Marker



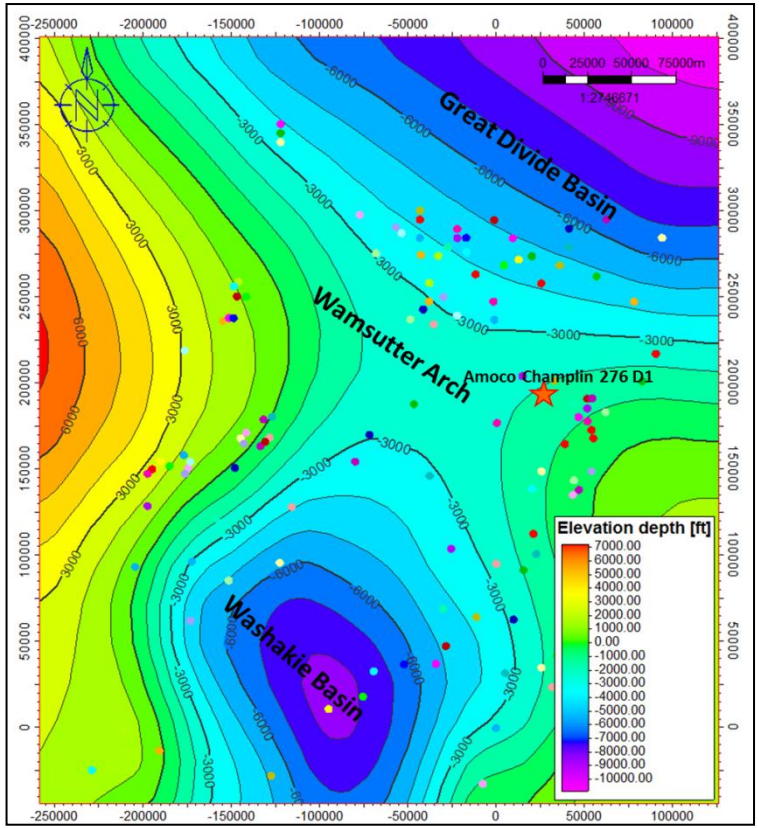
- 133 wells
- GR, Density, Resistivity, Neutron raster logs
- In some cases SP

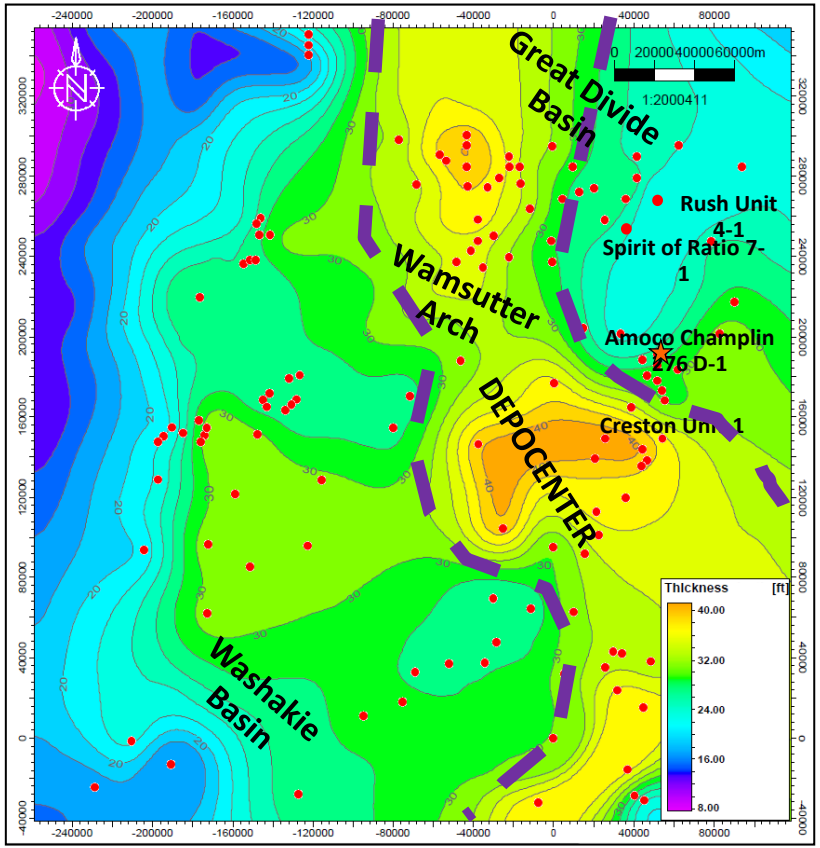
GR signature was the first constrain used to identify the Asquith marker

Structural and Isochore maps

Wells

Champlin 276 D-1 well





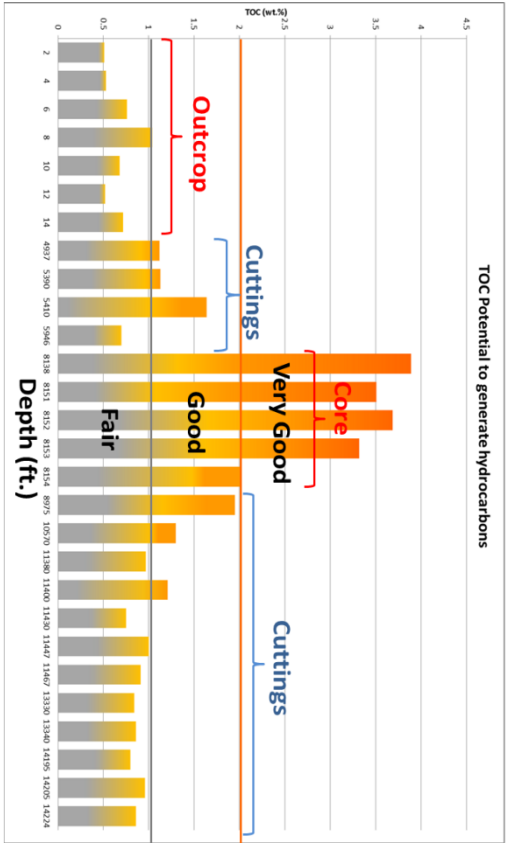
Geochemical Analysis

TOC Screening

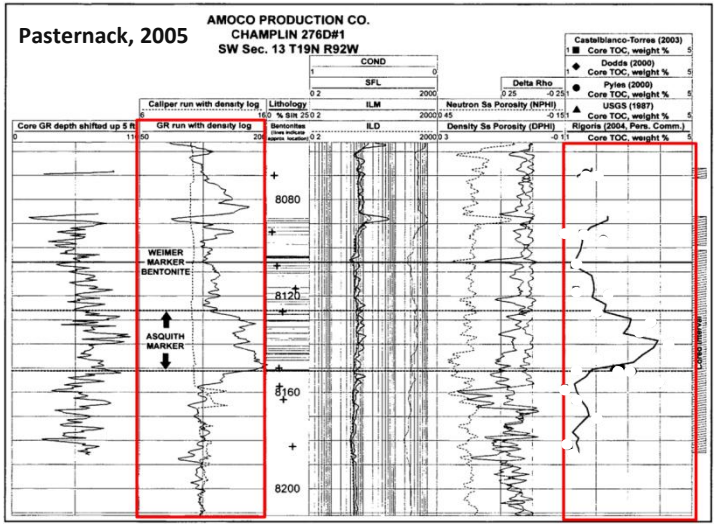
- 6 Wells
- 5 core samples
- 8 cutting samples
- 7 outcrop samples
- TOTAL: 20 samples

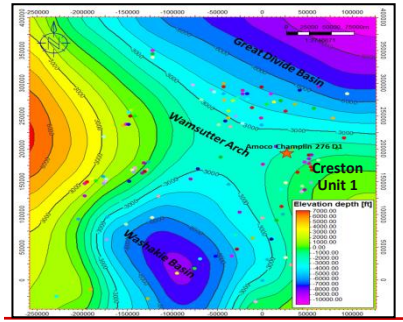
Generation Potential	TOC in Shales (wt.%)
Poor	0.0-0.5
Fair	0.5-1.0
Good	1.0-2.0
Very Good	2.0-5.0
Excellent	>5.0

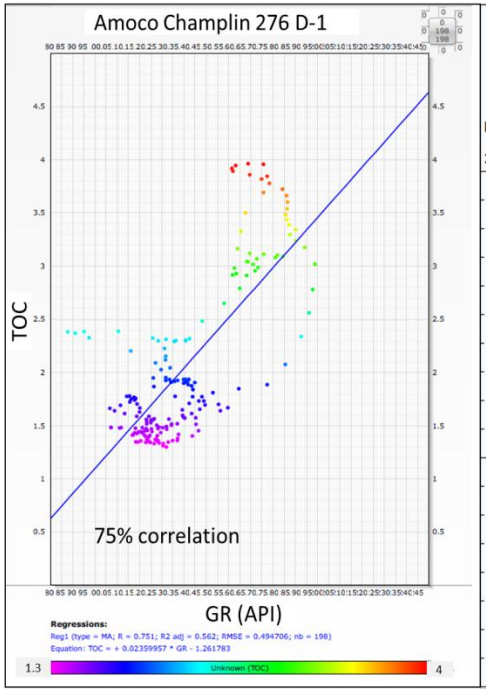
Jarvie, 1991

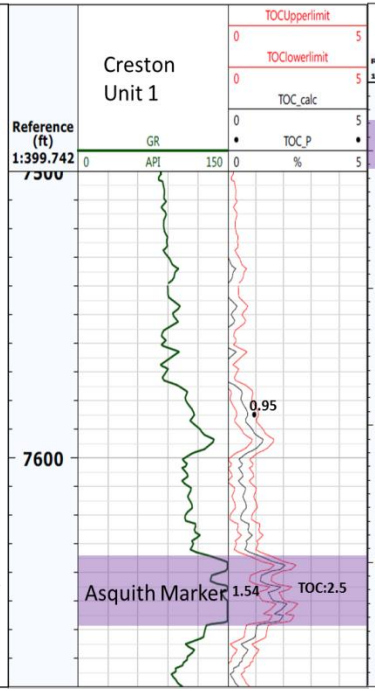


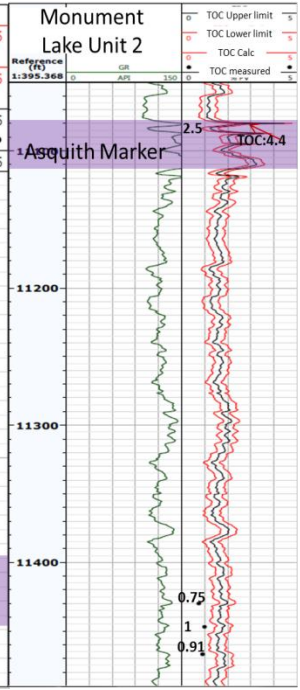
TOC from logs





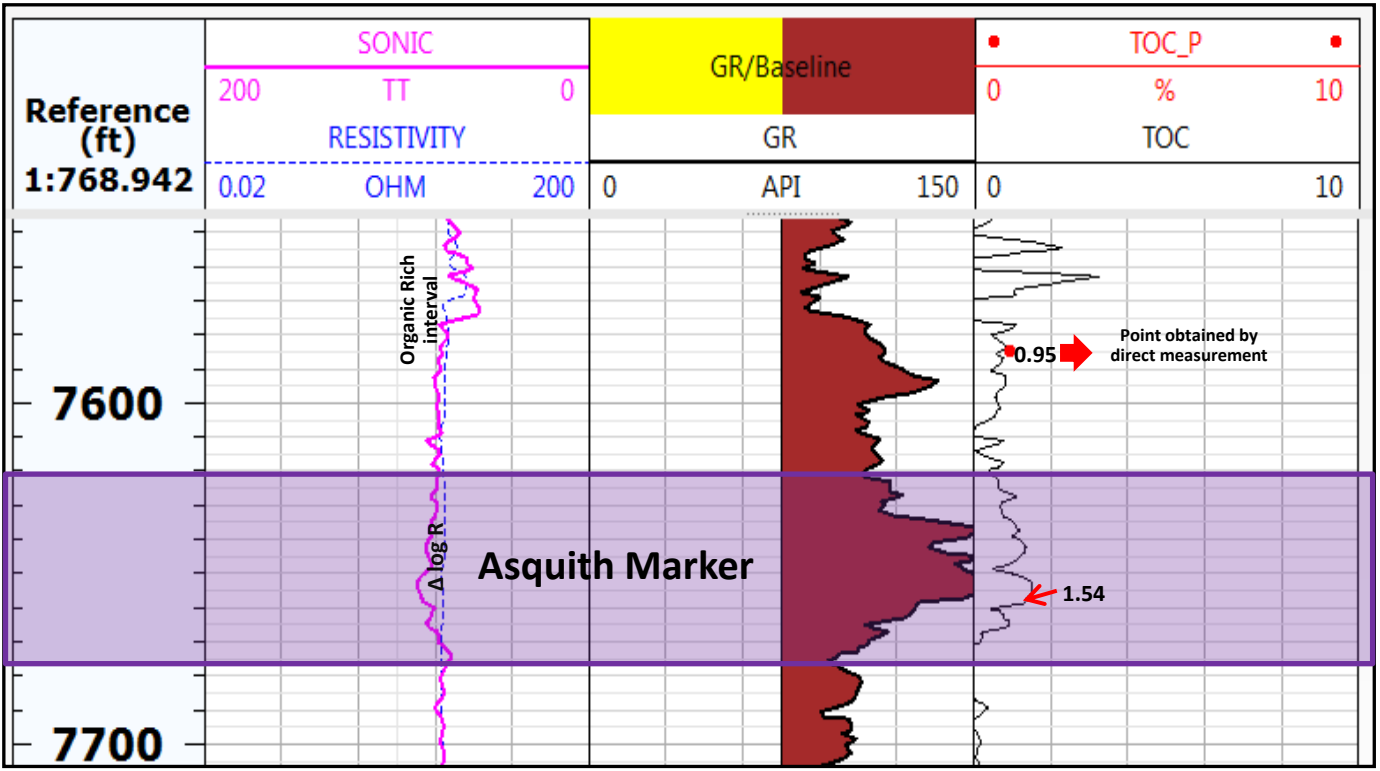


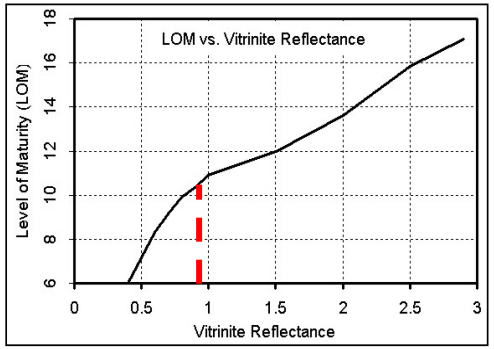




TOC Passey

Creston Unit 1 well

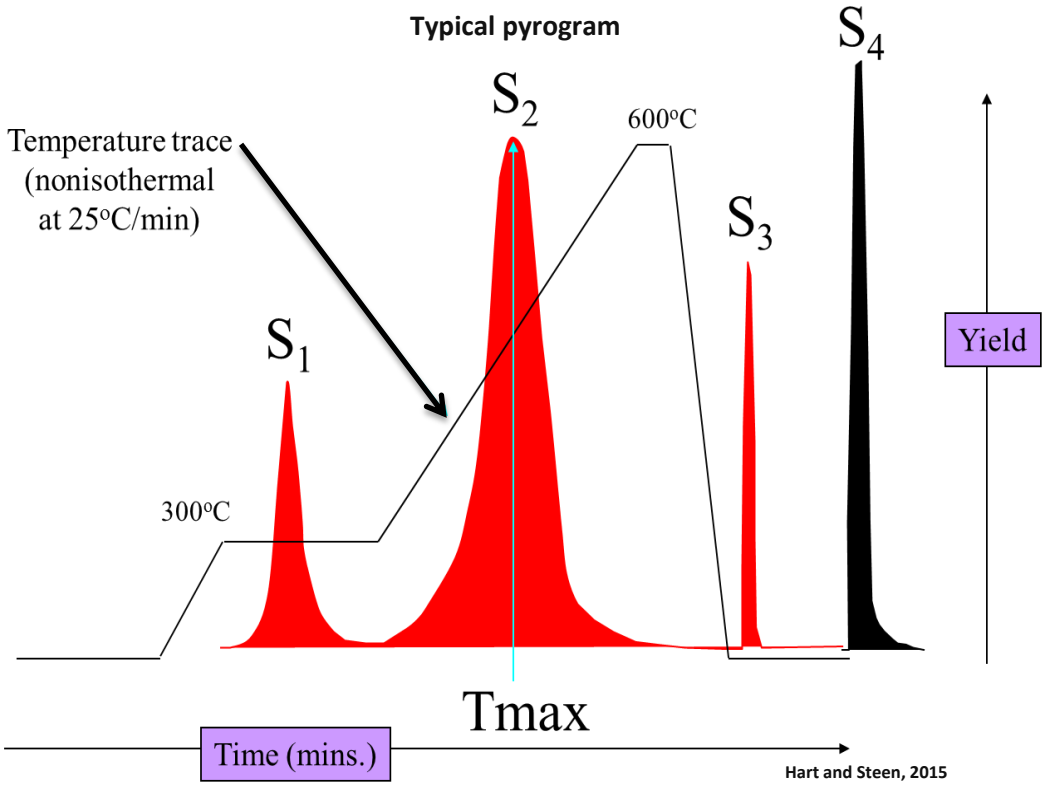




- One Vitrinite reflectance value from the Creston Unit 1 well between 0.7-0.9 %Ro
- Values range from Good-Very Good potential to generate hydrocarbons.

$$TOC=(\Delta \log R) * 10^{(2.297-0.1688*LOM)}$$

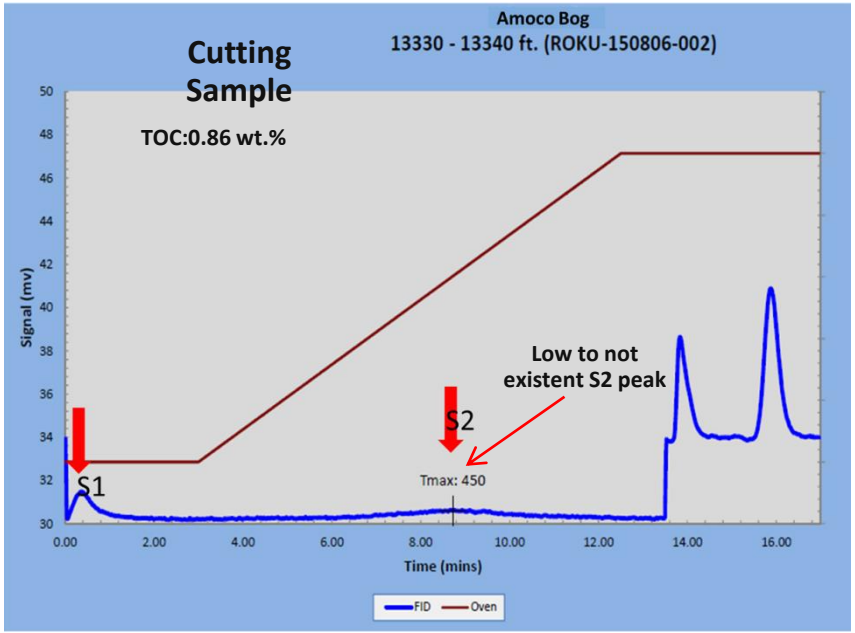
Rock-Eval – Programmed pyrolysis

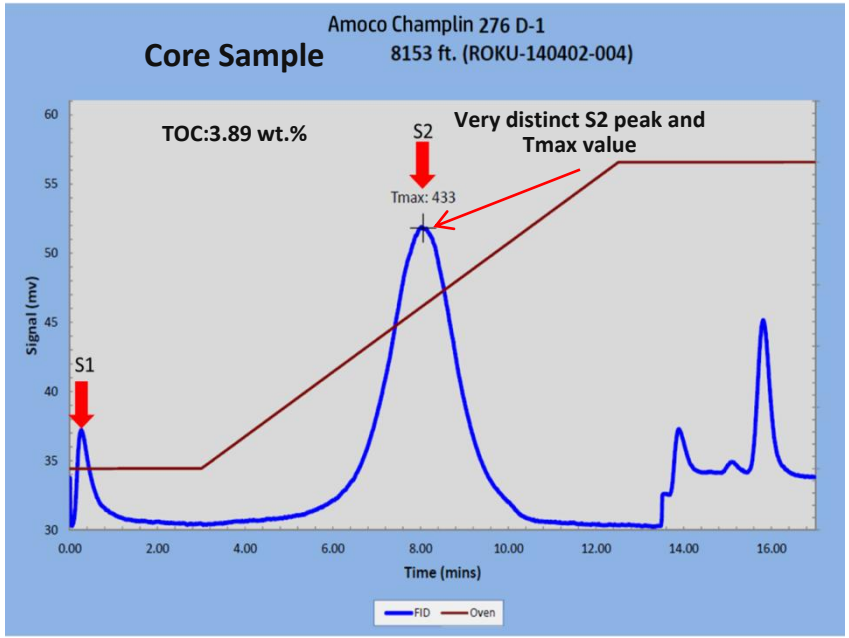


- Total organic carbon (TOC) (wt. % carbon)
- S1 (mg HC/g), S2 (mg HC/g), S3 (mgCO_2/g) peaks, S4 residual carbon from oxidation of dead carbon remaining after pyrolysis.
- Tmax (C)
- Hydrogen Index (S_2*100/TOC)
- Oxygen Index (S_3*100/TOC)

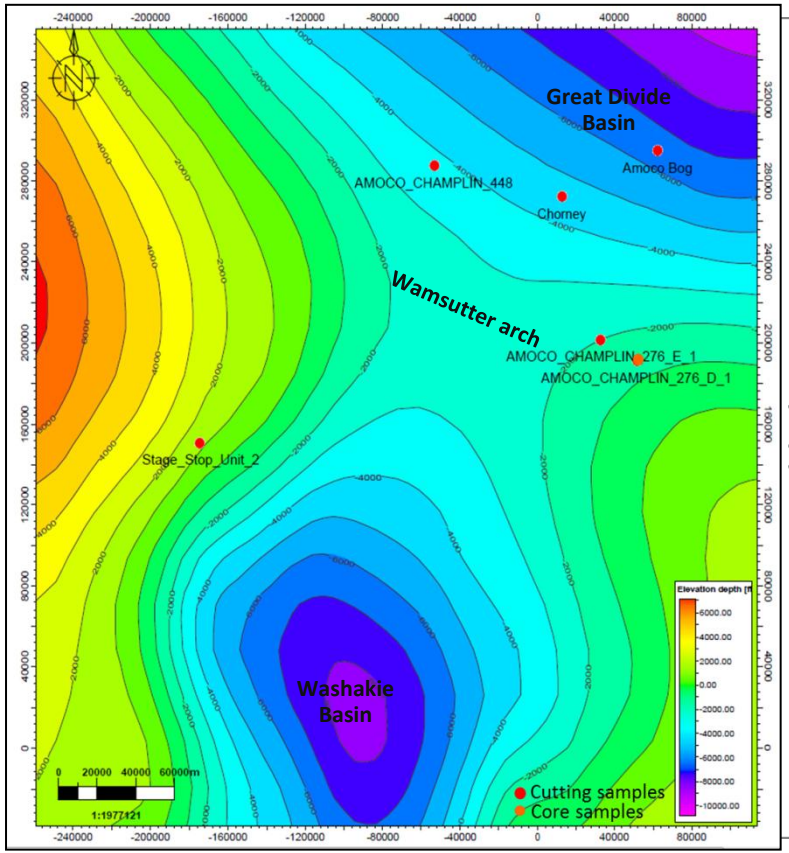
- Hydrogen Index (S_2*100/TOC) is closely related to oil generation. Its higher in marine organisms and algae.
- Oxygen Index (S_3*100/TOC) is usually higher in remains of land plants and inert organic material (residual organic matter).

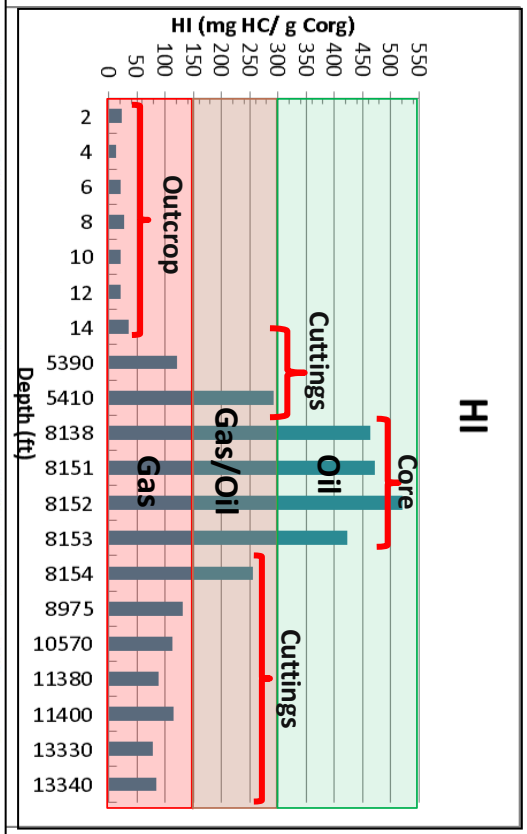
Rock-Eval – Programed Pyrolysis-Pyrograms





Rock-Eval – Hydrocarbon potential from the Asquith Marker



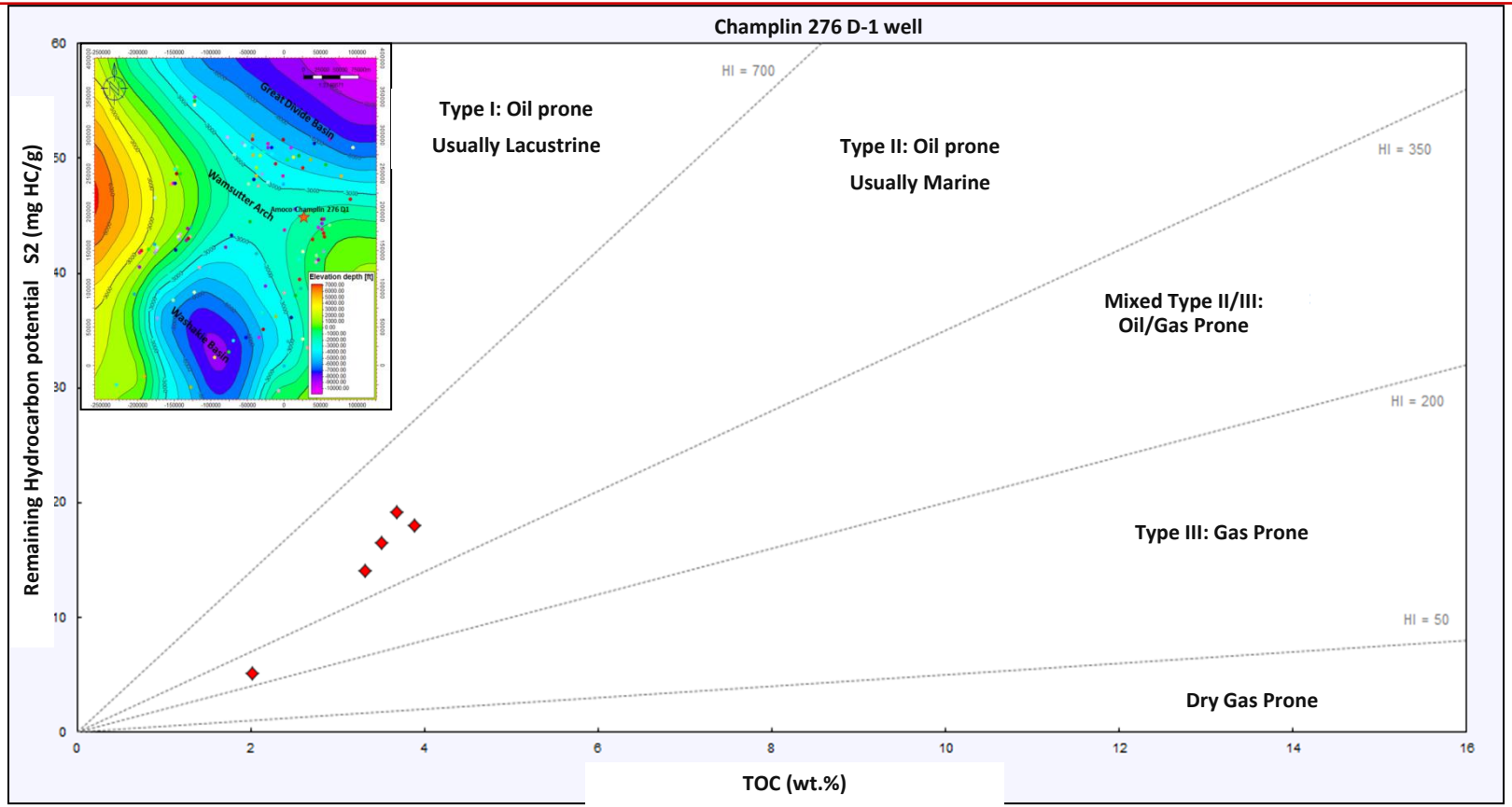


- 6 Wells
- 5 core samples
- 8 cutting samples
- 7 outcrop samples
- TOTAL: 20 samples

Type	HI (mg HC/g Rock)	S2/S3
Gas	0-150	0-3
Gas and Oil	150-300	3-5
Oil	300+	5+

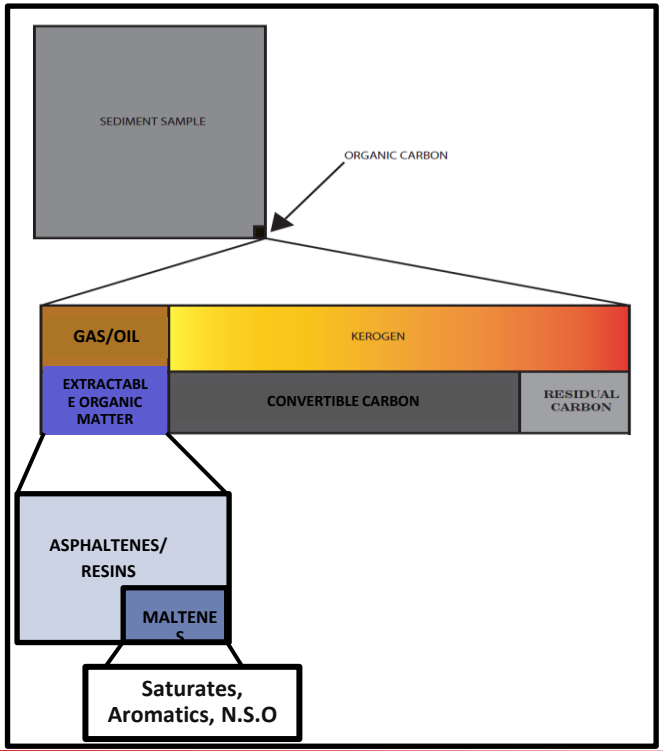
Peters, 1986

Rock-Eval – Kerogen Type present in the Asquith Marker



Biomarkers as continental and maturity proxies

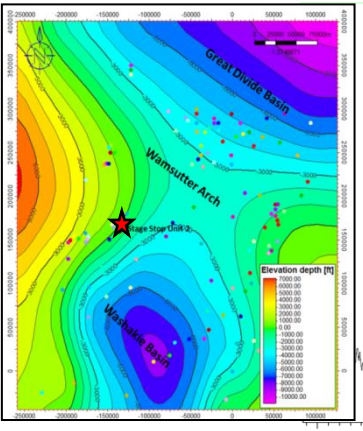
Biomarkers are usually known as molecular fossils that retain chemical similarities with their precursor, such as plant, animal, bacteria, spore, fungi or any other possible organic source (Philp and Lewis, 1987).

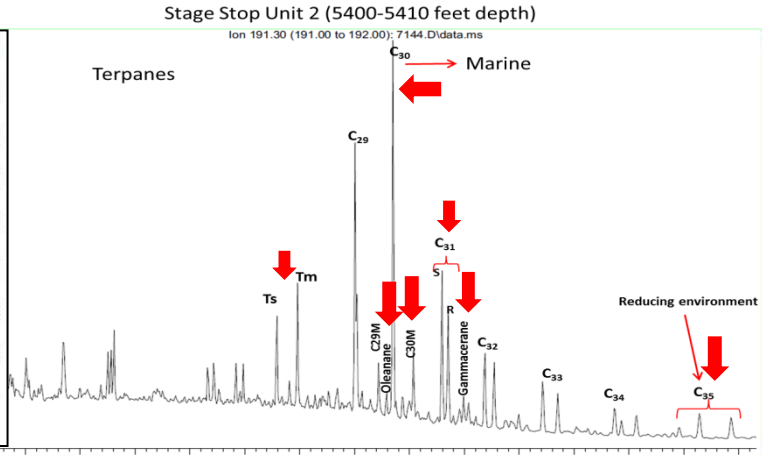


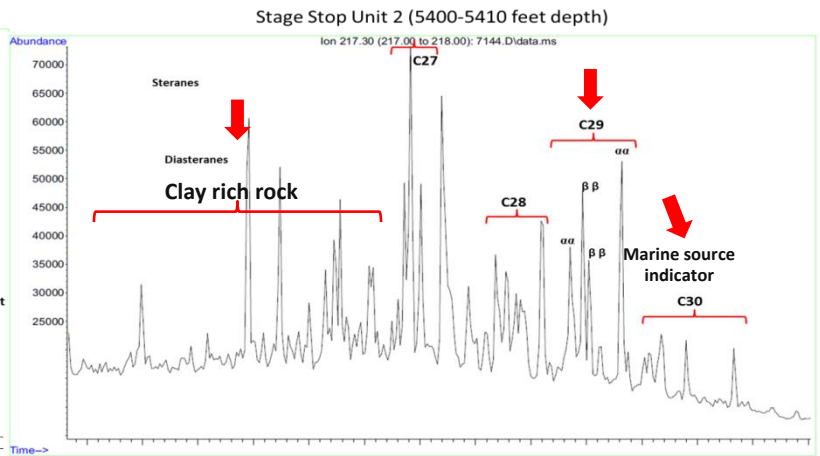
Well Name	
Champlin 276 D1 core sample (8138 ft.)	GC, GCMS
Champlin 276 E1 cutting sample (8770-9000 ft.)	GCMS
Stage Stop 2 cutting sample (5400-5410 ft.)	GCMS

- **Gas Chromatography (GC) only separates compounds**
- **Gas Chromatography Mass Spectrometry (GCMS) identifies compounds**

Biomarkers – Stage Stop Unit 2 Well







Well Name	Ratio	Meaning
Stage Stop 2 cutting sample (5400-5410 ft.)	Ts/(Ts+Tm):0.55	Main Oil window
	C_{31} 22s/22s+22r:0.542	Immature
	C_{29} ββ/ββ+αα:0.563	Main Oil window
	C_{29} (S/S+R):0.49	Main Oil window

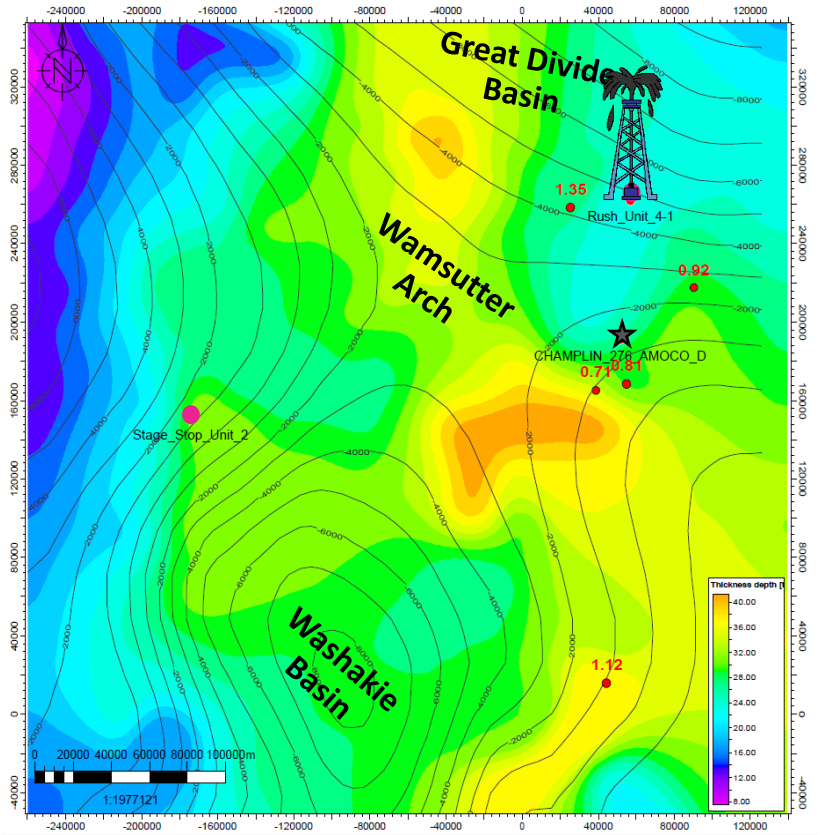
Compound	Meaning
C30 Hopane	Marine Environment
Oleanane	Higher plant input/ Age narrowing to at least Late Cretaceous
C35 Hopanes	Reducing environment
Gammacerane	Hypersaline Stratified waters
Moretanes	Low maturity

Terpanes

Compound	Meaning
C30 Steranes	Marine source indicator
Diasteranes	Clay rich rock

Steranes

Potential Areas



- TWO WELLS DRILLED THE ASQUITH MARKER AND PRODUCED OIL
- Rush Unit 4-1H Asquith Marker depth: 12038-12051; 26775 Bbls since Dec,2012- Jan,2016
- Spirit of Radio: 14350 Bbls since 2011

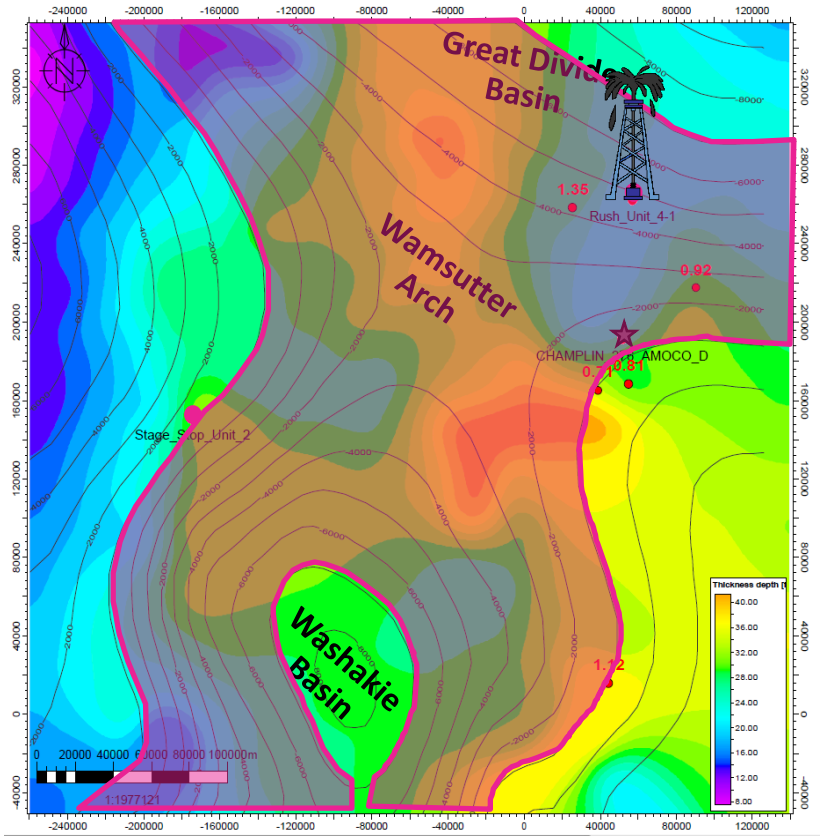
Depth:1400-(-6700) ft. TVDSS

Biomarkers

Thickness: 30-50 ft.

Total area: $2.53*10^7$ acres

Potential Areas



- TWO WELLS DRILLED THE ASQUITH MARKER AND PRODUCED OIL
- Rush Unit 4-1H Asquith Marker depth: 12038-12051; 26775 Bbls since Dec,2012- Jan,2016
- Spirit of Radio: 14350 Bbls since 2011

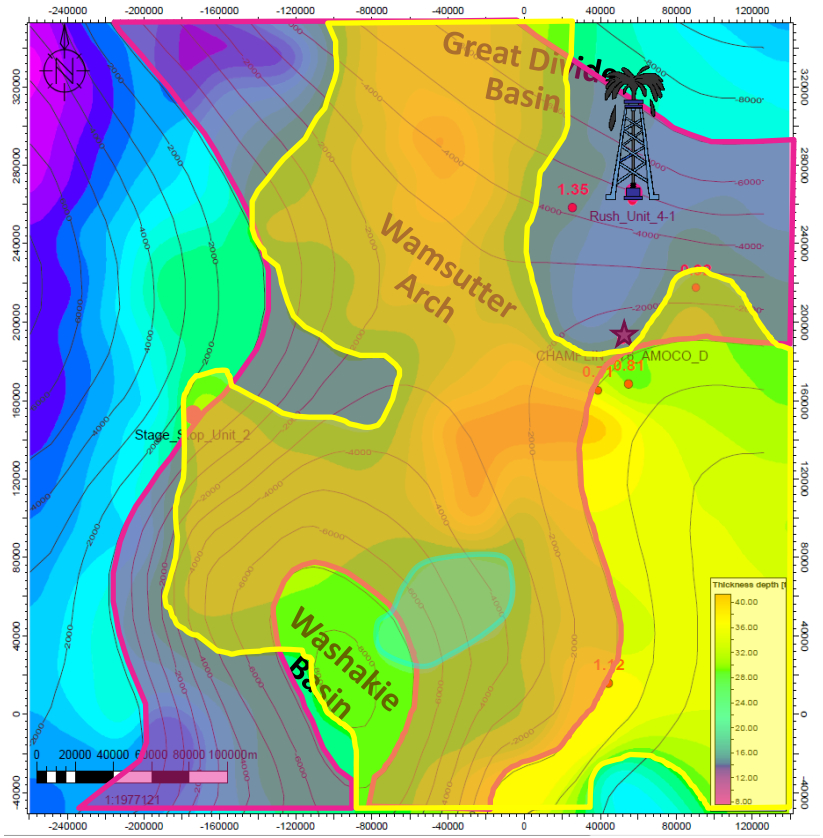
Depth:1400-(-6700) ft. TVDSS

Biomarkers

Thickness: 30-50 ft.

Total area: $2.53*10^7$ acres

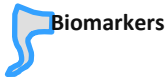
Potential Areas



- TWO WELLS DRILLED THE ASQUITH MARKER AND PRODUCED OIL
- Rush Unit 4-1H Asquith Marker depth: 12038-12051; 26775 Bbls since Dec,2012- Jan,2016
- Spirit of Radio: 14350 Bbls since 2011

Depth:1400-(-6700) ft. TVDSS

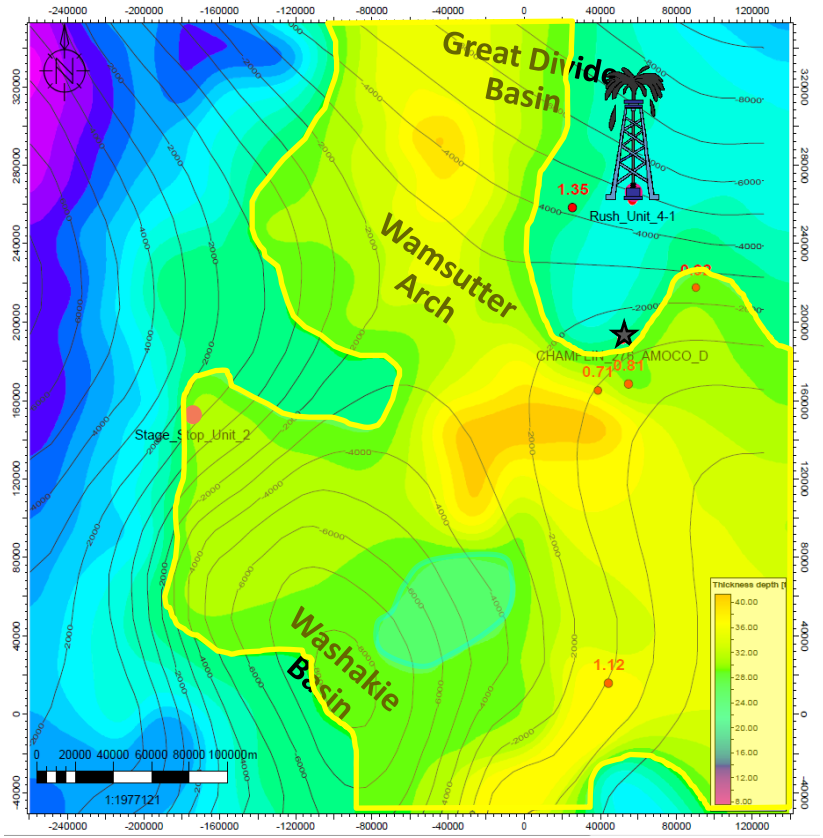
Thickness: 30-50 ft.



Biomarkers

Total area: $2.53*10^7$ acres

Potential Areas



- TWO WELLS DRILLED THE ASQUITH MARKER AND PRODUCED OIL
- Rush Unit 4-1H Asquith Marker depth: 12038-12051; 26775 Bbls since Dec,2012- Jan,2016
- Spirit of Radio: 14350 Bbls since 2011

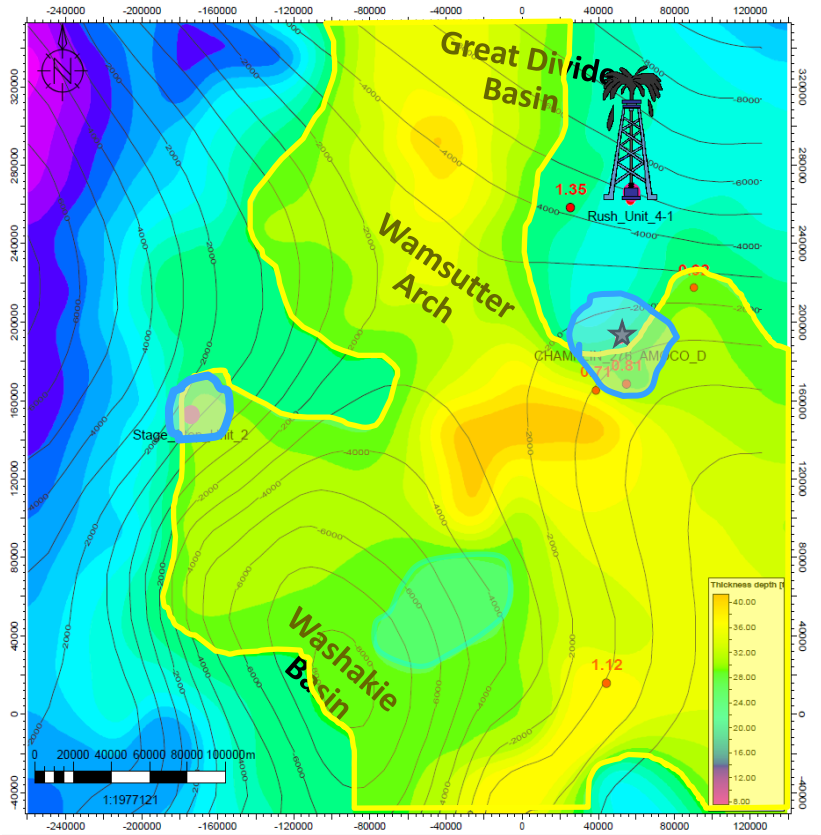
Depth:1400-(-6700) ft. TVDSS

Thickness: 30-50 ft.

Biomarkers

Total area: $2.53*10^7$ acres

Potential Areas



- TWO WELLS DRILLED THE ASQUITH MARKER AND PRODUCED OIL
- Rush Unit 4-1H Asquith Marker depth: 12038-12051; 26775 Bbls since Dec,2012- Jan,2016
- Spirit of Radio: 14350 Bbls since 2011

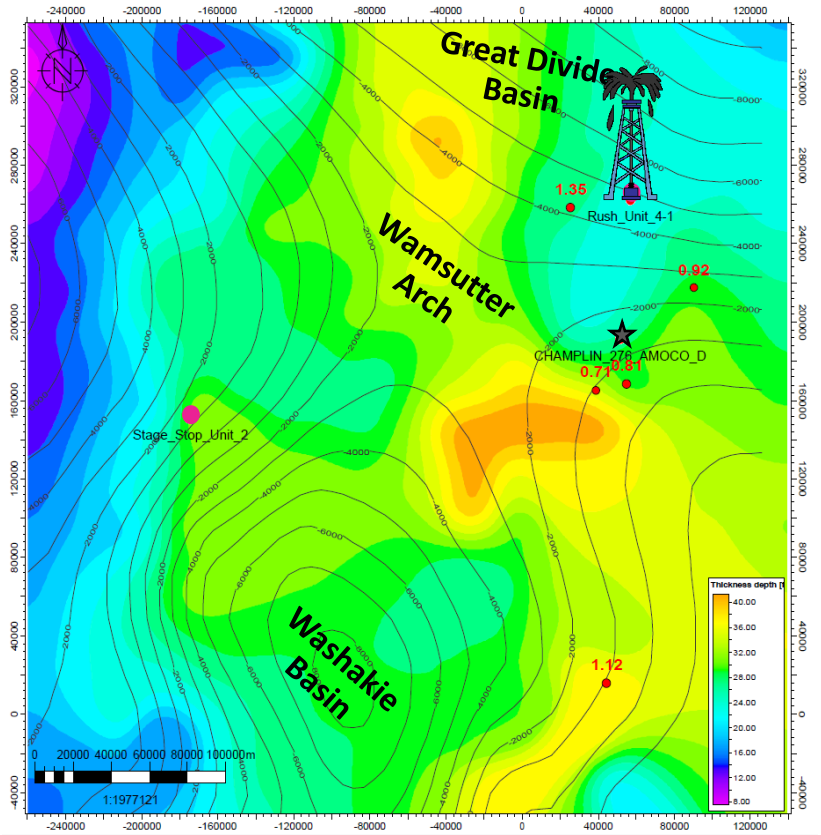
Depth:1400-(-6700) ft. TVDSS

Biomarkers

Thickness: 30-50 ft.

Total area: $2.53*10^7$ acres

Potential Areas



- TWO WELLS DRILLED THE ASQUITH MARKER AND PRODUCED OIL
- Rush Unit 4-1H Asquith Marker depth: 12038-12051; 26775 Bbls since Dec,2012- Jan,2016
- Spirit of Radio: 14350 Bbls since 2011

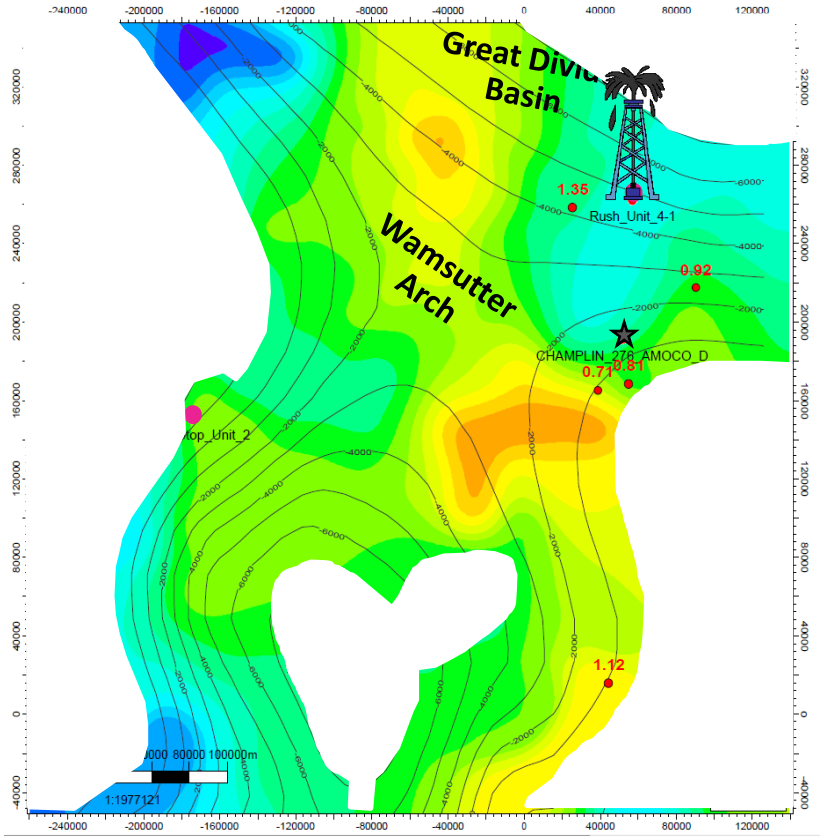
Depth:1400-(-6700) ft. TVDSS

Biomarkers

Thickness: 30-50 ft.

Total area: $2.53*10^7$ acres

Potential Areas



- TWO WELLS DRILLED THE ASQUITH MARKER AND PRODUCED OIL
- Rush Unit 4-1H Asquith Marker depth: 12038-12051; 26775 Bbls since Dec,2012- Jan,2016
- Spirit of Radio: 14350 Bbls since 2011

Depth:1400-(-6700) ft. TVDSS

Thickness: 30-50 ft.

Biomarkers

Total area: $2.53*10^7$ acres

Conclusions

- Initial TOC showed that the Asquith Marker has good-very good potential to generate hydrocarbons. Cutting samples can be subject to some pitfalls due to caving and sample handling.
- From Rock Eval data, it was determined a type II kerogen (marine, oil prone), and later on confirmed by the biomarker analysis which also gave information about saline, stratified waters, with higher plant material input, in the main oil window or entering the oil window.
- Some of the assumptions made regarding the potential productivity of this basin were based on very few samples. Cutting samples usually have some pitfall due to drying and handling.
- There are two oil wells producing from the Asquith Marker (Rush Unit 4-1H and Spirit of Radio 7-1H).

THANK YOU

Acknowledgements

- To Dr. Slatt and the Reservoir Characterization Institute
- The University of Oklahoma
- Dr. David Pyles
- Dr. Paul R. Philp
- Dr. Matthew Pranter
- Brian Cardott